ICRISAT Archival Report 2008

ICRISAT
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International Crops Research Institute for the Semi-Arid Tropics

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International Crops Research Institute for the Semi-Arid Tropics
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MTP Project 1: Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT

Project Coordinator: **Cynthia Bantilan**

Project profile:

This project is implemented in accordance with CGIAR System Priority 5 -- Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger. It specifically covers priorities 5A, 5B, 5C and 5D. This project provides the essential social science context for ICRISAT research. Strategic assessments for agricultural and economic growth in the semi-arid tropics are vital. This project also focuses on mapping the complex development pathways and alternative livelihood options to help make critical interventions to address poverty, vulnerability, marginalization and social exclusion.

Project 1 is coordinated through the Global Theme on Institutions, Markets, Policy and Impacts. The project implements social science and policy research at ICRISAT with focus on improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT. ICRISAT's social science and policy research thrust is to inform and provide strategic direction and prioritization of research issues within an IGNRM context and to provide appropriate capacity building. It scrutinizes the key driving factors influencing farmer to market linkages, optimal input and output options (including seed systems) and more effective policy and impact generation. Through social science and policy research, the Institute builds an enhanced capacity to help generate pro-poor policies, tools, lessons, and investment guidelines that contribute to improved food security, livelihood resilience and poverty reduction while protecting the environment of the production systems in the semi-arid tropics. As the poor faces a wide range of social and economic constraints, ICRISAT maintains a constant communication with them through village level studies to understand their needs and seek solutions. In this way, ICRISAT generates and shares vital information and analytical tools that provide a rational foundation for decisions that will benefit poor farmers and consumers.

Objectives

- Evaluate and develop alternative institutional arrangements and policy options for expanding access and utilization of new technologies and services for smallholder producers for greater impact of agricultural innovations on poverty and sustainable management of SAT agro-ecosystems (links to System Priority 5A)
- Develop and promote strategies that enhance market access and competitiveness of dryland commodities for smallholder farmers and agro-enterprises and food safety for consumers (links to System Priority 5B)
- Examine, develop and promote strategies for strengthening rural institutions and pro-poor institutional change to improve access of smallholders to markets and technologies and reducing vulnerability of livelihoods (links to System Priority 5C)
- Analyze the effectiveness of agricultural and rural development strategies and identify development pathways and policies that facilitate poverty reduction and livelihood protection under chronic and transitory emergencies (links to System Priority 5D)

In the MTP 2008-2010, Project 1 targeted ten outputs to be achieved through social science research focusing on four research areas: (1) strategic assessments, (2) rural livelihoods and development pathways, (3) market studies, outlooks, and institutional innovations, and (4) research priority and impact assessment. The research area on strategic assessments seeks to identify major changes, emerging trends, driving factors influencing agricultural transformation in the SAT, and their implications for ICRISAT's longer-term research priorities and overall research strategy. Research in rural livelihoods and development pathways addresses issues related to poverty dynamics. ICRISAT is revitalizing its Village Level Studies (VLS) to track changes in rural poverty in rural household and village economies. Research in market studies, outlooks and institutional innovations draws lessons learned from market and institutional studies and prospects for SAT mandate crops, as well as conduct research on market linkages and commercialization for technology uptake. Finally, the focus on research priority and impact assessment studies is to continue to develop analytical methods for assessment of impacts, thereby strengthening institutional capacity for analyzing impact pathways within ICRISAT and among NARS, and provide technical backstopping for adoption and impact assessment research in the other Global Themes.

Highlights for 2008

Significant IPGs

Social science research at ICRISAT provides well-documented analysis of changes in resource and social environments through micro-level studies. It continues to support the Institute's efforts towards science quality, relevance and impact in the semi-arid tropics. Some of the significant IPGs are:

- VLS database and analyses of the VLS household longitudinal panel. These are important international public goods. In particular, the resumption of the second generation VLS has produced an extended longitudinal panel that now provides a powerful analytical tool for understanding long term changes and generating insights on the dynamics of poverty in the rural SAT economy.
- IMPACT model redesigned to include SAT crops in the analysis of the global and regional situation outlooks for ICRISAT mandate crops
- ReSAKSS-SA website launched in July 2008 and fully operational

Outcomes and impacts achieved

- ICRISAT social science research has engaged stakeholders worldwide in Village Level Studies to understand rural poverty dynamics with focus on the SAT. For instance, economists, rural planners, sociologists and anthropologists from several universities in Canada have formed the first Canadian Village Level Studies group to focus on rural poverty in India and Africa in November 2008. The researchers will capitalize on the access to the longitudinal household panel data spanning 1975 to 2007 collected by ICRISAT to gain a better understanding of the factors that perpetuate poverty and hinder the equitable distribution of wealth.

  In addition, the ICRISAT VLS captured the interest of The Bill and Melinda Gates Foundation. Considered as one of the "jewels" of ICRISAT, the Village-Level Studies (VLS) has been cited for its significance in providing valuable insights on rural development pathways in meeting the Global Development Challenges. The Foundation's Agricultural Development initiative is investing across the complete agricultural value chain, from improved seeds and crops to market access and related research, with a special focus on small farm households, women headed households, and protection of their natural environment. The Foundation believes that to break the cycle of hunger and poverty, better information will enrich all efforts to improve the plight of small farmers in sub-Saharan Africa and South Asia. Hence the Foundation has agreed to support data collection efforts, research and policy analysis for agricultural development and GT-IMPI has been asked to lead a project proposal on the VLS for funding from the Foundation.

- Agricultural institutional innovation using coalition approach accessible to the rural poor and linking them with markets for higher income.
- Agreements (on variety evaluation release and registration procedures, seed certification, and phytosanitary procedures on shortening the time improved seed reaches farmers) were finalized and endorsed at the highest level of government by all the 15 countries of SADC.

Achievements in 2008

Output 1: Best innovative practices and mechanisms for harmonization and utilization of seed-related and biosafety regulations and policies suitable for the specific conditions of the SAT piloted, promoted and adopted with new knowledge shared with partners. [This output is shared regionally with projects 3 and 4]

System Priority 5: Improving policies and facilitating institutional innovation to support sustainable reduction of poverty and hunger

Priority 5A: Improving Science and Technology Policies and Institutions

Priority 5A, Specific goal 3: Improving incentives for technology generation, access and use

This research area is closely linked to that of Projects 3-6 but as a global generic policy issue it is felt it would be better to address it as a whole in Project 1 rather than to disarticulate it between 4 other projects.

Output target 2008 1.1.1 Critical gaps in understanding safety standards and food safety regulations identified and new knowledge shared with partners for capacity development in ESA.
Comment from BS: We discussed this before – I do not know anyone working on this in ESA. Richard only works on Aflatoxins

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Angola; Botswana; Burkina Faso; Congo; Ethiopia; Ghana; Kenya; Lesotho; Malawi; Mali; Mauritius; Mozambique; Namibia; Niger; Nigeria; Senegal; Seychelles; South Africa; Sudan; Swaziland; Tanzania; Uganda; Zambia; Zimbabwe

Partners Involved:
[List partner institutions actually involved in reaching the output target]

Comments/Explanations:

Progress/Results:
[Describe activities, progress and results achieved during 2008]

Special Project Funding:
[List special projects that contributed to the 2008 research]

Output target 2008 1.1.2 Best practices for harmonization of seed-related regulations and policies suitable for the specific conditions of the SADC (2008) region promoted

Agreements on shortening the time improved seed reaches farmers were finalized and endorsed at the highest level of government by all the 15 countries of SADC. These areas are: variety evaluation release and registration procedures, seed certification and phytosanitary procedures. A sticking point now remaining is the signing off on these agreements by individual countries' Ministers of Agriculture. This, although planned for 2008 has not happened yet. When signed, then, seed flow across national boundaries will increase. This will also lead to more seed choices to farmers as well as lowering of seed prices.

Achievement of Output Target (%):
>75% Achieved
Countries Involved:
Democratic Republic of Congo; Lesotho; Madagascar; Malawi; Mauritius; Mozambique; Namibia; Seychelles; South Africa; Swaziland; Tanzania; Zambia; Zimbabwe

Partners Involved:
Iowa State University, private sector seed Companies, National Seed Trade Associations in the SADC countries and the NARES of SADC

Comments/Explanations:
Achievement is rated at >75% because all has been done but the signature from the Ministers of Agriculture is being awaited. Implementers already are aware of what is to be done but they are awaiting a legal green light which is to come from the signing of a Memorandam of Understanding (MoU).

Progress/Results:
Approval of Harmonization Agreements by SADC Council of Ministers and the Ministers of Agriculture. The approval process began with SADC Permanent Secretaries of Agriculture meeting to receive and discuss the harmonized seed policy agreements. This was followed by the Inter-Ministerial Council of Ministers who recommended the agreements to be passed onto the next stage—Ministers of Agriculture meeting. It is expected that final signatures will be obtained in early February 2009

Advisory Assistance to Seed Industry to Support Implementation of Accreditation/Certification Agreement. Iowa State University continued to provide on-the-ground support in terms of training to the NARS and private seed companies in the individual countries. Follow-up by ISU has been made in 2008 to assist different seed companies in the development of their quality manuals.

Establishment of Regional Variety Catalogue to Support Implementation of the Variety Release Agreement.
The USAID-funded program SCOSA contracted the development of the software for the web-based variety catalog and later brought together three regions of Africa to complete the structure and content of the database for the regional catalogs, which will be the same for all three regions. Software has been installed at the SADC Seed Security Network.

Establishment of Seed Import/Export Manuals and Quarantine Pest Lists in Support of Implementation of Phytosanitary Seed System. All 14 SADC were trained and developed their Seed Import/Export Procedures Manual following the process management tool and draft manual prepared by ISU. These manuals establish responsibilities, timelines, and core activities in each country to establish a smooth flow for seed being traded in the SADC region. A regional quarantine pest list was also developed with the Plant Health departments of all 14 SADC countries, reducing considerably the number of quarantine pests based on science.

Establishment of Regional and National Plant Breeders' Rights Agreement. The 2006, protocol for Plant Breeders Rights based on the UPOV Convention was used in 2008 to develop the national legislation and regulations of the target countries. To date, Mozambique and Zambia join Tanzania and South Africa in having PBR legislation. Malawi is in the process of forwarding the draft PBR bill to Parliament.

A Plant Breeders' Rights policy brief was prepared by ISU and is currently being reviewed. This will be followed by printing and distribution to key stakeholders. The policy brief addresses the following issues:

- i The role and benefits of Plant Breeders Rights in seed systems development
- ii Plant variety protection institutions (UPOV) and how they can be of help in supporting plant breeders rights
- iii The value of a regional plant variety protection (PVP) agreement as compared to stand alone country PVP

Seed Regional Workshops. Regional Workshops –one for breeders and one for seed certification officers were held. These brought together practitioners from the 15 SADC countries to come and share and exchange experiences and agree on a unified strategy on key operational issues. A regional manual that contains the protocols agreed upon was developed and distributed to all the participants in all the countries

In 2008 the Ministers of Agriculture from the Common Market for Eastern and Southern Africa (COMESA) included the following statement in the Victoria Declaration: "Member States commit to harmonizing, within two years, seed trade regulations in the region and to finalize a regional protocol for the protection of new varieties of plants within the same period." COMESA has been consulted in the development of the Eastern and Southern Africa Seed Alliance (ESASA), and the inclusion of this statement endorses the strategy to expand the seed trade harmonization agenda beyond the Southern African Development Community (SADC) to include the non-SADC COMESA countries.

Special Project Funding:
USAID project funding facilitated this activity at a funding level of US $ 350,000.

Output 2: Ex-ante and ex-post impact studies conducted on representative ICRISAT NARS innovations for the SAT to enhance accountability and facilitate priority setting

Priority 5A, Specific goal 5: Enhancing the structure, conduct and performance of knowledge-intensive institutions

Output target 2008 1.2.0 Ex-post impact studies conducted as part of ICRISAT research impact agenda 2007-2011.

Achievement of Output Target (%):
100% achieved. The impact assessment research agenda for 2007-2011 was developed in coordination with scientists, Global Theme Leaders, and Directors across themes and regions (both core and special projects). For 2008, the implementation and completion of impact pathway analysis was jointly led by Global Themes Crop Improvement and GT-IMPI.

Countries Involved:
India; Tanzania; WCA

Partners Involved:
Indian Institute of Technology, Bombay – Prof D Parthasarathy
IAR (Nigeria); INRAN (Niger); IER (Mali)
Salien Agricultural Research Institute (SARI) and Ministry of Agriculture in Tanzania

Progress/Results:
Groundnut improved varieties in Nigeria, Niger and Mali
Legumes in ESA (Tanzania, Kenya, Uganda, Malawi, Ethiopia)

Groundnut improved varieties in Nigeria, Niger and Mali: This study investigates the early adoption of modern groundnut varieties in the pilot sites of the Groundnut Seed Project (GSP) in Mali, Niger and Nigeria following government and donors' investment. Seventeen varieties were disseminated in the pilot sites of the three countries. Uptake has increased significantly during the last three years partially as a result of project intervention. The proportion of area planted with modern varieties has increased by 22% in Nigeria, 12% in Mali and 10% in Niger in the pilot sites since 2003. Farmers using modern varieties have derived significant yield gains of 24%, 43% and 31% over the local varieties in Mali, Niger and Nigeria respectively. The modern varieties had significantly lower per unit cost of production estimated to 9.8%, 11% and 11% in Mali, Niger and Nigeria respectively. The net income derived by adopters is 66% higher than non-adopters in Mali, 73% in Niger and 111% in Nigeria. Relative to household types, income gains are estimated to be less than 20% compared to poor households in Mali, while it is more than 50% in Nigeria. Results from the Logit models indicate that the major determinants of adoption in the three countries include the participation of farmers to on-farm trials, the build up of social capital through the empowerment of farmers' associations and small-scale farmers at producing and marketing seed. Constraints to adoption remain the poor access and availability of seed of modern varieties, pest and disease pressure in at least two out of three countries. Tobit results indicate that intensification of modern varieties is dependent essentially on seed availability, social capital, exposure to the varieties through farmers' participatory variety trials.

Ndjeunga J, Ntare BR, Waliyar F, Echekwu CA, Kodio O, KapranI, Diallo AT, Amadou,A Bissala, HY and Da Sylva A. 2008. Early adoption of modern groundnut varieties in West Africa. Working Paper Series no 24. Sahelian Center, BP 12404 Niamey, Niger: International Crops Research Institute for the Semi-Arid Tropics. 60pp

Sorghum in ESA (Tanzania, Kenya): Pigeonpea in Tanzania: Dryland legumes well adapted to drought-prone areas have largely been neglected in the past despite the good opportunities they offer for income growth and food (and nutritional) security for the poor. This study evaluates the adoption and impact of two farmer and market-preferred and disease-resistant pigeonpea varieties that were developed and promoted in semi-arid Tanzania. The new varieties were resistant to fusarium wilt, a fungal disease devastating the crop. However, farmers wanting to adopt new varieties did not adopt due to seed access constraints and under developed seed delivery systems. Adoption of new varieties is therefore analyzed using an augmented double hurdle model which allows estimating variety adoption conditional on seed access thresholds accounting for the additional information on sample separation. The study identifies the crucial role of seed access (local supply), extension, education, participatory decision marking, capital and household assets in determining adoption. The social economic benefits of the technology and policies for improved seed access were further analyzed using the extended economic surplus method (DREAM model). Even under restrictive assumptions, overall discounted benefits were found to be quite attractive, indicating the need for additional efforts to scale- up the success story. Analysis of changes in research benefits from relaxing the seed access constraint showed that net gains would increase by up to 30% if farmer access to improved seeds can be assured. Smallholder farmers are the major beneficiaries along with consumers and rural net-buyers who gain from productivity-induced lower market prices.

Shiferaw B, Kebede TA and You Z. 2008. Technology adoption under seed access constraints and the economic impacts of improved pigeonpea varieties in Tanzania. Agricultural Economics 39:1-15

In addition to the above, publications based on ex-post studies that were conducted in 2007 were also published in internal peer reviewed journals. One of them includes a social analysis of the Groundnut Production Technology uptake and impact:

- Bantilan MCS and Padmaja R. 2008. Empowerment through social capital build-up: Gender dimensions through technology uptake. Journal of Experimental Agriculture: 44 (1), pp 61-80, 32 Avenue of the Americas, NY 10013-2473, New York, Cambridge University Press.
  The learning from the long-term observation of men and women farmers who used the Groundnut Production Technology an integrated crop and natural resource management innovation, illustrates that social capital is important for both adoption and impact to occur. Social capital is not merely an 'input' to development; it is also one of its most significant outputs. While social capital build-up plays a crucial role in bringing about positive economic changes, it also has a significant role in influencing impacts, especially empowering the men and women in agriculture. The findings of this study confirmed that the build-up of social capital mediated the technology uptake process for GPT. It facilitated procuring inputs for crop production (especially gypsum and culture for seed treatment), access to resources (implements, broadbed and furrow, seed drill), diversification of farm activities, knowledge sharing and dissemination, learning, and empowerment of both men and women farmers.

  The study observed that social networks, whether developed through formal organizations, kinship, neighbourhoods, work groups or informal interactions, are a critical component of social capital. Social resources embedded in networks may provide various benefits, such as information, influence and control. Social capital strengthens access to these resources. Women's networks facilitated communication, coordination, and the provision of information/knowledge regarding agricultural production, income generation, skill enhancement and family food security. They created obligations and expectations of reciprocity among their members. The trust, common understanding and knowledge generated multiplier effects in terms of evolving social networks, which stimulated new institutional arrangements.

Special Project Funding:
Treasure Legumes in ESA, Tropical Legumes II

Output target 2008 1.2.1 Ex-post impact studies conducted on selected dryland technologies: Groundnut in Uganda; conservation farming and micro-dosing in Zimbabwe

Groundnut adoption and impacts in Uganda:

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Uganda

Partners Involved:
National Agricultural Advisory Development Services (NAADS) and National Agricultural Research Organization (NARO) in Uganda

Progress/Results:
Two papers prepared from Uganda adoption study and submitted to IAAE conference (2009).
The papers evaluates the role of information, seed supply and credit constraints for adoption of improved groundnut varieties in rural Uganda. We use large-scale primary survey data collected in seven districts. Owing to the interdependence of variety choice decisions, we use a multivariate probit specification to identify variety-specific drivers of adoption. About 10% of farmers lack information on new varieties, while 18% and 6% cannot adopt mainly due to seed supply and capital constraints, respectively. This indicates that tobit-type specification which considers all non-adopters as disinterested in the technology would lead to inconsistent parameter estimates. We therefore estimate a modified hurdle specification which takes into account the information, seed supply and capital constraints in determining the desired demand and intensity of adoption of new peanut varieties. These findings provide new insights as to why adoption of new agricultural technologies in Africa has lagged behind – not so much due to lack of economic incentives, but due to the persistent failure to provide vital information along with seeds and credit to translate the desired positive demand into effective and actual adoption of new varieties. These are important lessons that need to be considered as Africa is searching for a green revolution.

Special Project Funding:
NAADS support in Uganda, ICRISAT core funds for groundnut improvement)
African Development Bank and, DANIDA for pigeonpea improvement
ICRISAT core funds for adoption and impact assessment in Tanzania

[Isaac/Twomlow to provide on micro-dosing in Zimbabwe]

Output target 2009 1.2.1 Ex-post impact studies on sorghum and pearl millet in Nigeria; sorghum and pearl millet for poultry feed in Asia

Intermediate output target in 2008 - Adoption of pearl millet and sorghum in Northern Nigeria

Achievement of Output Target (%):
33%

Countries Involved:
Nigeria

Partners Involved:
IAR, LCRI and ADPs

Progress/Results:
Pearl Millet: In Northern Nigeria, since 1990, ICRISAT in partnership with IAR developed a large range of pearl millet and sorghum varieties and hybrids that are preferred by farmers and some of these varieties have the traits required by the markets. Adoption survey results showed that yields from improved varieties are significantly higher than the local landraces. The average yield for improved pearl millet varieties is estimated to about 1126 kg per hectare against about 940 kg/ha for the local for the period 2003-2005. This represents a yield advantage of about 20%. As for sorghum, the productivity gains are estimated to about 31% (1324 kg per hectare for improved cultivars and 1011 kg for local varieties). The gains are realized from the reduced productivity loss as a result of drought and disease resistance of improved varieties. Kano State enjoyed the highest yield increase (43%) for sorghum whereas the mean yield (1474 kg per hectare) from improved millet cultivars was highest in Borno State.

The proportion of farmers growing improved sorghum varieties were estimated to 78% for ICSV400, 66% for ICSV 111, 92% for SK5912 and 66% for KSV8. Concerning improved millet varieties, the rates of awareness were 91% for Ex-Borno, 76% for SOSAT-C88 and 67% for GB8735. On average, about 56 % (1.28 ha) of the total area under sorghum in 2004/05 was planted with improved sorghum and 47% (1.07 ha) of the total area under was planted with improved millet varieties. These represented increases of 21% (1.05 ha) for sorghum areas and 30% (0.82 ha) for millet areas relative to the preceding 2003/04 cropping year. ICSV 400 and SOSAT-C88 have the highest proportions of area planted estimated to 47% and 31% respectively.

The most important drivers for adoption of improved sorghum varieties were different from the ones cited for improved millet varieties. For sorghum, high yield was ranked first followed by early maturity, selling price, storage ability, food quality and drought/disease resistance. For millet, early maturity ranked first, followed by high yield, food quality, selling price and drought/disease resistance. The high ranking of early maturity trait is a confirmation that drought is the major constraint to pearl millet production in northeastern part of Nigeria. In effect, most farmers are small-scale and semi-subsistence farmers whose major goal is to ensure food security for their families. Early maturing cultivars provide an early end to the annual hunger period (June's first rain to September's first harvest). The high ranking of the high yield trait for sorghum can be explained by the fact in Kano and Kaduna, sorghum competes with high yielding crops such as maize.

Special Project Funding:
None

Intermediate output target in 2008 - Enhanced utilization of sorghum and pearlmillet in Asia

Achievement of Output Target (%):
75%. The project is now into its fourth year and data pertaining to the latest crop season are being collected currently.

Countries Involved:
India; China; Thailand

Partners Involved:
ICRISAT, Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad; Marthwada Agricultural University (MAU), Parbhani; Andhra Pradesh Federation of Farmers Association (APFFA), Hyderabad; Krishi Vigyan Kendra (KVK), Beed, JK Agri-Genetics, Hyderabad; Janaki Feeds, Hyderabad. China: Liaoning Academy of Agricultural Sciences, Shenyang, and local partners. Thailand: Field Crops Research Institute (FCRI), Bangkok and local partners.

Progress/Results:
ICRISAT, along with the participation of the local partners are currently implementing a project on "Enhanced Utilization of Sorghum and Pearl Millet Grains in the Poultry Feed Industry to Improve Livelihoods of Small-Scale Farmers in Asia" funded by the Common Fund for Commodities (CFC) and FAO as supervisory body. The project target regions are in India (2 clusters in Andhra Pradesh and 3 clusters in Maharashtra); China (1 cluster in Lioning province) and Thailand (1 cluster in Suphanburi and Nakhon Sawan). The project engages seed and grain suppliers, credit agencies, poultry feed manufacturing companies, and poultry producers. The ultimate objective of this intervention is to increase the income of farmers by 15% at the end of three years of the project intervention. In total the project covers 80 villages and 6500 farm families in the three countries.

The project aims at enhancing crop production using improved production technologies, ensuring better input and output linkages. A new concept of "Bulk marketing" was evolved and implemented through the project. It involves the complete surpassing of all the intermediaries of the traditional supply chain and the direct sale of produce from the farmers to the industrial consumers such as poultry feed manufacturers, poultry farmers (who have in-house feed manufacturing), breweries, distilleries and mushroom farms. Under the project the farmers were grouped into associations and trained in use of improved crop production and harvesting technologies, grain storage, bulking and grading and bulk marketing.

The project has completed has completed 3 years and is now in its fourth year. To measure the impact of the project at the farm household level an impact assessment survey was carried out and the findings compared with the key parameters from the baseline survey carried out under the project prior to its implementation. Additionally, farmers from control villages (not participating in the project) were surveyed for a 'With and Without Comparison' i.e., with project intervention and without any intervention.

The findings from the impact survey indicate that farmers participating in the project were able to increase their returns from growing sorghum / pearl millet compared to the returns prior to project implementation. Net returns increased across the board in all clusters of the project. On an average the returns increased at least four fold for pearl millet farmers in India (mainly Palvai cluster in Andhra Pradesh). For sorghum, the net returns in the Indian clusters of Andhra Pradesh and Maharashtra more than doubled.

In, China sorghum yields were higher by more than 5% compared to baseline yields, and farmers obtained 33% higher prices. The yields and prices were also higher for the project farmers compared to non-project participating farmers ensuring higher net returns due to project intervention.

In Thailand two kinds of sorghum are grown, white and red. For white sorghum grown in Suphan Buri and Kanchanaburi yields increased by 40% compared to the baseline, and prices by 48%. Net incomes increased by about 100%. For red sorghum the commonly cultivated type net returns increased by nearly 15)% on an average.

Thus the increase in net returns for the project farmers in all clusters under the project can attributed to yield increases due to the adoption of improved technology, the higher prices that the farmers were able to command owing to bulk marketing of grain, and the increase in output prices for all commodities driven by global price rise.

Presently, the sustainability of the project intervention is being strengthened in all the clusters by institutionalizing the Farmers Association, and their linkages with key stakeholders for inputs and outputs. The association members are being further trained on management of stored produce, and their bulk sales.

Special Project Funding:
Common Fund for Commodities (CFC)
In kind contributions from partner organizations

Output target 2010 1.2.1 Tropical Legumes/IFAD project early adoption studies on chick pea, pigeon pea and groundnut in selected countries

Intermediate output target in 2008 – South Asia

Achievement of Output Target (%):
25% completed. The project has been implemented less than a year ago and consequently the preliminary results are restricted to baseline surveys and not impact assessments.

Countries Involved:
India; South and South East Asia

Partners Involved:
ICRISAT; University of Agriculture Sciences, Bangalore; University of Agriculture Sciences; Dharwad; Punjabrao Krishi Vishwavidyalaya (PKVK), Akola; Tamil Nadu Agricultural University, (TNAU) Coimbatore; Acharya NG Ranga Agricultural University, Hyderabad
Countries Involved

Progress/Results:
The socioeconomic studies in the project "Enhancing grain legumes' productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia" establish an overall baseline framework for assessing *ex-post* the technology uptake and impact of improved varieties on the food security and poverty status of the farm households producing groundnut, chickpea and pigeon pea in drought-prone regions of South Asia and Sub-Saharan Africa. The baseline household and market survey questionnaires have been adapted from the standardized instruments developed under the project. In Asia, selection of the baseline and market survey sites were undertaken in the four major growing states of chickpea, pigeon pea and groundnut targeted by the breeders. The district and village survey sites were selected in coordination with biological scientists following a set of criteria including: importance of the crop, rainfall pattern, soil types, and access to markets.

Baseline and market surveys of chickpea in Karnataka have been completed. These surveys cover a wide range of variables including input supply, output production and marketing, value addition, decision making, gender issues, constraints in production and marketing, current levels of adoption of existing cultivars, preferred traits in new cultivars by farmers and market intermediaries, among others. Data collection, analysis and report preparation are completed.

Some highlights of the results are given below:

- Chickpea was grown in rabi season, mostly as a sole crop, though intercropping with sorghum or safflower is also seen rarely. Chickpea occupied highest proportion of the gross cropped area of the sample farmers both in Dharwad district (nearly 35 per cent) and Gulbarga district (38 per cent).
- Nearly 99 per cent of the sample farmers consumed chickpea to the extent of nearly 48 kg per household per year. Chickpea consumption accounted for nearly 5.4 per cent of the total annual food consumption expenditure.
- Relatively higher crop income was the most important reason (97 per cent) that motivated the sample farmers to cultivate chickpea, followed by restoration of soil fertility, food/home consumption, better fitment into cropping system, better fitment in crop rotation, fodder/animal consumption, suitability to soil and lower cost of cultivation, in that order.
- Majority of the sample farmers (83 per cent) grew chickpea every year. However, the proportion of farmers who cultivated chickpea every year was higher in Dharwad district (98 per cent) than in Gulbarga district (68 per cent). As many as 28 per cent of the sample farmers opted to cultivate the crop once in two years in Gulbarga district.

- The most important crops that were grown before chickpea on the same piece of land were maize, green gram, onion, sorghum and cotton in Dharwad district, while in Gulbarga district, it was green gram followed by pigeon pea and sorghum.
- The area under chickpea cultivation was almost constant as per 62 per cent of the farmers, while 30 per cent of them opined that the area under the crop was increasing. Remaining farmers felt that the area under the crop was decreasing.
- Nearly 56 per cent of the farmers expressed that the frontier area or the potential area for chickpea cultivation was to the tune of 5.33 acres per household.
- The yield of chickpea under rainfed condition was to the tune of 525 kg/ac in good year as against 624 kg/ac in the best year. The worst possible yield was 218.86 kg/ac (i.e., in the bad year). Under irrigated condition, the corresponding figures were 629 kg/ha, 788 kg/ha and 265.43 kg/ac. The pattern was almost similar between adopted and control areas.
- Annigeri was the most popular and ruling variety cultivated by 78 to 94 per cent of the farmers in an area of 2.88 to 3.87 acres per household during the last three years. The other varieties, namely, Kabuli, Bhima and local were adopted by insignificant proportion of farmers.
- Annigeri variety was adopted by the sample farmers on a sizeable land area for the first time in the year 2000-01 with a cropped area of 2.81 ac/household which reached a peak of 3.85 ac/household during the year 2005-06.
- High seed price, lack of information about recommended variety, non-availability of required variety, non-availability of credit and poor quality of seed were the major constraints related to seed purchase.
- Pod borer and wilt were the major pest and disease, respectively, affecting the crop as expressed by 100 per cent and 53 per cent of the farmers, respectively, which correspondingly reduced the yield by 42 per cent and 35 per cent.
- These pest and disease problems were found to be increasing according to about 80 per cent of the farmers. The major causes for increased pest and disease incidence were weather related factors, non-adoption of crop rotation and susceptibility of varieties. The most important measure adopted to control pests and diseases was the use of chemical pesticides, followed by adoption of IPM/IDM technologies and altering sowing time.
- The major sources of information to the farmers for control of pests and diseases were input suppliers (84 per cent), fellow-farmers (51 per cent) and friends and relatives (17 per cent). The research institute, radio and print media catered to the information needs of negligible proportion of the farmers.
- Low yield (Garrett Score, GS=20.93) was the major constraint confronted by the farmers in chickpea production. The major constraints in descending order of priority were high pest incidence (GS=16.20), small grain size (GS=14.01), low market price (GS=12.02), low recovery/shelling percentage (GS=11.42), high disease incidence (GS=10.73) and long crop duration (GS=9.83).
- High yielding performance was the most single preferred trait across all study situations (district-area-variety combinations), with a lone exception of Bhima in Dharwad-adopted situation, wherein the farmers preferred pest resistance to high yield.
- The other preferred traits, in general, were drought resistance, pest resistance, improvement in soil fertility, disease resistance, short duration, fitness into cropping system and more recovery/shelling percentage, in that order, across varieties and locations.
- In general, across districts and areas (adopted and control), high yielding variety was the most desired trait in a new chickpea cultivar as expressed by 93.33% of farmers, followed by pest and disease resistance (47.04%), bigger grain size (11.11%), drought resistance (11.11%), high shelling percentage (2.22%), better taste (1.11%), short duration variety (1.11%), grain colour (0.37%) and high demand in market (0.37%), in that order.
- In general, across districts, areas (adopted and controlled) and constraints, the farmers were willing to pay a premium price for the seeds to the extent of 25.23% (ranging from 15 to 50 per cent for various desired traits).

Special Project Funding:
Bill and Melinda Gates Foundation

Intermediate output target in 2008 – ESA

Achievement of Output Target (%):
25% completed. The project has been implemented less than a year ago and consequently the preliminary results are restricted to baseline surveys and not impact assessments.

Countries involved:
Ethiopia, Kenya, Malawi and Tanzania

Partners Involved:
EIAR, KARI, SARI, CARD/UoM, TechnoServe

Progress/Results:

- In ESA, baseline data has been collected during 2008 in four countries (Ethiopia, Kenya, Malawi and Tanzania) for the two legumes projects. Data cleaning and analysis commenced immediately in September 2008 following the completion of data entry process for Ethiopia and Malawi (August/September 2008). The preliminary results from the analysis of these two datasets (Ethiopia and Malawi) were presented during the Year I Project Review and Planning meeting that was held in Addis Ababa (29 September – 03 October 2008).
- For Ethiopia, the results shows that average area cultivated is about 2.4 ha of which 0.33 ha is allocated to chickpea. Only 28.5% of the chickpea area is allocated to improved varieties suggesting relatively good adoption and the potential for promoting awareness about the varieties. Average household size is about 6.4 and the level of education of household head is about 1.8 years. Only 6.1% of the sampled households own mobile phones which is relatively lower compared to other countries. However a large share of the sample households (77.5%) own radio, making it a major means of reaching farmers.

- In Malawi the socio-economic profile suggest a different picture. Cultivated land is on average 1.06 ha of which 0.3 ha and 0.29 ha is allocated to groundnut and pigeonpea, respectively. Of the land allocated to groundnut and pigeonpea, the share of improved varieties of the respective crops is 24% and 5.5% respectively. Family size and the level of education of the household head are on average 4.8 and 4.4 years respectively. About 55% of the sample households own mobile phone whereas 53% own radio and 2.6% television. Poverty and income profile of the target farmers in Malawi suggest that about three quarters of the farmers live below the poverty line, which is relatively higher compared to the national poverty level which is about 65%. The preliminary results also show that farmers in both countries want low risk and high-yielding varieties with traits preferred for local consumption. Demand for new varieties is high but limited by lack of awareness, seed supply and cash capital constraints. About 65-70% of the legume seed is own-saved and recycled; only about 15-20% is bought.

- The data for the other countries will be analyzed during 2009.

Special Project Funding:
Treasure Legumes and TL-II

Intermediate output target in 2008 – WCA
Achievement of Output Target:
75%

Countries Involved:
Mali, Niger and Nigeria

Partners Involved:
IAR and ADPs (Nigeria), INRAN, Alheri Seed Company (Niger), IER, EUCORD and AOPP (Mali),
Comments/Explanations:

Progress/Results:
Baseline data (households and market) collection completed in the 3 countries. Preference survey data compiled and available.
Special Project Funding:
Tropical Legumes II

Output 3: Database and new methodologies addressing the impact of bio-physical and social science research developed

Output target 2009 1.3.1 Impact assessment master classes in Asia completed

Intermediate output target in 2008 –Preparation underway for the impact assessment master classes

Achievement of Output Target (%):
15% completed. Preparatory work for organizing the master classes underway.

Countries Involved:
Australia; Bangladesh; Cambodia; China; India; Indonesia; Laos; Nepal; Pakistan; The Philippines; Sri Lanka; Thailand; Vietnam

Partners Involved:
Participants are expected to be drawn from NARES in Bangladesh; Cambodia; China; India; Indonesia; Laos; Nepal; Pakistan; The Philippines; Sri Lanka; Thailand; Vietnam.

Progress/Results:
The Crawford Fund, the Australian Centre for International Agricultural Research and the International Crops Research Institute for the Semi-Arid tropics are jointly organizing a Master Class on Concepts and Tools for Agricultural Research Evaluation and Impact Assessment at the International Crops Research Institute for the Semi-Arid Tropics on 18 – 27 March 2009. The First Announcement of the Master Class is ready for dissemination, together with a pre-course survey Form designed to assess the suitability of potential participants. The primary focus of the Master Class is to provide participants with the knowledge and skills necessary to undertake robust ex ante and ex post economic impact assessments of agricultural R&D and to make them aware of methodological advances in impact assessment and pathway analysis. The outputs of the Master Class will be two-fold. First, the capacity of the participants to undertake quantitative impact assessment will be enhanced. Second, a collaborative bond will develop between the participants themselves, and between the impact groups of ACIAR and ICRISAT and the participants. It is hoped that this will continue into the future.

The main presenters of the Master Class will be Debbie Templeton (ACIAR) and Cynthia Bantilan (ICRISAT), with support from several specialized resource persons.

Special Project Funding:
The Crawford Fund
Australian Centre for International Agricultural Research (ACIAR)

Output target 2010 1.3.1 Impact pathways approach applied in ICRISAT planning and M&E process for enhancing relevance of R&D interventions in the SAT

[Discuss the research impact agenda of ICRISAT 2007-2011 implemented in 2008; presented in EPMR initial phase and GB-Hybrid pigeonpea, Microdosing, Sustainable land management, Warrantage system, African market gardens – KPC, JN and BS to provide inputs]

West and Central Africa

Achievement of Output Target (10%):

Countries Involved:
Mali, Niger, Burkina Faso, Ghana, Senegal and Benin

Partners Involved:
Several NGOs (Jean-Paul II,AFRIPA Sud, USADF, USAID, World Development Market Place, Green Senegal, MASHAV, ANPIP, World Vision, IDRC(Dates for the Sahel project),SELF,PDRI, CARITAS,CRS, OCADES, INERA (Burkina Faso), AGHRYMET, Projet FAO Intrants .. etc

Progress/Results:
Data collection on impact pathways initiated for micro-dosing, warrantage system and African Market Garden.

Special Project Funding:
None

East and Southern Africa

Achievement of Output Target (75%):

Countries Involved:
Zimbabwe

Partners Involved:
NGOs working in the region
Progress/Results:
Since 2004, there has been a series of initiatives in Zimbabwe to promote conservation agriculture (CA) through various donor-funded relief initiatives with the aim of improving crop production among vulnerable farmers. In April 2007, ICRISAT implemented a survey to collect data from 12 districts and 232 households that had been practicing hand hoe-based conservation farming (CF) for at least one prior season with extension and input support from non-governmental organizations. This study was undertaken to better understand the household and institutional factors that influence CF adoption patterns among the beneficiaries of these relief initiatives. Results from the study show that institutional support and agro-ecological location have strong statistical influence on the adoption intensity of different CF components.
Besides the practice of preparing basins, at least 70% of the households had also adopted the following components of CF: manure application in the planting basin, topdressing with nitrogen fertilizer at the 5–6 leaf stage of the cereal crop, and timely post-planting weeding. Household labor availability and impacts of HIV/AIDS did not limit the intensityof adoption of CF. An enterprise budget analysis proved that because of the significant yield gains realized with CF, the technology is more viable than conventional tillage practices of broadcasting manure and overall spring tillage on the day of planting. The increased profitability in adopting CF was also reflected in steady increases in thearea each household committed to CF from an average area of 1450 m2 in 2004 to more than 2000 m2 in 2007. This is published in the journal *Agricultural Systems* (2009).

Special Project Funding:

Protracted reflief program in Zimbabwe

Output target 2011 1.3.2 New methodologies tackling impact on social processes (social capital and networks), capacity building and policy developed

An intermediary output target under this activity completed in 2008 is the development of methodologies for establishing the network architecture in the six villages under the village-level studies. The details are given under Output 9.

Output target 2011 1.3.3 Lessons learnt from analysis of impact pathways of representative ICRISAT –NARS innovations documented

Intermediate output target in 2008 –Preliminary results based on baseline surveys in India and WCA

Achievement of Output Target (%):
25% completed. The project has been implemented less than a year ago and consequently the preliminary results are restricted to baseline surveys and not impact assessments.

Countries Involved:
India; Mali; Niger; Nigeria; South and South East Asia
Partners Involved:
ICRISAT; University of Agriculture Sciences, Bangalore; University of Agriculture Sciences; Dharwad; Punjabrao Krishi Vishwavidyalaya (PKVK), Akola; Tamil Nadu Agricultural University, (TNAU) Coimbatore; Acharya NG Ranga Agricultural University, Hyderabad

Institute of Agricultural Research at Ahmadu Bello University (ABU), Institut de la National de la Recherche Agronomique du Niger (INRAN), Institut d'Economie Rurale (IER)

Progress/Results:
The socioeconomic studies in the project "Enhancing grain legumes' productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia" establish an overall baseline framework for assessing *ex-post* the technology uptake and impact of improved varieties on the food security and poverty status of the farm households producing groundnut, chickpea and pigeon pea in drought-prone regions of South Asia and Sub-Saharan Africa. The baseline household and market survey questionnaires have been adapted from the standardized instruments developed under the project. In Asia, selection of the baseline and market survey sites were undertaken in the four major

growing states of chickpea, pigeon pea and groundnut targeted by the breeders. The district and village survey sites were selected in coordination with biological scientists following a set of criteria including: importance of the crop, rainfall pattern, soil types, and access to markets.

The phenomenon of ruling varieties for decades in India and WCA. Farmers were asked about the cultivars currently grown. Based on the preliminary summaries derived for groundnut, pigeon pea and chickpea, it is striking to note that cultivars released as long as 15 to 50 years ago continue to be adopted by farmers and they seem to dominate farmers' fields in major growing states of India. Likewise in WCA also, 55-437 in Niger and 47-10 in Mali are grown in large areas. These cultivars released as long as 15 to 50 years ago continue to be adopted by farmers and they seem to dominate farmers' fields in major growing groundnut growing areas of Niger and Mali. The phenomenon of ruling varieties for decades in India and WCA raises several questions. Systematic analysis of the data collected (data entry and processing currently underway) is expected to provide essential information for better targeting breeding efforts as well as in addressing constraints faced in India and West Africa.

Assessment of preferences across the value chain in India. Preliminary results from the first set of validated data from baseline and market surveys provide insights on the distinct preferences of key players along the market value chain - farmers, commission agents, traders, processors, exporters/importers, retailers and consumers. The illustrative pattern is a useful tool in drawing attention on the critical value of users' preferences and the importance of a Coalition Approach involving key actors throughout the value chain in technology development and adoption. In this case, research objectives may need to be reevaluated to reflect the relevance of critical factors in addition to traditional research objectives.

Insights focusing on issues related to drought in India. The questions often asked about drought are: by how much would crop productivity or production decline due to drought? Similarly what is the converse in a good year? How often does drought occur in say 5 -10 years? Additionally, there are other questions related to coping strategy once drought has accrued. Using 38 years of district level data for India, we try to understand or partially address the first two questions raised above. Preliminary findings indicate that in the Semi-Arid Tropics where most of the groundnuts are grown every 3rd year could be a drought year, affecting productivity by 10-25% at least. The highest variability in chickpea yields is in the Arid zone with yields declining by more than 10% in 16 out of 38 years and the highest decline being 30%. In the semi-arid tropics, in only 6 out of 38 years chickpea yields declined by more than 10% and the highest decline was 20%. For pigeon pea, in only 7 out of 38 years, yields declined by more than 10%. The yield instability however, seems to have increased over time particularly after the nineties. Insights into farmers' coping strategies would be obtained from household level surveys.

Special Project Funding:
Bill and Melinda Gates Foundation

Output 4: Current agricultural growth trends and future outlooks for the SAT analyzed and shared with key stakeholders

Output target 2008 1.4.1 Annual regional agricultural growth trends reports for southern Africa (2008-11)

Achievement of Output Target (%):
The report for 2007 was completed in September and shared with IFPRI for final comments before publication and distribution. However, the results obtained thus far have been shared by stakeholders in relevant forums

Countries Involved:
The main focus was on the focal countries which until now remain to be Malawi, Mozambique and Zimbabwe. But the trends generally refer to all countries of SADC

Partners Involved:
Mozambique: Ministry of Agriculture—Policy Analysis Department, Michigan state in Mozambque
Malawi: Malawi Agricultural Sector Support Program (MASIP)
Zambia: Agricultural Consultative Forum (ACF), Michigan State University, Food Security Project (FSR).
IFPRI, Washington, DC.
National Statistical Bureaus of all SADC Countries

Progress/Results:
<u>Agricultural subsidies</u>
It is generally agreed that subsidies in eastern and southern Africa region is the same as fertilizer subsidies. It is also thus agreed that in some countries of the region, subsidies has become accepted as a key driver in accelerating agricultural and rural development. The question now is therefore how "smart" can we make these subsidies to be and is not about 'whether subsidies are necessary? A summary on this as noted in the relevant publication shown above runs as follows:

Factors determining the costs and benefits of fertilizer subsidies

- The full economic cost of implementing the fertilizer subsidy program. These costs go beyond the economic costs of acquiring and distributing the fertilizer to include the opportunity costs of the resources used in the program as well, e.g., the flow of benefits that otherwise could have been achieved with the resources used for the subsidy program.
- The price of output. World food grain prices have increased dramatically in the recent past, which boosts the potential returns to fertilizer subsidy programs. In an extreme case where needed grain could not be obtained from regional or world markets, the benefits of additional domestic food production generated from a subsidy program would include saved lives and malnutrition averted.
- The price of fertilizer. World fertilizer prices have more than doubled over the past year, reducing the potential returns to fertilizer subsidy programs. Bringing fertilizer prices down to levels considered affordable to low-income farmers will require more from national budgets than in prior years.
- Agronomic response rates. The payoffs to fertilizer subsidy programs could be enhanced by improving the aggregate crop yield response rates to fertilizer application. This requires making complementary investments in training for farmers on agronomic practices, soil fertility and water management and efficient use of fertilizer, investing in crop science to generate more fertilizer-responsive seeds. There is evidence from research that highest response to yield on crops is obtained when improved seed, fertilizer and good agronomic practices are in place. The first two alone are not enough (Heinrich 2004). . Survey data commonly indicate that the contribution of fertilizer to food grain yields varies tremendously across farms even within the same villages. Simply bringing fertilizer response rates among the bottom half of the distribution up to the mean would contribute substantially to household and national food security (Nyoro, et al., 2004).
- The degree to which subsidized fertilizer crowds out or displaces commercial fertilizer sales. The contribution of fertilizer subsidies to national crop production must take into account the extent to which subsidized fertilizer may "crowd out" the purchase of fertilizer from

commercial sources. This concept may be best understood in a "with/without" framework. Assume, for example, that in the absence of a subsidy program a given farm would purchase 2 bags of fertilizer. If this farmer is allocated 4 bags of subsidized fertilizer, then she may no longer purchase the 2 bags from the trader. In this case, the additional fertilizer use as a result of the program would be only 50% not 100% of the amount supplied, i.e., 2 bags instead of 4. The two bags that she would have purchased from the trader now remain unsold in the trader's shop. This displacement of commercial sales will be low or zero if subsidized fertilizer is sold to households who otherwise would not have access to fertilizer or could not afford to buy it. Findings from Malawi and Zambia indicate that an additional kg of fertilizer distributed under the subsidy program adds only 0.5 to 0.8 kg to the amount of fertilizer used by farmers (implying a displacement rate of 20-50%), and that crowding out is lower when the subsidy is targeted to relatively poor households than when targeted to non-poor farmers (Dorward et al., 2008; Ricker-Gilbert and Jayne, 2008; Weber, 2008).

- Timely arrival and utilization of the fertilizer by farmers. The fertilizer needs to be in the farmer's hands before the time for application to ensure maximum benefits from the fertilizer. In a study on Fertilizer transport subsidy in Tanzania (MOAFC 2007) it is reported that in almost all regions visited, there was late arrival of subsidized fertilizer—arriving after the farming season had already started. For example in the major maize producing regions (the Southern Highlands), the fertilizer was reported to arrive in December/January at regional centers, and late January/February at farm level.

Contract Farming
This is represented in the publication that has been referred to above. The key messages emanating from the study are as follows:

Key Messages

- Contract farming is an economic arrangement entered into by parties seeking mutual advantage. In some instances these arrangements do serve poor farmers who would not otherwise be able to access remunerative agricultural markets.
- Contract farming appeals to donors and governments because of its potential to link resource-poor smallholder farmers with remunerative, high-value crop markets, and thus to help pull them out of poverty
- However, certain technical, marketing, institutional, policy and legal conditions need to be in place for contract farming to succeed – the 'appeal' factor is not sufficient.
- A commodity that can be produced, processed, sold and purchased virtually by everyone is not amenable to contract farming due to selling and buying on the side.
- Governments and development partners need to think carefully before deciding whether it is socially and economically worthwhile to use tax-payer funds to support contract farming. For example, with a crop like maize, which millions of farmers can produce and which has many buyers, it is virtually impossible to satisfy contract farming conditions.
- Governments should strive to provide a conducive environment (including legal protection and farmer organisation) and to encourage self-regulation by firms and farmer organisations in order for contract farming to perform more efficiently where conditions for it are promising.
- Because interest in contract farming is due largely to poor performance of markets for seasonal credit and inputs, governments need to promote policies and investments to improve the functioning of factor and product markets, as this would eventually reduce the need for contract farming.

Special Project Funding:
This was made possible by funding from—USAID, DfID and Sida

Output target 2008 1.4.2 Website for monitoring agricultural growth trends for southern Africa

Achievement of Output Target (%):
>75% Achieved

Countries Involved:
All the SADC countries are involved in the sense that potentially, they are the data providers

Partners Involved:
IFPRI

Comments/Explanations:
Output Target status 75% achieved. The website for ReSAKSS-SA was launched in July 2008 and is fully operational. The URL is www.sa.resakss.org. The achievement target is 75%.The reason is that we continue to fine tune the format as well as populating it with relevant materials
Progress/Results:
A number of activities were carried out and some publications and dissemination were developed and shared. These are already shown above in output target 1.4.1

Special Project Funding:
This is same as above—USAID, DFID and Sida

Output target 2009 1.4.1 Global economic outlook (supply, demand, trade, prices) report of ICRISAT mandate crops

Intermediate output target in 2008 – data collection and preliminary analysis for the global economic outlook report of ICRISAT's mandate crops initiated

Achievement of Output Target (%):
50% completed. Data collection and preliminary analysis on groundnut, chickpea and pigeon pea data commenced. Consolidation of data its analysis and write up will be undertaken forthwith.

Countries Involved:
Global project

Partners Involved:
ICRISAT

Progress/Results:
The global Situation and Outlook reports help in capturing the broad trends that govern the production, consumption and trade patterns of the ICRISAT mandate crops. They are essential in providing a bird's eye view of the global scenario which document the inter-regional shifts for the crops. The latest data from FAOSTAT indicate that the main growing countries for chickpea are India, Turkey, Pakistan, Iran and Canada which together account for 87% of the global production. For pigeon pea, the main growing countries are India, Myanmar, Kenya, Uganda and Malawi, together accounting for 97% of global pigeon pea production. Groundnut is grown mainly in China, India, Nigeria, United States of America and Indonesia, which together account for 76% of the global production. The largest producers of chickpea, pigeon pea and groundnut are still the developing countries of the world and their share of the global pulse production is largely unchanged at around 70%. However, yield levels and yield growth rates are considerably higher in the developed countries.

Among the growing regions Asia and South Asia in particular, accounts for a significant portion of global production of the three crops --- 89% of chickpea production, 90% for pigeon pea, and 66% of groundnut production.

Production trends in chickpeas, pigeon peas, and groundnuts have followed an increasing trend with the global production doubling from 8.6 million t in 1980 to 16 million t in 2006. Over the period 1980-2006, production of groundnut has increased by 3% per annum, led by growth in acreage and yields in Asia, due to the policies that China introduced to increase its domestic oilseed production. Africa, also contributed significantly to the global growth in groundnut production through area expansion. Growth in the global production of pigeon pea has been the slowest among the three legumes, growing at 1.4% per annum during 1980 to 2006, which can be attributed to an area expansion in India and the export oriented production of the South East Asian countries. Chickpea production grew at 1.48% in the same period, helped by the entry of Canada and Australia.
Trade in groundnut has suffered owing to the aflatoxin contamination and consequent restrictions that were imposed. This led to a greater concentration of its trade within Asia. Chickpea trade has increased to 12% of its production owing to the increased grain consumption demand from India and the entry of Myanmar, Australia and Canada as significant trading countries since the late 80s.

In line with prices of agricultural commodities the real prices of chickpea, pigeonpea and groundnut have decline between 1970 and 2000. However, since 2000 the prices for the three crops as also other agricultural commodities are on the rise. This is reflected in positive growth rates in their real prices between 2000 and 2005. Latest data indicate that the price increase was the sharper between 2007 and 2008. The price rise for agricultural commodities is attributed to a number of factors on the demand and supply side. Droughts, decreases in global stocks, diversion of food crops for biofuel production etc are some of the key factors cited on the supply side. The legume crops under consideration are not very different, and for chickpea and pigeonpea, shortfall in global production and rising import demand from India /south Asia were driving the prices up for these crops. The prices of groundnut oil increased in line with the rise in prices for other oils /oilseeds. Estimates indicate that global nominal prices for groundnut have shown sharp increases of 30% in the period 2005-08. A number of technological, institutional, trade related barriers, post harvest constraints and policy issues act as hurdles to their more efficient production and trading.

Special Project Funding:
For legume crops from Bill & Melinda Gates Foundation

Output target 2011 1.4.1 Regional outlook (supply, demand, trade, prices) reports of ICRISAT mandate crops

Intermediate output target in 2008 – data collection and preliminary analysis for legume crops (groundnut, chickpea and pigeonpea) for Asia regional economic outlook report initiated

Achievement of Output Target (%):
50% completed. Data collection and preliminary analysis on groundnut, chickpea and pigeon pea data concluded. Write up of findings in progress.

Countries/Regions Involved:
India, South and South East Asia

Partners Involved:
ICRISAT; University of Agriculture Sciences, Bangalore; University of Agriculture Sciences; Dharwad; Punjabrao Krishi Vishwavidyalaya (PKVK), Akola; Tamil Nadu Agricultural University, (TNAU) Coimbatore; Acharya NG Ranga Agricultural University, Hyderabad

Progress/Results:
The regional Situation and Outlook report provides a detailed look at the regional and country level trends in the ICRISAT mandate crops. These reports are essential in capturing the intra-regional shifts and changes, and help in identifying specific patterns that might get masked when aggregated at a global level.

Chickpea trends in India: At the all-India level between 1965 and 2004 chickpea production was more or less static while area declined marginally, while yields increased by marginally by close to 1%. However, these historical growth rates at the all-India level mask the dynamic changes taking place in chickpea area and production at a more regional level resulting in a shift in the centre of production away from the traditional chickpea growing areas in northern and north-eastern India to central and peninsular India.

Between 1965-69 (avg.) and 2000-04 (avg.), the chickpea area in the northern and north eastern states of Uttar Pradesh, Bihar, Haryana, Punjab and West Bengal declined from 4.3 million ha to 1.1 million ha while its production fell from 3.1 million t to 1.0 million t. In contrast, there has been expansion in the area under chickpea in the central and peninsular states of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Chhattisgarh, and Maharashtra, from 2.2 million ha to 4.2 million ha and the production from 1.0 to 3.2 million t during the same period.

As a consequence of these shifts in 2004, the semi-arid tropic region contributed 58.2% of total chickpea production in India compared to 18.3% in 1968. The temperate SAT region now accounts for only 29% of the total production compared to 54% in 1968. Despite slower growth in yields, the percentage of districts which recorded yields of over 800 kg/ha increased from 10% in 1966 to 52% in 2003.

Pigeon pea trends in India: The country wide trends of pigeon pea suggest that unlike chickpea and groundnut, the growth in the production over the period 1965-2004 is mainly driven by area expansion while yields have remained static. As in case of chickpea, there have been dynamic changes in pigeon pea area across districts /states within the country with area increasing in a number of districts while at the same time decreasing in several others. Among the major pigeonpea growing states, the relative share of Maharashtra in pigeon pea production has increased the most from 18% in 1970 to 31% in 2004, while that of Uttar Pradesh has declined drastically from 36% to 18% during the same period.

The semi-arid tropics in India have always been the traditional growing region for pigeon pea. With the adoption of short and medium duration varieties that fit in the semi-arid cropping systems, the share of the SAT region to all-India production increased to 70% in 2004 from 50% in the sixties. As a consequence, the relative shares of all other regions- humid, semi arid temperate and arid- have declined.

In 40% of the pigeon pea growing districts in India, the yields are below all-India average yields while they are high (more than 770 kg/ha) in 36% of the districts. In 2004, 40% of the total pigeon pea area was in areas with yields less than 600 kg/ha.

Groundnut trends in India: Groundnut production in India has followed a cyclical and generally upward trend. Despite high fluctuations and stagnant or decreasing area, production in India has grown by more than 1% during 1965-2004 due to yield increases which grew at 1.2% per annum. The trends in the major growing regions are reflective of the national trends. Semi-arid tropics in India continue to be the dominant source of groundnut production, contributing 73% of the country's production in 2004. Due to the yield growth between 1966 and 2004, the percentage of districts with high yields (over 1,050 kg/ha) increased from 6% to 41%, and 53% of groundnut area falls under high yield districts.

Price trends: The prices for chickpea, pigeon pea and groundnut in India rose sharply (more than 40%) between 2005-08. To check the price rise a number of measures are being implemented like duty free imports, export bans etc. Preliminary analysis for chickpea, pigeon pea and groundnut in south Asia suggests that demand is not a constraint as indicated by growth in production, import demand, rising prices, and demand responsiveness to income growth etc. On the contrary, supply of pigeonpea and chickpea are not keeping pace with demand as reflected in growing import demand for these crops. Besides low yields, yield stability is a major issue confronting the 3 legume crops. Large year to year fluctuations in yields (+- 20% or more) are observed at the district level. The potential areas for targeting technology can be identified using the district level arcview maps on area and yield that would help reducing per unit cost of production making these crops competitive at the farm level.

A number of marketing and policy issues related to trade, storage, processing, pricing, etc adversely impact on the production of these crops.

Special Project Funding:
For legume crops from Bill & Melinda Gates Foundation

Intermediate output target in 2008 – data collection and preliminary analysis on groundnut trends and market prospects in WCA regional initiated

Achievement of Output Target (%):
50% completed. Data collection and preliminary analysis on groundnut in progress. Write up of findings in progress.

Countries / Regions Involved:
West and Central Africa

Partners Involved:
INRAN (Niger), IER (Mali), IAR (Nigeria)

Progress/Results:
During the last 4 decades, West Africa has lost its world groundnut production and export shares. Groundnut production shares declined from 23% to 15% whereas export shares decreased from 55% to 20%. China, the leading producer, has significantly increased its shares from 11% to 41%. Argentina, the leading oil exporter, has more than doubled its world share from 12% to 29%. In addition, imports from other oil seeds have significantly increased in West Africa. Soybean and palm oil imports have more than doubled. However, since 1984, groundnut production in West Africa has been increasing by about 6% annually mainly due to area expansion. Senegal and Nigeria remain among the largest world groundnut producers. Groundnut still remains a major source of employment, income and foreign exchange in many West African countries. Therefore there is a need to reassess market prospects and highlights opportunities for West Africa to regain to its market shares.

The competitiveness of west African groundnut in the domestic, regional and international markets has been limited by the low productivity, aflatoxin regulations, and stricter grades and standards. Relative prices of groundnut oils are higher in the international markets making these products less competitive compared to oil palms, cotton oil and others oil fruits. There are market niches for confectionary groundnut. Access to this market would require knowledge of market requirements. To regain its competitiveness, groundnut productivity and production has to increase significantly, technologies to reduce aflatoxin contamination have to be promoted and grades and standards satisfied.

Special Project Funding:
For legume crops from Bill & Melinda Gates Foundation

Output 5: Investment and policy options for increasing agricultural productivity and mitigating climatic related shocks identified and shared with key stakeholders.

Output target 2008 1.5.1 Agricultural input subsidies and contract farming policies to improve agricultural productivity in southern Africa

Achievement of Output Target (%):
Fully Achieved
Countries Involved:
Kenya, Malawi and Zambia for fertilizer subsidies

Comments/Explanations:
These activities are contained in ReSAKSS-SA activities and are explained above under output 4, output target 2008 1.4.1

Progress/Results:
The findings are elucidated under output 4, output target 2008.1.4.1

Special Project Funding:
USAID, DfID and Sida

Output target 2009 1.5.1 Development domains report for southern Africa

[Isaac to provide]

Output target 2010 1.5.1 Policy options for increasing agricultural productivity to mitigate HIV susceptibility

[Isaac/Jannake to provide]

Output target 2010 1.5.2 Constraints, challenges and opportunities for regional cooperation in R&D and alternative regional research and development strategies in southern Africa report

[Isaac to provide]

Output target 2011 1.5.1 Adaptation strategies and layers of resilience to climatic related shocks in Asia

Intermediate output target in 2008 –Project entitled, "Vulnerability to climate change: Adaptation strategies and layers of resilience" operationalised and commenced

Achievement of Output Target (%):
20% completed. The special project although commenced in May, but actual operationalisation took place in July, 2008

Countries Involved:
Bangladesh; China; India; Pakistan, Srilanka; Thailand; Vietnam

Partners Involved:
Central Research Institute for Dryland Agriculture in India; Chinese Academy of Agricultural Sciences in People's Republic of China; Council for Agricultural Research and Policy in Sri Lanka; Centre for Policy Dialogue in Bangladesh; Pakistan Agricultural Research Council in Pakistan; Vietnam Academy of Agricultural Sciences in Vietnam; and Chiangmai Field Crops Research Station, Department of Agriculture in Thailand

Progress/Results:
This project entitled, "Vulnerability to climate change: Adaptation strategies and layers of resilience" aims to provide science-based solutions and pro-poor approaches for adaptation of agricultural systems to climate change for the rural poor and most vulnerable farmers in semi-arid regions of Asia especially of Bangladesh, India, Pakistan, Sri Lanka, The Peoples' Republic of China (PRC), Thailand and Vietnam. The overall objective of the project is to identify and prioritize the sectors most at risk and develop gender equitable agricultural adaptation and mitigation strategies as an integral part of agricultural development in the most vulnerable areas.

The focus of the project is on ground level realities linked or integrated with macro level factors to evolve adaptation strategies that will address the issues of vulnerability in the most vulnerable sites of semi-arid tropics (SAT) and develop various layers of resilience. The expected outputs from the project are:

- Improved understanding of climate variability and adaptation-coping strategies of the rural poor in SAT region
- Best practices and institutional innovations for mitigating the effects of climate change
- Strategies to address socioeconomic problems relating to changing weather patterns and availability of a range of initiatives for their alleviation

ICRISAT with support from the Asian Development Bank (ADB) organized a 3-day Project Inception Workshop on 7-9 May 2008, at ICRISAT, Patancheru, Andhra Pradesh, India. The 3-day workshop program was interspersed with presentations, group discussions and development of work schedules and timeline. All the presentations flagged pointers to stimulate discussions on the conceptual, methodological and other technical issues related to vulnerability to climate change and development of adaptation strategies. The deliberations concluded that this social engineering project will build the knowledge and capacity, and will serve as a platform for other projects looking at climate change.

A harmonized project implementation plans were drafted integrating the seven Asian countries based on the participating countries presentations of work plans and further discussion based on guidelines presented by ICRISAT and desired by ADB. The importance of the training component for this project was reiterated / emphasized by all participating developing member countries (DMCs). This critical need was recognized also by the participating officials from ADB. A discussion was held on the nature of the required methodologies covering vulnerability mapping and social indexing, baseline survey design and implementation, bio-economic modeling, crop modeling, water balance models socioeconomic and econometric models. Later, a concept note for Small Grants strengthening the training and capacity building component of the project which was identified as a critical gap for NARS partners in the countries implementing the project was developed and submitted to ADB.

Flagging off of the project commenced with signing of Memorandum of Agreements (MoA) between ICRISAT and other participating member countries. The disbursal of funds is underway. As an exemplar to other partner countries, the macro level climatic data analysis especially of rainfall for two states of Semi-Arid Tropics was initiated namely, Andhra Pradesh and Maharashtra in India. The meteorological sub-division wise rainfall was analyzed categorizing into various sub rainfall periods. Further, Rainfall pattern in districts namely Mehboobnagar and Anantpur in Andhra Pradesh and Sholapur and Akola in Mahrashtra was analysed for the period 1971-2007. The report on rainfall pattern in Semi-Arid Tropics (SAT) is underway. The survey instrument to analyse the various adaptive strategies is under pre-testing in Maharashtra villages. The semi-annual progress report of the project for the period (May-October, 2008) is submitted to ADB. Outputs in 2008 include: a) Seminar on "Vulnerability to climate change: Adaptation strategies and layers of resilience" (Delivered at ADB Manila, Jan 2008); b) ADB project inception workshop report; c) A draft report on vulnerability and adaptation strategies: Framework and review of country studies in Asia and Africa; d) An outline of the review of literature on economic perspectives on climate change; e) partner country reports during inception workshop and f) invited lecture entitled, “Addressing climate change vulnerability through adaptation strategies and layers of resilience”, Model Training Course on “Impact of Climate Change on Rainfed agriculture system and adaptation Strategies”, at Central Research Institute for the Dryland Agriculture (CRIDA), Hyderabad.

Special Project Funding:
Asian Development Bank (ADB)
In kind contributions from partner organizations.

Intermediate output target in 2008 –A report focusing on **Rural poverty, common property resources and land degradation.**

Achievement of Output Target (%):
100%. The thesis is completed and submitted to San Fransisco University as a requirement for the Master’s degree

Countries Involved:
India
Partners Involved:
San Francisco University : Emily Leon
ICRISAT : KPC Rao, MCS Bantilan

Progress/Results:
Forests and common property resources in India: Aurepalle case study.
In the face of rapid industrialization, endemic poverty and population pressure, India faces a balancing act between economic development and environmental conservation, goals that are rarely compatible in the short run. The government of India has a goal of reaching 33% forest cover by 2012.

Aurepalle is a rural village in the Mahbubnagar District of Andhra Pradesh, about 70 km south of Hyderabad, it is within India’s semi-arid tropical region and like much of this region, rain-fed agriculture is the primary source of income. Livelihood, therefore, is extremely vulnerable to variability in the annual monsoon. In many ways the green revolution bypassed this climatic region. New varieties of high yielding crops could not necessarily be cultivated so extensive agriculture was needed to support growth. As land became increasingly scarce more marginal land was cultivated. Today, no forest cover can be found in Aurepalle. Discussions with locals reveal that much of the land at the base of the hills was once forest area that provided many important common property resources to the local people.

In Aurepalle, privatization and land reform provided incentives to irrigate and cultivate any fertile land; this increased output and income and improved food security over the last 30 years. Landless labor was once heavily dependent on common land, now they are land owners themselves or have left the village. While common land is no longer a productive available resource, there are new opportunities and welfare has improved as the commons have disappeared.

The story in Aurepalle initially appears to be a win for poverty alleviation and loss for the environment. Extensive and intensive agriculture have grown and increased food security and incomes. However, extensive agriculture appears to have reached its limit, as only the most marginal and unproductive land remains uncultivated. Today, the locals do not complain about the loss of common land because they are now almost all land owners. They complain about a labor shortage.

Has privatization benefited Aurepalle’s most marginal groups by making them land owners? The change that has occurred in this village appears to have increased equality. But simultaneous changes in the economic situation may mask the truth. If privatization was inequitable, those who did not benefit may have chosen to leave in search of better opportunity. Further analysis of data collected in Aurepalle will shed light on the relationship between rural poverty and environmental degradation. The relationship has drastically changed in recent years as extensive agriculture reaches its limit and market forces bring new opportunities.

Special Project Funding:
USAID - US-University Linkage Program

Intermediate output target in 2008 – A review of sociological literature on assessment and analysis of past and present adaptation practices by the poor for mitigating the effects of climate change initiated

Achievement of Output Target (%):
25%. A review of sociological literature on assessment and analysis of past and present adaptation practices and strategies by the poor and vulnerable was initiated in October 2008 and is underway, scheduled for completion in early 2009. This work falls under Output 2 of the ADB funded project entitled, “Vulnerability to climate change – adaptation strategies and layers of resilience.”

Countries Involved:
This is a desk study and is global in nature but emphasis is on South Asian countries namely India, Bangladesh, Pakistan, Sri Lanka, China, Thailand and Vietnam

Partners Involved:
Indian Institute of Technology-Bombay : D Parthasarathy
ICRISAT : MCS Bantilan, NP Singh, R Padmaja

Progress/Results:
The document based on a review of literature will focus on understanding the issues facing socially vulnerable communities in the context of climate change. It will focus on strategies for climate change adaptation and mitigation that rural communities can use in addressing climate change. The framework of the study will focus on issues around poverty, capacity of the populations at risk, and how to assist vulnerable populations in coping as well as mitigating the effects of climate change. Aside from highlighting the lessons learned from past experience relating to climate change, it will also discuss current research on climate change and social vulnerability.

The objective of this document is to outline a conceptual model of vulnerability to climate change as the first step in appraising and understanding the social and economic processes which facilitate and constrain adaptation. By vulnerability, we mean the state of individuals, groups, communities, of their ability to cope with and adapt to any external stress placed on their livelihoods and well-being. This approach puts the social and economic well-being of society at the centre of the analysis. The vulnerability of any individual or group is determined by the availability of resources and, crucially, by the entitlement of individuals and groups to have access to these resources. This perspective extends the concept of entitlements developed within neoclassical and institutional economics. Within this conceptual framework, vulnerability can be seen as a socially-constructed phenomenon influenced by institutional and economic dynamics. It is argued (Adger, 2005) that the socio-economic and biophysical processes that determine vulnerability are manifest at the local, national, regional and global level but that the state of vulnerability itself is associated with a specific population.

Supporting policies and infrastructure required for large-scale adoption by the farmers will also be assessed in this desk study which is scheduled to be completed in 2009.

Alongside the desk study, qualitative assessments and social analysis using tools (eg PRAs, wealth ranking, social mapping, case histories, venn diagrams, etc) are being planned to elicit and document best practices and strategies in adapting to climate change including mapping institutional arrangements. The objective of this qualitative field research is to enrich the quantitative panel data by qualitatively tracking of rural poverty and vulnerability; get an in-depth understanding of the dynamics of the village, understanding shocks and their responses by various groups in the study villages. The set of activities in each village include:

- Village profiles to understand the changes in village, identify pockets of poverty and resource endowments of the people
- Time lines to gain an understanding of the evolution of the village and various negative and positive events that has shaped the village.
- Tracking life histories of selected households to understand their moving in and out poverty
- Identify wealth and well – being, use formal and non formal interventions, impact of shocks especially droughts on the different sections of the community

Based on the results of the analysis, suitable strategies will be developed to identify the role of social institutions in adaptation processes, and mechanisms to mitigate the effects of climate change. The findings will help identify not only who are most vulnerable (in terms of extent as well as magnitude) to climate change and its effects but also who can adapt to climate change and how. This learning will help identify the characteristics as well the relationships and institutional access people have to deal with the external shocks.

Special Project Funding:
Asian Development Bank (ADB)

Output 6: Strategies for increasing competitiveness through identifying preferred market traits and introducing quality control systems to meet social, food safety and environmental standards for dryland crops established and promoted

Priority 5B: Making international and domestic markets work for the poor

Priority 5B, Specific goal 1: Enhanced livelihoods and competitiveness for smallholder producers and food safety for consumers influenced by changes in national and international markets

Priority 5B Specific goal 2: Improved marketing environment for smallholders by improving the efficiency of domestic markets

Output target 2008 1.6.1 The role of existing grading and quality control systems in selected legume, livestock and cereal marketing systems identified
Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Kenya

Partners Involved:
University of Nairobi, Kenya Agricultural Research Institute, TechnoServe

Progress/Results:
Research report on "Role of grades and standards in pigeonpea markets in Kenya" published. There are no established quality grades and standards for pigeonpea in Kenya. Quality is therefore subjectively measured by physical inspection. This makes it difficult to describe and compare with precision the quality supplied by different traders/market participants. The market for pigeonpea is mainly characterized by fair, average quality (FAQ) grain with the major quality parameters considered being grain insect damage, foreign matter, moisture content, grain color, and size. However, as the grain moves through the different market participants in the supply chain, each agent tries to improve its quality on the basis of the above physical attributes. Due to lack of standardized quality grades, there is no visible price differentiation based on quality. Those with a superior quality product have only the advantage of being able to sell their product faster. For more commercialized agents like the processors/exporters who possess cleaning equipment, foreign matter is not a major consideration when procuring the grain because they routinely clean the purchased grain before processing. Therefore the most underlining factor, once FAQ standards are met, is the grain price. Indeed, a recent study found that farm-gate grain prices do not depend on quality aspects. Some buyers prefer particular seed sizes of pigeonpea. Most processors prefer large grains because they yield more (70% of the original weight) when milled into *dhal*. However, local processors do not pay a price premium for large grains. The absence of price discrimination based on grain quality has reduced incentives for farmers to produce and market quality grain. This is a major challenge for targeting high-value markets (such as Europe and North America) that require differentiated and quality products.

Special Project Funding:
IFAD Treasure Legumes Project (2007-2010)
Lucrative Legumes (USDA) 2006-2007

Output target 2009 1.6.1 Preferred market traits identified for selected tradable legumes in three regions (ESA, WCA and Asia), livestock (in southern Africa) and dryland cereals in WCA region

Intermediate output target in 2008 – Data collection on preferred market traits completed for India.
Achievement of Output Target (%):
50%. Data collection has been completed and data analysis is underway.

Countries Involved:
India

Partners Involved:
ICRISAT
University of Agriculture Sciences, Bangalore
University of Agriculture Sciences, Dharwad
Punjabrao Krishi Vishwavidyalaya (PKVK), Akola
Tamil Nadu Agricultural University, (TNAU) Coimbatore
Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad

Progress/Results:
Preliminary results from the first set of validated data from baseline and market surveys provide insights on the distinct preferences of key players along the market value chain - farmers, commission agents, traders, processors, exporters/importers, retailers and consumers. The illustrative pattern is a useful tool in drawing attention on the critical value of users' preferences and the importance of a Coalition Approach involving key actors throughout the value chain in technology development and adoption. In this case, research objectives may need to be reevaluated to reflect the relevance of critical factors in addition to traditional research objectives.

Preferred market traits for chickpea in Karnataka were identified and prioritized. As regards marketing traits, the order of preference by the farmers was high demand (that is, variety with traits preferred by traders, processors and consumers), fetching higher price, low price fluctuations and bigger grain size. Annigeri variety completely matches this observation. For Kabuli variety, high demand and low price fluctuations were the most preferred ones, in that order, in both the districts.

In general, across districts and areas (adopted and control), high yielding variety was the most desired trait in a new chickpea cultivar as expressed by 93.33% of farmers, followed by pest and disease resistance (47.04%), bigger grain size (11.11%), drought resistance (11.11%), high shelling percentage (2.22%), better taste (1.11%), short duration variety (1.11%), grain colour (0.37%) and high demand in market (0.37%), in that order.

In general, across districts, areas (adopted and controlled) and constraints, the farmers were willing to pay a premium price for the seeds to the extent of 25.23% (ranging from 15 to 50 per cent for various desired traits).

Farm women mainly preferred the cultivars with high market demand (90.74%) for cultivation on their farm. The other preferred traits in the cultivars were low price fluctuation (53.70%), higher price for the crop output (53.33%) and bigger grain size (41.85%).

Pest and disease resistance and high yielding variety were the two most important traits preferred by the farm women, for which they were willing to pay a premium price of 23 to 25 per cent over the existing seed price.

Special Project Funding:
Bill and Melinda Gates Foundation

Intermediate output target in 2008 – Uncovering farmers' preference for traits: the case of groundnut varieties in Western Niger

Achievement of Output Target (%):
100%

Countries Involved:
Niger
Partners Involved:
INRAN and PDRI

Progress/Results:
Farmer participatory variety trials were implemented in 3 villages of Western Niger using a mother and baby trial approach to assess household preferences for plant and seed traits on 5 groundnut varieties. Using a random utility based choice experiment, data were collected through a structured survey administered on 47 farmers. Median ranking of varieties show that farmers' preferred by order RRB, 55-437, ICGV 9346, Fleur 11 and ICG 96894. Preference for yield trait followed the same patterns as the overall ranking of varieties. However, ICGV 9346 yield significantly more haulm than others varieties. Ordered probit results show that color (red), maturity (short cycle), pod yield and disease pressure (low) are the most important attribute by order of importance.

These characteristics should be accounted for when designing or selecting varieties likely to be preferred by groundnut farmers. Best performing varieties should be the basis of seed multiplication and distribution programs in those areas. This study should be completed with sensory analysis of consumer preferences for major groundnut products such as oil, cakes, butter and edible.

Special Project Funding:
Groundnut Seed Project (GSP) funded by the Common fund for Commodities (CFC)

Output target 2010 1.6.1 Policy options for establishing quality-based agricultural marketing systems for selected legumes, livestock and cereals identified and communicated to policy markers and partners

Intermediate output target in 2008

Achievements: Considering the ban on field work in Zimbabwe, and delays in Mozambique and Namibia, cross country results need to be consolidated, and the output target is achieved at 75%. Descriptive information on existing grading and quality control systems is available for cattle and goat marketing systems, based on secondary information, documentation of IP meetings and baseline reports. A synthesis report covering Namibia, Mozambique and Zimbabwe is in progress. Further details are expected through the Value Chain Analysis.

Output 7: Institutional innovations for reducing transaction costs and improving coordination in input and output market chains for dryland commodities in domestic and international markets identified and promoted

Output target 2008 1.7.1 Performance of existing formal and informal markets for selected dryland commodities (legumes and ruminants) and inputs (seed, feed, fodder and services) understood and documented

Achievement of Output Target (%):
>75% Achieved

Countries Involved:
Kenya, Zimbabwe, Mozambique, Namibia

Partners Involved:
University of Nairobi, Kenya Agricultural Research Institute, TechnoServe

Comments/Explanations:
Fully Achieved for Kenya; 75% for Zimbabwe, considering the ban on field work in Zimbabwe

Progress/Results:
Analysis of pigoenpea value chains and collective marketing options in Kenya completed The pigeonpea marketing system in Kenya involves many intermediaries. These intermediaries convey the product, usually with minimal value addition (e.g. cleaning). While wholesale prices are generally high, farm-gate prices remain quite low and less competitive. Smallholder farmers produce only small surplus for markets, which is typically sold at the farm gate to rural grain assemblers often soon after harvest when prices are very low. Farmers face high transaction costs in marketing their small produce. Reorganizing this system by helping farmers develop viable marketing groups can reduce transaction costs and enable farmers to take advantage of economies of scale by consolidating buying and selling activities. Such farmer groups can also use forward marketing contracts to sell their products hence allowing access to reliable markets. This will require strengthening the capacity of the already existing farmer groups through training in group dynamics; management, analyses, and utilization of market information; and running the groups as viable business entities. Where farmer groups do not exist, farmers should be trained in group formation, collective marketing, and agribusiness skills. Group marketing also benefits traders/processors since large volumes sold by groups reduce average procurement costs. Groups can also serve as entry points for building farmer capacity in introducing grades and standards. Group marketing therefore presents an avenue for increasing the productivity and competitiveness of pigeonpea and an opportunity to exploit international markets for processed pigeonpea. The increased demand for export of processed grain to high-value markets could improve market prices for suppliers at the bottom of the supply chain and create incentives for smallholder farmers to adopt improved and high quality seeds. The above findings are published in *Natural Resources Forum* 32: 25-38

Ruminants value chain and collective marketing: Achievements: Considering the above mentioned delays (see output target 2010 1.6.1), the output is also achieved at 75%. The value chain actors and their activities were identified, and constraints in market processes were analyzed, using IP meeting documentation, and baseline surveys. Cross country comparisons allow further insights on the impact of policy frameworks and other external influences (agro-ecological potential, socio-economic parameters). The identification of institutional innovations and evaluation of market performance is part of the further research and analysis.

Special Project Funding:
IFAD Treasure Legumes Project (2007-2010)
Lucrative Legumes (USDA) 2006-2007

Output target 2009 1.7.1 Innovative arrangements for better coordination of production, access to inputs and services, and output marketing (for selected legumes (ESA), cereals (Asia) and ruminants in ESA) along the value chain for reducing transaction costs identified and communicated

Intermediate output target in 2008 – Innovative arrangements for better coordination, access to inputs and services and output markets for cereals in Asia

Achievement of Output Target:
For cereals in Asia. 75%. The project is now into its fourth year and data pertaining to the latest crop season are being collected currently.

Countries Involved:
India, China, Thailand

Partners Involved:
ICRISAT, Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad; Marthwada Agricultural University (MAU), Parbhani; Andhra Pradesh Federation of Farmers Association (APFFA), Hyderabad; Krishi Vigyan Kendra (KVK), Beed, JK Agri-Genetics, Hyderabad; Janaki Feeds, Hyderabad. China: Liaoning Academy of Agricultural Sciences, Shenyang, and local partners. Thailand: Field Crops Research Institute (FCRI), Bangkok and local partners.

Progress/Results:
ICRISAT along with the participation of the local partners are currently implementing a project on "Enhanced utilization of Sorghum & Pearl millet grains in the Poultry feed industry to improve livelihoods of small-scale farmers in Asia" funded by the CFC in India, Thailand and China. A new concept of "Bulk marketing" was evolved and implemented through the project. It involves the complete surpassing of all the intermediaries of the traditional supply chain and the direct sale of produce from the farmers to the industrial consumers such as poultry feed manufacturers, poultry farmers (who have in-house feed manufacturing), breweries, distilleries and mushroom farms.

The back end linkages such as those with credit institutions and input providers have proven to reduce supply uncertainty and have led to a wide spread adoption of high yielding varieties by the project farmers. This effect was more prominent in India with 80% of the project farmers using hybrids and high yielding varieties. Consequently yields have increased by close to 100% for pearl millet in Andhra Pradesh clusters and by 20-70% for sorghum in both Andhra Pradesh and Maharashtra clusters. In China where the yields are already high this effect was less marked, but the project farmers consistently recorded a higher yield than the baseline. The output linkages that were established under the project show the most promise. The marketing costs to the farmers were reduced by Rs. 45/kg on average in India and 0.015 USD/kg in China in 2007. In addition to the decrease in marketing costs, the linkages with the private industry have opened new channels of demand for sorghum and pearl millet for fodder and industrial uses that the farmers were unable to tap into earlier.

Special Project Funding:
Common fund for Commodities
In-kind support from partner organizations

Output 8: Policies and strategies that enhance agricultural diversification into high value products (e.g., legumes, livestock, biofuels, vegetables, etc) to harness emerging demand opportunities and facilitate agribusiness enterprises developed and promoted

Output target 2009 1.8.1 Research report on economic feasibility of diversification using legumes and livestock (ESA) completed

Intermediate output target in 2008 – Baseline data collection completed

Achievement of Output Target (%):
75%.

Countries Involved:
Zimbabwe

Progress/Results:
Considering the above mentioned delays (see output target 2010 1.6.1), the output is also achieved at 75%. Baseline information is collected; a deeper policy analysis and economic evaluation are outstanding.

Output target 2010 1.8.1 Research report on economic feasibility of diversification into high value products with emphasis on biofuels (ESA, Asia) and vegetables (WCA) completed

Intermediate output target in 2008 – Data collection and analysis completed for one season

Achievement of Output Target (%):
Biofuels in Asia. 25%. Data from one crop season was collected and analyzed. More data will be forthcoming from 2-3 crop seasons from all project clusters.
Countries Involved:
India

Partners Involved:
ICRISAT, Patancheru
National Research Center for Sorghum

Progress/Results:
Sweet sorghum, which requires less water than sugarcane and is less costly to produce, is being researched by ICRISAT to be a viable alternate feedstock for bio-ethanol. The use of sweet sorghum will also reduce the food-fuel divide as the non-edible stock is used for the extraction of the fuel-stock. The use of sweet sorghum, which is capable of growing in marginal arid lands, is being promulgated in India, Philippines and Indonesia as a part of the BioPower initiative.

To establish the benchmark, a baseline survey of farmers involved in sweet sorghum production was carried out and the data are being analyzed. This survey would establish monitoring indicators for future impact assessment. Initial findings indicate that farmers are willing to grow sweet sorghum with appropriate linkages with the distillery industry with assured buy back of stalks at mutually agreed upon price, and if they have access to credit for purchase of necessary inputs prior to planting of the crop. Other sample surveys will help to address issues related to the food vs. fuel tradeoff, feed/fodder availability, costs and returns to quantify the profits across soil types, seasons, climatic and irrigation regimes, agronomic practices and resource endowments (socioeconomic strata) of the farmers. The survey would also take into account constraints faced by the farmers in growing and selling sweet sorghum.

Preliminary studies of ICRISAT-Rusni Distillery experience involving large-scale sweet sorghum cultivation in 538 ha in 2007 rainy season by 791 farmers sowing NTJ 2 variety indicated that it is commercially feasible to cultivate and use sweet sorghum for ethanol production. The break-even analysis indicated that farmers should harvest 21.8 t ha^{-1} green stalk yields priced at Rs. 600 t^{-1} (US$14.3). The average yield of sweet sorghum was 19.57 tons per hectare. At this yield, the break-even price worked out to Rs.668 (US$16) per ton. By and large, the crop performance was satisfactory under good soil and rainfall conditions and where the farmers adopted the recommended crop management practices. Presently the profitability of the decentralized crushing unit (cane crushed in the village itself) that was operationalized this year is being evaluated. The profitability of growing sweet sorghum in 2008 rainy season is also being investigated.

Special Project Funding:
National Agricultural Innovation Project (NAIP)

Output 9: Alternative institutional innovations to strengthen rural institutions that facilitate and enhance adoption of technological and market innovations and policy recommendations developed and shared with partners.

Priority 5C, Specific goal 1: Identify mechanisms for the strengthening of producers organizations and for modes of participatory research

Priority 5C, Specific goal 2: Identify new forms of partnerships with NARS, the private sector, public extension agencies, NGOs and producers organizations, and public agencies from other sectors, such as environment and health to enhance the conduct and impact from agricultural research

Output target 2010 1.9.1 PhD dissertation on 'Evolution and returns to social networks (formal and informal) with focus on gender and technological innovations' in India

Intermediate output target in 2008 – Understanding village dynamics and social relationships: methodological advancements finalized and implementation underway

Achievement of Output Target (%):
50% completed. Pilot testing of the draft questionnaire to capture social relationships and village dynamics completed. The finalized instrument is being implemented in all the six VLS villages. Training for resident investigators was also undertaken for this activity.

Countries Involved:
India

Partners Involved:

Indian Institute of Technology-Bombay	: D Parthasarathy, Rowena Robinson, KR Narayanan
Expert consultants	: Mark Rosenzweig, Hans Binswanger
ICRISAT	: MCS Bantilan, R Padmaja

Progress/Results:
The methodology for understanding village dynamics and social relationships and networks is completed as an intermediary output target in 2008. The methodology for the study is briefly outlined below.

The study of social networks is well established in sociological research, spearheaded in contemporary American sociology by Wellman (19990, Fishcer (1992) and Granovetter (1985). In spite of these advances, there is still scope to expand the network-based perspective to the analysis of the entire social structure, in accordance with current trends of social evolution. This implies incorporating many social processes and institutions as expressions of networks while analyzing social networks.

In the past twenty years many sociologists have worked to expand network concepts into a structural formulation. Greatly increasing the scope of and claims of network analysis, they seek to treat all social structures as social networks. The diversity of contemporary research is a result of sociologists linking network concepts with a variety of technical and substantive concerns. These include the works of : Simmel (1971) with an emphasis on the pattern of ties affecting social behavior, Freeman (1979), who used a sociometrically based desire to measure network properties quantitatively; an epidemiological and communications interest in resource diffusion process (Coleman, Katz and Menzel, 1966; Rogers 1979); and a contemporary bent in mathematical reasoning (White 1965; Lorrain and White 1971). Steeped in quantitative traditions, many sociologists have sought to describe the structure of network as precisely as possible. While some researches analyze whole networks – all the ties of a certain kind among all the members of a population – to study the underlying structural patterns of links between large groups such as corporations (Levine, 1972; Berkowitz, 1982), others analyze personal networks – to study how the composition, content and configuration of ties affect the flow of resources to focal individuals (Gottlieb, 1981; Wellman, 1981a). By and large, many scholars have been concerned with the effects of network properties on the integration of large-scale social systems.

The application of these methods in real world situations is seen in studies analyzing social networks from different perspectives. A few approaches are cited here which form the basis for the proposed methodology for field work in 2008. Paulo and Barrett (2006) used an approach quite similar to the one suggested by Granovetter (1973) in sampling social networks and studying them. Individuals who are part of a random sample are randomly matched with other individuals from the same sample and asked about their willingness to establish a link with the random match. A similar approach was used by Goldstein and Udry (1999) also. Using original data on real social relations, Paulo and Barrett (2006) demonstrate that these data prove statistically equivalent to data on the same respondents' actual social networks.

Another approach cited in the literature is to identify survey respondents' actual networks by the set of links existing within a random sample of the relevant population. An alternative approach is to randomly select some individuals and use respondent-driven sampling, augmenting the random sample with the individuals belonging to the social networks of the initial (randomly selected) respondents. This provides a reliable characterization of the respondents' networks, although at the cost that inference about the (typically more interesting) characteristics of the population is possible only under certain circumstances (analyzed, for example, in Heckathorn (2002). and would require, in any case, additional sampling waves such that the bias due to the non-random generation of each wave after the first is finally eliminated

Based on the above review and expert consultations with Drs Hans Binswanger and Mark Rosenzweig it was decided that a village census will be done to capture village dynamics and social relationships both within and outside the villages. The village census instrument used in the census rounds until 2007 was examined in detail. The VLS census instrument covered vital statistics on demographic, landholding and asset details of the entire population of the village. It was strongly recommended by the experts that the 2007 census be methodologically enhanced to capture village dynamics. Inclusion of key variables measuring relationships, key transactions and networks among individuals/households in the village was recommended to augment the recently completed 2007 census. The instrument was finalized after the initial pilot testing by research team.

Special Project Funding:
Bill and Melinda Gates Foundation
DGs Fund for Impact Assessment namely social impact assessment

Output target 2011 1.9.1 Policy report on impact of rainfall insurance and recapitalization of cooperatives in India

Intermediate output target in 2008 – Baseline surveys completed in Andhra Pradesh and Orissa, India

Achievement of Output Target (%):
25%.We have completed the baseline survey in 2004 with 1050 respondents from 37 villages in Mahabubnagar and Anantapur districts of Andhra Pradesh. A marketing survey was conducted in 2006 to assess the value of education about the relationship between quantum of rainfall and depth of moist zone in different types of soils. A follow-up survey was implemented in 2006. It was planned to have randomized interventions with sub-samples of the respondents during 2008 but this experiment was deferred to 2009 by the World Bank to have sufficient time for planning the experiments. The second follow up survey of rainfall insurance will be implemented during 2009-10. In case of the study which aimed to assess the impact of recapitalization of cooperatives in India, we have carried out baseline surveys of 2160 farmers from 72 villages drawn from six districts of Andhra Pradesh and Orissa.

Countries Involved:
Rainfall Insurance survey project: Mahabubnagar and Anantapur districts of Andhra Pradesh, India
Recapitalization of cooperatives in India: Mahabubnagar, Anantapur and Vizianagaram districts of Andhra Pradesh and Ganjam, Bolangir and Puri districts of Orissa.

Partners Involved:
Rainfall Insurance survey project**:** ICRISAT: KPC Rao ; World Bank, Washington D.C: Xavier Gine
Recapitalization of cooperatives in India**:** ICRISAT: KPC Rao; World Bank, Washington D.C: Xavier Gine and Tara Viswanath

Progress/Results:
Rainfall Insurance survey project: It was found that the purchase of rainfall insurance did not bring about any substantial change in the risk taking behavior of the farmers. It was because of a very limited coverage of risk as the farmers bought only one unit of insurance because of high premium and because of lack of subsidy. The competing crop loan insurance scheme provided subsidies on the premiums as well as in the payment of indemnities. Through the scheme of randomized interventions, the World Bank proposes to estimate the degree of coverage required to bring about a change in the decision making behavior of the farmers. It was also found that the premiums were loaded heavily because of the high administrative costs and turned less interesting to the buyers of rainfall insurance.

Recapitalization of cooperatives in India: The baseline surveys were completed in three districts of A.P namely Mahabubnagar, Anantapur and Vizianagarm in April, 2008. We have drawn a sample of 1080 Households (360 per district) from 108 villages (36 per district) and 72 Primary Agricultural Cooperatives at the rate of 24 per district. Out of the 24 PACs per district, 5 PACs which had a recovery rate of just above 50% and 7 PACs which had recovery rates just below 50% were selected. Another 7 PACs had recovery rates just above 30% and the remaining 5 PACs had recovery rates below 30% were also selected as per the special audit conducted in 2004. One village was chosen for the study in case of PACs with smaller operational area. Two villages were included in the study when the selected PACs had larger operational area. From each village, eight households (PACs president and seven active borrowers from the PACs) and two non-PACs members were interviewed. The data entry as well as cleaning of the datasets was completed in June, 2008 and the datasets were sent to the World Bank. It was found that most of the PACs were operating with huge losses and were waiting for recapitalization amounts. Most of the farmers did not have access to credit due to their indebtedness and outstanding dues. In the trust game played with the sample farmers, about 30% farmers came back to return the excess amounts paid to them.

Similarly, the baseline surveys in Orissa were completed in July with the same sampling strategy followed in A.P. We have completed the data entry and cleaning of datasets by the end of October, 2008. As per the TOR, the datasets were delivered to the World Bank. At present, we are carrying out the preliminary analysis of data from both the states.

Special Project Funding:
The World Bank

Output target 2008 1.10.1 Panel dataset on village and household economies in West- Africa (2004-2006) fully documented

Achievement of Output Target (100%):
Fully Achieved

Countries Involved:
Niger

Partners Involved:
INRAN (Niger)

Progress/results:
Data was collected on 12 modules including (1) Socio-economic characteristics of Households, (2) Household transactions, (3) Input/output data , (4) Production stocks and flows, (5) Agricultural equipment use, (6) Land cultivated, (7) Migration (8) Credit (9) Livestock stock and flows (10) Affiliation to Associations, institutions and development projects , (11) Wealth proxies and (12) Major household risks.

Output target 2008 1.10.2 Report on rural livelihoods in the context of relief programs in Zimbabwe completed

Achievement of Output Target (%):
>75% Achieved

Countries Involved:
Zimbabwe

Partners Involved:
Non-Governmental Organizations funded by the DFID's Protracted Relief Program (PRP): Save the Children (UK), CAFOD, CRS, CARE, WVI and Oxfam GB

Comments/Explanations:
75% achieved. Study succeeded in carrying a sample survey of farmers trained in microdosing and adoption trends of the technology. However there are still concerns on the timing of training, as this is commonly implemented at the period of relief fertilizer delivery.

Progress/Results:
Farmer Knowledge and Adoption of Fertilizer Microdosing Technology in Zimbabwe: The relief program has been the main source of fertilizer as accessibility and affordability of this input in alternative markets remains a challenge to the farmers. The majority of farmers in Zimbabwe's semi-arid areas had limited experience with fertilizer use before 2000. With the onset of agricultural relief programs, fertilizer deliveries were followed up by training, during which NGO government extension staff explained to farmers the microdosing recommendations. Based on study results, farmers are now generally aware of the concept of reduced fertilizer applications through the microdosing concept. Farmers' knowledge is nevertheless limited and constrained by the timing of microdosing training and the extent of coverage. Farmers were commonly trained well before the timing of fertilizer top dressing; raising concerns on whether farmers would still remember the training by the time they apply the fertilizer. In some instances, farmers were trained in previous seasons and no follow up training was done to refresh their knowledge for the current season. In some areas, these training materials, including posters and pamphlets, were distributed only to a limited number of farmers. Farmers highlight some challenges associated with fertilizer use such as methods and timing of application, and tools associated with microdosing. Improved linkages between research and extension are important in identifying and resolving some challenges with the microdosing technology. Improvements in relief program efficiency through timely input deliveries and greater involvement of the markets will facilitate access to fertilizer, even in remote locations.

Special Project Funding:
DFID, The Protracted Relief Program (PRP I)

Output target 2009 1.10.1 Database and documentation of 'Changes in household economies on SAT Asia' based on the panel data from 1975-2007 completed; VLS webpage developed
Intermediate output target in 2008 – Data collection and documentation completed. Analysis underway

Achievement of Output Target (%):
75%. Data collection for the cropping year 2008-09 is in progress in all the six villages.The analysis of data for the cropping year 2007-08 is in progress.

Countries Involved:
Canada; India; UK; USA

Partners Involved:
ICRISAT: KPC Rao
USA: Mark Rosenzweig of Yale University and Chris Barrett of Cornell University
U.K: Stefan Dercon of Oxford University
Canada: Harry Cummings of University of Guelph

Progress/Results:
Bi-annual surveys were conducted to collect data from all the six VLS villages during the cropping year 2007-08. Data collection for the cropping year 2008-09 is in progress in all the six villages. About one half of the sample is being tracked through high frequency rounds. One-fourth of the sample is being interviewed through bi-annual surveys while the remaining one-fourth of the sample households will be interviewed at the end of the cropping year 2008-09. The data entry for the 2007-08 seasons is completed and the data pertaining to endowments of resources as on 1st July, 2008 is being entered. We have completed the analysis of data up to the cropping year of 2006-07. The results up to 2005-06 cropping year were presented at the VLS-Canadian Universities Linkage Workshop held at the University of Guelph, Canada during 13-14 November, 2008. The analysis of data for the cropping year 2007-08 is in progress.

The documentation of the panel data was completed up to the cropping year 2006-07 and the same for the later years is in progress. We are in the process of development of building blocks for VLS webpage development. We have uploaded the entire VLS data up to 2005-06 to the test-site.

The research bulletin published in 2008 entitled, "Changes in agriculture and village economies" documents the salient findings from the comparative study of VLS samples during 1975-84 and 2001-06. A summary is presented below.

Only a little more than one-half of households consider agriculture as the main occupation in 2001-06 as against more than three-fourths of households in 1975-78. During favorable agricultural years, a higher proportion of farmers get more than 50 per cent of their income from agriculture. Over the years, the occupational distribution is getting more diversified. Drastic reduction in the proportion of area under food grains. More pronounced in case of mixed crops than in case of sole crops Higher degree of market orientation even in case of food crops In about one-third of the plots, even variable costs were not recovered. While all the costs were covered in case of less than one-third plots, fixed costs were not recovered in more than one-third of the plots When the concept of returns to land and management was used, profits were made only in case of those with irrigation coverage.

Only about one-third of the sample households belong to non-poor category. 7.6 per cent of them are mired in chronic poverty, the remaining 58.5 per cent of the households move up and down the poverty line based on seasonal conditions and opportunities in non-agricultural sector. The incidence of poverty decreased with the increase in size of holding. 63 per cent of the large farm households and 44 per cent of medium farm households belong to never poor category. 13.4 per cent of labor households and 9.3 per cent of small farm households are trapped in chronic poverty. The average family size which was 5.9 in 1975-78 has declined to about 5.0 in 2005-06. The only exception is Dokur where it increased. It is the smallest at 4.6 in Aurepalle and Kinkheda and highest at 5.5 in Dokur. Nuclear families are increasingly replacing the joint families. The family size increased with the size of holding. Nuclear families are more common in case of labor households while joint families are still dominant in large farm households. Literacy rates improved substantially for both males and females between 1975-76 (22 to 35%) and 2005-06 (46 to 80%). Literacy rates are much higher in Maharashtra villages than in Andhra Pradesh villages. Still, a gender gap exists with the women having lower literacy rates than men. However, the gender gap is closing in case of younger groups, particularly in Maharashtra villages. Small farm size group has the highest literacy rate, while labor group has the lowest literacy rate. Medium and large farm households have literacy rates ranging between them

Asset values are lower in Andhra Pradesh villages than in Maharashtra villages. Kanzara has the highest average value of assets while Dokur reported lowest value of assets per household. The value of assets per household increased with the size of holding. A gradual increase of asset values noted in case of all size groups over the five years period. Overall reduction in the number of livestock owned in all the villages, particularly in case of bullocks due to tractorization. More small ruminants are in A.P villages and more milch animals are in Maharashtra villages. Substantial increase in value of assets in all the villages. Land value accounted for about three fourths of assets in Maharashtra villages while the asset structure was more diversified in A.P villages. Higher asset values in Maharashtra villages than in A.P villages

Households are net borrowers in all villages, except Kinkheda. Dependence on non-institutional sources of credit more in A.P villages while institutional sources provided more credit in Maharashtra villages. The net household income was the lowest during the drought year of 2002-03. It was negative in Kanzara, which has the highest agricultural potential. In general, an increasing trend was noted over the years. Shirapur had the highest net household income while Kanzara had the lowest income in 2005-06. The dominance of non-farm income is conspicuous in all the villages. Kinkheda is at the top in terms of crop income, while Shirapur dominates others in livestock income. In general, the net household income increased with the increase in size of holding. In bad agricultural years like 2002-03, there is hardly any difference in the income levels of different categories of households. The net household income has more than doubled in Kalman, Shirapur and Aurepalle over the three decades period. The lowest growth was noted in Kanzara. Due to a reduction in the family size, the growth in per capita income was much higher than that in household income, except for Dokur. The per capita income of sample households in 2001-06 was only $ 170 per year, which is only $ 0.47 per day per person The shares of crops and farm labor earnings in the net household income declined drastically between 1975-78 and 2001-06. The share of livestock in the total income increased in all the villages except Aurepalle and Kinkheda. Non-farm income emerged as the most important source of income in all the villages, particularly conspicuous in the two Solapur villages. Migration and caste occupations are also contributing increasing shares to household income.

Consumer expenditure dipped during the drought year of 2002-03. It is fairly stable from 2003-04 onwards. In 2005-06, Kalman reported the highest consumer expenditure per household in 2005-06, while Dokur registered the lowest consumer expenditure. The average expenditure per household amounted to $ 766 per household per year. The average consumption expenditure per capita in 2005-06 was only $ 0.41 per day.

There is a declining trend in the expenditure on food grains, while there is an increasing trend in the expenditure on other foods. The share of expenditure on total food declined slightly, while that on non-food items showed some improvement. The consumer expenditure increased with the size of holding. It received a setback in the drought year, 2002-03 in case of all the size groups. For the medium and large farm households, highest expenditure was noted in 2003-04, while labor and small farm households achieved highest level of consumption in 2005-06 and 2001-02 respectively. Obviously, the livelihood opportunities for different categories of households fluctuate between years. Dokur and Shirapur villages reported lower levels of energy in take when compared with the other four villages. Maharashtra villages had higher levels of protein in take than the two Andhra Pradesh villages. The consumption levels touched low levels during the drought year, 2002-03. The calorie intake generally increased with the increase in the size of holding, with the exception of 2004-05. Protein intake is slightly better in medium and large farm households. The short fall in calorie availability was more than that in protein availability during 2001-02, 2003-04 and 2004-05. Their incidence was about the same in 2005-06. The protein deficiency was more severe than calorie deficiency only in the drought year of 2002-03.

Migration has emerged as an important source of income, particularly to the poorer households. Migration became an important strategy in Dokur which is facing persistent droughts. It is also an important source of income in Kanzara, Shirapur and Aurepalle.The benefits received from government programs were the highest in Kalman. On an average, a household received Rs.12058 during 1985-2004 from the government programs

Special Project Funding:
The World Bank
Bill and Melinda Gates Foundation

Intermediate output target for 2008 - Analyzing dietary diversity of agrarian households and their female members in rural south India – a case study of four villages

Achievement of Output Target (%):
100% completed. The thesis is completed and submitted to Cornell University as a requirement for the Master’s degree

Countries Involved:
India

Partners Involved:
Cornell University : Deeptha Chittoor Umapathy, Per Pinstrup Anderson
ICRISAT : MCS Bantilan, R Padmaja

Progress/Results:
This thesis attempts to identify some of the important determinants of dietary quality in South Indian rural agrarian households. It uses dietary diversity score as a measure of dietary quality. One of the key issues analyzed is the impact of seasonality on dietary quality of households. It particularly analyzes the diet quality of women to see if they are the most vulnerable group in the household with regard to access to nutrients.

The analysis shows that seasonality does not have a large impact on household or individual dietary diversity, however we can see weekly diversity scores increase during the lean season. Religion (Hinduism) and village level differences have the largest impact on diet quality along with child and adult female status. There is evidence that women in large families and richer households have lower diversity scores than other members in the household. Finally, the study shows that women and children are not the most vulnerable section in the household but due to lack of data on other members of the household, the thesis was unable to identify the group that was eating at the lowest level of diversity in the household.

Special Project Funding:
USAID - US-University Linkage Program

Intermediate output target in 2008 – Research project proposal entitled, "Tracking change in rural poverty and household economies in south Asia" developed and submitted to BMGF

Achievement of Output Target (%):
100%. A full project proposal entitled, "Tracking Change in Rural Poverty in Household and Village Economies in South Asia" was developed and submitted to BMGF

Countries Involved:
Bangladesh; India; USA

Partners Involved:
ICRISAT: GT-IMPI Team
IRRI: Sam Mohanty, Thelma Paris and Sushil Pandey
USA: Mark Rosenzweig, Tom Walker, Prabhu Pingali, Hans Binswanger, Gero Carletto, Sateesh Aradhyula
NARS partners from India, Bangladesh, Nepal,

Progress/Results:
A scoping meeting was with key stakeholders and experts working on longitudinal panel data. ICRISAT with support from the Bill and Melinda Gates Foundation (BMGF) organized a three-day Scoping Meeting on Village Level Studies for Evidence Based Decision- Making at ICRISAT Patancheru from 3-5 May. The main objective of the meeting was to define the scope of a full project on evidence-based decision-making. BMGF is funding the scoping study, which will be helpful for developing a full project proposal and detailed research plan for the project on evidence-based decision making. It was reiterated that the project will create a high quality longitudinal panel database for South Asia (India, Bangladesh and Nepal). Dr Prabhu Pingali of BMGF participated and stated the expectations of BMGF from ICRISAT's VLS. About 50 persons from USA, Nepal, Bangladesh, Philippines and India actively participated and shared their experiences. The participants included economists of ICRISAT associated with the first phase of VLS started in 1975, notably Drs Tom Walker, NS Jodha and PK Joshi.

This scoping meeting addressed the establishment of high quality longitudinal micro-level panel data and aimed to draw expertise world-wide from the CGIAR, ARIs, think tanks, universities and NARS. The meeting provided a fora for addressing important methodological and operational issues in establishing a longitudinal panel data for evidence-based decision making. The discussion focused on methodologies, analytical framework and approaches for generating longitudinal panel databases (survey design, sampling and stratification procedures, design of instruments), and operational issues relating to site selection, common data protocol, database management and dissemination. The workshop proceedings were documented and the publication is underway.

Based on the planning meetings, field tours and discussions with expert counsultants, a full project proposal entitled, "Tracking Change in Rural Poverty in Household and Village Economies in South Asia" was developed and submitted to the Foundation for their review and approval.

The charitable purpose which is envisioned through this project is to decrease the incidence and severity of absolute poverty in South Asia's semi-arid and humid tropics by markedly increasing the availability of time-series district-, household-, individual-, and field-level data. This project seeks to improve the quantity and quality of time-series meso- and micro-data so that decision-making is based on evidence on impacts on the poor. The project is driven by three initiatives: the compilation of longitudinal household, individual, and field data over five years in 42 villages, the assembly of secondary meso-level agricultural data into integrated data bases for distribution, and the nurturing of policy and data analysis, and capacity building.

This project is guided by over 30 years of previous work that establishes a basis for structuring partnerships to enhance sustainability, for assessing risk, and for innovating over time. That experience shows that a large share of the benefits from the proposed work will accrue to society years after its projected completion. Tracking poverty should be interpreted broadly as the proposal's foci is on why and how changes in natural hazards, government programs, market prices, and institutions are mediated in village and district settings and affect the poor over time.

Special Project Funding:
Bill and Melinda Gates Foundation

Intermediate output target in 2008 – Commissioning of research activities to support the project proposal submitted to BMGF

Issue of treatment effect of VLS
Many analysts apprehend that the continuous engagement of ICRISAT Village Level Studies provide an added advantage to the six villages to access technologies and develop faster than their neighboring villages. A detailed comparative analysis of the VLS villages with their neighboring ones is required to conclude either way. It is also expressed by some researchers that the households from whom the data are collected on a regular basis by ICRISAT investigators are at an advantage to learn about new technologies and opportunities better than others who are not part of the sample. In order to test this hypothesis, the sample of 2001-02 was divided in to two groups – those that belong to original VLS households and those that were added to the sample in 2001-02. The asset structures of these two categories were compared. It was found that those from the original VLS households belonged more to the medium and large farm households, while those households which were added belonged more to labor and small households. It was because the sampling structure followed in 1975-76 was not a representative one. To illustrate this, about one-third of the households in the villages belonged to labor category but they received only one-fourth representation in the VLS sample. The sampling process followed in 2001-02 aimed to have a sample that is representative of the distribution of different categories in the villages. Since the original households or their split-offs were retained in the sample and balance of the sample was filled up randomly from the households in the village using probability proportion to size method, more of the new households were drawn from the relatively poorer categories. As can be expected, the average asset values of original VLS households or their split-offs were relatively higher than those of the new sample households. But it is more due to differences in sampling methods followed in 1975 and 2002, rather than due to any treatment effects.

The growth rates in the asset values of both these categories between 2001-02 and 2007-08 were compared. It was found that the rate of growth in asset values for the new households added in 2001-02 was higher than that for the original VLS households (or their split-offs), although the asset values of the later category are still higher than those of the first category. This provided no support to the hypothesis of treatment effect in favor of original VLS households. But, this aspect merits further investigation. As a benchmark, the average sizes of land holdings of those who are in VLS sample during 2006-07 and those who are not can be compared from the household census data conducted in that year. The same can be compared at a later date to draw some conclusions about the treatment effects.

Trade-off on cost of data quality
Higher the frequency of data collection, greater will be the cost and lower would be the recall bias. Thus, there is a trade-off between cost and precision. In order to assess the additional value of high frequency data collection, the income and consumption estimates generated from the sample during 2001-02 to 2005-06 were compared. The estimates for 2001-02 to 2003-04 were estimated through annual surveys while those for 2004-05 were arrived at from bi-annual surveys. The estimates for 2005-06 were from high frequency surveys with three to four weeks recall periods. Since the performance of agriculture and income sources differed with the cropping years, no firm conclusion could be drawn about the relative merits of data collection with different recall periods. Hence, an experiment is designed during the cropping year 2008-09 with about one half of the sample being tracked through high frequency rounds. One-fourth of the sample is being interviewed through bi-annual surveys while the remaining one-fourth of the sample households will be interviewed at the end of the cropping year 2008-09. It is observed that high frequency data collection reduces recall bias and gives better estimates of income, consumption and enterprise economics. Another advantage of this method is in having resident investigators who can build a good rapport with the villagers in general and sample households in particular.

Village census enhanced to capture village dynamics
The details about this activity is already reported under Output 9.

Use of mixed techniques augmenting quantitative-qualitative data
The VLS methodology enhancement and preparation for complementing mixed methods for the quantitative data collection efforts with qualitative methods. The objective is to enrich the quantitative panel data by qualitatively tracking of rural poverty and vulnerability for in-depth understanding of poverty dynamics in the village including understanding shocks and their responses. The activities recommended to address this issue include:

- Village profiles – to understand the long term changes impacting on the household's resource endowments and welfare
- Time lines – understanding the evolution of the village and various negative and positive events that has shaped the village.
- Tracking life histories of select households to understand their moving in and out poverty
- Identify wealth and well–being: impact of shocks and use of formal and non formal interventions

Special Project Funding:
Bill and Melinda Gates Foundation

Output target 2009 1.10.2 Report on rural livelihoods in West-Africa completed

Intermediate output target in 2008 – VLS data validated and descriptive statistics generated

Achievement of Output Target (%):
50%
The VLS data has been cleaned and descriptive statistics have been generated.

Output target 2010 1.10.1a Case studies on livestock and livelihoods in Zimbabwe published

Intermediate output target in 2008 – Evaluation of few project sites completed. Synthesis in progress

Achievement of Output Target (%):
75%

Participating Countries:
Mozambique; Namibia; Zimbabwe

Participating Partners:
International Livestock Research Institute (ILRI): Dr Derek Baker; Dr Siboniso Moyo
Dr Rosa Costa, Directorate of Animal Sciences, Mozambique
Namibian National Farmers Union (NNFU)
Matopos Research Institute, Zimbabwe
Agricultural Technical And Extension Services
Progress/Results:
Certain project sites were evaluated and draft reports are available. Certain research components need to be finalized. The country reports need to be aligned. A draft synthesis is in process. Research reports on additional sites are in process.

Considering the fact that results need to be consolidated, I present trends that can be confirmed by the available data, for output 1 and 2 (see 3a):
1) Role of grading and quality control systems identified: Grading and quality control systems fulfill different functions under different market scenarios (across country and research site comparison), and for different farmer types (within country and research site comparison). Different approaches are thus necessary to establish and promote grading systems, which a) respond to farmers' different needs, and b) take care of the preferences of different consumer groups (low budget and affordable meat as compared to high budget and higher quality protein). It is expected that through grading systems, higher prices would be an incentive for farmers to increase livestock productivity and increasingly comply with market requirements, triggered by improved market access and higher value chain efficiencies:

In Zimbabwe, economic trends are negative, and a large part of the population is facing food shortages. Barter trading livestock against grains has become a common strategy. More farmer households bought/exchanged grains than self produced. The consumption of meat and milk has been largely reduced, due to low livestock productivity and non-affordability. Supply of meat to urban centers becomes increasingly difficult, due to low livestock productivity, variable product quality standards, high transaction costs, and other market distortions (lack of foreign currency, high input costs). Most farmers have small herds and management strategies are geared towards enhancing the survival of livestock, market criteria are less important. Establishing grading systems is important for these farmers, to ensure fair and transparent pricing mechanisms, so that they can achieve appropriate prices when they need to sell animals; grading systems thus play an important role to protect against market risk and for trust building. For the fewer farmers, who have larger herds and eventually more market oriented, grading systems ensure common quality standards, and help to attract investments in continuous market flows; in this case grading systems involve incentives for more commercially oriented production and market development. Grading systems existed in the former commercial cattle sector, and need to be adapted to small-scale farmers' needs and evolving market requirements. They also need to target alternative livestock species, particularly goats - for which a great unexploited market potential was identified.

In Namibia markets are better developed and farmers are more familiar with market requirements. Farmers have developed a better understanding of product quality criteria, and invest in management strategies to respond to the market criteria. Grading systems are part of local market systems. They ensure farmers' standard prices for delivering product quality, and provide incentives for higher product quality. Farmers collect standard price information to decide about livestock sales. Buyers of livestock commonly declare prices according to quality criteria and thereby can better calculate the market flows.

In Mozambique, certain areas have dynamic livestock markets, but for most areas markets and grading systems need to be established. A more general approach is required, to sensitize farmers for livestock market values and operations.

2) Performance of existing formal and informal markets for selected dryland commodities and inputs understood and documented:
The role of livestock is generally increasing, as a source of cash income for farmers in an increasingly cash driven economy (eg, expenses for food, education, human health), and as a source of quality protein for rural and urban consumers. The demand for alternative feed will increase dramatically in this process, also in the light of climate change. Currently, input and product market facilities are underdeveloped and not well integrated, market operations are poorly organized and transaction costs are high. Under non-functional markets, farmers remain with low prices for their products, and other stakeholders also invest little in product development. The performance of livestock related product and input markets is thus poor, but a considerable potential for improvements exists.
The Innovation Platform approach is as one way to enhance farmers' participation in market development, and involve all stakeholders in these processes. Developing such an innovative approach helps to define locally adapted impact pathways, to set research into the local context, to test market-led technology development, and thereby creating direct linkages between research and development. The IP approach helps to find ways HOW research can respond to local needs, facilitating dialogue and strengthening the linkages among value chain players to identify local solutions, rather than coming up with new technologies/forms of organization.

Feed markets are not yet established. More than 80% of farmers responded to livestock feed shortages by using crop residues to feed their cattle and goats. The value of crops residues as feed resources has long been underestimated. Value addition to crop residues and developing the necessary input and services, could enhance livestock performance substantially. Development of improved feed systems can thus have a real impact on the development of a healthy livestock sector. Even farmers without livestock can benefit by venturing feed and fodder production for sale/exchange, a commercialization process which is driven by those farmers with surplus livestock for sale, and the poor benefiting from higher animal productivity and better access to markets, thus higher prices.

Special Project Funding:
EU ICRISAT and ILRI LiLi: Markets ("Livestock and Livelihoods: Improving market participation by small-scale livestock producers")
Zimbabwe NARES
BMZ IWMI
DAAD

Output target 2010 1.10.2 Uptake pathways of SAT technologies documented based on case studies and shared with national program partners in Asia
Intermediate output target in 2008 – Data analysis for the period 2006-07 completed

Achievement of Output Target (%):
30% of output target is completed till 2008. The analysis of data is completed for the period 2006-07. The relationship between yield levels and adoption of technologies are being studied. To achieve this output target, analysis has to be carried out up to the cropping year 2009-2010. The uptake pathways of different SAT production technologies during 2001-02 to 2009-10 will be documented.

Countries Involved:
India – Maharashtra and Andhra Pradesh villages up to 2008-09 and Gujarat, Karnataka and Madhya Pradesh villages besides Maharashtra and Andhra Pradesh villages during 2009-10

Partners Involved:
ICRISAT and NARS partners

Progress/Results:
The adoption of technologies by different categories of farmers in VLS villages is being assessed through the construction of adoption indices. The yield levels are being segregated by variety, fertilizer level and other important technologies besides isolating the effects of rainfall, soil type and depth.

Special Project Funding:
DG fund for impact assessment
Bill and Melinda Gates Foundation

Output target 2011 1.10.2 Report on household economies in SAT Asia (2001-2009) completed

Intermediate output target in 2008 – Data collection and analysis underway

Achievement of Output Target (%):
25% of the output target has been achieved. The analysis of households mired in chronic poverty and those who are moving up and down the poverty line has been completed up to 2005-06. The analysis has to be taken up for the years 2006-07 to 2010-11 to complete the output target.

Countries Involved:
India – Maharashtra and Andhra Pradesh villages up to 2008-09 and Gujarat, Karnataka and Madhya Pradesh villages besides Maharashtra and Andhra Pradesh villages during 2009-11
Partners Involved:
ICRISAT and NARS partners

Progress/Results:
It was found that only about one-third of the sample households belonged to never-poor category during 2001-06. 7.6 per cent of them are mired in chronic poverty, while the remaining 58.5 per cent of the households moved up and down the poverty line based on seasonal conditions and opportunities in non-agricultural sector.

Special Project Funding:
World Bank
DG fund for impact assessment
Bill and Melinda Gates Foundation

Output target 2011 1.10.3 Analysis of alternate investment options and their trade-offs completed and accessible to rural poor in Asia

Achievement of Output Target (%):
25% of the output target was achieved. The analysis of returns to investment on irrigation was completed up to 2005-06. Investments in education of children are assuming greater prominence over the years since the perceived rates of return on education are going up with the time. This analysis has to be carried out for the years 2006-07 to 2010-11.

Countries Involved:
India – Maharashtra and Andhra Pradesh villages up to 2008-09 and Gujarat, Karnataka and Madhya Pradesh villages besides Maharashtra and Andhra Pradesh villages during 2009-11

Partners Involved:
ICRISAT and NARS partners

Progress/Results:
The percentage irrigated area was higher in Shirapur, Kanzara and Kinkheda. The average area commended per irrigation source was about 1.8 ha. The average return on investment was estimated at 10.5 per cent. Shirapur had the highest rate of return at 25.7 per cent. In all other villages, it was less than 10 per cent.

Special Project Funding:
World Bank
DG fund for impact assessment
Bill and Melinda Gates Foundation

Output target 2011 1.10.4 Policy package elements on risk management strategies for mitigating the impact of risks inherent in rainfed agriculture developed and shared with partners in Asia
Intermediate output target in 2008 –Baseline survey data analysis underway - Rainfall insurance and credit studies

Achievement of Output Target (%):
25% of the targeted output has been achieved. The extent of credit supply from the financial institutions and the attendant coverage of crop loan insurance are documented up to 2005-06. The data from baseline survey on rainfall insurance conducted in 2004 and the first impact survey carried out in 2006-07 are being analyzed for the comparing risk mitigation between crop loan and rainfall insurance products. This analysis has to be continued till 2010-11 to assess the relative effectiveness of different insurance products.
Countries Involved:
India – Maharashtra and Andhra Pradesh villages up to 2008-09 and Gujarat, Karnataka and Madhya Pradesh villages besides Maharashtra and Andhra Pradesh villages during 2009-11

Partners Involved:
ICRISAT and NARS partners
Progress/Results:
Households are net borrowers in all six VLS villages, except Kinkheda. Dependence on non-institutional sources of credit was more in A.P villages while institutional sources provided more credit in Maharashtra villages. Hence, farmers in Maharashtra villages received better insurance coverage for their crop and livestock enterprises.

Special Project Funding:
World Bank
Bill and Melinda Gates Foundation

Intermediate output target in 2008 – PhD thesis on "Livelihood insecurity in the semi arid tropics of Rural Andhra Pradesh: A Focus on HIV/AIDS and Migration"

Achievement of Output Target (%):
100% Complete. Rationale: Thesis is complete and submitted to the Department of Humanities and Social Sciences, IIT Bombay

Countries Involved:
India

Partners Involved:
Global Theme on Institutions, Markets Policy and Impacts, ICRISAT
Department of Humanities and Social Sciences, IIT Bombay

Progress/Results:
This thesis was aimed to understand the complex livelihood dynamics of rural households in the semi arid tropics of Andhra Pradesh. The focus being rural to urban migration of labor and assessing its role in influencing HIV risk behavior among rural households in the Semi Arid Tropics (SAT). The context in which this was done is the fragile landscape of the semi arid tropics: engulfed by lack of safety nets and climatic disadvantages such as water scarcity, where the poorest of the poor live on conditions of persistent drought, subsistence agriculture and poor access to markets. Data triangulation was done for the thesis, using the 30 year VLS panel data of ICRISAT, Andhra Pradesh State AIDS control society datasets as well as extensive field level data collection. The thesis found that most vulnerable population in these drought prone regions are the migrant labourers, and their vulnerability is influenced by three major factors—the vulnerability and unstable productivity in the degraded and marginal landscape, the caste system that has traditionally kept them backward and vulnerable, and experiences in the external environment to which they migrate. This study—based on a theoretical framework, whereby livelihood risks lead to health risks, particularly HIV infection—outlines the process that causes a further deterioration of the household and the occurrence of cyclical health risk. The thesis recommended a multi sectoral approach to tackle the issue of migrant vulnerability in the semi arid tropics, and calls for interventions with a more migrant-need sensitive approach. The thesis used both qualitative and quantitative tools. A research paper from the thesis has been published so far, through UNU – WIDER. A book chapter is forthcoming in year 2009 from this thesis.

Special Project Funding:
None

Intermediate output target in 2008 – Qualitative tracking of rural poverty and vulnerability in 6 VLS villages of India

Achievement of Output Target (%):
25% Complete. Field work is complete for three villages (Aurepalle, Dokur and Kanzara) and is underway for the remaining villages (Shirapur, Kalman and Kinkheda). Analysis will begin in 2009.
Countries Involved:
India

Partners Involved:
Global Theme on Institutions, Markets, Policy and Impacts
Bill and Melinda Gates Foundation

Progress/Results:
- Have an in-depth understanding of the dynamics of the village, understanding shocks and their responses by various groups in our 6 village. The information generated through these tools coupled with our VLS quantitative analysis is aimed at tracking the evolution of poverty through time.

Set of activities include, Time lines – understanding the evolution of the village, changes in village, pockets of poverty and resource endowments; Case histories- tracking life histories of select households to understand their moving in and out poverty; Focus Groups – Wealth and well – being ranking and impacts of formal and non formal interventions in the light of social, economic and structural shocks.

- Data was collected using the following tools. Wealth Ranking Guide, Timeline Guide, Resource Map Guide, Focus group guide on Vulnerabilities, Coping strategies and Impact of interventions, Case History Guide and Village Demography Sheet. These were conducted so far in three VLS villages of Dokur, Aurepalle and Kanzara and are underway in Shirapur, Kalman and Kinkheda.

Special Project Funding:
Bill and Melinda Gates Foundation

Output target 2011 1.10.5 A PhD dissertation on Options for mitigating susceptibility to HIV through agricultural technologies that increase food security in Malawi

Intermediate output target in 2008 – Field data collection through participant observation, formal and informal interviews to increase the understanding on the impact of livelihood insecurity of rural women in Malawi on their susceptibility to HIV

Achievement of Output Target (%):
50%. Field data collection underway in the selected sites

Countries Involved:
Malawi

Partners Involved:
University of Amsterdam (more specifically the Amsterdam School of Social Science Research) and the Dutch Ministry of Foreign Affairs.

Progress/Results:
Findings from literature review, on which the research question builds: Women are disproportionately infected, already constituting 59% of all infected in SSA. Furthermore, while infection rates are still highest in the urban areas, rates increase fastest in the rural areas, where the total number of infected now outnumbers the total urban infected. Within the field of agriculture and AIDS, by far most attention is directed at identifying and mitigating the devastating impacts of AIDS on food security. Far less attention has been directed at the reverse relationship: how food insecurity fuels the pandemic. This fueling is both through weakened, malnourished and thus more susceptible bodies, as well as pushing the hungry to survival strategies such as male migration and female transactional sex that increase risk of HIV spreading. More understanding is urgently needed of the mechanisms that put especially rural women at risk of infection, and ways through which the resistance of poor women farmers can be increased.

Preliminary findings that are particularly interesting is that very few women have permanent businesses. Most start their small scale trade whenever they find some surplus money (for example after a bumper harvest, or when a man gives them some money), buy and sell for some time until they are forced to use their investment money for something else than buying new merchandise (e.g. increasing food prices, a child that needs to go to the hospital etc). It may take months before they find some new investment money to take up a business again. This new business can be of a different type than the previous: trading vegetables/bananas/dried fish/groundnuts; baking/frying snacks; cooking a maize drink etc.

Villagers do respond to the AIDS pandemic. Many volunteer to assist when a funeral has to be prepared (men dig the grave, women cook, fetch water and firewood), because: "Death is everywhere these days, it's not like before, when only the elderly were hit, nowadays it's omnipresent, every household will be affected one day." To be assured of assistance when their own household is hit, more people than before volunteer to help preparing funerals. But when a temporary HIV testing centre was opened at walking distance of the two villages, few villagers dared to go, rationalizing that they will face their problems when those appear, not before. Promiscuity and unprotected sex with new partners still takes place, even though everybody seems very well informed about ways of avoiding HIV infection, as I found at a seminar on tree planting organized by an international NGO, where unannounced several hours were dedicated to teach about HIV prevention. Most participants were able to sum up, using perfectly correct terminology, the facts about HIV and AIDS. During my stay in the village a survey team was dropped in the villages to ask a handful of randomly selected young men and women questions about HIV, AIDS, their sexual behavior etc. These questions were experienced as very intrusive by the respondents, who complained fiercely about it when they later came to knit at our house. It was clear that to a number of questions (e.g. "How many times have you had sex with your partner?") they had not answered truthfully.

Data analysis will follow data collection which will be completed by 2009.

Special Project Funding:
University of Amsterdam
Dutch Ministry of Foreign Affairs

Intermediate output target in 2008 – Adding social dimension to ICRISAT-NDF project on uptake of improved groundnut variety JL24

Achievement of Output Target (%):
75%. Report drafted

Countries Involved:
Malawi

Progress/Results:
A report "Small scale qualitative assessment of JL24 adoption for ICRISAT-NDF project" is drafted. The findings from the two sites reveal that in both sites other cash crops such as cotton and tobacco would bring farmers higher profits, but require investments such as fertilizer and pesticides. As these inputs are for many farmers difficult to obtain due to lack of capital, growing groundnuts as a cash crop is an appreciated alternative. Furthermore, groundnuts can also be eaten at household level. For most farmers this combination was the reason they started growing groundnuts in general.

JL24 in specific was in Thukwi, Salima District, valued for its shortening of the hunger season. The main disadvantage as perceived by the villagers was the low price that vendors are prepared to pay for this variety compared to CG7. In Njereza, Chikwawa District, both these considerations did not seem to be an issue. Here maize can be harvested as early as February or March, thus around the same time as JL24. Few farmers have as yet been able to sell JL24 due to lack of surplus, which may explain the fact that low prices were not complained about. The advantages and disadvantages mentioned here were less unanimous than in Thukwi. Possibly because Njereza farmers can only base their judgment on one partly successful harvest, they are not yet fully aware of the distinctive traits of the new variety compared to others.

Special Project Funding:
Nordic Development Fund

MTP Project 2: Sustaining biodiversity of Sorghum, Pearl Millet, Small Millets, Groundnut, Pigeonpea and Chickpea for current and future generations

Project Coordinator: **HD Upadhyaya**

Executive Summary: In 2008, we added 192 accessions of our mandate crops at ICRISAT Patancheru genebank, totaling 119,074 accessions from 144 countries. Likewise, the regional genebank in Kenya added 745 sorghum accessions and identified gaps for future collection of unique pearl millet and sorghum accessions from the region. Similarly, the regional genebank in Zimbabwe identified 657 unique finger millet accessions to enrich ICRISAT genebank. Using several tools (Microsoft Encarta^R, Arc View, FloraMap, and DivaGIS), we identified additional 395 sorghum accessions from Japan and 558 groundnut accessions from USA for acquisition in our genebank. We continued our efforts to characterize/evaluate the germplasm accessions of staple crops and small millets, which resulted in identification of accessions with useful variation for agronomic and seed quality traits. Testing of plant/seed health during regeneration and storage has been another major activity. ICRISAT genebank at Patancheru distributed 13,358 seed samples in 24 countries and 7081 samples to its own researchers. In addition, we contributed 20,000 seed samples of staple crops and small millets to the Svalbard Global Seed Vault in Norway. Germplasm database has been further updated for its completeness using SINGER format. Our participation in GPG2 project has been on diversity assessment and developing global crop registry for chickpea using FAO/IPGRI Multi-crop Passport Descriptors.

A major evaluation program of finger millet and foxtail millet core collections has been initiated, with support from BMZ/GTZ, in India, Kenya, Tanzania and Uganda to promote on-farm conservation and use of these nutritionally rich small millets in Asia and Africa.

Core and mini core collections and genotype-based reference sets in chickpea, groundnut, pigeonpea, pearl millet, sorghum, finger millet and foxtail millet are available to users of germplasm from ICRISAT genebank upon signing of SMTA. We continued our efforts to evaluate these sets to identify new sources of variation for agriculturally beneficial traits, and identified a large number of trait-specific germplasm, which include resistance to biotic and abiotic stresses, agronomic and seed quality traits. Few advanced generation interspecific derivatives and groundnut mini core accessions showed good degree of resistance to ELS and/or GRD under high disease pressure in Malawi.

We continued our efforts to generate genetic (identifying mapping parents, developing RILs and TILLING populations) and genomic resources (SSRs and genetic maps) for our staple crops. The first tetraploid-based genetic linkage map has been developed in groundnut. Several tetraploid-based synthetics involving A and B genome species have been developed and are being backcrossed with elite groundnut cultivars to introgress useful traits (resistance to biotic and abiotic stresses) into improved genetic background. In addition, we isolated several drought-responsive candidate genes and their promoters, and sequencing of some of these genes is in progress using diverse chickpea and sorghum accessions. Likewise, some progress has been made towards developing Information System for Marker Assisted Breeding (ISMAB) to support crop breeding.

We assembled and preserved a number of agriculturally beneficial microorganisms that possibly will have potential to enhance crops adaptation. Some of the isolates when tested were either entomo -pathogens, or antagonistic to pathogens or siderophore producers.

Center of Excellence in Genomics (CEG) also conducted training courses on various aspects of diversity assessment and marker-aided selection to crop breeders in India as well few participants from other countries.

Output 2.1: Germplasm of staple crops assembled and conserved and germplasm characterized and documented for utilization and knowledge shared with partners

Summary: Identification of gaps in the germplasm collection is necessary to achieve completeness of the collection, and further exploration. We used Microsoft Encarta^R (MS Encarta^R Interactive World Atlas 2000), Arc View, FloraMap, and DivaGIS tools to identify the gaps and priority area for germplasm collection.

Our efforts to assemble new germplasm in 2008 added 192 accessions of chickpea, groundnut and sorghum, totaling 119,074 accessions from 144 countries in ICRISAT genebank at Patancheru, India. Likewise, in two collection mission with national programs in Eastern and Southern Africa, the ICRISAT regional genebank in Kenya added 745 new sorghum accessions, and also identified gaps for future collection mission in South Africa. In addition, we also identified a large number of unique pearl millet and sorghum accessions that will be obtained for conservation. A large number of accessions of staple crops were further characterized to update database. Further characterization and evaluation of germplasm at Patancheru led to the identification of useful variation for agronomic traits. For example, a number of Pennisetum pedicellatum accessions with high fodder value; chickpea accessions from ICARDA, groundnut accessions from Japan, and sorghum accessions from Niger showed large variation for agronomic traits including tolerance to biotic and abiotic stresses. In addition, accessions with improved seed quality were also identified: high protein content in chickpea; large-seeded chickpea and groundnut; vegetable type pigeonpea (large green-seeded pods, high in protein and good taste); sorghum accessions with high brix reading (sweet stalk) for biofuel.

Seed distribution has been one of the major activities. ICRISAT genebank at Patancheru distributed 8266 samples of staple crops germplasm for utilization to scientists in 21 countries, in addition to supplying 6023 samples of germplasm to its own researchers. Likewise, regional genebank in Niger distributed seed samples of sorghum and groundnut.

Testing for seed health and identifying critical accessions (with less stock or low germination), in addition to monitoring plant health (for suspected diseases) during the regeneration of germplasm, has been an important activity to ensure that only disease-free seed samples with good germination goes into medium- and long- term storage in the genebank.

A long-term global experiment on lettuce in collaboration with USDA-USA, Bioversity and CAAS-China to explore ultra seed storage technology revealed a finite longevity at storage temperatures (50, 35, and 20^{0}C), with seed stored at low temperatures surviving longer.

We are committed to place 111,000 FAO-designated germplasm of the staple crops and small millets in the Svalbard Global Seed Vault (SGSV), Norway, in phased manner over next five years, and contributed 20,000 seed samples to SGSV in 2008.

We continued to update our database for completeness of germplasm using SINGER format. In addition, we also participated in the chickpea global crop registry activity of GPG2 project, using standardized format FAO/IPGRI Multi-Crop Passport Descriptors.

Output target 2.1.1 New germplasm of staple crops assembled for conservation and utilization (2009)
Priorities areas identified for chickpea and pigeonpea for collection/assembly in collaboration with NARS (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Ukraine; Kenya

Partners Involved:
NARS partners in Ukraine, NBPGR-India, ICRISAT regional genebank at Nairobi, Kenya

Progress/Results:
The passport databases of chickpea and pigeonpea were reviewed to identify gaps in the collection and priority areas for collection/assembly of germplasm.

Methodology to identifying gaps in collection: Identification of gaps in the germplasm collections is necessary to achieve completeness of the collection, and exploration for further collection.

We have established a methodology to identify gaps in our collection, which include:

- Using Microsoft Encarta[R] to an electronic atlas (MS Encarta[R] Interactive World Atlas 2000) to retrieve the geographic coordinates of locations to fill the gaps for accessions not having the information.
- Using Arc View, a GIS tool, to check the accuracy of the coordinates by plotting all accessions on latest political boundary map of each country.
- Using the FloraMap, a GIS tool, to create the probability distribution map for each species in different countries. Collection sites or sampled sites are overlaid on the probability map and identify the districts with high probability (>70%) areas, where there is no collection or few collections, for exploration in each country.
- Use land cover maps to know the type of vegetation and land cover in the areas of high probability and consult local government officials about the cropping pattern and then finalize the area for exploration.
- Using DivaGIS to assess the diversity in the assembled germplasm for each trait. Overlay the probability map, collection sites and the diversity index of assembled germplasm and identify the gaps in trait-wise diversity.

Chickpea: We have identified the geographical areas as being under sampled in our collection with respect to landraces of *Cicer arietinum*. These are - Hindhu Kush-Himalayan region (India, Pakistan, Afghanistan and Nepal); West and north China; Ethiopia (Desi chickpea) and Uzbekistan, Armenia and Georgia. The putative progenitor *Cicer reticulatum* and the primary genepool species *Cicer echinospermum* and a secondary genepool species *Cicer bijugum* are under represented in our collection. These species are distributed mainly in west, south and southeastern Turkey, northern Iraq and northeastern Iran. Other priority species identified was *Cicer cuneatum*.
Based on our work on Global Crop Registry for Chickpea in collaboration with Bioversity and ICARDA, we have identified important regional and national collections. We are comparing these databases for identifying important gaps and unique germplasm in chickpea for assembling.
Seventy-two germplasm accessions identified from Ukraine national collection were grown in quarantine area before pre-release testing by NBPGR Unit based at ICRISAT Patancheru, India. A total of 44 accessions were released for regeneration while remaining 28 accessions were detained for further testing under quarantine green house conditions.
Pigeonpea: The pigeonpea germplasm passport database of ICRISAT Patancheru genebank was compared with that of pigeonpea germplasm collection in ICRISAT regional genebank at Nairobi, Kenya, and identified 88 unique accessions. The priority areas for additional pigeonpea collection include local landraces/varieties from Mozambique and Vietnam. We also identified several priority collections (regional and national) of pigeonpea germplasm while developing a strategy for the global conservation of pigeonpea genetic resources in collaboration with Bioversity.
Special Project Funding: NA

HD Upadhyaya and CLL Gowda

Output target 2.1.2 Sorghum germplasm from USDA (30 accessions), pearl millet from Niger (400 accessions) and pigeonpea collections from Tanzania, Uganda and Mozambique (200 accessions) assembled (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
China, Kenya, Mozambique, Niger Tanzania and Uganda

Partners Involved:
CAAS-China, NBPGR-India and ICRISAT regional genebank at Niamey, Niger

Progress/Results:
Sorghum: NBPGR released 25 and 21 sorghum germplasm accessions, respectively, from China and USA for observations in post entry quarantine isolation area (PEQIA) prior to release.
Pearl millet: Pearl millet germplasm passport database of ICRISAT Patancheru genebank was compared with that of ICRISAT regional genebank at Niamey, Niger, and identified 775 unique accessions not available at Patancheru. These unique accessions were acquired in two consignments (354 and 421 samples) and grown in one row of 8 m length accommodating about 80 plants, in the PEQIA at ICRISAT, Patancheru, for inspection against exotic pests and diseases and subsequent release to the genebank at ICRISAT, Patancheru.
Pigeonpea: We acquired from the ICRISAT Regional Genebank at Nairobi, Kenya 198 samples of germplasm collections from Tanzania, Mozambique and Uganda. Of these, 153 accessions were released for post-entry quarantine isolation area (PEQIA)-grow out test while 45 samples were detained due to infection from seed borne pathogens.
Special Project Funding: NA

HD Upadhyaya, CLL Gowda and RP Thakur

Output target 2.1.4 Global databases of sorghum and groundnut compared to identify unique germplasm and to identify gaps in collection (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Australia, Brazil, China, Japan, Kenya, Niger, Syria, USA and Zimbabwe
Partners Involved:
NBPGR-India, NARS from China, Japan, and Ukraine, USDA- USA and ICRISAT regional genebank in Bulawayo, Zimbabwe.

Progress/Results:
The passport data of sorghum germplasm maintained at ICRISAT genebank, Patancheru was compared with sorghum data base of regional genebank at Bulawayo, Zimbabwe and identified 807 unique accessions that will be obtained for conservation at ICRISAT genebank, Patancheru, India. Similarly, we identified 2708 unique accessions of sorghum to acquire from USDA collection maintained at NSSL, Fort Collins, USA, of which, 640 accessions assembled and added to our collection earlier.

The germplasm databases of ICRISAT and NIAS, Japan were compared for sorghum and with USDA for groundnut for identifying unique germplasm for assembly. This exercise has identified 395 accessions of sorghum from NIAS and 495 cultivated and 63 wild relatives of groundnut from USDA for acquisition.

Other progress
Groundnut: Two hundred fifty-one seedlings of 59 groundnut accessions from Japan were released for pre-release testing in green house by National Plant Quarantine Unit based at ICRISAT Patancheru, India. Additionally, all the 2190 seedlings of 428 groundnut accessions from Japan, when grown under field conditions in quarantine area, were rejected due to peanut strip virus infection and destroyed.
Germplasm assembly: In 2008, we added 192 accessions to the collection, which includes 39 sorghum (USA 14 - and China - 25), 127 chickpea (ICARDA – 67, USA – 57, Australia – 2 and ICRISAT-1) and 26 groundnut (Brazil – 25 and USA-1) accessions, bringing total collection to 119,074 accessions from 144 countries. Several germplasm samples are under regeneration for seed increase and/or plant quarantine clearance for subsequent release to ICRISAT.
Special Project Funding: NA

HD Upadhyaya, CLL Gowda and RP Thakur

Output target 2.1.3 Sorghum germplasm from Niger (450 accessions), chickpea germplasm from ICARDA (500 accessions) and groundnut germplasm from Japan assembled and characterized for morpho- agronomic traits (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Sorghum: In 2007-2008 postrainy season at Patancheru, 482 newly assembled sorghum germplasm accessions from Niger were characterized for days to 50% flowering, plant height (cm), plant pigmentation, basal tillers, nodal tillers, midrib color, panicle exsertion (cm), panicle length (cm), panicle width (cm), panicle compactness and shape, glume color, glume covering, seed color, 100 seed weight (g), endosperm texture, seed luster, and seed subcoat following sorghum descriptors, and classified these accessions into races and intermediate races. This material consists of race Bicolor (59 accessions), Guinea (40 accessions), Caudatum (43 accessions) and Durra (24 accessions), and intermediate races Guinea-caudatum (78 accessions), Caudatum-bicolor (130 accessions), Durra-bicolor (8 accessions), Kafir-caudatum (2 accessions) and Durra-caudatum (98 accessions).

Of the 46 sorghum accessions from China and USA grown during 2007/2008 season at PEQIA, 18 accessions from USA and 25 accessions from China were released for further characterization.

Chickpea: 500 newly acquired chickpea accessions from ICARDA were grown in an augmented design with three desi (Annigeri, G 130, and ICCV 10) and two kabuli (L 550 and KAK 2) controls. These accessions were evaluated for 24 descriptors (7 qualitative and 17 quantitative traits). A wide range of variation was observed for agronomic traits: days to 50% flowering (37 to 98 days), flowering duration (16 and 50 days), maturity (107 -132 days), plant height (19-120 cm) and width (46-65 cm), pods per plant (7-188), 100-seed weight (10-58 g), seed yield (71-2846 kg ha^{-1}). Ten accessions in desi (ICCs 517, 1273, 1503, 2950, 6067, 9006, 18213 and 18218, ICCV 93952 and IG 71756) produced 2.23 to 2.90 t ha^{-1} above that of the best control ICCV 10 (2.23 t ha^{-1}) while only two accessions (ICC 17457 and IG 70514) in kabuli yielded at par with KAK 2 (1.40 t ha^{-1} seed yield and 34.8 g 100-seed weight) and had similar 100-seed weight. IG 70432 among pea-shaped was identified as a high yielding (2.26 t ha^{-1}) accession.

Groundnut: Thirty newly acquired groundnut germplasm from Japan along with two controls (Chico and Gangapuri) were evaluated in an augmented design for 16 qualitative and 17 agronomic traits during 2007-08 postrainy season at Patancheru. A wide range of variation was observed for agronomic traits: 9-12 days to 50% emergence, 31-43 days to 50% flowering, 123-141 days to maturity, 14-40 cm plant height, 4-8 primary branches, 4-13 pods per plant, 333-4883 kg ha^{-1} pod yield, 44-75% shelling percentage, and 33-72 g 100-seed weight. Similarly large range variation was also observed for growth habit, flower color, seed color, pod- beak, constriction, and reticulation. JP 42503 and JP 45584 produced higher pod yield (4.6-4.9 t ha^{-1}) than highest yielding control Gangapuri (3.4 t ha^{-1}).

Other progress
Pigeonpea: A total of 692 pigeonpea accessions were characterized in 2007-08 in an augmented design with three controls (ICP 11543, ICP 8863 and ICP 7221) and recorded observations on 34 morpho-agronomic traits while in 2008-09 season planted 670 accessions together with same controls for characterization to fill the gaps in characterization database.

Almost all accessions of genus *Cajanus*, except *C. scarabaeoides*, assembled at ICRISAT genebank were grown in field genebank at ICRISAT, Patancheru, during July 2007-08 for characterization. Flowering in *C. platycarpus* ranged from 35 to 40 days while *C. albicans* plants took 460 to 502 days to flower. Seeds per pod were highest (7.9-8.6) in *C. mollis*. In addition, in 2008 rainy season, all accessions of *C. scarabaeoides* were grown, and characterization for 25 morpho-agronomic traits is in progress. Flowering among *C. scarabaeoides* accessions ranged from 51 (ICP 15747) to 118 (ICP 15723) days.

Pearl millet: Characterization of 134 accessions of *Pennisetum. pedicellatum* during 2007-08 seasons revealed considerable diversity: 43 to 109 days to 50% flowering, 275 to 2247 total tillers, 114 to 1261 productive tillers, 16 to 53 cm leaf blade length and 1 to 2.3 cm leaf blade width. These accessions also showed diversity in plant color and panicle traits (glume color and bristle color). IP 21881 among all accessions flowered early (43 days). IP 21821 showed the highest number of tillers (2247 total tillers/plant) while IP 21821 had most productive tillers (1261 productive tillers/plant). IP 21849 showed highest leaf blade length (53 cm). These accessions are therefore the most promising sources for forage. In 2008 rainy season, 88 *P. polystachion* accessions and 439 cultivated pearl millet accessions were grown along with three controls (IP 3616, IP 17862 and IP 22281) for characterization of over 23 traits. Recording of post-harvest data is in progress on these materials.

Special Project Funding:
NA

HD Upadhyaya and CLL Gowda

Characterizing regional collection at Nairobi

Achievement of Output Target (%):
>75%

Countries Involved:
Burundi; Ethiopia; Eritrea; Kenya; Rwanda; Sudan; Tanzania; Uganda

Partners Involved:
NARS from Burundi, Eritrea, Ethiopia, India, Kenya, Rwanda, Sudan, Tanzania, and Uganda,

Progress/results:
A regional composite collection of 1720 sorghum accessions representing landraces, farmer varieties and breeders' lines was phenotyped using 27 consensus descriptors representing all the sorghum developmental stages. Additionally, 1405 of these accessions were also genotyped using 39 SSRs. A data analysis workshop involving the project partners was held in October 2008. The partners were equipped with data cleaning and analysis skills using four different softwares. The morphological and molecular data is being compiled and analyzed.

Special Project Funding:
Generation Challenge Program, The Rockefeller Foundation and BecA.

D Kiambi

Output target 2.1.3 Germplasm sets of staple crops evaluated for useful traits (2009)

Achievement of Output Target (%):
>50%

Countries Involved:
India, Ethiopia, Kenya, and Tanzania

Partners Involved:
ICRISAT Patancheru and NARS partners from Ethiopia, Kenya, and Tanzania

Progress/Results:

1. Chickpea
Early maturity: Early-maturity helps chickpea to avoid terminal heat and drought and increases its adaptation in the sub-tropics. Breeding for early maturing, high-yielding and broad-based cultivars require diverse sources of early maturity. When evaluated 17 germplasm and three controls (ICCV 2, ICCV 96029 and Annigeri) under irrigated and non-irrigated (sown on 25th Oct 2007) and late sown (sown on 25th Jan 2008)-irrigated environments at Patancheru, India, ICC 11916 and ICC 14368 (2.10 -2.16 t ha^{-1}) among desi's and ICC 14197 (1.73 t ha^{-1}) among kabuli's produced higher seed yield than the best controls (Annigeri 2.08 t ha^{-1} or ICCV2 1.45 t ha^{-1}) under irrigated environment. ICCs 5829, 11916, 12426, 13839, and 13925 (1.14 – 1.37 t ha^{-1}) produced higher seed yield under un-irrigated environment in comparison to control cultivar Annigeri (1.09 ha^{-1}). ICCs 13044, 14346, 14368, 16347, and 16349 (0.67-0.78 t ha^{-1}) produced higher seed yield than Annigeri (0.57 t ha^{-}1) under late sown environment. In desi group, ICC 11916 and, ICC 12426 on an average produced relatively higher seed yield (1.31 – 1.34 t ha^{-1}) in three environments than Annigeri (1.25 t ha^{-1}). None of the entries in kabuli group were superior to control ICCV 2. However, ICC 12197 had twice the seed size of ICCV 2 (20 g 100 seed weight) (Table 1).

Table 1. Performance of early-maturing chickpea germplasm accessions under irrigated, un-irrigated, and late sown environments, 2007-08 postrainy season

Identity	Days to 50% flowering				100-seed weight (g)				Seed yield (kg ha^{-1})			
	Irrigated	Un-irrigated	Late sown irrigated	mean	Irrigated	Un-irrigated	Late sown irrigated	mean	Irrigated	Un-irrigated	Late sown irrigated	Mean
Desi												
ICC 11916	40	40	39	40	13	15	13	14	2163	1142	612	1306
ICC 12426	42	38	40	40	17	19	16	17	2048	1367	609	1341
ICC 14368	42	41	39	41	16	17	14	16	2104	1016	696	1272
Annigeri	41	40	40	40	16	21	18	18	2078	1093	586	1252
Kabuli												
ICC 14197	29	29	33	30	39	47	38	41	1731	846	626	1068
ICCV 2	35	34	36	35	21	24	16	20	1458	958	754	1057
Trail mean	40	38	37	-	15	18	14	-	1674	970	639	-
CV %	5.9	4.5	7.8	-	7.8	5.5	10.25	-	11.2	12.3	25.5	-
SE±	1.57	1.16	2.02	-	0.83	0.68	1.24	-	124.03	77.8	81.13	-

Large seed size in Kabuli type: Large seed has always been a trait of consumer preference besides an important component of yield and adaptation. Large seeded kabuli's fetch more prices than the small- seeded desi or pea-shaped types. Fifty large-seeded kabuli germplasm were evaluated under irrigated and un-irrigated environments in two trials (16 in one trial and 34 in another trial) along with ICCV 2, JGK 1, KAK 2, and L 550 as controls. In the first trial, ICC 19191 (28 days to 50% flowering, 50.6 g 100-seed weight, 1626 kg ha^{-1} yield) flowered 12 days earlier than KAK 2, produced similar seed yield as KAK 2 but with 34% higher 100-seed weight. Similarly ICC 18591 (31 days to 50% flowering, 47 g 100-seed weight, 1650 kg ha^{-1} seed yield) flowered 9 days earlier but with similar yield (1743 kg ha^{-1}) to control KAK 2 (40 days, 38g 100-seed weight, 1743 kg ha^{-1}) under irrigated environment. ICCs 17450, 17456, and 17458 (31-35 days to 50% flowering, 50-53 g 100-seed weight, 1.15 – 1.24 t ha^{-1} seed yield) flowered 3 to 6 days earlier, and produced 12 to 22 % higher seed yield, and larger-seed size (29 to 42 % higher) than KAK 2 (38 days, 38 g, 1.02 t ha^{-1}) under un-irrigated environment. On average ICCs 17450, 17456, 17458, 17459, 18591, and 19191 (27-35 days to 50% flowering, 47-54 g 100-seed weight, 1.25-1.38 t ha^{-1}) took 10 to 31% less days to 50% flowering and produced similar seed yield but with 24 to 42% higher seed size than KAK 2 (39 days, 38 g, 1.38 t ha^{-1}) (Table 2).

Table 2. Performance of large-seeded kabuli chickpea germplasm accessions under irrigated and un-irrigated environments, 2007-08 postrainy season.

Identity	Days to 50% flowering			100-seed weight (g)			Yield (kg ha^{-1})		
	Irrigated	Un-irrigated	Mean	Irrigated	Un-irrigated	Mean	Irrigated	Un-irrigated	Mean
ICC 18591	31	30	31	47	60	54	1650	995	1323
ICC 17459	27	27	27	45	48	47	1579	949	1264
ICC 19191	28	30	29	51	51	51	1626	863	1245
ICC 17450	35	36	36	47	53	50	1316	1244	1280
ICC 17456	32	31	32	44	52	48	1553	1146	1350
ICC 17458	35	35	35	44	50	47	1597	1169	1383
Control									
KAK 2	40	38	39	38	38	38	1743	1023	1383
L 550	62	61	62	19	19	19	1428	709	1069
ICCV 2	34	33	34	22	27	25	1462	967	1215
JGK 1	40	38	39	33	39	36	1441	1168	1305
Trail mean	40	38	-	44	50		1450	943	-
CV %	2.74	4.79	-	4.5	7.79		14.11	22.48	-
SE±	0.77	1.29	-	1.40	2.65		124.44	130.66	-

In the second trial, ICC 14197 (30 days to 50% flowering, 43 g 100-seed weight, 1.78 t ha^{-1}) took 25% less days to 50% flowering and produced similar seed yield with 16% higher seed size than KAK 2 (40 days, 38g, 1.75 t ha^{-1}) under irrigated environment. Similarly ICC 13821 (35 days to 50% flowering, 53 g 100-seed weight, 0.82 t ha^{-1}) flowered earlier and showed greater seed weight but recorded relatively less seed yield than KAK 2 (37 days, 36 g, 0.86 t ha^{-1}) under un-irrigated environment. Large-seeded, early-maturing and agronomically superior diverse parents are useful germplasm in breeding program. Additionally, early-maturity combined with large-seed size is advantageous in chickpea to avoid terminal drought as chickpea is usually grown on conserved soil moisture, where soil moisture reduces towards maturity.

Heat tolerance in chickpea: In addition to evaluating a select group of germplasm for agronomic traits, we also evaluated 16 accessions for heat tolerance in an un-replicated experiment under late sown (25th January 2008) and fully irrigated conditions. The preliminary observation from this study revealed that ICC 17452 and ICC 17459 may do well under heat stress conditions as they flowered in 31 to 36 days and produced 0.44-0.47 t ha^{-1} seed yield with 40-45 g 100-seed weight.

Additionally, we screened 31 chickpea germplasm accessions for heat tolerance in two trials. The percentage decrease in seed yield from normal sown irrigated environment to late sown irrigated high temperature environment (the average maximum temperature ranged from 30.5^{o}C to 35.7^{o}C) was less in ICCs 17459, 12670, 14345, 14368, 16347, 16348, and 16349 (33.6 to 58.0 %) in comparison to heat tolerant control ICCV 92944 (60.0%). These accessions produced (676 – 776 kg ha^{-1}) above that of controls (522-675 kg ha^{-1}) (Table 3).

Table 3. Performance of chickpea germplasm under normal and high temperature environments, 2007-08 postrainy season

Identity	100-seed weight (g)			Late sown % decrease over irrigated	Seed yield per plant			Late sown % decrease over irrigated	Seed yield per plot			Late sown % decrease over irrigated
	Irrigated	Un-irrgated	Late sown		Irrigated	Un-irrgated	Late sown		Irrigated	Un-irrgated	Late sown	
ICC 14648	31.4	25.5	25.5	18.75	7.7	5.0	2.2	71.65	1844	925	676	63.35
ICC 17459	46.7	39.0	36.0	23.00	7.1	4.9	4.1	42.72	1666	699	700	58.00
Annigeri	22.2	17.5	23.4	-5.40	7.5	4.9	3.3	55.82	1942	892	522	73.11
ICCV 92944	22.8	25.5	19.3	15.57	7.7	4.9	3.0	61.18	1723	767	675	60.86
Trial Mean	36.29	38.03	31.21		7.78	4.94	3.16		1720	762	482	
CV%	7.27	11.15	9.9		11.32	19.57	20.2		14.14	17.2	15.8	
SE±	2.23	3.89	2.11		0.61	0.11	0.38		170.5	112	51.6	
ICC 12670	13.3	15.7	12.3	7.8	6.2	4.3	4.0	35.6	1391	1006	674	51.5
ICC 14345	12.8	14.6	11.7	8.7	4.9	5.1	4.6	4.9	1169	704	776	33.6
ICC 14368	15.8	18.8	12.9	17.9	4.9	4.4	5.4	-9.6	1275	979	669	47.5
ICC 16347	16.3	20.0	14.7	9.8	7.2	5.8	5.2	28.7	1456	852	646	55.6
ICC 16348	11.3	14.5	9.9	11.8	6.3	5.8	6.3	1.0	1460	851	716	51.0
ICC 16349	20.8	23.8	15.4	25.8	7.0	5.4	6.1	13.4	1458	958	754	48.3
ICCV2	11.1	13.3	10.4	6.0	6.3	4.6	3.5	44.8	1548	716	544	64.9
Annigeri	15.0	21.0	17.9	-19.3	9.6	5.9	3.7	61.2	2079	1093	587	71.8
ICCV 92944	22.8	25.5	19.3	15.6	7.7	4.9	3.0	61.2	1723	767	675	60.9
Trial Mean	15.26	17.86	14.26		6.96	5.17	4.79		1674	970	639	
CV%	7.8	5.45	10.25		20.88	30.03	5.26		11.16	12.3	25.5	
SE±	0.83	0.69	1.25		0.84	0.68	0.21		124	77.9	81.1	

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Performance of drought tolerant chickpea: The 51 large-seeded kabuli accessions with high root length density, a trait related to drought tolerance, were evaluated for agronomic traits. ICCs 7345, 12034, 17458, 18591, and 19192 flowered early (31-36 days to 50% flowering), produced 27 to 57% higher seed yield (1.51 – 1.85 t ha^{-1}) and 62 to 79% large-seed weight (42-52 g 100-seed) than the drought control ICC 4958 (35 days, 29g, 1.18 t ha^{-1}).

Performance of salinity tolerant chickpea: We evaluated 14 salinity tolerant (vegetative and reproductive) chickpea germplasm accessions with six controls under irrigated and un-irrigated environments for yield and yield attributing traits. Salinity tolerant accessions ICCs 4495 and 15996 produced higher seed yield (2.21 to 2.34 t ha^{-1}) compared to controls (080 – 2.16 t ha^{-1}) under irrigated environments. Similarly ICCs 67, 5003, 8950, and 15996 produced higher seed yield (1.23 – 1.37 t ha^{-1}) than controls (0.77 – 1.19 t ha^{-1}) under un-irrigated environment. On average ICC 15996 produced more pods per plant (35) and higher seed yield (1.79 t ha^{-1}) than controls (21 - 31 pods per plant and 0.78 – 1.67 t ha^{-1}) (Table 4).

Table 4. Performance of salinity tolerant chickpea germplasm accessions under irrigated and un-irrigated environments, 2007-08 postrainy season.

Identity	Pod plant^{-1}			Seed yield plant^{-1}			Seed yield kg ha^{-1}		
	Irrigated	Un-irrigated	Mean	Irrigated	Un-irrigated	Mean	Irrigated	Un-irrigated	Mean
ICC 67	41	36	38.5	7.4	5.8	6.6	1924	1373	1649
ICC 4495	52	27	39.5	9.7	5.3	7.5	2213	1128	1671
ICC 5003	40	22	31	10.3	5.7	8	2057	1228	1643
ICC 8950	43	24	33.5	7.4	5.0	6.2	2014	1278	1646
ICC 15996	41	28	34.5	8.5	5.8	7.15	2339	1244	1792
Control									
ICCV 2	30	23	26.5	6.0	5.5	5.75	1220	949	1085
ICCV 96029	30	27	28.5	4.5	4.8	4.65	795	769	782
JG 11	36	25	30.5	7.4	5.3	6.35	2156	1192	1674
JG 62	41	31	36	6.9	5.2	6.05	2133	1167	1650
Jumbo 2	24	17	20.5	7.9	5.8	6.85	1745	832	1289
L 550	33	28	30.5	7.1	5.5	6.3	920		920
Trial mean	42	28	-	7.8	5.5	-	1834	1063.0	-
CV%	22.3	24.2	-	24.5	27.8	-	13.7	16.4	-
SE±	5.56	4.1	-	1.1	0.6	-	161.98	105.7	-

Variation on root length density on chickpea yield: Extensive and deep roots have been recognized as one of the most important traits for improving chickpea productivity under receding soil moisture conditions. We evaluated 10 accessions each of small and large root length density along with controls (ICC 4958, Annigeri, and ICCV 2) under irrigated and non-irrigated conditions. ICCs 2072, 10945, 11198, and 15868 produced higher seed yield (1.62 t ha^{-1} to 1.93 t ha^{-1}) in comparison to drought tolerant control ICC 4958 (1.58 t ha^{-1}) under irrigated conditions. None of the accessions produced greater seed yield than ICC4958 under non-irrigated conditions.

Evaluation of deep root length chickpea lines for yield: Root depth is also a drought tolerance related trait in chickpea. We evaluated 10 accessions each of large deep root and small deep root along with ICC 4958, Annigeri, and ICCV 2 as control cultivars under irrigated and non-irrigated conditions. ICC 95 and ICC 1356 (1.97 – 2.00 t ha^{-1}) produced similar seed yield in comparison to drought tolerant control ICC 4958 (2.00 t ha^{-1}) under irrigated environment. None of the accessions produced greater seed yield than ICC 4958 under non-irrigated conditions.

HD Upadhyaya, J Kashiwagi, SL Dwivedi, CLL Gowda, L Krishnamurthy and V Vadez

Evaluation of chickpea reference set for agronomic traits: Chickpea reference set (293 accessions) and five controls (desi -Annigeri, G130 and ICCV10; kabuli - L550 and KAK 2) were evaluated for 24 phenotypic traits (7 qualitative and 17 quantitative traits) in alpha design during 2007/08 post-rainy season at Patancheru, India. Among desi types 18 accessions produced higher seed yield (2.77-3.23 t ha$^{-1)}$ than Annigeri (2.76 t ha$^{-1)}$, G 130 (2.54 t ha^{-1}) and ICCV 10 (2.23 t ha^{-1}). ICCs 11498, 13124, 1882, 4567, 3325 (2.9-3.2 t ha^{-1}) were the best five high yielding accessions. Among kabuli types 20 accessions produced higher seed yield (2.33 to 2.7 t ha^{-1}) than L550 (2.32 t ha^{-1} seed yield and 21 g 100 seed weight), KAK 2 (2.01 t ha^{-1} seed yield and 38.3 g 100-seed weight). ICCs 4841, 10466, 7668, 2482 and ICCV 95311 were the top 5 kabuli accessions that produced greater seed yield (2.5-2.7 t ha^{-1}). IGs 74052, 70826, 5949, ICCs 16796, 9137 were the best large seeded kabuli accessions (44-55g). ICCs 14595, 8318, 12654, 16374, 4533 were the earliest flowering lines (38-44 days).

HD Upadhyaya, N Lalitha, CLL Gowda and SL Dwivedi

Resistance to pod borer (*Helicoverpa armigera*): Reference set accessions (300) together with resistant (ICC 506) and the susceptible (L 550) checks was evaluated for resistance to pod borer in a randomized complete block design were three replications during the 2007/08 postrainy season. Data were recorded on leaf and pod damage, egg and larval density per 10 plants, overall resistance score, and grain yield. The material was also evaluated for resistance to *H. armigera* using detached leaf assay at the vegetative (30 days after seedling emergence) stage. For this purposes the terminal branches (5 to 7 cm long, with five fully expanded leaves) were infested with 10 neonate larvae in a 250 ml plastic cup in the laboratory. Data were recorded on leaf feeding on a 1 – 9 scale (1 = <10%, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

In detached leaf assay, leaf feeding scores ranged from 2.0 to 6.5, and 88 lines suffered a leaf damage rating of <3.0 compared to 3.0 in the resistant check, ICC 506. Larval weights on 54 lines were <2.0 mg (range 1.18 to 13.26 mg per larva) compared to 2.05 mg per larva on ICC 506. Nineteen lines exhibited low leaf feeding, and also resulted in low larval weights comparable to the resistant check, ICC 506.

Under natural infestation in the field, leaf feeding scores varied from 1 to 7, and 50 lines showed a leaf damage rating of <3.0 as compared to 4.5 in L 550, and 1.0 in the resistant check, ICC 506. There were 3.5 to 38.0 larvae per 10 plants, and 72 lines had lower larval numbers (<10 larvae per 10 plants) than the resistant check, ICC 506 (9.5 larvae per 10 plants). During the reproductive stage, there were 0 to 13.5 larvae per 10 plants and 102 lines had a larval density of <5 larvae compared to 3.0 in ICC 506. Pod damage ranged from 3.4 - 66.4%, and 75 lines had a pod damage of <10% compared to 4.0 % in ICC 506 and 12.3% in L 550. The grain yield of the test lines ranged from 10 to 1920 kg ha^{-1}, and 84 lines had a yield potential of >1,000 kg ha^{-1} under unprotected conditions. The accessions ICCV 10, ICC# 10939, 7413, 7272, 4872, 12155, 867, 8950, 3325, 10393, 16915, 1356, 1230, 283, 15802, 1098, 16903, 8384, 637, 5221, 15868, 14402, 14669, 11121, and 10018 showed lower susceptibility to damage by *H. armigera* and a yield potential of >1000 kg ha^{-1} under unprotected conditions. A further evaluation and selections from these lines will be used to identify lines for multiplication, and testing in the *H. armigera* resistance screening nursery, and for use in breeding programs by the national programs.

HD Upadhyaya, HC Sharma, N Lalitha and CLL Gowda

Evaluation of chickpea germplasm for protein content: Crude protein content was higher (20.34 to 26.94%) in 138 accessions than in Annigeri (19.06%), G 130 (20.26%), ICCV 10 (20.10%), L 550 (19.28%) and KAK2 (18.27%). ICCs 12654, 11903, 9418 and IG 69974 (26.07-26.94%) were the best lines with highest protein content.

HD Upadhyaya, N lalitha, CLL Gowda and KL Saharawat

Evaluation of chickpea reference set for drought tolerance: Using PVC cylinder screening technique, reference set was evaluated for drought avoidance root traits: root length density (RLD) and plant dry weight (PDW) to RLD (PDW/RLD) ratio. PDW was higher (2.25-3.2g) in about 50 accessions than in Annigeri (2.24 g), G 130 (1.84 g), ICCV 10 (1.79 g) and L 550 (1.97 g). ICC 9137, ICC 15406, ICC 15518, IG 5909 and 6055 (2.8 to 3.2 g) were best lines with highest PDW.

Root dry weight (RDW) was higher (0.623 to 0.903 g) in 115 accessions than in Annigeri (0.610 g), G 130 (0.580 g), ICCV 10 (0.620 g), and L 550 (0.590 g). ICCV 95311, ICCs 9862, 5504, 9137 and IG 10701 (0.840 to 0.903 g) are five lines with high RDW.

Root depth was higher (130-143 cm) in 7 accessions compared to Annigeri (128 cm), G 130 (120 cm), ICCV 10 (130 cm), and L 550 (108 cm). Accessions with maximum root depth (130-143cm) were ICCs 8740, 13764, 1882, 8647 and IG 6343.

RDW to total dry weight (TDW, which is sum of RDW and shoot dry weight) ratio was higher (27.4 to 32.7%) in 32 accessions than in Annigeri (21.1%), G 130 (24.5%), ICCV 10 (27.3%) and L 550 (24.7%). Five accessions with highest RWD/TDW ratio (30.2 – 32.7%) were ICCs 9942, 9434, 10885, 8195, and 2919.

Root surface area (RSA) was higher (876.70-1198.60 cm^2) in 51 accessions compared to Annigeri (876.50 cm^2), G 130 (798.19 cm^2), ICCV 10 (828.87 cm^2), and L 550 (699.0 cm^2). Accessions with maximum RSA were ICCV 95311, ICCs 5504, 15518, 8740, and 9137. Similarly, root volume was higher (11.59-16.16 cm^3) in 39 accessions compared to Annigeri (11.57 cm^3), G 130 (9.93 cm^3), ICCV 10 (10.18 cm^3) and L 550 (8.75 cm^3). ICCV 95311, ICCs 5504, 8740, 2277 and IG11045 showed the maximum root volume (14.39-16.16 cm^3).

HD Upadhyaya, N Lalitha, J Kashiwagi, V Vadez,
L Krishnamurthy, SL Dwivedi and CLL Gowda

Sources of resistance to diseases:

1. Chickpea

Two hundred and fifty new germplasm accessions were evaluated for resistance to ascochyta blight (AB), botrytis gray mold (BGM), fusarium wilt (FW), collar rot (CR) and dry root rot (DRR) diseases under controlled environment conditions at ICRISAT-Patancheru. Standardized resistance screening techniques based on sound epidemiological principles were used to evaluate these accessions for individual diseases. Severities of AB, BGM and DRR were scored on 1-9 rating scale and the incidence of FW and CR was recorded as percentage of mortality.

Resistance to AB: Sixteen lines were found resistant (0.1-3.0) and 103 moderately resistant (3.1-5.0) to AB.

Resistance to BGM: No line was found resistant however 46 lines were moderately resistant (3.0-5.0) to BGM.

Resistance to FW: Forty two lines were asymptomatic (0% incidence), one resistant (0.1-10%) and one moderately resistant (10.1-20%) to wilt.

Resistance to DRR: One line (ICC 2709) was resistant (0.1-10%) and 41 were moderately resistant (10.1-20.0%) to DRR.

Resistance to CR: One line (ICC 3988) was found moderately resistant (10.1-20.0%) to CR. Rest all the lines were susceptible.

Confirmation of wilt and SM in promising selections of pigeonpea: Fifteen pigeonpea wilt and sterility mosaic promising selections from glasshouse were reevaluated to confirm their resistance to wilt and SM in field under artificial epiphytotic conditions. Five lines (KPL 44-P7, KPL 44-P8, ICPL 93179 P1, KPBR 80-2-4P2 and V71B-P3) were found asymptomatic (0% incidence) and nine resistant (0.1-10%) to both wilt and SM.

S Pande, Mamta Sharma, HD Upadhyaya and CLL Gowda

2. Groundnut

Evaluation of confectionary germplasm: Twenty-five accessions along with five controls (Gangapuri, ICGS 76, ICGS 44, M 13 & Somnath) were evaluated during 2007-08 postrainy season at Patancheru. ICGs 5662, 12755, 8268, and 12256 produced higher pod yield (1.70 – 1.81 t ha^{-1}) and larger seeds (76-103 g 100-seed weight) than the controls (pod yield 1.49-1.70 t ha-^{1}; 100-seed weight 53.9-75.0 g). Per day productivity of these accessions was higher (12.2 – 13.4 kg ha^{-1} pods) than controls (11.0-12.1 kg ha^{-1}) (Table 5).

Table 5. Evaluation of large-seeded groundnut germplasm accessions, 2007-08 postrainy season

Identity	Shelling percentage	100-seed weight (g)	Pod yield plant^{-1} (g)	Pod yield (kg ha^{-1})	Productivity day^{-1} (kg ha^{-1})
ICG 5662	67.7	82.3	33	1813	13.2
ICG 9127	66.2	66.9	33	1803	13.4
ICG 12755	61.9	89.0	32	1789	13.1
ICG 8268	65.7	103.2	34	1773	12.6
ICG 12256	68.3	76.0	33	1695	12.2
Gangapuri	68.0	53.9	33	1489	11.2
ICGS 76	68.8	71.0	33	1651	12.1
ICGS 44	62.2	64.8	34	1637	11.9
M 13	68.6	75.0	34	1690	12.0
Somnath	68.8	69.4	30	1632	11.9
Trial mean	66.6	73.7	32	1539	11.10
CV%	5.3	9.1	34	30	29.85
SE±	1.9	4.3	3	207	1.54

Early maturity: Nineteen early maturing elite groundnut lines and three controls (Chico, Gangapuri, and JL 24) were evaluated for pod yield and other agronomic traits. Four lines with maturity similar to Chico produced higher pod yield (1.71 – 1.95 t ha^{-1}) than controls (1.49 – 1.71 t ha^{-1})

Evaluation of groundnut germplasm for agronomic traits: Two hundred and sixty four reference set accessions together with control (Gangapuri, M 13, ICGS 44 and ICGS 76) were evaluated in an alpha design during 2007-08 post-rainy and 2008 rainy seasons. In 2007/2008 postrainy season, ICG 11088, ICG 8285, ICCV 01276, ICCV 02266, and ICCV 02290 were the best performing (pod yield 4.48 – 5.25 t ha^{-1}) accessions over controls (3.13 – 4.45 t ha^{-1}) while in 2008 rainy season ICG 11426, ICG 11088, ICGV 01276, ICGV 02266, and ICGV 97182 produced higher pod yield (3.18-5.03 t ha^{-1}) than controls (1.52 – 2.06 t ha^{-1}) (Table 6). Accessions with higher pod yield in both seasons were ICG 12625 (*aequatoriana* type), ICG 9315, ICG 15415, and ICGV 86590 (*fastigiata* type), ICG 10053, ICG 11088 (*peruviana* type), ICG 3343, ICG 4955, ICG 14985, and ICGVs 01276, 02194, 02266, 02286, 95377, 97182, and 98294 (*vulgaris* type), and ICG 8285 and ICGV 02290 (*hypogaea* type). ICGs 3421, 11687, 442, 5779, and 1137 had greater shelling percentage (77-78%) while ICGs 7883, 5745, 2857, 8760, and 9905 higher 100-seed weight (83.3-89.2 g) over controls (shelling percent 71-72%; 100-seed weight 50.0-72.5 g).

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Table 6. Performance of cultivated accessions of groundnut reference set, 2007-08 postrainy and 2008 rainy seasons.

Identity	Botanical variety	Day to 50% emergence	Days to 50% flowering	Plant height (cm)	Days to maturity	Pods plant-1	Pod yield plant-1(g)	Shelling percentage	100-seed weight (g)	Pod yield-postrainy (kg ha-1)	Pod yield-rainy (kg ha-1)
ICG 12625	*aequatoriana*	10	33	34	125	29	37	65.9	61.4	3966	1843
ICG 15415	*fastigiata*	10	32	32	129	28	36	75.3	51.6	3810	2156
ICG 9315	*fastigiata*	9	31	33	127	31	33	75.1	53.0	3872	1947
ICGV 86590	*fastigiata*	10	34	34	127	28	35	72.8	54.6	4395	2889
ICG 10053	*peruviana*	10	32	31	129	26	35	65.4	57.5	4169	1908
ICG 11088	*peruviana*	9	33	31	129	26	33	70.3	53.7	5008	3185
ICG 14985	*vulgaris*	10	30	28	127	22	30	70.5	76.9	3942	1983
ICG 3343	*vulgaris*	10	31	31	125	27	27	72.8	54.0	3895	2054
ICG 4955	*vulgaris*	10	31	30	127	29	31	74.9	54.4	3804	1934
ICGV 01276	*vulgaris*	10	35	27	128	32	34	71.3	56.6	5248	4390
ICGV 02194	*vulgaris*	10	33	37	129	30	31	71.8	48.7	3879	3090
ICGV 02266	*vulgaris*	10	34	27	131	32	38	76.6	69.8	4759	5026
ICGV 02286	*vulgaris*	10	33	31	126	32	31	75.1	56.4	4328	3005
ICGV 95377	*vulgaris*	10	30	36	128	24	32	77.7	73.5	4154	2560
ICGV 97182	*vulgaris*	11	36	25	133	33	32	71.8	58.5	4102	3520
ICGV 98294	*vulgaris*	10	39	30	128	29	35	70.8	58.2	4516	4651
ICG 8285	*hypogaea*	10	43	28	134	32	37	70.8	61.4	4513	2149
ICGV 02290	*hypogaea*	11	34	24	142	29	31	76.1	64.9	4671	2335
Control											
Gangapuri	*fastigiata*	10	30	28	126	22	25	72.1	50.0	3133	1520
ICGS 44	*vulgaris*	11	32	22	135	28	28	71.1	59.0	3265	1893
M 13	*hypogaea*	10	38	26	138	25	31	70.3	69.0	4256	1892
ICGS 76	*hypogaea*	10	39	25	137	27	36	71.5	72.5	4452	2061
Trial mean		10.02	35.28	27.76	130.48	27.90	29.41	72.5	55.3	3270.58	1512.29
CV%		7.77	8.97	10.44	2.95	25.80	27.26	4.6	10.5	17.69	21.7
SE±		0.33	1.71	1.61	2.58	3.34	3.74	1.9	3.6	307.56	232.1

Evaluation of bud necrosis and defoliation tolerant germplasm for agronomic traits: Sixty-two previously identified bud necrosis disease (BND) resistant and defoliator tolerant accessions were evaluated for agronomic traits including pod yield along with controls (M 13, Gangapuri, ICGS 44, ICGS 76, Chico, JL 24, and TMV2). ICG 3027 and ICG 14228 produced greater pod yield (1.77 – 2.13 t ha^{-1}) while ICG 14355 and ICG 15060 showed higher 100-seed weight (79-80 g) over controls (pod yield 1.11- 1.73 t ha^{-1} and 100-seed weight 39-77g).

Additionally, 874 accessions were evaluated for resistance to BND and defoliation under field condition during 2007-08 postrainy season. Accessions with least BND incidence (0-3%) were 144 while 73 recorded less foliage damage (0-3%) over controls (BND 3-4% and defoliator damage 6-17%). Thirteen accessions were resistant to both BND and defoliation. Accessions with high yield (4.30– 4.87 t ha^{-1} compared to 2.58-4.03 t ha^{-1} in controls) and resistant to BND and defoliator were ICGs 875, 8285, and ICGVs 01276, 02276, and 02446. Another set of 911 accessions were evaluated for resistance to BND and defoliation under field condition during 2008 rainy season. A total of 192 accessions were resistant (0-2.5% damage) to BND and 178 defoliator damage (0-1%) in comparison to controls (BND 5-10% and defoliator damage 1-2%). Thirty-five accessions were resistant to both BND and defoliation. Of these, ICG 532 and ICGVs 01276, 87354, 01328, 86011, 02446, 86590, and 97182 produced higher pod yield (2.25 – 4.25 t ha^{-1}) over controls (0.78-1.11 t ha^{-1}).

GV Ranga Rao, HD Upadhyaya and SL Dwivedi

3. Pigeonpea

(i) Vegetable pigeonpea: Green pigeonpea pod is a more nutritious vegetable and than green pea (*Pisum sativum*) for which it forms a substitute. Long green pods with nutritious large sweet seeds are the preferred traits for vegetable type pigeonpea. Using characterization data, 105 vegetable type accessions and three controls (ICP 7119, ICP 11543 and 7035) were evaluated for days to 50% flowering, days to 75% maturity, fresh pod length (cm), pod width (mm), pod color, seeds/pod, seed shelling (%), 100-seed weight (g), seed color and taste as well for seed protein content (%), and soluble sugars (%) during 2007-08 season at ICRISAT Patancheru. ICP 13524, ICP 13438, ICP 14085, ICP 13387, ICP 15214 and ICP 13831 for fresh pod length (>10 cm); ICP 15222, ICP 15195, ICP 14362, ICP 13820 and ICP 13740 for fresh pod width (>15 mm); ICP 13831, ICP 13450 and ICP 13438 for seeds per pod (5.75); ICP 12746 for 100-fresh seed (>39.5 g) and ICP 13131 for soluble sugar (8.5%) were identified. Based on the initial evaluation, 51 vegetable type accessions were further grown in 2008-09 season to identify most promising vegetable pigeonpea germplasm accessions.

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(ii) Resistance to wilt and sterility mosaic: When re-evaluated the previously identified 15 wilt and sterility mosaic (SM) resistant lines from glasshouse evaluation to field evaluation under artificial epiphytotic conditions, five lines (KPL 44-P7, KPL 44-P8, ICPL 93179 P1, KPBR 80-2-4P2 and V71B-P3) were found asymptomatic (0% incidence) while nine resistant (0.1-10%) to both wilt and SM.

S Pande, Mamta Sharma and HD Upadhyaya

4. Sorghum

(i) Grain mold and rust resistance: Sixty-six of the sorghum core collections were screened for grain mold resistance during 2008 rainy season. The accessions (a score of <= 3 on 1-9 scale) were IS 472, IS 3387, IS 14333, IS 15121, IS 21461, IS 22063, IS 22996, IS 23521, IS 23528, IS 23560, IS 23586, IS 25733, IS 29877, IS 29901, and IS 30635. The same sets of 66 accessions were also evaluated for rust. IS 10302, IS 25419, IS 25733, IS 26869, and IS 29798 were resistant to rust. IS 25733 is found resistant to both for grain mold and rust.

RP Thakur, Rajan Sharma and HD Upadhyaya

(ii) Sweet sorghum: Eighty-nine sweet stalk accessions from 2007 rainy and 149 accessions from 2007-2008 post-rainy seasons' evaluation were further grown during 2008 rainy season to confirm high brix reading values recorded in earlier evaluations. Some of the accessions with high brix (> 17.99%) reading (total sugar content in stalks) were IS 995, IS 3390, IS 3393, IS 8348, IS 9883, IS 14290, IS 22555, IS 30405, IS 32300, IS 32569, IS 41382, IS 41406, IS 41409, IS 41411, IS 41414, IS 41495, IS 41518, IS 41519, IS 41525, IS 41526, IS 41530, IS 41621, IS 41636, and IS 41637. A total of 394 accessions (66 grain mold, 238 sweet sorghum, and 90 tan sorghum germplasm), 375 accessions of sorghum reference set, and 242 accessions of mini-core were grown during 2008 rainy season for further evaluation for brix reading.

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(iii) Kharif basic collection: Additionally, purely based on days to 50% flowering, plant height, panicle exsertion, ear head length and width, we identified 14-1 (16) 480, 393 (411) 659, 403 (418) 662, 447 (471) 496, 62 (73) 509, SSM 1057, SSM 1267, SSM 215, SSM 379, and SSM 505 as part of kharif basic collection for use in breeding programs to develop sorghum cultivars/hybrids adapted to kharif season.

(iv) Characterizing wild sorghum accessions: One hundred wild sorghum accessions in 2007 rainy season were characterized for days to 50% flowering, culm height, plants whether rooting at culm nodes, culm branching above, culm hairiness, culm pigmentation, waxy bloom, nodal hairiness, nodal hair type, nodal pigmentation, leaf sheath clasping, leaf shape, leaf color, midrib color, leaf blade (abaxial), leaf blade (adaxial), leaf margin hairiness, leaf sheath hairiness, ligule form, leaf length (5^{th} leaf) cm, leaf width (5^{th} leaf) cm, panicle exsertion (cm), panicle length (cm), panicle width (cm), rachis node number, plants whether rhizomatous or not, basal tillers, panicle shape, rachis continuity, branches at each node, spikelet pairing and raceme length. Likewise, 141 accessions were grown during 2008 rainy season, and recording of observations is in progress.

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Variability for Biological Nitrification Inhibition (BNI) in sorghum: In a collaborative work with JIRCAS, Japan, soil samples were taken from wild sorghum accessions (12) grown plots for BNI. The wild sorghum grown in this experiment included two accessions each of *S. aethiopicuum* and *S. arundinaceum*, and four accessions each of *S. verticilliflorum* and *S.* v*irgatum* during 2008 rainy season. The sample has been collected and yet to be analyzed.

Special Project Funding:
Partly from TL 1 for legume research

GV Subba Rao (JIRCAS), HD Upadhyaya and CLL Gowda

Output target 2.1.4 Germplasm accessions regenerated for conservation and distribution (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
India; Italy; Norway

Partners Involved:
GCDT (Global Crops Diversity Trust), Bioversity and Nordic Gene Bank (NGB)

Progress/Results:

Testing for seed viability and identification of critical germplasm for regeneration: We planted critical chickpea (cultivated – 79 and wild species - 49), groundnut (cultivated – 130 and wild species - 130) accessions in special facilities to increase seed number for subsequent field plantings. In a similar exercise we secured from 2007 plantings sufficient seeds of pearl millet (2) and groundnut (cultivated – 175 and wild species accessions – 130).

In 2008, we tested the seed viability of 4,524 accessions, which included 3,101 (sorghum-625; pigeonpea -763; and groundnut-1,713) critical accessions regenerated for active collection and 1,423 groundnut accessions multiplied for base collection. We also monitored the seed viability of 2,442 accessions representing chickpea (1,660) and pigeonpea (782) conserved as base collection for over 10 years. The seed viability ranged from 86-100% in chickpea and 68-100% in pigeonpea accessions. We identified eight pigeonpea accessions with viability <85% for regeneration.

Inventory on active collections of 23,169 accessions of sorghum (7,907), pearl millet (6,633), chickpea (2,269) and pigeonpea (6,360) has resulted in the identification of 10,119 accessions in these crops with seed stocks as critical for regeneration.

A total of 5,811 freshly harvested germplasm seed samples of different crops have been transferred to the cold rooms following standard protocols. This included 3,101 (sorghum: 625, pigeonpea: 763; and groundnut: 1,713) accessions as active collection and 2,710 (sorghum: 1,467; pigeonpea: 93; and groundnut: 1,150) accessions as base collection. With this addition, the total number of accessions as base collection increased to 106,528 accessions representing 89.6% of total collection. Likewise, seed viability data of 36,483 sorghum germplasm accessions conserved as active collection was analyzed. Large part of the tested sorghum active collection (95.6%) has maintained recommended levels (>85%) of seed viability for the past 22 years. Differences in sorghum seed viability are attributed largely to the growing environmental conditions of the season in which the accessions were regenerated. Germplasm accessions of race guinea and kafir have seed traits more desirable for storage. The classification and analysis of sorghum active collection based on viability is valuable for developing/improving existing protocols in managing the *ex-situ* collections. Results of these studies and data from future monitoring would be useful in estimating the approximated seed deterioration curves for different races of sorghum germplasm.

Ultra seed storage technology: A global experiment on lettuce in collaboration with USDA-ARS –NCGRP, Fort Collins, USA, CAAS, China and Biodiversity International, Italy to explore ultra dry seed storage technology and optimum conditions for seed storage was concluded after 14 years. A finite longevity (based on germination data) is achieved at storage temperatures of 50, 35 and 20ºC. Seeds stored at lower temperatures survive longer. Significant benefit or detriment by drying below the critical water content was not detected. A temperature x water content interaction affecting longevity was detected. The critical water content increased from about 0.012 to about 0.040 g/g when storage temperature decreased from 50 to 20ºC. These critical water contents correspond to a similar RH range of 15-25% for all storage temperatures but a different drying RH.

Germplasm at Svalbard Global Seed Vault (SGSV): Located on the Norwegian island of Spitsbergen near the town of Longyearbyen (130 m above seas level) in the remote Arctic Svalbard Archipelago, a Seed Vault has been established to preserve unique duplicate samples of seeds held in genebanks worldwide. The Seed Vault is managed under a tripartite agreement between Norwegian Government, the Global Crop Diversity Trust (GCDT), and the Nordic Genetic Resource Center (NGRC). GCDT has played a key role in the planning of seed Vault, provides operating costs for the facility, and coordinate shipments of seed samples to the Seed Vault in conjunction with the NGRC, while Norwegian government finance upkeep of the structure itself. With support from Bill & Melinda Gates Foundation and other donors, GCDT is assisting selected genebanks in developing countries as well as the CGIAR institutions to package and ship seeds to the Seed Vault. The Seed Vault provides an insurance against the loss of seeds in genebanks, as well as a refuse for seeds in the case of large scale regional or global crisis. Norwegian Prime Minister, Jean Stoltenberg and the noble laureate, Wangari Maathai, the founder of African Green Belt Movement, inaugurated this facility on 26th Feb 2008. ICRISAT Director General, Dr William D Dar, was part of the delegation that participated in the opening of this global initiative to store the seeds of agricultural crops from across the world.

Seed Vault has capacity to conserve 4.5 million seed samples, with each sample containing on average 500 seeds, a maximum of 2.25 billion seeds can be stored at -18^{o} C. The seed samples are sealed in specifically-designed four-ply aluminum foil packages that will be placed in sealed boxes and stored on shelves inside the Vault as black box storage. ICRISAT has committed to place 111,000 FAO-designated germplasm of the staple crops and small millets, in phased manner over next five year. We have deposited the first lot of 20,000 duplicate seed samples (sorghum: 5,000; pearl millet: 4,050; chickpea: 2,000; pigeonpea: 2,000, groundnut: 1,550; finger millet: 4,400; and foxtail millet: 1,000) as back-up storage at Svalbard Global Seed Vault during September 2008 and 950 samples of these crops for germination monitoring in due course. This is achieved through successful seed regenerations during 2007 at Patancheru, India. A similar set is projected for deposition in 2009.

Regenerating seeds for medium and long-term storage

(i) Chickpea and groundnut: In 2007/08 postrainy season, 1705 chickpea and 1773 groundnut accessions were regenerated. Similarly, 308 groundnut accessions were regenerated during 2008 rainy season. Additionally, we regenerated reference set accessions of chickpea and groundnut (300 each) for distribution to collaborating scientists of TL1 project.

(ii) Pigeonpea: In 2007/08, we have regenerated a total of 320 cultivated pigeonpea accessions for medium-term and long-term conservation. Our efforts to regenerate wild *Cajanus* species accessions have been successful: *C. scarabaeoides*, *C. platycarpus* and *C. cajanifolius* produced considerable quantity of seed for conservation and utilization. Some accessions of *C. albicans*, which flowered in 450 days, also produced seed by November 2008.

In 2008-09 season, 505 accessions of cultivated pigeonpea grown under insect proof cages are in podding stage. Crop growth is good and we are expecting good harvest from all accessions, A total of 100 assembled accessions of *C. scarabaeoides* were grown in field genebank and harvested good quantity of seeds (vary from 100-300 g) from all the accessions for conservation in medium-term store.

(iii) Pearl millet: We harvested sufficient seeds for conservation of 88 accessions of *P. polystachion*, planted in field genebank during 2008 rainy season. In addition, we planted 600 accessions of cultivated pearl millet in 2008/09 postrainy season for regeneration. Bagging of panicles to control the pollination is in progress.

(iv) Sorghum: In 2007-2008 post-rainy season, we regenerated 1260 accessions, which consists of 472 accessions for long-term conservation and 788 accessions for conservation at Svalbard (Norway). In addition, another set of 1119 accessions (reference set: 375, mini core 242, new germplasm from Niger 482, and yellow endosperm 20) were grown for regeneration and characterization. We also regenerated 240 accessions, where the seed quantity has gone below critical level (< 50 g) or viability < 85%. In the same year, 2379 accessions were processed for medium-term (1119 accessions) and long-term conservation (1260 accessions).

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Plant and seed health testing during regeneration and storage

(i) Plant health: In 2008 rainy season, a total of 1,148 germplasm accessions (groundnut - 643 and pigeonpea- 505) consisting of reference collection, diverse germplasm and regeneration accessions were inspected in the field plots during active growth period for their plant health status. In pigeonpea, *Sclerotium* rot during seedling stage in 25 accessions and yellow vein mosaic virus in 5 accessions were observed. At seedling stage in groundnut, crown rot caused by *Aspergillus niger* was noticed (0.5% in few accessions). Infected plants with these diseases were uprooted and burnt. Carbendazim (0.05%) + Mancozeb (0.2%) were sprayed three times at 2-week intervals to control leaf spots (*Cercospora arachidicola* and *Phaeoisariopsis personata*) in groundnut.

In 2008/09 post-rainy season, sorghum (1,695) and pearl millet (600) accessions consisting of reference set, regeneration for long-term conservation, and critical germplasm accessions were grown and these will be inspected during active growth period for plant health.

(ii) Seed health: A total of 1,358 germplasm accessions (sorghum - 577, groundnut - 501 and pearl millet - 170) regenerated from medium term storage of the genebank were evaluated for their seed health using the standard blotter method. Ninety-one accessions (sorghum 24, groundnut 23 and pearl millet 44) were free from pathogens. In the remaining accessions we detected 23 fungi in sorghum, 9 in groundnut and 9 in pearl millet. Major seed borne fungi were *Alternaria, Fusarium, Curvularia, Bipolaris* and *Phoma* in sorghum and pearl millet, while *Aspergillus, Rhizoctonia, Sclerotium* and *Fusarium* in groundnut. The accessions that were found unfit for storage and distribution varied from 3 to 24% across the three crops as the germination was below 80% and fungal infection from 2 to 100 %.

Special Project Funding:
GCDT, partly funded from TL1 project

RP Thakur and HD Upadhyaya

Output target 2.1.5 Germplasm databases updated for utilization (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
Australia; Denmark; India; Italy; Russia; Syria; USA

Partners Involved:
Bioversity (Italy), ICARDA (Syria), ATFCC (Australia), ECPGR (Italy), EURISCO (Rome, Italy), GBIF (Denmark), GRIN (USDA-ARS), VIR (Russia) and WIEWS (FAO)

Progress/Results:
Updating for completeness of germplasm database: Germplasm database on passport information, characterization and distribution were updated for completeness of data following SINGER format. ICRISAT is participating in the global crop registry activities of GPG2 project for chickpea crop. Chickpea Crop Registry is a tool to cross reference the global chickpea passport data to recognize and avoid the duplication and provide uniqueness in chickpea collections. As part of this system we are collecting data on global and national chickpea germplasm collections. Some of the collections identified are - ICRISAT (India), ICARDA (Syria), ATFCC (Australia), ECPGR (Italy), EURISCO (Rome, Italy), GBIF (Denmark), GRIN (USDA-ARS), VIR (Russia) and WIEWS (FAO). These collections have different data structures and to bring these collections into a standardized format FAO/IPGRI developed Multi-Crop Passport Descriptors. The list of multi-crop passport descriptors include Institute code (INSTCODE), Accession number (ACCNUMB), Collecting number (COLLNUMB), Collecting institute code (COLLCODE), Genus (GENUS), Species (SPECIES), Species authority (SPAUTHOR) etc. Developing into this format facilitates the germplasm passport information exchange very easy and the templates makes cross referencing easy and the data will be more relevant. After developing this system, we could be able to enhance many more features of the chickpea database and it could also be used for implementing for other crops.

Further, we identified 692 accessions of pigeonpea having gaps in characterization database and planted these during 2007-08 season to record observations on 34 morpho-agronomic traits. There upon, updated the pigeonpea characterization database by filling gaps with the data obtained from this evaluation. Likewise, 1130 new sorghum germplasm accessions from 35 countries were characterized for plant height (cm), plant pigmentation, basal tillers, nodal tillers, midrib color, days to 50% flowering, panicle exsertion (cm), panicle length (cm), panicle width (cm), panicle compactness and shape, glume color, glume covering, seed color, 100-seed weight (g), endosperm texture, seed luster, seed subcoat, seed size, threshability and for racial classification. We also updated our sorghum data base by including data for 100 seed weight (g), endosperm texture, seed luster and seed subcoat on 1640 accessions and threshability on 648 accessions.
Special Project Funding: GPG2

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Output target 2.1.6 85% of germplasm characterized and documented for utilization (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru, India

Progress/Results:
For updating groundnut database, 225 accessions in 2007-08 postrainy and 80 in 2008 rainy seasons were characterized. Likewise, in case of chickpea, 70 accessions in 2007-08 postrainy season were characterized to fill the gaps in chickpea database.

Special Project Funding:
NA

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Output target 2.1.7 Germplasm of staple crops assembled and conserved for utilization at regional genebanks in Africa (Bulawayo, Nairobi and Niamey) (2010)

Regional Genebank Niamey

Achievement of Output Target (%):
100%

Countries Involved:
Niger (ICRISAT) (germplasm from all over WCA)

Partners Involved:
M.Sc. student Judith Jäger from University of Hohenheim, Germany.

Progress/Results:
2006 accessions of groundnut, 7622 accessions of finger millet, 5205 accessions of pearl millet were conserved at -20° C in the deep freezers room at ICRISAT-Niamey.

A comprehensive strategy was developed and implemented for the pearl millet collection held at Niamey. This was done within the frame of the MSc thesis of Judith Jäger (University of Hohenheim, Stuttgart, Germany), entitled "A systematic approach to analyze the eco-geographical origin of germplasm exemplified for pearl millet in the genebank of ICRISAT Niger". All pearl millet germplasm data are now managed in an Access database enabling optional queries (instead of data dispersion in different excel sheets); passport and characterization data were completed as much as possible; maps were produced on the geographic distribution of the conserved germplasm; and gaps in the collection were identified (Table 7). The major gaps in the collection are wild millets.

Table7. "Before and after" status of the data of the pearl millet collection in the genebank of ICRISAT – Niger.

Subject	Before the thesis	After the thesis
Storage program	Excel® -table sheets	Access® database
Structure of passport data	Five incoherent table sheets	One table with all given data
Structure of characterization data	Altogether on table sheet for one belonging passport table sheet	One table for each characterization event
Structure of conservation data	Altogether one table sheet for one belonging passport table sheet	One table with all given data
Structure of "characterization on field"	Integrated into one of the "Passport" tables	On table with all given data of "Characterization on field"
Structure of descriptors	Each table has different descriptors and often other names for the same content	Uniform descriptors created, by combining the same content of the different descriptor names
Total number of Accessions	4.931: listed in all five tables together	5.355: listed in one table (including just new added 424 accessions from the active collection)
Quantity of Passport data exemplified at "Country of origin"	2.815	4.167
Quantity of Passport data, exemplified at "location"	2.068	3.623
Quantity of coordinates	1.092	3.644
Quantity of Conservation data	872	5.355 obvious declarations
Quantity of Characterization data	820: with comparable characterization information	2.750 comparable information from five characterization events
Quantity of "Characterization of collection site" data	449	557

A total of 1600 groundnut accessions were tested for germination. 150 critical groundnut accessions with very low germination rate (less than 50%) were regenerated in greenhouse yard pots. Two hundred sorghum accessions were regenerated under field conditions and characterized for twelve traits. Furthermore, 1500 groundnut accessions were regenerated in the field. About 300g of seeds of both sorghum and groundnut per accessions will be conserved after harvest for each accession.

Special Project Funding:
World Bank Genebank Upgrading Project; The Eiselen Foundation (stipend for MSc student from Germany)

Bettina Haussma

Regional Genebank Nairobi

Achievement of Output Target (%):
100%

Countries Involved:
Kenya, RSA and Tanzania

Partners Involved:
ICRISAT Nairobi, National Plant Genetic Resources for Kenya, South Africa and Tanzania

Progress/Results:
Data available at the ICRISAT and national gene banks was collated. The National Plant Genetic Resources (NPGR) of Kenya provided 994 data sets while the Genetic Resources Unit of the National Department of Agriculture of South Africa availed 257 data sets. The NPGR unit of Tanzania did not have additional data other than that available from ICRISAT. All the available collection sites were mapped using GIS and national partners assisted in identifying collection gaps. The NPGR of Kenya, KARI and ICRISAT carried out a joint collection mission in July-August 2006. Sorghum seed samples and passport data were collected in Western and Eastern Kenya. A total of 281 accessions were collected from Eastern Kenya and 385 cultivated and 34 wild sorghums were collected from western Kenya. The accessions collected from Western Kenya were characterised during the 2007-8 short rains in Alupe, western Kenya. Principal component analysis revealed that greatest variability among the accessions existed in seed vigour, plant height, agronomic score, and plant colour; stalk juice, panicle shape; length and weight, threshability (%) and grain weight. The collections have been incorporated in the GIS map of Kenya and have also been planted for morphological characterization at KARI-Embu.

Further, a sorghum germplasm collection mission was undertaken in the highlands of Tanzania by ICRISAT and NPGR Unit - TPRI-Arusha Tanzania between 29th July and 6th August, 2008. The collections were done in Karatu, Mbulu, Babati and Hanan'g districts in the northern Zone in altitudes ranging from 998 to 1899 meters above sea level. A total of 45 accessions were collected, one set left with NPGR unit Arusha and a second set sent is kept by ICRISAT-Nairobi. Part of the seed has been planted for characterization at Kiboko in the 2008/9 season and the remainder of the seed processed and stored at the gene bank in Nairobi. Characterization will also be done at the high altitude Kabete site –Nairobi in 2009.

Collection gaps were identified in South Africa especially within the former homeland areas. Collections will be done after obtaining an authorization form the NPGR unit of South Africa

Special Project Funding:
Africa Biofortified Sorghum –ABS (For Kenya) and DFID project R8445 for Tanzania

MA Mgonja, E Manyasa, H Ojulong, J Kibuka and P Sheunda

Output target 2.1.8 Unrestricted access and movement for staple crops germplasm ensured (2009)

Achievement of Output Target (%):
>50%

Countries Involved:
Forty-six countries including Australia; Brazil; Barbados; China; Ethiopia; France; India; Italy; Japan; Kenya; Mali; Niger; Nigeria; Norway; Pakistan; Senegal; South Africa; Syria; Tunisia; Taiwan; United States of America

Partners Involved:
NARS from the above-mentioned countries

Progress/Results:
Seed distribution: In 2008, we distributed a total of 8266 samples of staple crops germplasm (sorghum-2823; pearlmillet-2338, chickpea-1095; pigeonpea- 458; and groundnut-1552) for utilization to scientists in 24 countries in 99 consignments following standard protocols. Some of the special requests (16 no's) for germplasm include core/mini core and reference sets of sorghum, pearl millet, chickpea and groundnut for collaborative evaluation with NARS in India and seven other countries (France, Kenya, Mali, Niger, Nigeria Senegal and Syria).

Additionally, we provided 6023 samples of germplasm on 55 requests for internal utilization. The total includes sorghum-808; pearl millet-702; chickpea-3183; pigeonpea-272; and groundnut-1058. Some of the special requests include core collection of pearl millet, mini core of sorghum and pigeonpea and reference sets of chickpea and groundnut.

ICRISAT regional genebank at Niamey, Niger distributed one sorghum accession and 40 groundnut accessions for research and/or seed multiplication in the WCA region.

Number of samples processed for export/import through NBPGR Hyderabad: We facilitated the export of 15,524 seed samples (sorghum-4,537, pearl millet-1,037, chickpea- 4,420, pigeonpea- 808, groundnut-3,558 and small millets-1,164) comprising of breeding lines and germplasm accessions to 46 countries under 148 phytosanitory certificates. Additional 2371 samples (pearl millet-2,168, chickpea-167 and groundnut 36) are under processing – for completion by Dec 08. A total of 216 seed samples (about 1% of the total) (sorghum-90, pearl millet-6, Chickpea-9, pigeonpea-51 and groundnut-60) were rejected either due to poor germination, and/or association with seedborne fungi (*Bipolaris setariae, Fusarium oxysporum* f.sp. *ciceri, Botryodiplodia theobromae, Rhizoctonia bataticola, R. solani* etc.), store-grain pests, bacteria of unknown etiology.
We also facilitated import of 618 seed samples (sorghum-203, chickpea-300, groundnut- 102 and Small millets-13) from 6 countries against 9 import permit through NBPGR, New Delhi. In addition one IP each for groundnut (4 samples) from Niger and chickpea (20 samples) from Ethiopia are under processing.

Using Dept of Plant Protection, Quarantine and Storage (DPPQS), Govt. India, we further facilitated import of 347 samples of maize, sorghum, soybean and groundnut for nutritional analysis by ILRI through special import permit obtained from DPPQS. In addition, three requests from ILRI for obtaining special permission were processed to import 947 different crops samples of grounded seed, leaf, kitchen waste mixture and plant stover of maize, sorghum, soybean, mustard, and groundnut. Special import permissions were obtained for 347 and for the remaining it is under process. Two specific IPs were also obtained for the import of 50 soil samples from farmers' field from Nepal for micro and macro nutrient analysis by groundnut breeding group.

NBPGR, Hyderabad released 1743 germplasm samples of sorghum (427), chickpea (212), and groundnut (581) and small millets (5).

Grow-out test for imported samples. During the rainy season 46 sorghum accessions (USA-21 and China-25) were grown in PEQIA that were found free from exotic seedborne pest and released to concerned scientist. Five hundred thirty-five groundnut germplasm accessions from Japan grown in PEQIA showed *Peanut strip virus* (*PStV*) symptoms in most accessions; suspected samples were confirmed by ELISA; seedlings uprooted and incinerated, and prophylactic sprays made to avoid spread of the disease. Another consignment of groundnut from USA consisting of

44 germplasm accessions were grown in plant quarantine greenhouse and found free from exotic seedborne diseases and these were released to concerned scientist.

Of 212 chickpea accessions released, 33 from USA were grown in the greenhouse for observation on bacterial infection (unknown etiology) as these were found infected with bacteria during blotter test. Results are awaited.

In 2008/08 post-rainy season, 776 pearl millet germplasm accessions, 2 sorghum breeding lines and 5 finger millet accessions were planted in PEQIA. In addition, 498 maize accessions from Mexico (410) and Thailand (88) for SM Sehgal Foundation were also planted in PEQIA. These all will be evaluated for exotic seed-borne pathogens.

Special Project Funding:
GCDT fund for sorghum and pearl millet

RP Thakur, HD Upadhyaya and NBPGR

Output 2.2: Germplasm of six small millets assembled and conserved germplasm characterized/ evaluated and documented for utilization and knowledge shared with partners

Summary: Continuing our effort to assemble new germplasm, we identified 657 unique finger millet germplasm from ICRISAT regional bank, Bulawayo, Zimbabwe to enrich Patancheru-based ICRISAT genebank. Additionally, we received 43 new small millets germplasm from India. Likewise, when compared the finger millet germplasm database from Kenya, Tanzania and Uganda, the regional genebank in Kenya identified gaps in finger millet germplasm collection from Tanzania for future collection mission. A total of 1069 small millet accessions were regenerated, and during the regeneration, these accessions were regularly monitored for plant health, with emphasis on to use seeds from disease free plants for conservation. Seed distribution of small millets germplasm during the year include 5092 samples, with mostly of finger millet and foxtail millet going either to researchers within ICRISAT or to our partners in BMZ/GTZ-supported project in India, Germany, Kenya, Tanzania, and Uganda. Additionally, 1058 samples were provided to our own researchers.

A major evaluation program of finger millet and foxtail millet core collections has been initiated, with support from BMZ/GTZ project, in India, Kenya, Tanzania, and Uganda to identify promising germplasm to facilitate on-farm conservation and utilization of these nutritionally important millets in Asia and Africa.

Blast disease is the major biotic constraint to finger millet and foxtail millet production in Asia and Africa. The pathologist at ICRISAT perfected greenhouse screening technique for blast, and identified few finger millet accessions with blast resistance. In addition, few finger and foxtail millet accessions with high grain and forage yield were also identified.

Output target 2.2.1 New germplasm of small millets assembled for conservation and utilization (2009)

Global databases of foxtail, little, kodo, proso and barnyard millet compared to identify unique germplasm (2008)

Achievement of Output Target (%):
Fully Achieved
Countries Involved:
India; Japan

Partners Involved:
Tamil Nadu Agricultural University (TNAU); Coimbatore; India; NIAS, Japan and ICRISAT regional genebank at Bulawayo, Zimbabwe

Progress/Results:
Finger millet germplasm passport data of the ICRISAT regional genebank at Bulawayo, Zimbabwe were compared with ICRISAT-finger millet passport data at Patancheru and identified 657 unique germplasm accessions for future assembly and filling the gaps in our collection. Additionally, 43 new small millets germplasm accessions (8 of finger millet and seven each of foxtail millet, proso millet, little millet, kodo millet, and barnyard millet) received from TNAU were grown for regeneration, characterization and conservation. Further, ICRISAT germplasm databases for small millets were compared with the database of NIAS, Japan for identifying unique germplasm for assembly, and identified for acquisition of 294 finger millet, 1286 foxtail millet, 296 proso millet, 3 kodo millet and 547 barnyard millet germplasm. Other priority areas for small millets germplasm collections are: Asia (Bangladesh, China, India, and Korea), Central Africa (Chad), Eastern Africa (Rwanda, Tanzania and Zaire), Southern Africa (Angola and Mozambique), and West Africa (Cote d' Ivoire)
Special Project Funding: NA

HD Upadhyaya, CLL Gowda and TNAU scientists

Output target 2.2.1 Gaps in finger millet collection identified and potentially filled in at least two countries in ESA (2009)

Achievement of Output Target (%):
<50%

Countries Involved:
Kenya; Tanzania; Uganda

Partners Involved:
ICRISAT Nairobi, National Plant Genetic Resources curators for Kenya, Uganda and Tanzania, ICRISAT- India.

Progress/Results:
Geographic data in the genebank database was analyzed to indicate areas of interest to collectors and also to deepen understanding of the distribution of biodiversity within and between the related species. Using GIS tools, these latitude and longitude values were converted to spatial point layers showing location of finger millet identification points. Quality control and data verification was undertaken via overlaying administrative boundary, towns and villages layers over these points, and checking correspondence village annotations both from the existing layers and input points. A data set of 3522 accessions was obtained from the entire database of finger millet. This data set includes 944, 820 and 33 for

Kenya, Uganda and Tanzania respectively. The database with complete geo-referencing was determined out of the entire collection for each country. The curators in the national gene banks for each country, Tanzania, Kenya and Uganda were contacted to provide additional collection points to complement the collections conserved at the ICRISAT gene-banks. For those accessions where only the village names were given, the GIS experts in the respective countries were contacted to assist in getting the coordinates for the villages. Mapping of finger millet identification points was undertaken in two levels: (a) conversion of the existing data into GIS environment and, (b) updating the missing information with help of auxiliary information. Initial maps are available for Kenya, Uganda and Tanzania. Gaps have been identified only in Tanzania. Within the next year the output target will be completed once special project funding is available.

Special Project Funding:
NA

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Output target 2.2.2 Germplasm of six small millets conserved with 50% of germplasm characterized/evaluated for desirable traits and documented for utilization (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
Acharya N.G. Ranga Agricultural University (ANGRAU), Hyderabad; University of Agricultural Sciences (UAS), Bangalore; Rajendra Agricultural University (RAU), Dholi, India

Progress/Results:
As a part of BMZ/GTZ collaborative project, In 2008 rainy season we evaluated 622 accessions of finger millet core collection for days to 50% flowering, plant pigmentation, plant height (cm), growth habit, basal tillers, culm branching, flag leaf blade length (mm), flag leaf blade width (mm), flag leaf sheath length (mm), peduncle length (mm), panicle exsertion (mm), inflorescence length (mm), inflorescence width (mm), length of longest finger (mm), width of longest finger (mm), panicle branches, plot yield (g), inflorescence compactness, lodging, grain color, disease resistance. Likewise, 155 foxtail millet core collection germplasm accessions were evaluated for days to 50% flowering, plant pigmentation, leaf color, plant height (cm), growth habit, basal tillers, culm branching, flag leaf blade length (mm), flag leaf blade width (mm), flag leaf sheath length (mm), peduncle length (mm), panicle exsertion (mm), inflorescence length (mm), inflorescence width (mm), bristle length, panicle lobing, inflorescence compactness, lobe compactness, grain color, weight of 5 panicles (g), lodging, and senescence. Recording of post harvest observations in both the experiment is in progress.

In 2007 rainy season, 40 and 20 finger millet accessions, respectively, were evaluated for grain and forage yield. The five accessions that produced more grains than highest yielding control VR 708 (3.01 t ha^{-1}) were IE 4679, IE 2678, IE 2827, IE 2712, and IE 667 (3.07 to 3.74 t ha^{-1}) while accessions with forage yield greater than control, PR 202 (also known as IE 2043) (13.75 t ha^{-1}) were IE 24, IE 96, IE 715, IE 2942, IE 2979, and IE 3789 (14.17 to 18.33 t ha^{-1}). Similarly, 40 foxtail millet accessions were also evaluated for grain yield and identified ISe 776, ISe 792, ISe 801, ISe 1434, and ISe 1745 that produced more grains (1.76 to 1.91 t ha^{-1}) than highest yielding control, ISe 376 (1.69 t ha^{1}).

In 2008, we planted 1069 small millets germplasm accessions, (critical accessions, diverse germplasm, newly acquired germplasm, and finger millet and foxtail millet core collections) for regeneration and/or characterization. Recording of observations are in progress.

Special Project Funding:
BMZ/GTZ project on finger millet and foxtail millet

HD Upadhyaya and CLL Gowda

Output target 2.2.3 Databases of small millets germplasm updated for utilization (2010)
Passport, characterization and evaluation data of small millets germplasm documented (2008)

Achievement of Output Target (%):
<50% Achieved

Countries Involved:
India

Partners Involved:
Tamil Nadu Agricultural University (TNAU), Coimbatore

Comments/Explanations:
The experiments have been harvested and documentation of the characterization and evaluation data is in progress in finger millet and foxtail millet.

Progress/Results:
Passport information of 43 newly acquired small millets germplasm accessions from TNAU, Coimbatore, India were documented in our database. Observations on characterization and classification on these accessions are in progress. We also documented yield data of the 40 foxtail millet accessions.

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda and TNAU scientists

Output target 2.2.4 Germplasm accessions regenerated for conservation and distribution (2009)

Achievement of Output Target (%):
50%

Countries Involved:
India; Italy; Norway
Partners Involved:
GCDT (Global Crops Diversity Trust), Bioversity and Nordic Gene Bank (NGB)
University of Hohenheim-Germany, Bioversity

Progress/Results:
Germplasm with low seed stock regenerated: In 2008, the inventory on active collections of 6,410 accessions of finger millet (4,951) and foxtail millet (1,459) has resulted in the identification of 1,010 accessions in these crops with seed stocks as critical for regeneration. Seed viability of the composite collections of finger millet (976) and foxtail millet (408) accessions regenerated during 2007 have been tested and processed to medium-term cold rooms. In 2008 rainy season, 1069 small millet accessions (finger millet 820, foxtail millet 179, little millet 33, proso millet 12, barnyard millet 15, and kodo millet 10) were regenerated.

ICRISAT has committed to place 111,000 FAO-designated germplasm of the staple crops and small millets, in phased manner over next five year. We have deposited the first lot of 20,000 duplicate seed samples (sorghum: 5,000; pearl millet: 4,050; chickpea: 2,000; pigeonpea: 2,000, groundnut: 1,550; finger millet: 4,400; and foxtail millet: 1,000) as back-up storage at Svalbard Global Seed Vault during September 2008 and 950 samples of these crops for germination monitoring in due course. This is achieved thru successful seed regenerations during 2007 at Patancheru, India. A similar set is projected for deposition in 2009.

HD Upadhyaya and CLL Gowda

Monitoring plant health of small millets accessions grown in the field: A total of 1,069 small millets (finger millet-820, proso millet-12, foxtail millet-179, little millet 33, Kodo millet-10 and barnyard millet-15) germplasm accessions were evaluated during active growth period in the field for their plant health status. In finger millet 96 accessions were found infected with neck blast disease, 16 accessions with neck and finger blast and only 2 accessions with finger blast. Blast disease infection ranged from 1-70 %. Six accessions (IE- 3104, - 6708, - 2820, - 680, - 5173 and –5791) were found with high level of blast infection (50 to 70 %). Other small millets were found healthy during active growth period.

Special Project Funding:
BMZ/GTZ project, GPG2 Project and GCDT Funds

HD Upadhyaya, RP Thakur and CLL Gowda

Output target 2.2.5 Germplasm of small millets supplied on request (2011)

Achievement of Output Target (%):
<50%

Countries Involved:
India; Germany; Kenya; Tanzania; Uganda

Partners Involved:
University of Hohenheim, Germany; Acharya N.G. Ranga Agricultural University, Rajendranagar, AP, India; University of Agricultural Sciences, Bangalore, India; Rajendra Agricultural University, Dholi, India; Kenya Agricultural Research Institute, Kenya; Agricultural Research Institute, Tanzania; National Semi-Arid Resources Research Institute, Uganda.

Progress/Results:
In 2008, 5,092 samples of small millets germplasm (finger millet-4,152; foxtail millet-832; proso millet-36; little millet- 6; kodo millet-34; and barnyard millet-32) were distributed, in 26 consignments, to researchers in five countries. Of these, 1164 seed samples (finger millet-995 and foxtail millet- 169) were exported to Germany (810), Kenya (194), Tanzania (80) and Uganda (80).

Additionally, we provided 1,058 (finger millet-732 and foxtail millet-326) samples of germplasm on eight specific requests (core collections of finger millet and foxtail millet and mini core of finger millet) to researchers within ICRISAT.

Special Project Funding:
BMZ/GTZ project

RP Thakur, HD Upadhyaya, CLL Gowda and NBPGR

Output 2.3: Core, and mini-core collections and trait specific germplasm identified and evaluated and composite collections and reference sets developed and genotyped for utilization and new knowledge shared with partners

Summary: Core (10% of the entire collection of a species capturing over 70% genetic variability) and/or mini core (10% of core collection or 1% of entire collection) collections have been suggested as a gateway to the enhanced utilization of germplasm in crop improvement programs. Core collections in chickpea, groundnut, pearl millet, sorghum, pigeonpea, finger millet and foxtail millet and mini core collections in chickpea, pigeonpea, groundnut sorghum, and finger millet have been developed. Likewise, composite collections have been developed in chickpea, groundnut, pigeonpea, pearl millet, sorghum, and foxtail millet. Further, genotype-based reference sets, constructed by using marker profiling data (SSRs) on composite collections, have also been formed in chickpea, groundnut, Pigeonpea, sorghum and finger millet. These sets are now available to users of germplasm from ICRISAT genebank upon signing of Standard Material Transfer Agreement (SMTA).
When evaluated core, mini core and or reference sets, we identified a number of genetically diverse germplasm with beneficial traits: chickpea accessions with specific adaptation (irrigated and/or un-irrigated environments), early maturity, high grain yield and large-seeded kabuli’s, resistance to drought, salinity and Helicoverpa; drought and salinity tolerant groundnut accessions or those with superior agronomic performance including resistance to ELS and GRD; pigeonpea accessions with early maturity and resistance to multiple diseases (fusarium wilt, phytophthora and sterility mosaic); sorghum accessions with high sugar content or resistant to grain mold and anthracnose or tolerant to salinity; finger millet

accessions with early flowering, high grain yield and micronutrient dense (Fe and Zn) seeds; foxtail millet accessions with early flowering, high inflorescence length and width, and high grain yield. Efforts have also been directed towards identifying adapted finger millet germplasm in Eastern and Southern Africa, and in this process, a few finger millet accessions either with blast resistance or those with grain yield greater than 1.0 t ha^{-1} have been identified. Few advanced generation interspecific derivatives also showed varying degree of resistance to ELS when tested under high disease pressure in Malawi.

ICRISAT is one of the Ortholabs involved in identifying the ortho/homolog sequences in DREB2A gene in seven targeted species including chickpea and sorghum. DREB2 gene and its promoter in chickpea have been isolated and subsequently a set of eight diverse genotypes were sequenced at these candidate orthologous sequences. Apart from DREB2, SuSy, SPS, ASR, and ERECTA gene have also been isolated successfully in chickpea. Likewise, DREB2 gene has also been isolated in sorghum.

Output target 2.3.1 Core and mini core collections of germplasm established for utilization (2010)
Mini core collection of sorghum germplasm established for utilization (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
NA

Partners Involved:
ICRISAT Patancheru

Progress/Results:
The previously developed sorghum core collection (2247 accessions) was further evaluated for 21 descriptors in an augmented design using three controls. The hierarchical cluster analysis of data using phenotypic distances resulted in 21 clusters. From each cluster, about 10% or minimum of one accession was selected to form a mini core that comprised 242 accessions. The mini core and core collections data were compared using statistical parameters such as homogeneity of distribution for geographical origin, biological races, qualitative traits, means, variances, phenotypic diversity indices and phenotypic correlations. Mean difference percentage, variance difference percentage, coincidence rate, and variable rate were also calculated. These tests indicated that the mini core collection represented the variability present in the core collection. Geographically, this mini core represented accessions from five basic races (Bicolor, Caudatum, Durra, Guinea, and Kafir) and ten intermediate races (Guinea-Bicolor, Guinea-Caudatum, Guinea-Kafir, Caudatum-Bicolor, Kafir-Bicolor, Durra-Bicolor, Kafir-Caudatum, Kafir-Furra, and Durra-Caudatum). However, Caudatum, Durra, Guinea, Caudatum-Bicolor and Guinea-Caudatum accessions were predominant. Geographically, the accessions represented 58 countries grouped into ten regions (Central Africa, Eastern Africa, Southern Africa, Western Africa, Americas, East Asia, South and Southeast Asia, West Asia, Mediterranean and Oceania). Further, the five traits that contributed maximum to the variance in the core and mini core subsets were plant height, panicle exsertion, grain yield, and basal tillers, which must find high priority in sorghum breeding research. The multi-location evaluation of this mini core will be economically feasible for agronomic traits including resistance/tolerance to stresses to identify parents for utilization in breeding.

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda and SL Dwivedi

Core collection of foxtail millet germplasm established for utilization (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
NA

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Using taxonomic and qualitative traits data on 1474 accessions from 23 countries, a core collection of 155 accessions was established. Firstly, the accessions were stratified into three taxonomic races (Indica, Maxima and Moharia). Principal coordinate analysis was performed on 12 qualitative traits for each of the biological races, separately, that resulted in the formation of 29 clusters. From each cluster, 10% of accessions were selected to constitute a core collection of 155 accessions. The composition and diversity of the core collection was validated by χ^2 tests of the frequencies of origin, races, subraces and data on qualitative traits. The analysis of quantitative traits for mean, range, variance, Shannon-Weaver diversity index and phenotypic associations indicated that the diversity from the entire collection was optimally represented in the core collection. This core collection represented accessions from three races (Indica, Moharia and Maxima) and subraces (Nana, Glabra, Profusa, Assamense, Aristata, Compacta, Spongiosa, Erecta, and Fusiformis). Geographically, it represents accessions from South Asia, East Asia, West Asia, Europe, USA, and CIS countries. This core collection is a good resource to identify new sources of variation for agronomic traits including resistance to biotic/abiotic stresses and seed quality traits.

Special Project Funding:
NA

HD Upadhyaya and CLL Gowda

Diversity of pearl millet core collection studied (2009)
Achievement of Output Target (%):
>75%

Countries Involved:
NA

Partners Involved:
ICRISAT Patancheru

Progress/Results:
The previously reported pearl millet core collection (1600 accessions) Euphytica 155:35-45, 2007) was further augmented by adding 501 accessions representing 4717 accessions registered in the past nine years at ICRISAT genebank. This revised core now consists of 2094 accessions including 1831 landraces, 247 breeding lines and 16 advanced cultivars from 46 countries, thus, representing more geographical diversity from the entire collection as the previously developed core collection consisted accessions from 25 countries. A comparison of mean data using Newman-Keuls test, variance using Levene's test, and distribution using χ^2 test indicated that the variation in the entire collection of 20,766 accessions was preserved in the revised core collection. The Shannon-Weaver diversity index for different traits was similar in the revised core and entire collection. The revised core collection was observed to be more valuable than the original core as it has sources of resistance for important diseases such as downy mildew. The revised along with three control cultivars (IPs 3616, 17862 and 22281) was evaluated in an augmented design. Data analysis is in progress.

Special Project Funding:
NA

HD Upadhyaya and CLL Gowda

Mini core subset of finger millet established (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India; Kenya; Tanzania; Uganda

Partners Involved:
ICRISAT Patancheru; ICRISAT regional Center Nairobi, Kenya; and NARS partners from above-listed countries
Progress/Results: Finger millet core collection (622 accessions), adequately representing variability among five races and nine subraces, is presently being evaluated for 14 quantitative traits at five locations in India and part of the accessions in Kenya, Tanzania, and Uganda during 2008 rainy season, the recording of post-harvest observations is in progress, and the formation of finger millet mini core subset will be reported in 2009.

Special Project Funding:
BMZ/GTZ-supported finger millet and foxtail millet project

HD Upadhyaya, SL Dwivedi, CLL Gowda and NARS from India,
Kenya, Tanzania and Uganda

Mini core collection of pearl millet germplasm established for utilization (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
NA

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Developing core collection will not solve the problem of low use of germplasm as the size of the core collection would be unwieldy for convenient exploitation by breeders and crop improvement scientists. Pearl millet core collection consists 2094 accessions (10% of entire collection) is very large to manage and evaluate. Therefore, a mini core collection of pearl millet comprising of about 10% of core collection or 1% of entire collection) need to be constituted by evaluating the revised core collection of 2094 accessions for 22 morpho-agronomic traits. Observations were recorded on 30 plants per accession and data analysis is in progress.

Special Project Funding:
NA

HD Upadhyaya and CLL Gowda

Output target 2.3.2 Composite collections of germplasm established for utilization (2009)

Germplasm composite collections for finger millet (1000 accessions) and foxtail millet (500 accessions) established (2009)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru; Generation Challenge Program

Progress/Results
1. Finger millet: It consists of 1000 diverse finger millet accessions, which included 622 accessions of core collection, 222 accessions for various agronomic traits, and 50 accessions from Indian national program core collection, 85 accessions for various stress resistance, 12 accessions for grain nutrition traits, and 9 accessions possessing most genetic diversity in the ICRISAT collection. From the characterization data of composite collection, it reveals that the classification of composite collection consisted of race Vulgaris [subraces Incurvata (249 accessions), Digitata (230), Stellata (64) and Liliacea (36)], 208 accessions from race Plana [subraces Confundere (183), Seriata (15), and Grandigluma (10)], 132 accessions from race Compacta which has no subraces, 71 accessions from Elongata [subraces Reclusa (31), Sparsa (20) and Laxa (20)], *spontanea* (7) and *Africana* (3). Geographically it consists of accessions from South Asia (328 accessions), Eastern Africa (362), Southern Africa (261), Western Africa (67), Central Africa (3), Europe (7), Americas (5), and Unknown origin (27).

2. Foxtail millet: It consists of 500 diverse foxtail millet germplasm accessions, which included 155 core collection accessions, 33 agronomically elite accessions, nine large grain size accessions, five accessions with high grain yield, 77 early flowering types, 21 dwarf types, 25 accessions with more number of basal tillers, 59 mono tiller, 18 accessions with long inflorescence and 40 accessions with short inflorescence length, 25 accessions with more inflorescence width, 23 accessions with less inflorescence width, and 10 cultivars.

Special Project Funding:
Generation Challenge Program

HD Upadhyaya, SL Dwivedi, CT Hash and CLL Gowda

Output target 2.3.3 New reference sets of chickpea, groundnut, pigeonpea and sorghum germplasm (300 accessions each) established and evaluated for utilization (2010)

Diversity of groundnut and pigeonpea composite collections analyzed and reference sets (300 accessions each) established (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Groundnut: The groundnut composite collection (1000 accessions) was molecularly profiled using 21 SSRs in high throughput assay (ABI3700). A total of 490 alleles were detected in the composite collection, of which 244 were rare and 246 common alleles. Gene diversity ranged from 0.559 to 0.926, with an average of 0.819. Group-specific unique alleles were 101 in wild *Arachis*, 50 in subsp. *fastigiata*, and only 11 in subsp. *hypogaea*. Accessions from America's revealed highest number of unique alleles while Africa and Asia, respectively, had only six and nine unique alleles. Two subsp. *hypogaea* and *fastigiata* shared 70 alleles. The wild *Arachis* in contrast shared only 15 alleles with subsp. *hypogaea* and 32 alleles with subsp. *fastigiata*. A tree-diagram using DARwin 5.0 separated majority of the subsp. *hypopgaea* accessions from the subsp. *fastigiata* while wild *Arachis* accessions clustered with subsp. *hypogaea*. A reference set (300 accessions, http://www.icrisat.org/GroundNut/Groundnut_Reference1.htm) has been developed (based on simple matching distance matrix), capturing 466 (95%) of the 490 composite collection (852 accessions) alleles, and possessing high gene diversity (mean 0.831, range 0.5484 – 0.9274).

Pigeonpea: The pigeonpea composite collection (1000 accessions) was molecularly profiled using 20 SSRs in high throughput assay (ABI3700). A total of 197 alleles were detected in the composite collection, of which 115 were rare and 82 common alleles. Gene diversity varied from 0.002 to 0.726. Biologically, group-specific unique alleles were 60 in wild types and 64 in cultivated types. Among cultivated accessions, 37 were in NDT (nondeterminate) type, geographically, 32 in Asia 4 (Southern Indian provinces, Maldives and Srilanka), 7 in Asia 6 (Indonesia, Philippines and Thailand), 5 in Asia 3 (Central Indian provinces), and 4 in Asia 1 (Northwestern Indian prvinces, Iran and Pakistan). Only two alleles in Africa differentiated it from other regions. Wild and cultivated types shared 73, DT (determinate) and NDT shared 10, DT and wild shared 4, and the NDT and wild shared 20 alleles. Asia 1 shared 4 alleles with Asia 3 and 3 alleles with Asia 4. Asia 4 shared 6 alleles with Asia 3 and 5 with Asia 6. Tree-diagram using DARwin 5.0 revealed wild types as a group were genetically more diverse that cultivated types. NDT types were more diverse than the other two groups based on flowering pattern (DT and SDT: Semi-determinate). Simple matching allele frequency-based distance matrix was used to identify a reference set (300 accessions; (http://www.icrisat.org/PigeonPea/Pigeonpea_Reference1.htm), capturing 187 (95%) of the 197 composite collection alleles, representing diversity of the entire composite collection (20 SSR data on 952 accessions).

Special Project Funding:
Generation Challenge Program

HD Upadhyaya, R Bhattacharjee, SL Dwivedi, RK Varshney,
DA Hoisington and CLL Gowda

Output target 2.3.4 Core, mini core, and or reference sets of germplasm evaluated for utilization in Asia (2009)

Mini core collections of chickpea, groundnut, and pigeonpea evaluated in multilocations in Asia

1. Chickpea
Achievement of Output Target (%):
>75% Achieved

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru and Indian NARS partners

Comments/Explanations:
Data from some NARS locations is awaited and analysis of the data that was received is in progress.

Progress/Results:
Chickpea mini core collection was evaluated for yield and yield attributing traits in seven environments during 2000 to 2004 at ICRISAT Patancheru. Data was analysed and genetic structure was studied for selecting donors with good potential and reasonable adaptation for different characters, which are likely to yield superior segregates in a hybridization program. This exercise enabled us to identify 23 accessions adapted to irrigated, 11 to non-irrigated, and 14 to both irrigated and non-irrigated environments. A total 40 accessions for early maturity, higher seed yield and large-seed weight was identified for use in crop improvement programs. (Table 8)

Table 8. Performance of elite genotypes of chickpea minicore germplasm for selected traits across seven environments.

Genotype	Regression coefficient values						Promising traits
ICC	DF	DM	PN	SW	YKGH	YPP	
440	1.039	1.402	0.475	0.326	1.052	0.66	YKGH,YPP,DF,SW
637	1.165	-0:925	0.139	0.618	0.865	0.676	YKGH,YPP,PN,DM
1098	1.125	1.686	1.289	0.682	0.974	1.133	YKGH,PN,DM,SW
1180	0.805	0.697	2.033	0.683	0.972	1.724	PN,DF,DM,SW,YKGH
1205	1.202	1.811	0.848	0.665	1.219	0.862	YKGH,YPP,PN,SW, DM
1392	1.08	1.647	0.644	1.278	1.177	0.97	YKGH,YPP,PN
1422	1.455	0.68	0.97	1.121	1.083	0.978	DM,PN,YPP
1882	1.472	2.765	0.857	0.682	1.102	1.067	YKGH,PN,SW
1915	0.401	-0.583	0.786	1.747	0.852	1.23	SW,DF,DM,PN,YKGH
3325	1.221	1.893	1.791	0.685	1.013	1.415	YKGH,PN,DM,SW
3362	1.172	1.458	1.936	0.283	1.265	1.021	YKGH,SW
4533	1.742	1.919	1.506	0.972	1.096	1.236	DM,SW
4567	1.268	2.005	2.162	1.462	1.28	2.189	YKGH
5135	0.962	0.315	1.408	0.486	0.939	1.021	YKGH,DF,DM,SW
5383	1.318	1.74	0.602	1.124	1.007	0.837	SW,PN,YPP
5845	0.52	1.053	-0.009	0.391	0.933	0.391	DF,PN,SW,YKGH,YPP,
6571	1.147	1.344	1.466	0.374	0.788	1.04	YKGH,SW
6802	0.677	-0.129	0.774	2.998	0.83	0.947	YKGH,YPP,DF,DM,PN
7441	1.53	3.076	1.022	0.602	0.985	0.921	YKGH,YPP,PN,DM
8384	1.384	0.974	1.466	0.682	0.962	1.082	YKGH,PN,DM,SW
8621	1.35	2.297	1.803	0.661	1.007	1.727	YKGH,DM,SW
8950	1.27	1.702	1.252	0.422	0.954	1.107	YKGH,DF,SW
9586	0.939	2.139	1.33	0.613	1	1.098	YKGH,DF,SW
10399	1.422	0.449	2.051	0.649	0.921	1.481	YKGH,PN,DM,SW
12307	1.195	0.911	1.429	0.335	0.972	1.14	YKGH,PN,DM,SW
12866	1.23	3.091	0.882	0.306	0.903	0.56	YPP,PN,YKGH,SW
14402	1.529	3.061	1.469	0.671	0.948	1.307	YKGH,PN,DM,SW
14595	1.612	3.137	0.494	1.099	1.049	0.886	YKGH,YPP,DM,PN,SW
14669	1.419	1.483	0.668	0.622	1.304	0.705	DM,PN,YPP,SW
14815	1.191	2.26	1.706	0.739	0.839	1.462	YKGH,PN,SW
14831	1.159	0.015	2.66	0.739	0.979	1.749	YKGH,PN,SW,DM
15333	1.033	1.604	0.361	2.133	1.079	0.758	YPP,PN,SW
15612	1.38	1.243	0.852	1.184	1.132	0.876	YPP,PN,SW
15618	1.52	2.31	0.918	0.547	0.899	0.889	YKGH,YPP,DM,PN,SW
15868	1.191	1.667	1.078	0.461	0.977	1.007	YKGH,PN,DM,SW
16207	0.914	0.918	1.408	0.673	1.074	1.343	PN,SW
16524	1.054	1.833	2.398	0.578	1.305	1.434	YKGH,SW
16796	0.699	-0.611	0.785	3.493	0.847	1.356	YKGH,DF,DM,SW,PN
16903	1.483	1.038	0.719	0.971	1.103	0.832	DM,PN,SW,YPP
16915	1.459	2.197	1.12	0.811	1.081	1.004	DM,SW

YKGH=yield (kg ha^{-1}), PN=Number of pods per plant, DM=days to maturity, DF=days to 50% flowering, SW=100 Seed Weight, YPP=Yield per plant (g)

Special Project Funding:
NA

HD Upadhyaya, S Kumar, R Kumar, SL Dwivedi and CLL Gowda

2. Groundnut
Achievement of Output Target (%):
>75%

Countries Involved:
China; India; Thailand; Vietnam

Partners Involved:
ICRISAT Patancheru and NARS partners from above-listed countries

Progress/Results:
The groundnut mini core collection accessions along with controls (Gangapuri, ICGS 44, ICGS 76 and M 13) were evaluated in 19 environments in India, and in China, Thailand, and Vietnam. Based on pooled analysis, 47 accessions with superior performance (top 10%) for days to 50%

flowering, pods/plant, shelling %, 100-seed weight and pod yield were selected. SLA and SPAD chlorophyll meter reading at 60 and 80 DAS were also taken as these relate to drought tolerance (Table 9).

Table 9. Groundnut accessions identified based on overall superiority for important agronomic traits along with data on certain qualitative morphological traits

Accession (s)	Variety	Source	Growth habit	Pigmentation	Branching pattern	Pod reticulation	Seeds per pod
ICG 36	*fastigiata*	India	Erect	Absent	Sequential	Slight	2 -1
ICG 332	*fastigiata*	Brazil	Erect	Present	Sequential	Slight	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 3673	*fastigiata*	Korea	Erect	Absent	Sequential	Moderate	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 3681	*fastigiata*	USA	Erect	Present	Sequential	Slight	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 3775	*fastigiata*	Brazil	Erect	Absent	Sequential	Slight	2 -3 -1/2 -1 -3
ICG 4670	*fastigiata*	Sudan	Erect	Present	Sequential	None	3 -2 -1/3 -1 -2
ICG 5609	*fastigiata*	Sri Lanka	Erect	Present	Sequential	Slight	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 6201	*fastigiata*	Cuba	Erect	Present	Sequential	None	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 6646	*fastigiata*	Unknown	Erect	Absent	Sequential	Very Prominent	3 -2 -1/3 -1 -2
ICG 10479	*fastigiata*	Uruguay	Decumbent-1	Absent	Alternate	Prominent	2 -1
ICG 10554	*fastigiata*	Argentina	Erect	Present	Sequential	Moderate	2 -3 -1/2 -1 -3
ICG 10566	*fastigiata*	Congo	Erect	Present	Sequential	Moderate	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 11144	*fastigiata*	Argentina	Erect	Present	Sequential	Slight	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 13858	*fastigiata*	Uganda	Erect	Present	Sequential	Slight	2 -3 -4 -1/2 -4 -3 -1/2 -3-1-4
ICG 15309	*fastigiata*	Brazil	Erect	Present	Sequential	Slight	3 -2 -1/3 -1 -2
ICG 15419	*hirsuta*	Ecuador	Erect	Present	Sequential	Very Prominent	3 -2 -1 -4
ICG 163	*hypogaea*	Unknown	Erect	Absent	Sequential	Slight	2 -1
ICG 297	*hypogaea*	USA	Erect	Absent	Sequential	Moderate	2 -3 -1/2 -1 -3
ICG 532	*hypogaea*	Unknown	Decumbent-2	Absent	Alternate	Moderate	2 -3 -1/2 -1 -3
ICG 1668	*hypogaea*	USA	Decumbent-2	Absent	Alternate	Moderate	2 -1
ICG 2381	*hypogaea*	Brazil	Procumbent-1	Absent	Alternate	Moderate	2 -1
ICG 4527	*hypogaea*	Uganda	Decumbent-2	Absent	Alternate	Moderate	2 -1
ICG 5016	*hypogaea*	USA	Procumbent-1	Absent	Alternate	Moderate	2 -1
ICG 5051	*hypogaea*	USA	Decumbent-1	Present	Alternate	Prominent	2 -1
ICG 5662	*hypogaea*	China	Decumbent-3	Present	Alternate	Moderate	2 -1
ICG 5745	*hypogaea*	Puerto Rico	Decumbent-3	Absent	Alternate	Moderate	2 -1
ICG 6766	*hypogaea*	USA	Decumbent-3	Absent	Alternate	Moderate	2 -1
ICG 8083	*hypogaea*	Russia & CISs	Erect	Absent	Sequential	Moderate	2 -1
ICG 8760	*hypogaea*	Zambia	Procumbent-1	Absent	Alternate	Moderate	2 -3 -1/2 -1 -3
ICG 11855	*hypogaea*	Korea	Decumbent-2	Absent	Alternate	Slight	2 -1
ICG 11862	*hypogaea*	Korea	Decumbent-2	Absent	Alternate	Moderate	2 -1
ICG 13099	*hypogaea*	Unknown	Procumbent-1	Absent	Alternate	Moderate	2 -1
ICG 14482	*hypogaea*	Nigeria	Decumbent-3	Absent	Alternate	Slight	2 -1
ICG 10890	*peruviana*	Peru	Erect	Present	Sequential	Slight	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 11088	*peruviana*	Peru	Erect	Absent	Sequential	Very Prominent	3 -2 -4 -1/3 -2 -1 -4/3 -4-2-1
ICG 1519	*vulgaris*	India	Erect	Absent	Sequential	Slight	2 -1
ICG 4543	*vulgaris*	Unknown	Erect	Absent	Sequential	Slight	2 -1
ICG 4729	*vulgaris*	China	Erect	Absent	Sequential	Slight	2 -1
ICG 4750	*vulgaris*	Paraguay	Erect	Present	Sequential	Moderate	2 -3 -1/2 -1 -3
ICG 5236	*vulgaris*	Chile	Erect	Absent	Sequential	Moderate	2 -1
ICG 6407	*vulgaris*	Zimbabwe	Erect	Absent	Sequential	Moderate	2 -3 -1/2 -1 -3
ICG 6703	*vulgaris*	Paraguay	Erect	Absent	Sequential	None	2 -1
ICG 9157	*vulgaris*	Puerto Rico	Erect	Absent	Sequential	Moderate	2 -1
ICG 9809	*vulgaris*	Mozambique	Erect	Absent	Sequential	Slight	2 -1
ICG 12625	*vulgaris*	Ecuador	Erect	Absent	Sequential	Very Prominent	3 -2 -1/3 -1 -2
ICG 12879	*vulgaris*	Myanmar	Erect	Absent	Sequential	Moderate	2 -1
	vulgaris	India	Erect	Absent	Sequential	Moderate	2 -1

Special Project Funding:
NA

HD Upadhyaya, L Boshou, L Giang, SL Dwivedi and CLL Gowda

3. **Pigeonpea**

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru and Indian NARS

Progress/Results:
We evaluated pigeonpea mini core collection at Sardar Vallabhai Patel University of Science and Technology, Meerut, India, and data analysis is in progress.

HD Upadhyaya, R Kumar, SL Dwivedi and CLL Gowda

Core collection of pearl millet evaluated in multi-locations in India (2008)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru and Indian NARS partners

Progress/Results:
We evaluated pearl millet core collection (2094 accessions) along with three control cultivars (IPs 3616, 17862, 22281) in augmented design during 2008 rainy season at Patancheru, India. IP 5719 and IP 8378 flowered significantly earlier (30-31 days) than all the control cultivars (40-56 days). IPs 10437, 11353, 22271, 12939, 11589, 11320, 17753, 17620, 13892, 17604, and 13900 had larger seed size (16.0-19.3 g) than controls (4.2-15.5 g). Twenty accessions scored high for seed yield (a score of 8) than controls (6 – 7), on 1-9 scale where 1 is poor and 9 excellent. Likewise, IPs 5964, 8512, 10437, 11834, 12898, 17435, 17442, 20416, and 20745 showed greater potential for green fodder yield (a score of 9) than controls (6-7). IP 5964 had excellent synchrony of panicle maturity (a score of 9) in comparison to controls (6-7).

Part of this core collection (504 accessions) together with controls (IPs 3616, 17862, 22281) was also evaluated in augmented design at Mandor and Durgapura in Rajasthan and at Jamnagar in Gujarat, India. At Jamnagar 18 accessions flowered earlier (50 days) than controls (51-64 days); IPs 3626, 4150, 11765, 11784, 13884, 15257, 15304, and 16131 had higher number of tillers (4) than controls (2); IPs 4952, 17862, 10456, 13191, 9496, 12925, 8972, 8426, and 9426 has greater 1000-seed weight (10.0 -12.0 g) had greater controls (5.4 – 9.6 g); IPs 6897, 6396, 3529, and 3749 scored high (a score of 7-8) for green fodder yield than controls (3.7-5.6), on 1-9 scale where 1 is poor and 9 is excellent. Likewise, IPs 11454, 13840, 11503, 19408, 13833, 5816, 13818, and 19175 had recorded greater over all plant aspect score (7-8) than controls (4- 6). The days to 50% flowering at Durgapura ranged from 37 – 72 days (25 accessions flowered earlier than controls) while 49-106 days at Mador. For seed yield, IPs 17350, 3150, 6769, and 17862 at Mandor and IPs 17945, 7095, 12591, 3163, and 12310 at Durgapura produced greater seed than controls. Promising accessions for green fodder yield were IPs 15304, 3616, 6125, 6148, and 5666 at Mandor and IPs 13885, 6146, 6396, 15257, 3382, and 19299 at Durgapura. IP 17566 (13.0 g 1000-seed weight) at Mandor, IPs 11893, 19160, 10705, 14160, 6125, and 5695 (13.0-17.0 g 1000-seed weight) at Durgapura had larger seed size than controls.

Special Project Fundings:
NA

IS Khairwal, CJ Dangaria, S Kant, HD Upadhyaya and CLL Gowda

Reference set of chickpea phenotyped for agronomic traits (2009)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru and Indian NARS

Progress/Results:
Chickpea reference set (293 accessions) and five controls (desi -Annigeri, G130 and ICCV10; kabuli - L550 and KAK 2) were evaluated for 24 phenotypic traits (7 qualitative and 17 quantitative traits) in alpha design during 2007/08 post-rainy season at Patancheru, India. Among desi types 18 accessions produced higher seed yield (2.77-3.23 t $ha^{-1)}$ than Annigeri (2.76 t $ha^{-1)}$, G 130 (2.54 t ha^{-1}) and ICCV 10 (2.23 t ha^{-1}). ICCs 11498, 13124, 1882, 4567, 3325 (2.9-3.2 t ha^{-1}) were the best five high yielding accessions. Among kabuli types 20 accessions produced higher seed yield (2.33 to 2.7 t ha^{-1}) than L550 (2.32 t ha^{-1} seed yield and 21 g 100 seed weight), KAK 2 (2.01 t ha^{-1} seed yield and 38.3 g 100-seed weight). ICCs 4841, 10466, 7668, 2482 and ICCV 95311 were the top 5 kabuli accessions that produced greater seed yield (2.5-2.7 t ha^{-1}). IGs 74052, 70826,

5949, ICCs 16796, 9137 were the best large seeded kabuli accessions (44-55g). ICCs 14595, 8318, 12654, 16374, 4533 were the earliest flowering lines (38-44 days).

Special Project Funding:
NA

HD Upadhyaya, N Lalitha, SL Dwivedi and CLL Gowda

Reference set of sorghum phenotyped for agronomic traits (2009)

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Sugar content in sorghum stalk: From the previously evaluated sorghum reference set and germplasm lines from East and west Africa for sugar content, a total of 190 germplasm lines were further evaluated for Brix reading (sugar content) in a replicated trial during 2008 rainy season which ranged from 7.9 to 23% (SSV 84: 21.5% and CSH 22SS: 18%; Mean: 17.3%; LSD: 3.87). A total of 68 germplasm lines with Brix >19% were selected and are being evaluated in a trial in 2008/09 postrainy season at Patancheru. The ten countries that contributed to the selections are: Ethiopia (32) Cameroon (9), Kenya (8), Sudan (7), Uganda (5), Republic of Yemen (2), Angola (1), Malawi (1), Nigeria (1), and Zambia (1).

Special Project Funding:
NA

BVS Reddy, P Srinivasa Rao and HD Upadhyaya

Output target 2.3.5 Core and mini core collections of germplasm evaluated and trait specificity identified (2011)

Mini core and reference collections of chickpea germplasm evaluated for resistance to AB, BGM, wilt, collar rot and dry root rot under controlled environment and field conditions (2008)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:
Sources of resistance to ascochyta blight (AB), botrytis gray mold (BGM), fusarium wilt (FW), collar rot (CR), and dry root rot (DRR) in chickpea: Chickpea mini core collections of 211 accessions were evaluated in the year 2005 and reevaluated in 2006 to confirm their resistance to FW, AB, BGM, DRR and CR at ICRISAT, Patancheru. The data has already been published in Plant Disease, 90: 1214-1218 (Pande et al. 2006).

Further, 67 accessions of reference set were evaluated for resistance to FW, AB, BGM, DRR and CR following standardized evaluation techniques for individual diseases at ICRISAT-Patancheru. Incidence of FW and CR was recorded as percentage of mortality and severities of AB, BGM and DRR were scored on 1-9 rating scale.

Of these, six accessions (ICCs 2580, 2720, 3218, 3230, 3239 and 3582) were found asymptomatic (0% incidence) and one accession ICC 2072 was found resistant (0.0-10% incidence) to FW. For AB, ICC 4363 was resistant (1-3 rating on 1-9 scale) and 13 moderately resistant (3.1 to 5 rating on 1-9 scale) under controlled environment. For BGM, **e**ight accessions were identified moderately resistant (3.1 to 5 rating on 1-9 scale) under controlled environment. For DRR, of the 67 accessions, no accession was resistant however, 14 accessions were moderately resistant. All the 67 accessions were found highly susceptible to collar rot in glasshouse.

Special Project Funding:
NA

Suresh Pande, Mamta Sharma, HD Upadhyaya and CLL Gowda

Chickpea mini core collection salinity evaluation data analyzed (2008)

Achievement of Output Target (%):
100%

Countries Involved:
Australia and India

Partners Involved:
PAU, HAU, and UAS Dharwad, India; CLIMA and UWA, Australia

Progress/Results:
The previously conducted salinity screening data have indeed been analyzed and published (Field Crop Research 104, 123–129 2007). Large variation in salinity tolerance is explained by differences in the sensitivity of reproductive stages in chickpea. Salinity is an ever-increasing problem

in agriculture worldwide, especially in South Asia (India, Pakistan) and Australia. Improved genotypes that are well adapted to saline conditions are needed to enhance and sustain production in these areas. A screening of 263 accessions of chickpea, including 211 accessions from mini-core collection showed a six-fold range of variation for seed yield under salinity (1.9 L of 80 mM NaCl per 7.5 kg Vertisol), with several genotypes yielding 20% more than a previously-released salinity tolerant cultivar. The range of variation in yields under salinity was similar in both kabuli and desi chickpeas, indicating that breeding for salinity tolerance can be undertaken in both groups. A strong relationship ($r^2 = 0.50$) was found between the seed yield under salinity and the seed yield under a non-saline control treatment, indicating that the seed yield under salinity was explained in part by a yield potential component and in part by salinity tolerance *per se*. Seed yields under salinity were therefore computed to separate the yield potential component from the residuals that accounted for salinity tolerance *per se*. Among the genotypes evaluated, desi genotypes had higher salinity tolerance than kabuli genotypes. The residuals were highly correlated to the ratio of seed yield under salinity to that of the control, indicating that both parameters can be used to assess salinity tolerance. A similar ratio was calculated for shoot dry weight at 50 days after sowing. However, no significant correlation was found between the shoot dry weight ratio and the yield ratio, indicating that differences in salinity tolerance among genotypes could not be inferred from measurements in the vegetative stage. The major trait related to salinity tolerance was the ability to maintain a large number of filled pods, whereas seed size was similar in tolerant and sensitive genotypes. Salinity tolerance was not related to the shoot Na^+ or K^+ concentrations". A number of genotypes tolerant to salinity have been identified from this study (Table 10).

Table 10. List of the salinity tolerant and sensitive chickpea accessions (Kab indicates Kabuli)

Genotype	Type	Day to flower	TDM control	TDM salinity	Seed Yield control	Seed Yield salinity
Tolerant						
ICC1431	Desi	69	35.32 ± 9.36	29.29 ± 3.87	16.99 ± 3.01	12.62 ± 1.51
ICC15610	Desi	75	43.60 ± 2.19	28.63 ± 5.04	15.23 ± 2.60	12.53 ± 2.00
ICC5003	nd	63	34.46 ± 8.44	23.81 ± 2.18	15.87 ± 2.92	12.17 ± 0.66
ICC4593	Desi	61	37.50 ± 2.89	26.86 ± 5.28	15.99 ± 1.11	11.87 ± 0.83
ICC12155	Desi	66	35.23 ± 0.71	26.11 ± 4.25	16.15 ± 2.60	11.82 ± 1.08
ICC2580	Desi	57	36.74 ± 3.61	23.68 ± 1.67	17.47 ± 0.61	11.79 ± 0.80
ICC67	Desi	58	39.34 ± 5.09	24.01 ± 1.81	16.98 ± 2.43	11.72 ± 0.61
ICC11121	Desi	64	35.06 ± 4.59	24.51 ± 1.91	16.52 ± 0.51	11.71 ± 1.06
ICC8950	Desi	59	35.97 ± 2.73	23.35 ± 3.99	15.77 ± 0.83	11.41 ± 1.32
L 550	Kab	61	36.57 ± 3.20	25.34 ± 4.06	16.63 ± 2.17	11.40 ± 1.83
ICCV10	Desi	60	35.35 ± 3.20	24.26 ± 3.00	19.68 ± 0.44	11.27 ± 4.12
ICC9942	Desi	63	34.38 ± 10.37	23.54 ± 3.22	16.76 ± 2.34	11.18 ± 1.39
ICC867	Desi	57	33.66 ± 2.40	24.33 ± 2.88	16.20 ± 0.60	11.13 ± 1.42
JG11	Desi	38	34.98 ± 3.98	19.11 ± 7.08	19.78 ± 2.64	11.10 ± 3.33
ICC4495	Desi	66	34.46 ± 3.64	25.21 ± 5.97	14.76 ± 3.63	11.09 ± 2.19
CSG8962	nd	64	38.15 ± 3.84	27.10 ± 2.19	16.52 ± 0.62	10.62 ± 0.61
JG62	Desi	53	32.80 ± 4.42	17.89 ± 2.12	18.30 ± 2.17	10.81 ± 1.32
Sensitive						
ICC6306	Desi	98	42.50 ± 4.89	29.75 ± 2.72	1.29 ± 0.58	0.24 ± 0.26
ICC8522	Desi	82	43.41 ± 4.22	34.17 ± 1.11	3.97 ± 1.22	0.55 ± 0.34
ICC1915	Desi	91	41.09 ± 6.51	32.52 ± 2.49	2.84 ± 1.41	0.58 ± 0.35
ICC13357	Kab	86	39.68 ± 4.47	26.99 ± 4.63	3.36 ± 1.86	1.00 ± 0.81
ICC8058	Kab	77	40.62 ± 10.08	23.31 ± 6.39	9.83 ± 5.33	1.50 ± 1.83
ICC15518	Kab	81	40.14 ± 4.69	28.97 ± 4.44	4.42 ± 1.70	1.73 ± 0.88
ICCV96029	Desi	30	25.44 ± 3.23	3.78 ± 2.09	14.63 ± 1.40	1.75 ± 1.35
ICC3946	Desi	84	38.93 ± 3.37	18.13 ± 7.15	10.48 ± 1.80	1.96 ± 3.17
ICC10885	Kab	81	43.46 ± 4.35	23.27 ± 2.25	4.85 ± 1.23	2.30 ± 2.04
ICC5337	Kab	87	38.96 ± 6.01	28.08 ± 2.59	5.21 ± 1.79	2.81 ± 1.17
ICCV2	Kab	37	27.30 ± 7.06	9.00 ± 0.84	15.88 ± 2.74	4.51 ± 1.28

nd, not determined

Special project fundings:
ARC-linkage and COGGO

V Vadez, P Ratnakumar, L Krishnamurthy and HD Upadhyaya

Identification and evaluation of trait-specific germplasm in finger millet and foxtail millet core collections (2008)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru and Indian NARS partners

Progress/Results:

1. Finger millet
(i) Agronomic traits: Trait-specific accessions identified from core collection include those with early flowering (40-50 days, IE# 501, 2093, 2957, 3543, and 4374), high grain yield (2.2-2.7 t ha^{-1}, IE 2587 and IE 2983), more number of fingers per ear head (11 to 15, IE# 2871, 4121, 4545, 5367, 5870, 6154, 6165, 6326, 6350, and 6473), and for high Fe (26.6 mg g^{-1}) and Zn (30 mg g^{-1}) contents, in IE 2217 and IE 3045.

HD Upadhyaya, A Bharathi, SL Dwivedi and CLL Gowda

(ii) Resistance to blast: A greenhouse screening technique was developed to evaluate finger millet for resistance to foliar blast. The main steps involved in the technique are: isolation and maintenance of pure culture of the pathogen (*Pyricularia grisea* –fm strain), mass multiplication of inoculum, artificial inoculation of pot-grown 20-day-old seedlings, exposure of inoculated seedlings to high humidity under misting for 15 days. These led to the development of the typical foliar blast symptoms. Disease symptoms appeared 5 days after inoculation and the disease further developed up to 30 days. Leaf blast severity was recorded 30 days after inoculation using 1-5 scale.

A total of 622 finger millet core collection accessions were planted in 1 row of 2m/plot in two replications in RCBD. Systematic susceptible checks (VL 149, VR 708, RAU 8, PR 202, IE 860, IE 2811 and IE 5367) were planted on every 5th row alternately. Plants were thinned to 20 plants/row 15 days after planting and other agronomic practices were followed as per local practices. Plants were spray-inoculated 30 days after emergence and also at pre-flowering stage with an aqueous conidial suspension (ca. $1{\times}10^5$ spores ml^{-1}) grown on autoclaved finger millet leaves at 28^{o}C for 15 days. High humidity was provided by perfo-irrigation twice a day on rain-free days, 30 min each to facilitate the disease development. Leaf blast was recorded using a progressive 1-5 scale where 1=<1% area infected with disease and 5=>50% leaf area infected with typical lesions of blast 15 days after first inoculation. Neck and finger blast incidence were recorded based on total and infected necks/fingers at the dough stage.

Most of the lines were free from leaf blast and only a few recorded leaf blast with a score of <3.0. Three of the 622 accessions were resistant (<10% incidence) to neck blast whereas, 330 were highly resistant to finger blast (0% incidence). Three accessions (IE# 1239, 1290 and 1294) were found resistant to both neck and finger blast compared to >80% incidence of both neck and finger blast in IE# 595, 5689, and 6013 and susceptible controls (VL 149 and VR 708).

We also recorded blast in the same set of 622 core collection grown at Vizianagaram, Nandyal (Andhra Pradesh), Mandya (Karnataka) and Dholi (Bihar). At Vizianagaram, of the 622 accessions, 14 were found free from leaf blast, while others were moderately resistant (<3.0 score). At Mandya, many accessions recorded leaf blast at seedling stage in the nursery but became disease free after transplanting and at Nandyal, only 52 accessions showed leaf blast with scores of 1-2. However, leaf blast was quite severe in many lines at Dholi and about 20% lines (early maturing) succumbed to foliar blast and produced no panicles. Neck blast incidence at Vizianagaram ranged from 3-40% and only 2 accessions (IE 501 and IE 3077) were found free from neck blast. At Nandyal neck blast was noticed in 4 accessions (IE 886, IE 5120, IE2323 and IE 4759) and no finger blast was observed. At Mandya 72 accessions were free from neck blast, 62 free from finger blast and 41 free from both neck and finger blast.

RP Thakur, R Sharma, HD Upadhyaya and CLL Gowda

2. Foxtail millet

(i) Agronomic traits: Trait-specific accessions identified from core collection include ISe 1575 and ISe 1647 for early flowering (< 23 days); ISe 792, ISe 1059, ISe 1067, ISe 1258, ISe 1474, ISe 1575, ISe 1581, ISe 1593 and ISe 1647 for high yield (> 1.7 t ha^{-1}); ISe 1789 and ISe 1851 for high inflorescence length (> 250 mm) and width (> 45 mm).

HD Upadhyaya, A Bharathi and CLL Gowda

(ii) Resistance to blast: Blast severity was recorded in 155 accessions planted at Vizianagaram and Nandyal (Andhra Pradesh) and Mandya (Karnataka) using the 1-5 scale. At Vizianagaram, only two accessions (ISe 1581 and ISe 1745) recorded neck blast infection. Two accessions (ISe 1808 and ISe 1419) were free from leaf, neck and tip blast and the remaining accessions had leaf blast with score ≤3. Only one accession each at Nandyal (ISe 1299) and Mandya (ISe 999) recorded leaf blast. No neck and tip blast was observed at Nandyal and Mandya.

Special Project Funding:
BMZ/GTZ-supported project on finger millet and foxtail millet

RP Thakur, R Sharma, HD Upadhyaya and CLL Gowda

Sorghum mini core and pearl millet reference set screened for salinity tolerance (2008)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:

1. Sorghum: The evaluation of the sorghum mini-core collection for salinity tolerance has been reported in 2007. In substance, the CIRAD sorghum collection (165 entries), mapping population parents for salinity tolerance (10) and stay green traits (13) and some of the contrasting breeding lines that needed further confirmation (36) have been tested for their response to salinity by irrigating with saline solution in two doses to an equivalent of 200 mM NaCl solution irrigation to fully saturate 9 kg of soil. A non-saline control was also planted as a treatment. The data has shown a wide range of variation to exist for both shoot biomass production as well as for the grain yield under saline condition. The ability to produce high shoot biomass under salinity also helped in high grain yield production in some accessions. The top ten of the CIRAD collection accessions that produced significantly high shoot biomass and shoot biomass ratio have been IS 10876, IS 30030, IS 11026, IS 26554, IS 29691, IS 10882, IS 26041, IS 33261, IS 3780 and IS 20706. The bottom ten accessions that produced significantly low shoot biomass and shoot biomass ratio have been IS 12531, IS 8882, IS 8685, IS 19847, IS 2416, IS 2814, IS 33116, IS 30417, IS 3971 and IS 10194. The top ten of the accessions that produced significantly high grain yield and grain yield ratio have been IS 27490, IS 22282, IS 31681, IS 26554, SSM 501, IS 20351, IS 30030, IS 22294, IS 31559 and IS 24139 and the bottom ten accessions with poor grain yield or grain yield ratio have been IS 8685, IS 10882, IS 19847, IS 9303, IS 2416, IS 16545, IS 29375, IS 33116, IS 3073 and IS 23645.

Among the breeding the lines CSV 15, ICSB 699, A 2267-2, ICSR 93024-1, SP 39262, ICSV 12, GD 65008 (brown), SPV 1022, ICSB 707 and SP 47519 turned out to be the tolerant entries for shoot biomass production and NTJ 2, ICSV 93046, ICSV 112, CSV 15, GD 65008 (brown), SPV 1022, SP 47519, ICSB 707 and SP 39105 have emerged to be the tolerant ones for grain yields.

The tolerant response of mapping population parents E 36-1, PB 15881-3, BTX 623 and IS 18551 have been confirmed for salt-tolerance in relation to the performance of IS 9830, N13, PB 15520 and B 35.

The salinity response of the stay green entries for both shoot as well as grain yield of ISIAP Dorado, IDSG 06146 and IDSG 06177 have been good compared to that of B 35, IDSG 06151 and IDSG 06169.

2. Pearl millet: The pearl millet reference set is yet to finalize (due to complexity of interpreting marker data from bulk DNA samples of highly heterogeneous, heterozygous accessions) for screening for salinity tolerance. This assessment will be done in 2009.

Special Project Fundings:
NA

V Vadez, P Ratankumar, L Krishnamurthy and HD Upadhyaya

Mini core collection of pigeonpea germplasm evaluated for resistance to wilt and sterility mosaic diseases under controlled environment and field conditions (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:
Twenty-two promising accessions of pigeonpea mini core were reevaluated for confirmation of resistance to fusarium wilt (FW) and sterility mosaic (SM) under artificial epiphytotic conditions in field. ICPs 6739, 13304 and 15049 were resistant to both FW and SM. Additionally, ICPs 6739, 8860, 13304, 15049 were resistant (0.1-10% incidence) and ICPs 11015, 14819, and 14976 were moderately resistant (10.1-20% incidence) to FW. For SM, 11 accessions were asymptomatic (0% incidence) and 8 resistant (0.1-10% incidence).

Special Project Funding:
NA

Suresh Pande, Mamta Sharma, HD Upadhyaya and KB Saxena

Finger millet core collection evaluated for agronomic traits in Asia and Africa (2009)

Achievement of Output Target (%):
>50%

Countries Involved:
India; Kenya; Tanzania; Uganda

Partners Involved:
ICRISAT-Patancheru, India; ICRISAT regional centers Kenya; and NARS from the above-listed countries

Progress/Results:
Five sets of finger millet core collection accessions together with controls are being evaluated at five locations in India including at Patancheru. In addition, 80 accessions from finger millet core and 20 regional controls are being evaluated at one location each in Kenya, Tanzania, and Uganda. These trials have been harvested and recording of postharvest observations is in progress.

Special Project Funding:
BMZ/GTZ project on finger millet and foxtail millet

HD Upadhyaya, SL Dwivedi, CLL Gowda,
RP Thakur, R Sharma and participating NARS from India,
Kenya, Tanzania and Uganda

Sorghum mini core (or reference) set screened for transpiration efficiency (TE) (2009)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:
The whole reference set of sorghum (384 accessions) have been phenotyped for water use efficiency during the Nov-Dec 08 period and data are still to be analyzed. A portion of the reference set (152 entries) with uniform phenology (flowering) is being evaluated for their capacity for water extraction under terminal drought conditions during the 2008/09 postrainy season at Patancheru.

Special Project Funding:
GCP-supported project on phenotyping reference set for drought tolerance

V Vadez, P Ratnakumar, L Krishnamurthy and HD Upadhyaya

Mini core collection of groundnut evaluated for resistance to seed infection by *Aspergillus flavus* and aflatoxin contamination (2009)

No report for 2008. Experiments planted in the 2008-09 post-rainy season.

Groundnut and pigeonpea mini core collections salinity evaluation data analyzed (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
CRRI Cuttack and CSSRI, Karnal, India

Progress/Results:
1. Groundnut: A screening of groundnut for salinity tolerance was carried out over two different seasons, based on yield under saline conditions, and using 275 accessions that included the mini-core collection and selected accessions from putatively salinity affected areas. We found over six-fold range of variation for pod yield under salinity (10-12.5 dSm^{-1} NaCl) across genotypes. Though, significant relationship was found between saline and control environment for shoot dry weight and pod weight, however these relationships were weak. Salinity appeared to affect less the number of pods, which was reduced only about 20-40% under salinity, than the pod weight which was reduced more than 50%. This suggested that salinity tolerance related to the ability to develop viable pods and to fill those up ie seed development is the most important phase under salinity stress than merely pod formation. This idea was also supported by a lower maturity index and delay in the days to flower under saline stress. Although days to flower had a positive and significant correlation with pod weight under salinity (R= 0.20 and 0.33) in 2006 and 2007 respectively, that relationship was weak, meaning that genotype duration had no weighing on plant tolerance to salinity stress. Shoot dry weight was negatively correlated with the total shoot Na^+ %, but there was no relationship between pod dry weight and shoot Na^+ %. The most tolerant and most susceptible genotypes for salinity tolerance were identified from that work and their molecular diversity analysis using SSR markers was also carried out to identify the most suitable parents for crossing". The groundnut phenotypic datasets are being posted in ICRIS.

The analysis of the two years of data has allowed us to identify 14 most tolerant and 16 sensitive genotypes, under salinity stress (summer 2006 and postrainy season 2006-07) (Table 11). In this screening, these genotypes were screened with 21 markers to assess their diversity at the DNA level, and then to choose the most suitable parents for crossing. Out of these, 18 showed polymorphisms between the lines. Interestingly, we found that genotypes JL24 (sensitive) contrasted with ICG (FDRS) 10 (tolerant) across seasons. Genotype CSMG 84-1 (sensitive) also contrasted with genotypes ICGS44 and ICGS76 (tolerant). RILs population ICGS44 x CSMG 84-1 and ICGS76 x CSMG 84-1 have been developed for TE in the past years and are now at F^8 stage. There are then 3 populations that can be potentially used to phenotype for salt tolerance and possibly to identify QTLs for salinity tolerance.

Table 11. Salinity tolerant and susceptible accessions across two season evaluation at Patancheru, India.

Susceptible	**Tolerant**
ICG 6402	ICG 5195
ICG5149	ICGV 86156
ICGV 86699	ICG (FDRS)10
ICG 6993	ICGV 99181
ICG 13856	ICGV 00309
ICG 8083	ICGS 44
ICG 8760	ICG 442
ICG 9905	ICG 7283
ICG 6022	ICG 1711
ICG 5016	ICGV 86155
ICG 4746	ICG 2106
ICGV 92196	ICGS 76
ICG 11426	ICG 1519
ICG 15419	ICGV 87187
ICG 5051	
CSMG-84-1	

2. Pigeonpea: The analysis of the data for the mini core collection of pigeonpea still has to be done after a repeat trial was conducted.

Special Project Funding:
TL1 and ICAR project on Water & Food

V Vadez, R Aruna, SN Nigam, L Krishnamurthy and HD Upadhyaya

Ten chickpea lines identified, which showed steady high water use efficiency (WUE) as well as high yielding in two locations (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
The chickpea mini core collection (211 accessions) and 5 control cultivars were evaluated for variation in the SPAD Chlorophyll Meter Reading (SCMR), a surrogate trait for Water Use Efficiency (WUE), during 2005-06 and 2006-07 postrainy seasons. Based upon the two years' results, 20 top ranking germplasm accessions were identified in each season and five accessions were the common ones. These were ICC 1422, ICC 4958, ICC 10945, ICC 16374 and ICC 16903.

Special Project Fundings:
NA

J Kashiwagi, HD Upadhyaya and L Krishnamurthy

Mini core collection of pigeonpea germplasm evaluated for resistance to *Helicoverpa* (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:
We evaluated 146 pigeonpea germplasm accessions for resistance to *H. armigera* along with resistant and susceptible checks under field conditions. There were three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 rating scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), and grain yield. The genotypes ICP 995, ICP 1279, ICP 6128, ICP 8840, ICP 10397, ICP 8863, ICP 332, and ICPL 187-1 exhibited moderate levels of resistance to pod borer, *H. armigera*. These lines also showed good yield potential (>15 q ha^{-1}) under unprotected conditions, and these lines can be used for developing pigeonpea vatrieties with less susceptibility to *H. armigera*.

Special Project Fundings:
NA

HC Sharma and HD Upadhyaya

Sorghum mini core collection evaluated for resistance to grain mold and anthracnose (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru

Progress/Results:
(i) Grain mold: Of 255 sorghum mini core collection accessions grown for grain mold resistance evaluation in 2007 rainy season, only 155 flowered for which grain mold scoring was done. The same set of 155 accessions along with three controls (resistant: IS 8545; susceptible: SPV 104 and H 112) were grown in a complete randomized block design with 2 replications during the 2008 rainy season to screen for resistance to grain mold and anthracnose in the respective disease nurseries.

Evaluation was done using the standard grain mold screening method by using sprinkler irrigation and mold development was recorded at physiological maturity in 10 plants/row on a progressive 1-9 scale, where 1 = no mold to 9 = 76-100% grains molded on a panicle. IS 3121, IS 20727, IS 20740 and IS 1212 were free from grain mold while 54 and 40 accessions, respectively, showed resistant (≤3.0 score) or moderate resistance (3.1-5.0 score). The resistant control, IS8545, scored 1.8 while susceptible control, SPV 104, rated as 8.5 score. Fifty-one lines were found resistant (≤3.0 score) to grain mold in both 2007 and 2008 screens.

(ii) Anthracnose: The lines were whorl-inoculated with infested sorghum grain 30 days after seedling emergence, and high humidity was maintained through overhead sprinklers twice a day on rain free days till physiological maturity of the grain. The anthracnose severity was recorded on 10 uniformly flowered plants at the soft dough stage using a progressive 1-9 scale where 1= no disease and 9 =76-100% leaf area covered with lesions. None of 155 lines was free from anthracnose, 12 were resistant (≤3.0 score); 20 moderately resistant (3.1-5.0 score) and the remaining 123 susceptible (5.1-9.0 score). The resistant controls (IS 10302 and IS 20956) scored 2.5 while susceptible (H 112) 9.0.

IS 20956, IS 2379 and IS 10969 were resistant to both anthracnose and grain mold whereas 17 accessions were moderately resistant (3.1 – 5.0) to both diseases.

Special Project Funding:
NA

RP Thakur, R Sharma and HD Upadhyaya

Foxtail millet core collection evaluated for agronomic traits in India (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru and Indian NARS partners

Progress/Results:
Foxtail millet core collection together with controls was evaluated in yield trial at five locations in India including at Patancheru during rainy season 2008. The trials have been harvested and postharvest observations in progress at these locations.

Special Project Funding:
BMZ/GTZ-supported project on finger millet and foxtail millet

HD Upadhyaya, SL Dwivedi, CLL Gowda
and NARS partners from India

Finger millet core collection evaluated for resistance to foliar and neck blast (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru and Indian NARS partners

Progress/Results:
A greenhouse screening technique for foliar and neck blast resistance has been perfected, that will be used to screen for resistance to blast using finger millet core collection accessions. In addition, natural blast incidence was monitored on finger millet core collection accessions grown at two locations in Andhra Pradesh, India during 2008 rainy season.

Special Project Funds:
BMZ/GTZ-supported project on finger millet and foxtail millet

RP Thakur, R. Sharma, HD Upadhyaya
and NARS partners from India

Groundnut mini core collection screened for root traits (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India; Malawi; Mali; Niger; Senegal; Tanzania

Partners Involved:
National Program from above-listed countries

Progress/Results:
In 2008, we had the first evaluation of the reference collection of groundnut (268 accessions + 32 entries including popular varieties and promising breeding lines). This reference collection includes the 184 entries and check of the mini-core collection. The evaluation has been carried out in lysimeters, i.e. PVC tube with 20 cm diameter and 1.2-m long, filled with alfisol at a bulk density of 1.4. In that work, we were not aiming at measuring roots but rather at the assessment of genotypic differences in water extraction capacity upon exposure to water deficit. To do so, the plants were grown for 35 days under well-watered conditions. Three seeds were planted in each cylinder and seedlings were thinned to one per cylinder. At 35 days after sowing (DAS), the cylinders were saturated and allowed to drain for one day and two nights. Cylinder weight was taken on a regular basis until plants were no longer able to extract water, and then plants were harvested. The experiment was carried out between Dec07 and March 08.

The results show a large range of variation in the amount of water extracted, i.e. about 2 fold between top and bottom genotypes, varying from as low as 2,000 g per plant to more than 6,500. Genotype TMV2 was among those with les water extracted, whereas ICG76 and Florunner were among the highest. We are currently repeating the trial to ensure the identification of a robust set of genotypes having the capacity to extract large amounts of water from a receding soil moisture profile.

Special project funding:
TLI

V Vadez, P Ratnakumar, L Krishnamurthy and HD Upadhyaya

Reference sets of chickpea, pigeonpea, and groundnut evaluated for salinity tolerance (2010)

No report in 2008

Pearl millet mini core collection evaluated for resistance to downy mildew and rust (2011)

Pearl millet mini core has not yet been established and therefore no report in 2008.

Foxtail millet core collection evaluated for resistance to blast disease (2011)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru and Indian NARS partners

Progress/Results:
A greenhouse screening technique for blast resistance has been perfected, that will be used to screen for resistance to blast using foxtail millet core collection accessions. In addition, natural blast incidence was monitored on foxtail millet core collection accessions grown at two locations in Andhra Pradesh, India during 2008 rainy season.

Special Project Funds:
BMZ/GTZ-supported project on finger millet and foxtail millet

RP Thakur, R. Sharma, HD Upadhyaya and NARS partners from India

Sorghum mini core or reference set screened for root traits (2011)

Achievement of Output Target (%):
<50%

Countries Involved:
Australia and India

Partners Involved:
NRCS (India) QDPI&F and Univ Queensland (Australia)

Progress/Results:
In 2008, lysimeters suitable for sorghum (25 cm diameter and 2.0 m long) have been installed in deep trenches in an area protected by a rain-out shelter. The cylinders have been filled up with approximately 137 kg of Alfisol at a bulk density of approximately 1.4. It is currently being tested with a sub-set of sorghum reference set (152 accessions with phenology fitting in a 15 days window of flowering time, based on field data collected in 2007-08). Two treatments have been used: (i) fully irrigated conditions throughout the entire cycle and (ii) terminal water stress by re-saturation of the profile at 30 days after sowing.

Special Project Fundings:
GCP-supported project on phenotyping reference set for drought tolerance

V Vadez, L Krishnamurthy and HD Upadhyaya

Output target 2.3.6 Reference sets evaluated and genotyped for enhanced utilization

Chickpea reference set field evaluated for drought response (2008)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru:

Progress/Results:
Extensive and deep roots have been recognized as one of the most important traits for improving chickpea productivity under receding soil moisture conditions. We evaluated 10 accessions each of small and large root length density along with controls (ICC 4958, Annigeri, and ICCV 2) under irrigated and non-irrigated conditions. ICCs 2072, 10945, 11198, and 15868 produced higher seed yield (1.62 t ha^{-1} to 1.93 t ha^{-1}) in comparison to drought tolerant control ICC 4958 (1.58 t ha^{-1}) under irrigated conditions. None of the accessions produced greater seed yield than controls under non-irrigated conditions.

Special Project Funding:
NA

HD Upadhyaya, N Lalitha, J Kashiwagi, V Vadez,
L Krishnamurthy, CLL Gowda and SL Dwivedi

Chickpea reference set phenotyped for root traits in PVC cylinders (120 cm height) (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru:

Progress/Results:
Reference set was evaluated for drought avoidance root traits: root length density (RLD) and plant dry weight (PDW) to RLD (PDW/RLD) ratio. PDW was higher (2.25-3.2g) in about 50 accessions than in Annigeri (2.24 g), G 130 (1.84 g), ICCV 10 (1.79 g) and L 550 (1.97 g). ICC 9137, ICC 15406, ICC 15518, IG 5909 and 6055 (2.8 to 3.2 g) were best lines with highest PDW.

Root dry weight (RDW) was higher (0.623 to 0.903 g) in 115 accessions than in Annigeri (0.610 g), G 130 (0.580 g), ICCV 10 (0.620 g), and L 550 (0.590 g). ICCV 95311, ICCs 9862, 5504, 9137 and IG 10701 (0.840 to 0.903 g) are five lines with high RDW.

Root depth was higher (130-143 cm) in 7 accessions compared to Annigeri (128 cm), G 130 (120 cm), ICCV 10 (130 cm), and L 550 (108 cm). Accessions with maximum root depth (130-143cm) were ICCs 8740, 13764, 1882, 8647 and IG 6343.

RDW to total dry weight (TDW, which is sum of RDW and shoot dry weight) ratio was higher (27.4 to 32.7%) in 32 accessions than in Annigeri (21.1%), G 130 (24.5%), ICCV 10 (27.3%) and L 550 (24.7%). Five accessions with highest RWD/TDW ratio (30.2 – 32.7%) were ICCs 9942, 9434, 10885, 8195, and 2919.

Root surface area (RSA) was higher (876.70-1198.60 cm^2) in 51 accessions compared to Annigeri (876.50 cm^2), G 130 (798.19 cm^2), ICCV 10 (828.87 cm^2), and L 550 (699.0 cm^2). Accessions with maximum RSA were ICCV 95311, ICCs 5504, 15518, 8740, and 9137. Similarly, root volume was higher (11.59-16.16 cm^3) in 39 accessions compared to Annigeri (11.57 cm^3), G 130 (9.93 cm^3), ICCV 10 (10.18 cm^3) and L 550 (8.75 cm^3). ICCV 95311, ICCs 5504, 8740, 2277 and IG11045 showed the maximum root volume (14.39-16.16 cm^3).

Special Project Funding:
NA

HD Upadhyaya, N Lalitha, J Kashiwagi, V Vadez,
L Krishnamurthy, CLL Gowda and SL Dwivedi

Chickpea reference set genotyped with 100 SSR markers (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
We have screened additional 350 SSR markers on two diverse chickpea germplasm, and identified 100 most polymorphic SSRs to generate additional data points on chickpea reference set (300 accessions). Of these, we have completed genotyping of 75 SSRs on 300 accessions using ABI3130xl automatic DNA sequencer (PE- Applied Biosystems, Foster City, California). The electrophoretic data were exported to the Genescan 3.1 software (PE- Applied Biosystems, Foster City, California) to size peak patterns, using the internal LIZ-500 size standard and GENOTYPER 3.1 (PE- Applied Biosystems, Foster City, California) for allele calling. The work is in progress to complete the genotyping of the remaining 25 SSRs on chickpea reference set accessions.

Special Project Fundings:
NA

N Lalitha, RK Varshney, HD Upadhyaya and CLL Gowda

Groundnut reference set phenotyped for traits associated with drought resistance (TE and root traits) (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India + African countries (Tanzania, Malawi, Senegal, Mali, Niger)

Partners Involved:
National Programs from above-listed African countries

Progress/Results:
Root traits: In 2008, we had the first evaluation of the reference set of groundnut (268 accessions + 32 entries including popular cultivars and promising breeding lines) for root traits. This reference set also included 184 mini-core collection accessions. The evaluation has been carried out in lysimeters, i.e. PVC tube with 20 cm diameter and 1.2-m long, filled with Alfisol at a bulk density of 1.4. In that work, we were not aiming at

measuring roots but rather at the assessment of genotypic differences in water extraction capacity upon exposure to water deficit. To do so, the plants were grown for 35 days under well-watered conditions. Three seeds were planted in each cylinder and seedlings were thinned to one per cylinder. At 35 days after sowing (DAS), the cylinders were saturated and allowed to drain for one day and two nights. Cylinder weight was taken on a regular basis until plants were no longer able to extract water, and then plants were harvested. The results show a large range of variation in the amount of water extracted, i.e. about 2 fold between top and bottom genotypes, varying from as low as 2,000 g per plant to more than 6,500 g. Genotype TMV2 was among those with les water extracted, whereas ICG76 and Florunner were among the highest. We are currently repeating the trial to ensure the identification of a robust set of genotypes having the capacity to extract large amounts of water from a receding soil moisture profile.

Transpiration efficiency (TE): The reference set of groundnut has been phenotyped for TE in 2008 under well watered and water stress conditions. The protocol use to assess TE is the one published in Field Crops Research, 103, 189-197, 2007). Under water stress conditions, the trial mean TE was 1.87 g biomass kg^{-1} water transpired, varying from 0.87 to 2.89 g biomass kg^{-1}, i.e. a 3-fold range of variation. Genotypes ICG 6407, ICG 6646, ICG 4527, ICG 9184, ICG 10920, ICG 12189, ICG 10950, ICG 6402, ICG 8083, ICG 8047, were those with the lowest TE, whereas genotypes ICG 14127, ICG 3010, ICG 15309, ICG 14705, ICG 14985, ICGV 02038, ICG 334, ICG 142, ICG 15213, and ICG 15236 were those with the higher TE.

Under well-watered conditions, the trial mean TE was 2.36 g biomass kg^{-1} water transpired, varying from 1.58 to 3.64 g biomass kg^{-1}, i.e. a 2-fold range of variation. Genotypes ICGL 3, ICG 434, JL 24, ICG 2381, ICG 6022, ICG 9037, ICG 7181, ICG 4906, ICG 3673, ICG6643 were those with the lowest TE values whereas genotypes ICGV 02022, ICG 11144, ICG 12235, ICG 12879, ICG 6375, ICG 11651, ICG 12988, ICG 11249, ICG 13787, ICG 1471, were those with the highest TE values. It was very interesting and a good confirmation to notice that genotype JL24 was among those with the lowest TE. In addition, we found a poor relationship between TE under well-watered conditions and TE under water stressed conditions (R2 = 0.04). The trial will be repeated early 2009.

Special Project Funding:
TLI, GCP, DBT

V Vadez, L Krishnamurthy, P Ratnakumar and HD Upadhyaya

Groundnut reference set genotyped with 100 SSR markers (2010)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru:

Progress/Results:
Genotyping of groundnut reference set completed with 21 SSR markers and work is in progress with remaining markers.

Source of Fundings:
Generation Challenge Program

HD Upadhyaya, R. Bhattacharjee and RK Varshney

Candidate gene diversity analyzed in chickpea reference set (300 accessions) for drought tolerant alleles (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
France and Peru

Partners Involved:
CIRAD, INRA-CNG, CIP

Progress/Results:
In order to isolate probable candidate genes involved in drought tolerance extensive bibliographic survey was made and candidate genes are identified, which might have role in drought tolerance across the plants. ICRISAT was one of the Ortholabs involved in identifying the ortho/homolog sequences in DREB2A in seven targeted species (chickpea, common bean, barley, sorghum, rice, potato and cassava) under the framework of GCP sponsored "Allelic Diversity on Orthologous Candidate Genes" project. Attempts were made to isolate DREB2 homologs from the mentioned species using phylogeny based degenerate primer approach and by using specific primers for the corresponding genes. As a result, isolation of DREB2 genes was successful in chickpea, common bean, rice, sorghum and barley. DREB2 promoter was also isolated in chickpea in order to identify the allelic diversity at the regulatory region. Subsequently a set of eight diverse genotypes of the reference collection was sequenced at these candidate orthologous sequences.

Eight diverse accessions (Annigeri, ICCV 2, ICC 4958, ICC 283, ICC 8261, IC 10029, ICC 1882 and ICC 4411) from the chickpea reference set were sequenced at CAP2 gene (homolog of DREB2A) and its promoter. Apart from the DREB2 isolation in five crop species, efforts were made to identify the other candidate genes like sucrose synthase (SuSy), sucrose phosphate synthase (SPS), abscisic acid stress and ripening gene (ASR) and vacuolar invertases in chickpea. Heterologous primers were designed using *Medicago* gene sequences and were tried to amplify respective genes in chickpea. Eventually putative SuSy, SPS and ASR have been isolated successfully in eight diverse genotypes of chickpea at ICRISAT. Other collaborative partners of ADOC project identified putative homolog of ERECTA in chickpea. The candidate genes conferring drought tolerance were sequenced in 300 accessions of reference set of chickpea. The results of which are explained in output target 2.4.7.

Special Project Funding:
Partly from TL1, GCP, and DBT

RK Varshney, S Nayak, B Jayashree, HD Upadhyaya and DA Hoisington

Diversity analyzed for the molecular markers and markers associated with drought related (root traits) in chickpea identified (2011)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
The chickpea reference set (300 accessions) was phenotyped for drought avoidance root traits: root length density (RLD), plant dry weight (PWD), PWD/RLD ratio, root dry weight (RDW), RDW/TDW (total dry weight, PDW+RDW) ratio, root depth (RD), root volume (RV), and for root surface area (RSA). A large range variation was observed for these traits: 145 accessions with high PWD (1.85-3.20 g as compared to 1.84 g in drought tolerant control ICC 4958), with ICCs 15406, 15518, and 9137 and IG 5909 and IG 6055 showing the highest PDW (2.8-3.2 g). Two hundred accessions showed greater RDW (0.534-0.903 g) than ICC 4958 (0.533 g). ICCs 8740, 13764, 1882, and 8647 and IG 6343 were the best accessions for RD (130-143 cm) than ICC 4958 (110 cm). ICCs 9942, 9434, 10885, 8155, and 2919 were the best accessions for RDW/TDW ratio (30.2-32.7%) higher than ICC 4958 (23.4%). ICCs 5504, 15518, 8740, and 9137 and ICCV 95311 were the best accessions for RSA (1067-1199 cm^2 as compared to 667 cm^2 in ICC 4958) while ICCs 5504, 8740, and 2277, IG 11045, and ICCV 95311 for RV (14.4-16.2 cm^3 as compared to 7.5 cm^3 in ICC 4958).

Further, this reference set was genotyped with 75 of the 100 additional SSR markers, and the work is in progress to complete the genotyping with remaining SSRs using high throughput assay,ABI-3130xl automatic DNA sequencer (PE- Applied Biosystems, Foster City, California). Both the genotyping and phenotyping data will be subjected to statistical analysis to study marker-trait association using association mapping approach.

Special Project Fundings:
NA

HD Upadhyaya, N Lalitha, J Kashiwagi, RK Varshney and L Krishnamurthy

Output target 2.3.7 Germplasm sets evaluated for utilization in Africa (2009)

Mini core collection of groundnut evaluated for agronomic traits at different locations in ESA (2008)

Achievement of Output Target (%):
100%

Countries Involved:
Malawi for ESA

Partners Involved:
ICRISAT Malawi

Progress/Results:
For the second season (2007/8), following the first season activities (2006/7), a groundnut mini core subset, comprising of 192 accessions, was evaluated under high disease (groundnut rosette Disease, GRD and early leaf spot, ELS) pressure at Chitedze Agricultural Research Station, Malawi using the infector row technique, which enables consistently high disease pressures and reduces possibility of 'escapes'. This screening exercise identified potential sources of resistance to both GRD and ELS. For GRD resistance, the lines identified were ICG 13099, ICG 14705 and ICG 6888 (<25% incidence in both seasons). This compares to the score of ≥ 80% for the susceptible control JL 24. For ELS, ICG 6913 and ICG 6022 showed good resistance (<5 on 1 to 9 point scale). This was as good as or better than the resistant check ICGV-SM 95741 as compared to the score of ≥ 8 for the control JL 24.

Special Project Fundings:
McKnight Foundation and Bill Melinda Gates Foundation

ES Monyo, M Osiru, H Upadhyaya and H Charlie

Promising and adapted materials identified and distributed and evaluated in regional finger millet trials in ESA (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
Kenya, Malawi, Burundi and Eritrea

Partners Involved:
ICRISAT Nairobi, National Plant Genetic Resources curators and Plant breeders for Kenya, Malawi, Burundi and Eritrea

Progress/Results:
The need to address issues of health and nutrition for all is increasingly becoming very important. Nutritionally, finger millet grain is superior to other staple cereals and is particularly rich in methionine, iron and calcium. Finger millet blast (*Pyricularia grisea (teleomorph= Magnaporthe*

grisea) is the most serious disease of finger millet world wide. Scientists have characterized and assessed finger millet germplasm for blast resistance and identified some lines that have some degree of resistance to this disease. There is increasing need to evaluate these materials across the finger millet production areas in the region to make available to farmers some of the identified blast resistant materials to enhance productivity and meet the growing demands for food and nutrition security as well as market needs. A regional finger millet trial with 16 elite and blast tolerant/resistant lines was constituted and planted at Alupe in Kenya and sets sent to Malawi, Burundi and Eritrea. Results indicated that KNE 688 (1.429 t ha^{-1}), KNE 689 (1.231 t ha^{-1}), KNE 1034 (1.164 t ha^{-1}), Acc.# 29 FMB/01 WK (1.457 t ha^{-1}), Acc # 32 FMB/01 WK (1.164 t ha^{-1}) and Acc # 14 FMB/01 WK (1.058 t ha^{-1}) are the best performing varieties with grain yields above 1.0 t ha^{-1}. The blast resistant/tolerant lines were P224, KNE 814, KNE 622 and KNE 434 with overall blast score of less than 2 on a 1-9 scale. In addition to the 506 characterized in 2007, this year we are characterizing 114 accessions to have a complete finger millet core collection characterized. 100 finger millet accessions are currently being evaluated in Kenya, Tanzania and Uganda and this will provide additional list of promising finger millet varieties for regional evaluation.

Special Project Funding:
DFID project R8445

MA Mgonja, EO Manyasa, J Kibuka, P Sheunda and H Ojulong

Diversity for micronutrients contents in a sorghum core collection from atleast 2 ABS target countries established (2009)

Achievement of Output Target (%):
100%

Countries Involved:
Kenya; RSA; Burkina Faso; Egypt; South Africa

Partners Involved:
ICRISAT-Nairobi, National Plant Genetic Resources and breeders from Kenya, RSA, Burkina Faso, Nigeria, Egypt and ICRISAT-India.

Progress/Results:
The African Biofortified Sorghum (ABS) project is targeting 5 countries namely Kenya, South Africa, Nigeria, Burkina Faso and Egypt. A core collection of sorghum germplasm from these countries was constituted and morphological characterisation was done in 2006 and 2007. The same core set consisting of 426 sorghum accessions was sent to ICRISAT-India for iron and zinc content analysis. Iron content ranged from 20.5 ppm in IS7455 to 108.5 ppm in IS18896 with a mean of 40.9±9.4. Analysis of variance showed country not significant for iron, though accessions from Kenya had highest average of 42.27 and Egypt the lowest of 38.45. Zinc was significant (P=0.021) for country with accessions from Egypt with the highest mean (19.36 ppm) and those from Burkina Faso the lowest (16.31ppm).

Special Project Funding: Africa Bio-fortified Sorghum –ABS

MA Mgonja, EO Manyasa, H Ojulong, J Kibuka and P Sheunda

Wild *Arachis* species evaluated for target traits (GRD, ELS, aflatoxin resistance) at hotspot locations in ESA (2010)

This study is planned for year 2009-10

Gene introgression carried out for foliar and viral disease resistance from wild Arachis germplasm into cultivated varieties (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
India; Malawi

Partners Involved:
ICRISAT Patancheru and ICRISAT Malawi

Progress/Results:
Advanced generation interspecific derivatives from *A. cardenasii*, *A. kempff-mercadoi* and *A. diogoi* which were resistant to late leaf spot were screened for peanut bud necrosis disease (PBND) and few of the lines showed resistant reaction to the disease under greenhouse conditions. The material is being screened again and the results are awaited.

Sixty advanced generation interspecific derivatives were screened for early leaf spot (ELS) under field conditions in Malawi. Three lines (4368-7, 38-4 and CS-64) were resistant to ELS (a score 3 on a scale of 1 to 9), four lines (4367-3, 4366-2, 4373-6, and 4367-5) showed moderate resistance (a score of 4), compared to susceptible check (JL 24) which had scored 7. One of the resistant line (4368-7) showed high yield and was comparable to the resistant control.

Special Project Fundings:
NA

N Mallikarjuna, V Wesley, E Monyo, M Osiru and HD Upadhyaya

Output 2.4: Genetic diversity and population structure of staple crops and small millets assessed and mapping populations, RILs developed and DNA extracts assembled, conserved and distributed and new knowledge shared with partners

Summary: Genetic structure, diversity, and allelic richness in chickpea, groundnut, pigeonpea, sorghum, finger millet, and foxtail millet composite collections have been studied using SSRs and high throughput assay. This analysis broadly grouped the accessions based on biological (cultivated vs. wild types or subspecies and races classification within cultivated accessions) and geographical origin (broadly defined geographic regions), and identified a number of group-specific unique alleles in each crops mentioned-above. Moreover, the genotyping data on these composite collection accessions have been uploaded in GCP web site. Efforts are on to supplement the genotyping data with passport and characterization data. Part of

the passport data have already been uploaded in GCP web site. Genotype-based reference sets are now available in chickpea, groundnut, pigeonpea, sorghum, and finger millet.

Several synthetics (AABB genome) have been produced and backcrossed to broaden the genetic base of groundnut, with emphasis to transfer resistance to late leaf spot and resistance to A. flavus and aflatoxin production. Likewise in pigeonpea, introgression involving C. platycarpus is in progress to transfer beneficial traits from this species into cultivated pigeonpea.

Sequencing of candidate genes for drought tolerance have been successful for CAP2, CAP2 promoter, SPS, ASR, and ERECTA and the sequence diversity is being analyzed in chickpea reference set. Likewise, in sorghum, a set of drought responsive candidate genes (DREB2, SuSY, ASR, Vacuolar invertase, ERECTA and SPS) were identified by GCP partners including ICRISAT for primer development, amplification and sequencing of their candidate gene homologs on a set of eight diverse accessions, which will be further studied for sequence diversity on 350 sorghum reference set accessions.

Our efforts resulted in discovery of large number of SSRs in chickpea, groundnut, pigeonpea, pearl millet and sorghum. Likewise, we have developed genetic linkage map in cultivated groundnut, involving 135 SSR loci that mapped into 22 linkage groups (LGs) with genome coverage 1270.5 cM. Moreover, the two LGs of this map aligned with available genetic maps of AA diploid genome of groundnut and Lotus and Medicago, which exhibited syntenic relationships. Efforts are on to develop reference genetic maps in all ICRISAT-mandate crops. Further, ICRIS database is being updated regularly with genotype, marker and phenotype data of mapping populations and germplasm accessions. LIMS has been further expanded to provide data capture support for information generated during parental screening and genotyping of mapping populations besides genotyping of germplasm collections. To support crop breeding, ISMAB is being developed in phased manner to manage information generated during the course of marker-assisted breeding programs, with four basic components in its structure: molecular breeding design tool (MBDT), interface with LIMS, MOLecular Selection Tool (MOSEL), and loading of data into the central database for future use and dissemination. TILLING population of pearl millet inbred line P1449-2-P1 has been further expanded to realize the population size of 10,000 M_2 lines for mining allelic variants in drought-responsive candidate genes.

Agriculturally beneficial microorganisms have the potential to enhance crops adaptation. Towards that end, we assembled and characterized a number of actinomycete isolates for morphological diversity. Further, we identified few actinomycete isolates that were either entompathogens, or antagonistic to phytopathogens, or siderophore producers. However, none of these isolates solubilized P (phosphorous). Clearly, more research is needed to identify microorganism that solubilize P and thus available to plants of utilization.

Center of Excellence in Genomics (CEG) also conducted training courses on various aspects of diversity assessment and marker-aided selection to crop breeders (84) in India as well few participants from other countries. Of these, there were 61 male participants and 23 female participants.

Output target 2.4.1 Genetic diversity and population structure of staple crops assessed (2010)

Data sets for chickpea and sorghum composite collections genotyping made available globally via internet (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
France; India; Syrian Arab Republic

Partners Involved:
ICRISAT and ICARDA; and partners from France

Progress/Results:
Genotyping data sets of chickpea and sorghum composite collections made available globally via Internet on GCP web site http://gcpcr.grinfo.net/index.php?app=datasets&inc=dataset_details&dataset_id=579. The datasets are also available through the ICRIS database (http://10.3.1.159/ICRIS) on the intranet. The dataset may be browsed or queried through the database interfaces and the result matrix may be downloaded in a number of export formats (such as the input format for Structure, Darwin, iMAS analysis software or the GCP data matrix).

Special Project Funding:
Generation Challenge Program

HD Upadhyaya, CT Hash, S Senthilvel, RK Varshney,
B Jayashree and DA Hoisington

Genetic diversity and population structure of groundnut and pigeonpea composite collections assessed (2008)

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results
1. Groundnut: Twenty-one SSR loci data on 852 accessions were analyzed using PowerMarker V3.0 and DARwin 5.0 version which showed rich allelic diversity (490 alleles, 23.3 alleles per locus, 246 common alleles and 244 rare alleles at 1%), group-specific unique alleles, and common alleles sharing between subspecies and geographical groups. Gene diversity ranged from 0.559 to 0.926, with an average of 0.819. Group-specific unique alleles in this composite collection were 101 in wild *Arachis*, 50 in subsp. *fastigiata*, and only 11 in subsp. *hypogaea*. Accessions from America's revealed highest number of unique alleles (109) while Africa and Asia, respectively, had only six and nine unique alleles. The two subsp. *hypogaea* and *fastigiata* shared 70 alleles. The wild *Arachis* in contrast shared only 15 alleles with *hypogaea* and 32 alleles with *fastigiata*. A tree-

diagram using DARwin 5.0 separated majority of the *hypogaea* from *fastigiata* accessions while wild *Arachis* accessions clustered with *hypogaea* (Refer ICRISAT Archival report 2007).

2. Pigeonpea: The 20 SSR loci data on 952 accessions were analyzed using PowerMarker V3.0 and DARwin 5.0 version which showed rich allelic diversity (197 alleles, 10 alleles per locus, 82 most common alleles and 115 rare alleles at 1%). Group-specific unique alleles were 60 in wild types and 64 in cultivated types. Accessions from Asia had 48 unique alleles while those from Africa had only two unique alleles. Non-determinate type (NDT) cultivated pigeonpea accessions were represented by 37 unique alleles while determinate types (DT) only one allele. Wild and cultivated types shared 73 alleles, DT and NDT 10 alleles, DT and wild types 4 alleles, and NDT and wild types 20 alleles. A tree diagram using DARwin 5.0 revealed wild types as a group genetically more diverse than cultivated types, while NDT were more diverse than DT (Refer ICRISAT Archival report 2007).

HD Upadhyaya, Ranjana Bhattacharjee, RK Varshney,
DA Hoisington, CLL Gowda, SL Dwivedi and KB Saxena

Phenotypic and molecular data for sorghum standardized and analyzed (2008)

Achievement of Output Target (%):
100%

Countries Involved:
France and Peoples Republic of China

Partners Involved:
ICRISAT Patancheru and researchers from France and China

Progress/Results:
An initial SSR marker-based diversity assessment of 3365 wild and cultivated accessions of the sorghum composite germplasm collection has been completed using allelic information from 41 SSR markers distributed across the 10 chromosome pairs of *Sorghum bicolor*. The SSR allelic data were used to produce a dissimilarity matrix based on simple matching, and this was then used for factorial analysis and to develop a neighbor-joining tree using the DARwin software package. This dendrogram depicts the population structure of sorghum germplasm that is available globally for crop improvement.

Sorghum landrace population structure is characterized by racial subgroups (five basic races and ten intermediate races) within geographic origin. Further, race bicolor shows little evidence of population structure, as expected for the original domesticate. Race kafir (largely from Southern Africa) is distinct. Accessions of the durra, caudatum and guinea races each form distinct geographic subgroups. The guinea race margaritiferum group forms its own cluster (along with the majority of wild and weedy accessions), suggesting its independent domestication. Intermediate races behaved similarly to the five basic races.

A manuscript describing this population structure (largely race within geographic origin), and the procedures used to determine it, has been drafted.

Special Project Funding:
Generation Challenge Program

CT Hash, S Senthivel and HD Upadhyaya and partners from France and China

Database of passport information, farmer-knowledge, pedigrees, phenotyping and genotyping data of sorghum accessions held in ESA national genebanks and international nurseries developed (2008)

Achievement of Output Target (%):
100%

Countries Involved:
Burundi; Eritrea; Ethiopia; Kenya; Rwanda; Sudan; Tanzania; Uganda

Partners Involved:

1. Mr. Johnnie Ebiyau - Serere Agricultural and Animal Production Research Institute, Uganda
2. Mr. Amanuel Mahdere - National Agricultural Research Institute, Eritrea
3. Dr. Tesfaye Teferra Tesso - Ethiopian Agricultural Research Organization, Melkassa Research Centre, Ethiopia
4. Mr. Ben M. Kanyenji - Kenya Agricultural Research Institute, Embu, Kenya
5. Dr. Ambosenigwe Mbwaga - Agricultural Research Institute Uyole, Tanzania
6. Dr. Abdalla Mohammed - Agricultural Research and Technology Corporation, Sudan
7. Mr. Theophile Ndacyayisenga - Institut des Sciences Agronomiques du Rwanda
8. Espérance Habindavyi - Institut des Sciences Agronomiques du Burundi, Burundi

Progress/Results:
A good understanding of the extent, nature and structure of genetic diversity in crop germplasm accessions is important for defining strategies for conservation and utilization. This should be supported by a good system of documenting the passport information and data generated from characterization of the germplasm. This activity aims at documenting passport information and characterization data on sorghum germplasm accessions held by genebanks in east and southern Africa. It is part of the GCP/Rockefeller/BecA funded project on assessment of genetic diversity using phenotypic and genotypic characters. A database with basic information on 1600 germplasm accessions from the 8 project partners has been established. The phenotype data on 1597 germplasm accessions has been collected, cleaned during the data analysis workshop and documented. The data is based on 27 morphological and agronomic descriptors for each germplasm accession. In addition, 1402 genotyping data points based on 39 SSR markers have been generated and documented. The genotyping data has been loaded onto ICRIS for ease of access by ICRISAT scientists and later by other interested parties.
Special Project Funding:
The project was funded through a grant provided by GCP, The Rockefeller Foundation and BecA.

D Kiambi, CT Hash and B Jayashree

Diversity assessment of chickpea published (2009)

Achievement of Output Target (%):
100%

Countries Involved:
India; Syrian Arab Republic

Partners Involved:
ICRISAT and ICARDA

Progress/Results:
Forty-eight SSRs data on 2915 accessions were analyzed using PowerMarker V3.0 and DARwin 5.0 to detect allelic richness and diversity. This analysis detected 1683 alleles in 2915 accessions, of which, 935 were rare, 720 common and 28 most frequent. The alleles per locus ranged from 14 to 67, averaged 35, and the polymorphic information content was from 0.467 to 0.974, averaged 0.854. Marker polymorphism varied between groups of accessions in the composite collection and reference set. A number of group-specific alleles were detected: 104 in Kabuli, 297 in desi, and 69 in wild *Cicer*; 114 each in Mediterranean and West Asia (WA), 117 in South and South East Asia (SSEA), and 10 in African region accessions. Desi and kabuli shared 436 alleles, while wild *Cicer* shared 17 and 16 alleles with desi

and kabuli, respectively. The accessions from SSEA and WA shared 74 alleles, while those from Mediterranean 38 and 33 alleles with WA and SSEA, respectively. Desi chickpea contained a higher proportion of rare alleles (53%) than kabuli (46%), while wild *Cicer* accessions were devoid of rare alleles (Upadhyaya et al. 2008, BMC Plant Biol. 8:106).

HD Upadhyaya, SL Dwivedi, RK Varshney, CLL Gowda,
DA Hoisington ICRISAT and M Baum and S Udupa from ICARDA

The diversity of sources of resistance to the groundnut rosette virus in groundnut assessed and documented (2009)

This study is planned for 2009-10

Diversity assessment of sorghum published (2010)

Achievement of Output Target (%):
>75%

Countries Involved:
India; France

Partners Involved:
ICRISAT and CERAD

Progress/Results:
Refer to mile stone "phenotypic and molecular data for sorghum standardized and analyzed (2008)" above under output target 2.4.1. A manuscript describing this population structure (largely race within geographic origin) and the procedures used to determine it has also been drafted.

Special Project Funding:
Generation Challenge Program

CT Hash, S Senthivel, HD Upadhyaya and researchers from France

Diversity and population structure of pearl millet composite collection analyzed and reference set (300 accessions) established (2010)

Achievement of Output Target (%):
>75%

Countries Involved:
India; China; France

Partners Involved:
Generation Challenge Program, ICRISAT, and researchers from India, China and France

Progress/Results:
As part of Generation Challenge Program (GCP), a global composite collection of pearl millet comprising 1021 accessions, representing 21,594 germplasm accessions conserved at ICRISAT genebank, was developed. This composite collection consists of core collection, genetic stocks, and accessions with resistant to abiotic and biotic stresses, trait specific selections, released cultivars, advanced lines, and close wild species (Table 12).

Table 12. Composition of pearl millet composite collection.

Type of material	No. of accessions
Core collection	504
Tolerant to abiotic stresses	
Drought	6
Heat	3
Salinity	20
Resistant to biotic stresses	
Downy mildew	42
Ergot	20
Rust	25
Smut	15
Multiple disease resistant	8
High seed iron and zinc content (>42ppm)	4
High seed protein (>17%)	20
Yellow endosperm	2
Trait-specific selections	197
Sweet stalks	12
Forage type	8
Released cultivars	6
Gene pools	4
Wild relatives	60
Pennisetum mollissimum	6
P. orientale	1
P. pedicellatum	15
P. polystachion	15
P. ramosum	2
P. schweinfurthii	1
P. violaceum	20
Advanced lines	62
Checks	3
Total	1021

Further, this composite collection accessions together with controls (IP 3616, IP 17862 and IP 22281) were evaluated for 12 quantitative and 10 qualitative traits (15 representative plants/accession) in augmented design at Patancheru. Analysis of morpho-agronomic data revealed wide range of diversity for important traits (Table 13).

Table 13. Range of variation in pearl millet composite collection.

Trait	Minimum	Maximum	Mean
Days to 50% flowering	36	139	53.17
Plant height (cm)	22	241	158.68
Total tillers (no.)	1.0	8.0	1.56
Productive tillers (no.)	0.0	4.6	1.41
Nodal tillers (no.)	0.0	7.0	0.13
Panicle exsertion (cm)	-18.4	13.0	2.30
Panicle length (cm)	4.4	65.2	22.05
Panicle width (mm)	7.6	36.4	19.75
1000-seed weight (g)	2.0	18.0	7.59
Synchrony of panicle maturity (1-9 scale)	2	8	4.94
Panicle density (1-9 scale)	2	7	4.40
Bristle length (1-9 scale)	1	6	1.49
Fodder yield potential (1-9 scale)	2	8	4.50
Seed yield potential (1-9 scale)	2	8	4.23
Overall plant aspect (1-9 scale)	2	7	4.59

More recently, this composite collection has been molecularly profiled using 19 SSR markers and high throughput assay (ABI3700). Molecular diversity analysis and determination of the population structure of the pearl millet composite collection, and identification of a reference set of germplasm accessions for this crop has not yet been finalized due to complexity of interpreting marker data from bulk DNA samples of highly heterogeneous, heterozygous accessions.

Diversity assessment of pearl millet published (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India; China; France

Partners Involved:
Generation Challenge Program, ICRISAT, and researchers from India, China and France

Progress/Results:
More input needed to short out the problems associated with heterogeneous nature of the crop before marker data, generated under previous milestone, is analyzed to detect population structure and formation of reference set.

Data sets for pearl millet, finger millet and foxtail millet composite sets made available globally via internet (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
Generation Challenge Program and ICRISAT Patancheru, India

Progress/Results:
Data sets have not been made available for uploading into ICRIS (http://10.3.1.159/ICRIS) or GCP (http://gcpcr.grinfo.net/index.php?app=datasets&inc=dataset_details&dataset_id=579) website.

Special Project Funding:
Generation Challenge Program

HD Upadhyaya, CT Hash, S Senthivel, RK Varshney,
B Jayashree and DA Hoisington

Crop-wild gene flow studied to provide national biosafety commission the scientific data on environmental risk of deploying GM sorghum in Kenya and Mali (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
Kenya; Mali

Partners Involved:
ICRISAT; IER, Mali; KARI, Kenya; CIRAD, France; University of Hohenheim, Germany

Progress/Results:
The study aims at measuring the historical amount of sorghum crop-to-wild gene flow at the country scale; identifying and quantifying the biological, environmental and human factors favoring or limiting the genetic introgression between wild and cultivated sorghums; measuring the fitness of crop-wild sorghum hybrids and assessing the risk of extinction of wild sorghum populations caused by hybridization.

Comparisons of phylogeographic and crop-wild gene flow in *Sorghum bicolor* have been made in Kenya and Mali. Between both locations, 6 different surveys were conducted for the collection of cultivated, wild and weedy sorghums. These included surveys on the national scale and local scale for each location as well as within-wild populations and mating system surveys in Kenya. In Mali 420 cultivated and 81 wild/weedy sorghums were collected and in Kenya 329 cultivated and 110 wild/weedy were found. In this project, 4300 samples were analyzed with SSR markers and more than 60,000 data points were produced between the BECA research platform, CIRAD and University of Hohenheim. The results of this study will be disseminated through three PhD dissertations and scientific publications in peer-reviewed journals in 2009.

In particular in Kenya, a total of 439 samples, comprised of 329 cultivated and 110 wild sorghums were collected at a national scale to study genetic relationships and gene flow between the two congeners. The samples were genotyped using 24 SSR loci. To study introgression between cultivated and wild sorghum at a local scale, 17 wild/weedy populations comprised of 25 panicles each and 22 cultivated populations comprised of at least 12 farmer-named varieties, each made up of 5 panicles, have been genotyped using 10 SSR loci. In addition, the genetic structure of weedy sorghum in Kenya has been studied. A total of 61 populations made up of 25 individuals each were genotyped using 18 SSR loci. Studies on pollen competition and wild sorghum outcrossing rates in Kenya have also been done. In order to determine whether pollen competition acts as reproductive barrier to crop-to-wild gene flow, a controlled mixed pollen field pollination experiment involving both male sterile and male fertile baits was conducted in Kenya. At least 3 SSR markers were employed to undertake paternity analysis in at least 300 progenies. To estimate the level of outcrossing in wild sorghum, four accessions collected from four different agro-ecological zones of Kenya were progeny tested using 6 polymorphic SSR markers.

Special Project Funding:
Environmental Risk Assessment of Genetically Engineered Sorghums

Santie de Villiers and D Kiambi

Output target 2.4.2: Reference sets of small millets germplasm established (2010)

Genetic diversity and population structure of finger millet composite collection assessed and reference set (300 accessions) established (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
A composite collection of 1000 accessions, which also consists of 622 core collection accessions, has been developed and molecularly profiled using 20 SSRs in high throughput assay (ABI3700), and extracted from it a reference set consisting of 300 genetically most diverse accessions.. This reference set captured 206 (89.2%) of the 231 composite collection alleles, representing diversity of the entire composite collection. Further, analysis is needed to determine which alleles for a given SSR primer pair are associated with the A and B genomes (finger millet being tetraploid) when, as is often the case, the SSR loci used in this study are present in more than one copy across these two halves of the finger millet genome.

Special Project Fundings:
Generation Challenge Program

HD Upadhyaya, A Bharathi, RK Varshney, CT Hash, S Senthilvel,
SL Dwivedi, DA Hoisington, CLL Gowda and B Jayashree

Genetic diversity and population structure of foxtail millet composite collection assessed and reference set (200 accessions) established (2010)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
This composite collection (500 accessions) was genotyped using 19 SSRs in high throughput assay to detect genetic structure and diversity and from it extract genetically most diverse accessions to construct a reference set. Allelic data of 19 SSR loci on 452 accessions detected 362 alleles, of which, 196 were common and 166 rare alleles. Gene diversity varied from 0.012 to 0.670. A number of group-specific unique alleles were detected: 40 in Indica, 21 in Moharia, 10 in Pumila, and eight in Maxima among races, while among regions, 57 in South Asia, 17 in West Asia, 14 in East Asia, and three in Africa. The shared common alleles were 28 between Moharia and Indica, 16 between Maxima and Indica, nine between Maxima and Moharia, four between Moharia and Pumila, three each between Italica and Indica and Pumila and Indica. Region-wise shared common alleles were 43 between East Asia and South Asia, 24 between South Asia and West Asia, 4 between Africa and South Asia, three each between East Asia and West Asia and Africa and West Asia, and two between Africa and East Asia. A reference set of 200 genetically most diverse accessions was established, capturing 316 (87.3%) of the 362 alleles detected in the composite collection. The utility of this reference set in foxtail millet genomics and breeding is being further investigated.

Special Project Fundings:
Generation Challenge Program

HD Upadhyaya, A Bharathi, RK Varshney, CT Hash, S Senthlivel,
SL Dwivedi, DA Hoisington, CLL Gowda and B Jayashree

Output target 2.4.3 Trait specific germplasm of staple crops and small millets available for utilization (2009)

Trait-specific germplasm regenerated/multiplied for distribution to partner on request (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
China; India; Thailand

Partners Involved:
ICRISAT Patancheru-based scientists and NARS from above-listed countries

Progress/Results:
Trait-specific accessions have been identified that are now available for utilization in crop improvement programs.

Chickpea: Early maturity (28), large-seeded kabuli (16), high yield (39), ascochyta blight (3), botrytis gray mold (55), wilt (67), dry root rot (5), pod borer (7), drought (18), salinity (12), multiple resistance (31), and high seed protein (5).

Groundnut: Early-maturity (21), high yield (60), salinity (12), drought (18), aflatoxin (5), bacterial wilt (14), high oleic/linoleic acid ratio (4), high oil content (7), large seed size (5), high shelling turn over (5), low temperature (24), rosette (3), and ELS (1).

Pigeonpea: High yield combined with other agronomic traits (54), Early-maturity (20), salinity (16), sterility mosaic (28), wilt (4), phytophthora blight (78), multiple resistant (2), seed yield (18), harvest index (10), and shelling percent (20).

Pearl millet: Green fodder yield (4-6), seed yield (4-5), large-seed size (1-9), productive tillers per plant (5) and for spikelet density (2-4).

Sorghum: High grain yield (14), extra early flowering (1), basal tillers (6), fodder yield (14), dwarf type (4), exertion (high) (7), low panicle exsertion (2), ear head length (6) and width (4), soluble sugar content in stalk (12), and grain mold (10).

Finger millet: High seed yield and early maturity (25), seed yield (2), fodder yield (7), early-maturity (2), basal tillers (1), inflorescence length and width (7).

Foxtail millet: High seed yield and early maturity (25).

Special Project Funding:
NA

HD Upadhyaya, CLL Gowda, V Vadez, L Krishnamurthy,
J Kashiwagi, SL Dwivedi, S Pande, M Sharma,
RP Thakur, R Sharma and HC Sharma

Output target 2.4.4 Germplasm reference sets available for utilization (2009)

Germplasm accessions of chickpea and groundnut reference sets regenerated for distribution to partners on request (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Reference sets of chickpea (300 accessions) and groundnut (300 accessions) regenerated that are available to researchers upon signing Seed Material Transfer Agreement (SMTA).

Special Project Funding:
GCP and partly TL1

HD Upadhyaya and CLL Gowda

Germplasm accessions of pigeonpea and sorghum reference sets regenerated for distribution to partners on request (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Reference sets of pigeonpea (300 accessions) and sorghum (375 accessions) regenerated that are available to researchers upon signing Seed Material Transfer Agreement (SMTA).

Special Project Funding:
GCP and partly TL1

HD Upadhyaya and CLL Gowda

Output target 2.4.5 DNA extracts of mini core collections and reference sets of germplasm conserved for utilization (2011)

DNA extracts of chickpea and groundnut mini core collections of germplasm conserved for utilization (2010)

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
1. Chickpea: DNA samples have been prepared for 300 accessions of the reference set (which also included mini core subset). The DNA of this reference set has been provided to INRA-CNG for analyzing the sequence diversity at candidate genes under ADOC project. The DNA of this reference set is also being used for undertaking SSR analysis by a PhD student (Ms N Lalitha). DNA samples of the part of reference set are also being used for preparing DArT array of chickpea.

2. Groundnut: Isolation of DNA from reference set (which also included mini core subset) of groundnut has been planned for the year 2009.

Special Project Funding:
GCP, and partly TL1

HD Upadhyaya and RK Varshney

DNA extracts of pigeonpea, groundnut and sorghum mini core collections and reference sets extracted and made available on request (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
France

Partners Involved:
CIRAD

Progress/Results:
Sorghum: Progress/Results: DNA samples of 350 of 384 accessions of the sorghum reference set were prepared at ICRISAT in 2007. Validation of these DNA samples was conducted at Cirad during 2008 with a set of 17 of the 41 SSR markers initially used to determine the population structure of the sorghum composite germplasm set (from which this reference set was selected). This validation exercise has identified several problematic markers and several problematic DNA samples. The problematic DNA samples have SSR marker genotypes that do not match those expected for the accession based on the original marker analysis of the sorghum composite germplasm collection. As the reference set DNA samples were produced from freshly grown seedlings, it appears that seed lots used for the problematic DNA samples for this were not representative of the seed lots from which DNA was isolated for the earlier composite collection analysis. In some cases these DNA problematic samples were from accessions contributed by Cirad, for which the original DNA isolation was performed at Cirad and seed was then introduced to ICRISAT for subsequent maintenance (providing several opportunities for seed lot tracking errors to occur). In other cases problematic DNA samples were from accessions contributed by ICRISAT (where there should have been fewer opportunities for sample tracking errors). In at least one case it appears that plants produced from the seed lot introduced from Cirad to ICRISAT did not match the descriptors for the accession. Assuming that these plants really should have matched the available descriptor information, this would explain the failure of the composite collection and reference collection DNA marker data sets to match for this accession. Work is underway to determine the probable causes of other problematic samples, and provide correct replacements for these.

Special Project Funding:
GCP

CT Hash, HD Upadhyaya, S Senthilvel and RK Varshney

DNA of finger millet mini core collection and reference set extracted and made available on request (2012)

No report for 2008

Output target 2.4.6 Broadening the genetic base of legumes through wide crosses (2011)

Diploid hybrids between Arachis AA and BB genome generated and reference map of AA and BB genome constructed (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru and Indian NARS

Progress/Results: Three diploid hybrids between AA genome and five diploid F_1 hybrids between BB genome have been identified as candidates for developing reference maps based on their genetic diversity and mature seeds set. F_2 seeds have been obtained in a few crosses. The advancement of crosses will be on hold till molecular analysis is undertaken.

Special Project Fundings:
DBT

N Mallikarjuna, HD Upadhyaya, F Waliyar, E Monyo and DA Hoisington

Develop hybrids between section *Arachis* and section *Procumbentes* and generate fertile backcross population and screen for desirable traits (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Hybrids between *A. hypogaea* x *A. kretschmeri* and *A. hypogaea* x *A. chiquitana* (BC_3F_2) did not set many seeds after self pollination. They were again backcrossed to *A. hypogaea* to produce large number of seeds.

Special Project Fundings:
Core

N Mallikarjuna and HD Upadhyaya

Hybrids between cultivated groundnut and synthetic amphidiploids created, variation for different traits (rosette and foliar diseases) analyzed and molecular map constructed (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
India; Malawi

Partners Involved:
ICRISAT Patancheru; NARS from India and Malawi

Progress/Results:
Diversity studies were carried out on *Arachis* species from section *Arachis* and genetic distance between the species was calculated. Crosses between different *Arachis* species were carried out and tetraploid synthetics were generated from diploid hybrids (Table 14). Depending upon the cross combination, some hybrids have produced seeds and some need to be harvested. Six of the 18 synthetics were tested for late leaf spot by detached leaf technique that showed resistant reaction to the disease. University of Agricultural Sciences and ICRISAT are using synthetics, in a DBT funded project, to develop backcross population and obtain late leaf spot resistant progeny. Only selected population will be used to develop tetraploid-based reference map. Populations at later stage will be evaluated for resistance to rosette disease in Malawi.

Table 14. Synthetics obtained in tetraploid genetic background in groundnut.

Cross combination	Genetic distance	Availability of seeds	LLS reaction
AB genome			
A. duranensis x *A. ipaensis*	0.875	√	R
A. duranensis x *A. batizocoi*	NA	√	R
A. duranensis x *A. hoehnei*	1.0	*	NA
A. valida x *A. duranensis*	1.0	*	NA
A. ipaensis x *A. duranensis*	0.857	*	NA
A. batizocoi x *A. duranensis*	NA	*	R
A. valida x *A. duranensis*	0.85	*	R
A. kempff-mercadoi x *A. hoehnei*	NA	*	NA
A. batizocoi x *A. cardenasii*	0.94	*	NA
A. kempff-mercadoi x *A. hoehnei*	NA	√	NA
A. valida x *A doigoi*	1.0	*	R
A. magna x *A. batizocoi*	0.87	*	R
A. batizocoi x *A. cardenasii*		√	
AA genome			
A. kempff-mercadoi x *A. stenosperma*	NA	*	R
A. duranensis x *A. cardenasii*	0.67	*	NA
BB genome			
A. trinitensis x *A. hoehnei*	NA	No seed set	NA
A. magna x *A. valida*	0.85	*	R

* To be harvested

Special Project Fundings:
DBT

N Mallikarjuna, HD Upadhyaya, F Waliyar, E Moyno and DA Hoisington

Tetraploid hybrids between synthetic and cultivated groundnut generated and molecular map generated for use in breeding program (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
India; Malawi

Partners Involved:
ICRISAT Patancheru; NARS from India and Malawi

Progress/Results:
Two synthetics, ISATR 278-18 and ISATR 1212, and four leading cultivars were selected to introgress resistance to LLS and *A. flavus* into improved genetic background using backcross breeding. Likewise, another four synthetics were crossed with groundnut cultivars to introduce resistance to *A. flavus* and low aflatoxin production. In a cross involving *A. hypogaea* and synthetic ISATR 265-5 (*A. kempff-mercadoi* x *A. hoehnei*), F_2 population segregated for pod morphology (Fig. 1). Although all the pods were single seeded, some were larger resembling *A. hypogaea* and some were small, resembling ISATR 265-5.

Fig. 1. Utilization of synthetic *A. hypogaea* (ISATR 265-5) for groundnut improvement.
Left to right: 1. Pods of *A. hypogaea*. 2. Pods of synthetic A. *hypogaea*. 3. F_1 hybrid between *A. hypogaea* and synthetic *A. hypogaea*. 4. F_2 pods.

Special Project Fundings:
DBT

N Mallikarjuna, HD Upadhyaya, F Waliar, E Monyo and DA Hoisington

Genetic variation for desirable characters using *Cajanus platycarpus* (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
India

Partners Involved:
ICRISAT Patancheru; NARS from India and Malawi

Progress/Results:
The previously selected advance generation interspecific derivatives with specific attributes (early flowering and pod set, high seed weight, brown seed, multiple locule, high seed number, short statured plants, good plant type, low *Helicoverpa* damage, low Phytophthora blight damage, and stay green trait) are being re-evaluated during 2008 crop season. Screening for Phytophthora blight was carried out at Ludhiana under artificial epiphytotic conditions. The line which showed low Phytophthora blight damage in 2007 also recorded low damage in 2008. In addition, selection was also made for male sterility, in which anthers do not dehisce and do not set seeds from natural self-pollination.

Special Project Funding:
TL1, DBT and core

N Mallikarjuna, HD Upadhyaya, RK Varshney,
V Wesley, HC Sharma, KB Saxena and Livinder Kaur (Ludhiana, India)

Output target 2.4.7 Allele specific sequence diversity in the reference sets staple crops studied (2011)

Allele specific sequence diversity in the reference sets of chickpea and sorghum studied (2011)

Achievement of Output Target (%):
>50%

Countries Involved:
France; Peru

Partners Involved:
CIRAD, INRA-CNG, CIP

Progress/Results
1. Chickpea: Under the Generation Challenge Programme sponsored ‘Allelic Diversity on Orthologous Candidate genes’ (ADOC) project, several drought responsive candidate genes such as CAP2 (homolog for DREB2A), CAP2 promoter, sucrose synthase (SuSy) (two fragments), sucrose phosphate synthase (SPS) (two fragments), abscisic acid stress and ripening gene (ASR) (two fragments) and ERECTA sequence have been identified. These genes were amplified and sequenced in a set of 8 chickpea genotypes and their allelic diversity was studied (Table 15 and Fig 2). These candidate genes, in collaboration with INRA-CNG (France) have been sequenced on a set of 300 accessions of the chickpea reference set. However, sequencing has been successful only for the CAP2, CAP2 promoter, SPS, ASR and ERECTA genes. Sequence diversity is being analyzed in the reference collection at present.

RK Varshney, S Nayak, B Jayashree, HD Upadhyaya and DA Hoisington

2. Sorghum: 50% Sequence data has been generated from 350 sorghum reference set DNA samples (some of which are problematic—see above output target 2.4.5) for homologs of several candidate drought-responsive genes, and analysis of the sequence data, and associated passport and SSR marker data, is underway.

Further, a set of drought responsive candidate genes were identified for primer development, amplification and sequencing in sorghum and several other staple food crops the under Generation Challenge Programme-sponsored ‘Allelic Diversity on Orthologous Candidate genes’ (ADOC) project. At ICRISAT, primer sequences for one of the candidate genes DREB2 were developed while primers for other candidate genes (SuSy, ASR, Vacuolar invertase, ERECTA and SPS) were developed by other collaborators. Subsequently, a set of 8 diverse sorghum genotypes (BTx623, B35, E 36-1, R 16, IS 9830, IS 27761, IS 29233, and IS 18933) representing the diversity of the reference collection was used for initial sequencing of their candidate gene homologs. The sequencing of these candidate gene homologs on DNA samples from 350 accessions of the sorghum reference collection was then carried out at INRA-CNG (France) and sequence diversity detected is being studied at Cirad (France). Initial analysis of these results suggest that detected SNP and insertion-deletion sequence variants for these candidate drought responsive genes across this diverse panel of sorghum germplasm accessions are behaving like neutral markers, as did the 41 SSR markers used in selection of the sorghum reference set from the larger sorghum composite germplasm collection.

Special Project Funding: Generation Challenge Programme

RK Varshney, S Nayak, B Jayashree, HD Upadhyaya and DA Hoisington

Table. 15. Allelic diversity of drought responsive candidate genes in 8 diverse chickpea genotypes.

	ASR2	ASR5	CAP2gene	CAP2promoter	SPS2	SPS3	SuSy3	SuSy4
No.of Genotypes	7	8	7	8	7	8	8	8
Sequence Length (bp)	848	668	707	603	494	371	739	755
No.of Indels	0	1	0	0	1	0	0	0
Indel Frequency	0	1/668.00	0	0	1/494.00	0	0	0
No.of SNPs	13*	3	0	2	16	0	5	6
Transition	9	2	0	0	8	0	4	1
Transversion	6	1	0	2	8	0	1	5
SNP Frequency (bp)	1/65.23	1/222.67	0	1/301.50	1/30.88	0	1/147.80	1/125.83
Nucleotide Diversity	0.0063	0.0017	0.0000	0.0013	0.0132	0.0000	0.0026	0.0031
Avg PIC of SNP	0.32	0.41	0	0.44	0.28	0	0.31	0.22
No.of Haplotypes	5	3	1	4	7	1	4	7
Haplotype Diversity	0.857	0.679	0.000	0.786	1.000	0.000	0.643	0.964
PIC of Haplotypes	0.735	0.594	0.000	0.688	0.857	0.000	0.563	0.844

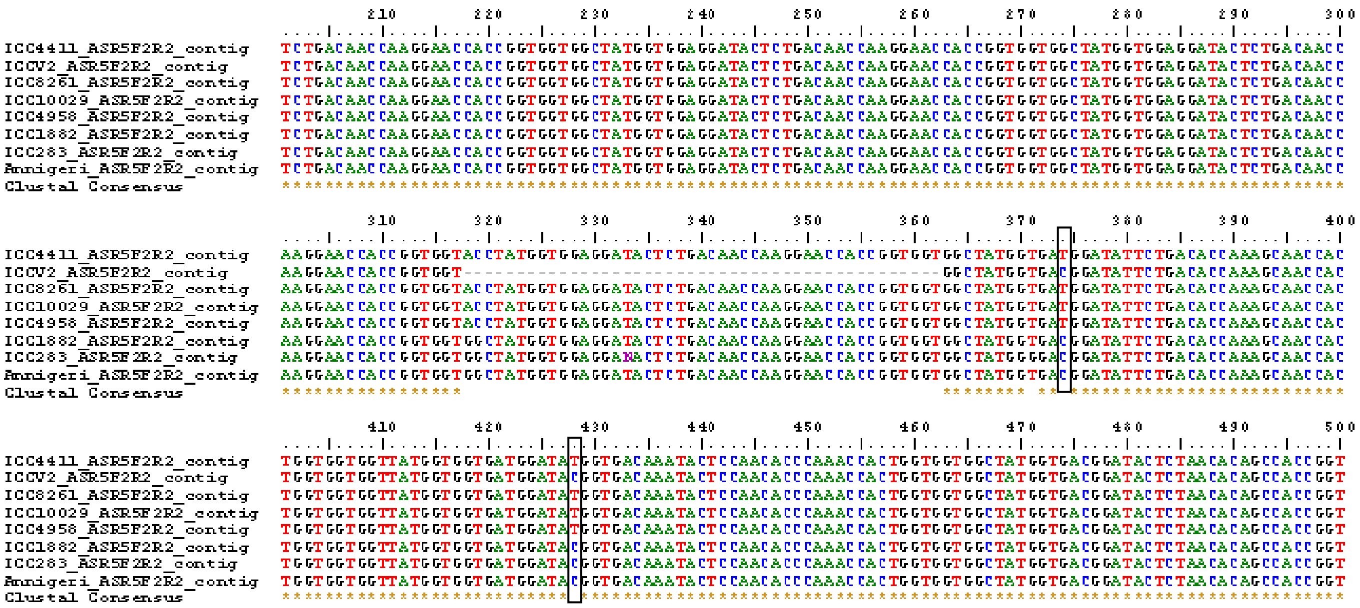

Figure 2. Multiple sequence alignment of ASR gene in eight chickpea genotypes.

Output target 2.4.8 Development of genomic resources for SAT crops (2011)

Novel set of microsatellite markers developed and characterized for chickpea, pigeonpea and groundnut (2010)

Achievement of Output Target (%):
>50%

Countries Involved:
Germany; India; USA

Partners Involved:
University of California-Davis, University of Frankfurt/ GenXpro, National Research Centre on Plant Biotechnology, Centre for Cellular and Molecular Biology

Progress/Results:
Novel SSR markers
1. Chickpea: As reported in the Archival Report -2007, a total of 1655 novel SSR markers have been developed in chickpea and thus in total the chickpea community has now access to >2000 SSR markers. Newly developed SSR markers have been checked for amplification on two genotypes namely ICC 4958 and ICC 1882. As a result, 1,299 primer pairs yielded an amplicon. While examining these markers on a set of 48 genotypes, 42% markers showed polymorphism within cultivated genotypes while 52 % markers showed polymorphism across the wild species and 31% of the total markers showed polymorphism across cultivated and wild types. These markers are being used to integrate in the genetic maps of chickpea.

In addition to above, 18,435 ESTs have been developed from four chickpea genotypes (ICC 4958, ICC 1882, JG 11, ICCV 2). These ESTs together with 7,097 EST available in public domain have been used for mining the SSRs. *In silico* analysis of a total of 9,569 unigenes derived from clustering 25,532 sequences (18,435 developed at ICRISAT and 7,097 sequences from public domain) provided 3,728 SSRs in 2,029 ESTs. Majority of SSRs identified so (1,793) however represents mono-nucleotide (N) SSRs. Among other classes of SSRs, the dimeric (NN) SSRs (126) and trimeric (NNN) (110) SSRs were found abundant (Figure 3). After exclusion of N SSRs, the primer pairs could be designed for 147 SSRs. Based on some criteria to get higher proportion of polymorphic markers, the primer pairs have been synthesized for 77 SSRs. These primer pairs are being used for checking the amplification and will be integrated into chickpea genetic maps, as mentioned above.

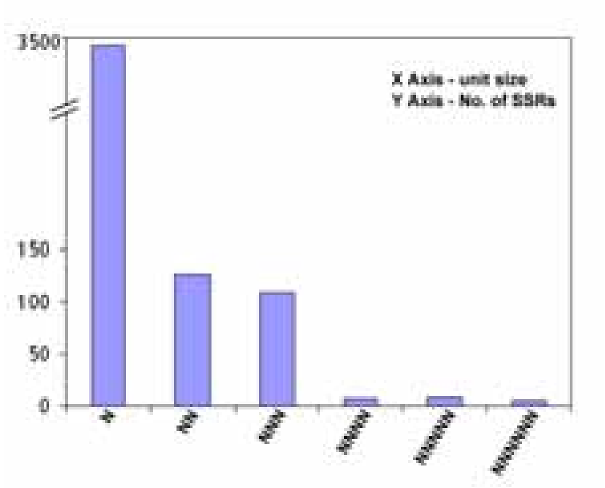

Figure 3. Distribution of SSRs in BAC-end sequences of chickpea.

Special Project Fund:
Generation Challenge Programme, National Fund of ICAR (Govt of India), Department of Biotechnology (Govt of India)
RK Varshney, S Nayak, P Hiremath, Jayashree B, DA Hoisington and DR Cook

2. Pigeonpea: Two approaches were used to develop microsatellite markers in pigeonpea.
1. Development of microsatellites from Bacterial Artificial Chromosome (BAC) end sequences (BES): In collaboration with University of California, Davis (Doug Cook), a total of 87,590 BAC end sequences representing 56.5 Mb genome size, were surveyed for the presence of microsatellite using MIcroSAtellites (MISA) tools. In total 16,308 SSRs were
identified in 14,001 BES at the frequency of 1 SSR per 3.52 kb. In this set dinucleotide repeat were most abundant (41%) while tri nucleotide repeats were second most abundant (8% of total SSRs). The percent abundance of different SSRs is graphically represented in Figure 4. Primer pairs have been synthesized for 3072 SSRs. These markers have been designated as CcM (*Cajanus cajan* Microsatellite) markers.

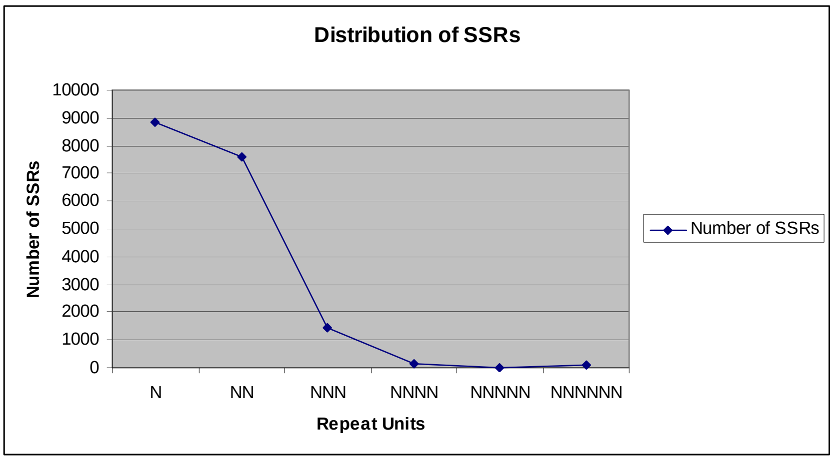

Figure 4. Distribution of SSRs in BAC-end sequences of pigeonpea.

2. Gene based markers: In the second approach, the SSR markers were developed from ESTs. A total of 9,888 expressed sequence tags (EST) were generated from 16 cDNA libraries derived from various developmental stages of root tissues of *Fusarium* wilt resistant (ICPL 20102) and susceptible (ICP 2376) genotypes in response to *Fusarium udum* infection; and leaf tissues of SMD (sterility mosaic disease) resistant (ICP 7035) and susceptible (TTB 7) genotypes in response to sterility mosaic disease infection respectively. In order to search for microsatellites a source of marker development, 908 pigeonpea ESTs available in the public domain were also included along with the 9,888 generated ESTs. Data mining of 5085 unigenes defined using the ESTs generated at ICRISAT and available in public domain provided 3583 SSRs in 1365 ESTs at the frequency of 1/ 1.2 kb. Mono-nucleotide SSRs (3498) were present in the highest numbers, followed by di- nucleotide SSRs (40) and tri- nucleotide SSRs (33). Tetrameric, pentameric and hexameric microsatellites were 9, 2 and 1 respectively (Figure 5). Based on the length of SSR motifs, 94 SSRs were chosen for primer synthesis out of 383 designed SSR primers.

Special Project Fund: Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Govt. of India)

RK Varshney, A Dubey, NL Raju, Jayashree B, RK Saxena and DR Cook

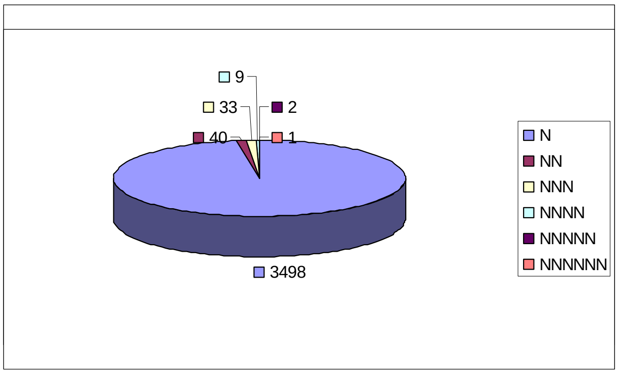

Figure 5. Distribution of microsatellites of different repeat units in ESTs of pigeonpea.

3. Groundnut: With an aim of developing novel set of microsatellite markers, in collaboration with University of California, Davis (Doug Cook), a total of 41,856 BAC end sequences (BES) spanning a length of 28,615,439 bp were mined for presence of SSRs. As result 4,869 SSRs were identified in 4,082 BES with a frequency of 1 SSR in 5.8 kb. Among different SSR repeat type classes mono- nucleotide SSRs were most abundant followed by di-nucleotide SSRs. Designing of primer pairs for the SSR containing BES is in progress.

Details on SSR markers isolated using enriched genomic DNA library approach have been published in a recent article by Cuc et al. (2008) in BMC Plant Biology.

Special Project Funding:
National Fund of ICAR (Govt. of India), Generation Challenge Programme

RK Varshney, A Dubey, S Nayak and DR Cook

Novel set of microsatellite markers developed and characterized for pearl millet and sorghum (2008)

Achievement of Output Target (%):
100%

Countries Involved:
France; Peru

Partners Involved:
CIRAD, INRA-CNG, CIP

Progress/Results

Pearl millet: As reported earlier in 2007, a total of 960 SSR-enriched clones isolated from the SSR-enriched library developed in collaboration with Centre for Cellular and Molecular Biology (CCMB), Hyderabad (Dr Ramesh Aggarwal) have been sequenced. A total of 454 primer pairs were synthesized from SSR-containing clones. Validation of these primer pairs was initially done using the two parental genotypes of the RIL mapping population based on cross ICMB 841-P3 × 863B-P2. Only 235 of these 454 primer pairs produced PCR products with the two pearl millet lines. These 235 primer pairs have been further screened across a set of 24 elite pearl millet inbred lines including 22 parents of various ICRISAT mapping populations. In total 105 polymorphic markers have been identified using these 24 inbred lines. A set of 50 polymorphic markers that were polymorphic were further genotyped on the (ICMB 841-P3 × 863B-P2)-based RIL mapping population. Genotyping data obtained for these markers along with other types of markers (pearl millet EST-SSR, pearl millet SSCP-SNP, and CISP markers) are being used to further saturate the pearl millet genetic linkage map for this cross. Independent validation of the 105 newly identified polymorphic SSR markers suggests that only 25 are sufficiently polymorphic and amplify reliably enough to be used routinely in pearl millet genetic analysis.

In addition, ICRISAT's initial set of pearl millet EST-SSRs was published in 2008 (Senthilvel et al. 2008 BMC Plant Biology 8:119), and with support from the Generation Challenge Programme work was initiated to develop large sets of ESTs from root and leaf tissues of pearl millet RIL mapping population parental lines ICMB 841-P3 and 863B-P2 for use in further developing further molecular markers (EST-SSRs, indels, and SNPs) to better saturate the pearl millet linkage map. During 2008, RNA samples were collected from the two tissues of the two parental genotypes, converted to cDNA, and shipped to a service lab for sequencing.

RK Varshney, T Mahender, RK Aggarwal, CT Hash,
T Nepolean, S Senthilvel, V Rajaram, V Vadez and DA Hoisington

Sorghum: Sorghum marker information in the LIMS database was curated to standardize marker names, add references and information on IP restrictions (if any) for the SSR primer pairs included in this database, and added information on linkage group position(s) of loci detected by these SSR primer pairs and references for these linkage group assignments.

A total of 600 sorghum EST-SSR primer sequences, developed by BLAST search of sorghum SSR-containing ESTs against the genome sequence of each of the 12 rice chromosomes, so as to provide reasonable coverage across the entire syntenic gene space of the sorghum nuclear genome, have been added to the LIMS database (Table 16).

RK Varshney, T Mahender, RK Aggarwal, CT Hash,
T Nepolean, S Senthilvel, V Rajaram, V Vadez and DA Hoisington

Table 16. 600 ICRISAT sorghum EST-SSR primer (ISEP) pairs developed during the course of the PhD thesis research program of Mr Punna Ramu.

Proposed locus name	Forward primer sequence	Reverse primer sequence	Repeat motif
Xisep0101	CAGATCTCCGGTTGAAGAGC	TGAGCCGAGCTCAACATACA	TG(9)
Xisep0102	CGCTGGAGTACCAGAGGAAG	AACAAAATCCGAGCCTGTTG	AAG(4)
Xisep0103	ACTTCACCTGGGAGGTGGT	GCAGCCAGTCACTGATCAAA	GCT(6)
Xisep0104	GGCGGTTTATCCTTCCTGTT	TCGGACCAACCAAAAGAAAC	AGC(6)
Xisep0105	CCACCTGAACCCTACTCCAC	GTCCTTGTTGCCCTCCATC	TCGCC(5)
Xisep0106	AGCTATGGCTCCTGCACCTA	TATGGCGCACTCAACATCAT	AT(8)
Xisep0107	GCCGTAACAGAGAAGGATGG	TTTCCGCTACCTCAAAAACC	TGG(4)
Xisep0108	GTACGTTCCCCATCCTTCCT	CTCCTGTTCTCTCCGCATTC	GGC(5)
Xisep0109	GGTGCTACAACCTCCTCTGC	GTTGCCATTGAACAAGCTAGG	TC(6)
Xisep0110	GAGGGGAAGCTGGAGACC	TCAAGTGTACAACGCATCCAG	CG(6)
Xisep0111	CTACCCGGAGCACTGGAAG	CGGCACAGTAGCAATCACAA	GCT(4)
Xisep0112	GGAGAGACGACCCCTCAAG	GTCCTGCACCTTCTCGATCT	CGAG(4)
Xisep0113	AGGATCACCGAGAAGCAGAA	TTCACACTGTCCCATTGCAT	ACG(4)
Xisep0114	CTTCGCCGCCTAGATCTATTT	GGGGATCATCAGATCACACA	GT(10)
Xisep0115	ATTCCCCAATTCGATTCCTT	CTCCGTCTTCTCGCACTTG	ACG(5)
Xisep0116	CAATCCGCAAACCCTTTCTA	TAGAGCTGCGACAGGGAGTT	CGG(4)
Xisep0117	GGATGTACCAGCACCAGCTC	GAGAACAGCCGAGGGAGAG	CCT(7)
Xisep0118	CCTCCTCCCTCCCTTCTTTT	GGCTCCTCCCAGATCTCTCT	CCGT(4)
Xisep0119	ACGAGCACCGTCCAGAAG	CAGAGCAATGTCTTCCAACG	CAG(4)
Xisep0120	CACGAGGCACATCTATCCAC	CTCGCTCCAGCAATCCTC	CCGT(4)
Xisep0121	AGGAGGACGACTTCCTTGC	CTGCATGATAAAGGCAGCAC	CGATC(3)
Xisep0122	TCGATCGAGCTCCAAAGAAC	ACAGCAGCACCAGCTTCC	CGA(5)
Xisep0123	CGACGACCTCAGGAGACG	CTTCCGCGAGATGGTCAC	AGG(7)
Xisep0124	CTCGACACGAATACGAGCAC	GCGATCTGGAGCTAGGGTTT	ATC(6)
Xisep0125	TCAACAAGAACAACGCCAAC	GGCTCTTGAACCTCTTGTCG	CAA(6)
Xisep0126	TGGAACGTCCTCTTCTACGC	AATCTTTTGACCCCCGCTAT	ACAG(5)
Xisep0127	ATCAGGAGCTGAAGGTGGTG	CTTGTGGTACCCCTGGATTG	GCT(5)
Xisep0128	GAGCACATCAAGGCAAACTTC	CAGCAATGTTCTCGAACCAA	TA(5)
Xisep0129	CTGATGACGCTGGGGTTC	CTGGCTAGTCCTGGCTCATC	ACG(4)
Xisep0130	GAGTACACAAGCGAGCGAAA	CCACCTCTCCTCCTGATCCT	CGC(4)
Xisep0131	TCAGTCTTGACACAAGCAAGC	CGCTTCTTCCTGAGCTTGAG	CTGCT(4)
Xisep0132	CGTCGATGAGTTCGTCAAGA	CTGAGCAGAGTTGTCGGTTG	CAG(5)
Xisep0133	ACACGGAGGAGACGAGCA	CAACATCCTGGTGAACAACG	GCG(4)
Xisep0134	AGCCGTCTGATTGAAGAACC	TTAATGTTTGGTGGGCTTGC	AT(5)
Xisep0135	CCCAAGAAGGGATGACTGAG	GTCTTCTGCAGGTCACACCA	TGAT(4)
Xisep0136	CGACTAAGCGGTTCGTTGTC	AAGCTTGCCACGAAACTTGT	CGT(4)
Xisep0137	TCCCCAAGATTTCCAAGATG	GTACAGGGGCGTCGTCAC	GCG(4)
Xisep0138	GAGATCGAGAGGCACTTTGG	CAGCGACAAGCCAATACCA	TA(6)
Xisep0139	GGAGGATATGTCGTCGTCGT	GCGGATCTTGTCGCAGTAG	CGG(4)
Xisep0140	CTTGCAGCAGCAATGGTC	CCTTGTCGGCGAAGTAGAAG	CGC(4)
Xisep0141	CCACGCTCCTCTCCCTCT	GGAGTTGGCTTGATTTTCCA	CCG(4)
Xisep0142	CTGCAGTCTGGACTCTGGTTC	GGGCTCATGTACCAGCTCAT	GGA(4)

Xisep0143	CACGTCCAAAAGCCATGTT	ACGGGAACGAGGAGGAGTAG	TCC(5)
Xisep0144	TCGACGAAGGCGAAACTAAT	TGGAACTGTGGATGTTACGC	GCG(4)
Xisep0145	ACGCGCATGAATGGATTAAC	GGTTGAACTGCTCGACGAA	GAG(6)
Xisep0146	CGACCGAGCTTGAGAGTGAT	CGATCTTGACGTCGTAGCAG	CGG(5)
Xisep0147	CTGGCGGTGATCCAGTTC	GAGAGTGCGAGGGTGAGC	GC(5)
Xisep0148	CGGAGTCCACGGAGTCTTC	CCGAGGTAGCAGAGCGACT	GGC(4)
Xisep0149	CGAACAAGCAAGCAACAATG	TTCATCCAACCAAGCATGTG	CTC(4)
Xisep0150	GTCTTCGGCCTCATCTGGT	CGCAAAAGTGAAGCTTAGATACAA	ATCC(5)
Xisep0201	GGAGGGTCCTCGGACAAG	GCTTTCAGCTTCGGACTCTC	CGC(4)
Xisep0202	CAACCTGTGATTGACCCATTT	AAACATGTCCAGATTCATCAAGG	TGA(7)
Xisep0203	CGATGGTGAGGATGGGTAAC	TTCTGCACAACCATCTTTGG	ATAC(3)
Xisep0204	GCATCTCATCTCAGCAGCAG	ACGGAGAACTCAGCCTCCTC	GGC(4)
Xisep0205	CAAGCGGCTAAGGTCGTG	AAAACAAAAAGCGTCGTCGT	CCG(5)
Xisep0206	AGGGCAAGGTGATGGAGAG	ACGTAGTCACCCTCCCGTAG	AAG(9)
Xisep0207	GACCGGTGATGGGACATTAT	CAATCGCAAGGAGGAAAAGA	CATTG(3)
Xisep0208	CCTCTCTCCCTCTCGGACTC	CGTCCATCTCCACCATCAC	GCAAA(3)
Xisep0209	GAGCCACGAGCCTAACAAAA	ACAGCATCGTGTCGTGAGTC	GCCG(4)
Xisep0210	ACGAGACACGACTCCTCCAT	CGAGGAGGTCGAGTAGAACG	GA(8)
Xisep0211	ACCCTACTGATGACCGTGCT	CCGTGCAAAAACACTACACAA	CG(5)
Xisep0212	CGAGGCAGGAACTGTAGGAG	CGACAATAGCAACCACATCG	GA(5)
Xisep0213	ACGGAAGGGAACAAACAGTG	ATCGATCAGATCAGGGCTTG	GGC(4)
Xisep0214	TCAAGATCGTGGTCAGCAAG	TGGCAGTCATCATCAGTTCAG	GCG(5)
Xisep0215	AGAAGGTGATGTCCCTGGTG	TGCAATTTCAGACCACCTTG	CGC(4)
Xisep0216	CTCCTCCATAGCCAGCCATA	TCGAACTCCGTCTTGATGTG	GA(7)
Xisep0217	ATAGGGACCGGTGGAGGA	GCAGCAGGCTGAGAATCTG	GGA(4)
Xisep0218	GCTCCTCTCTCCCTCTCTCG	TGGGAGTTTTGAGGAGCTGT	GCG(5)
Xisep0219	CACGAGGGCAAAAACCAC	AGCCCTCGATCTTCACCAC	CGG(4)
Xisep0220	CTCCAGAACAGAAGCGATGG	ACATGAGCTGCTCGTCGTC	CGG(4)
Xisep0221	TCATCGTCCAGCACCAGA	CACGAATGGATCGGACGTAT	GCC(6)
Xisep0222	CACAGACAGACACGGTCGAG	GAAGCCGATGAAGAGGTACG	CGT(6)
Xisep0223	ATCTTTTCCTCCCACCCAAC	GGCTTGAATCTCGTGTAGCC	TCCT(3)
Xisep0224	ACTGGGGTTCCTTTTCCTGT	TCCCTGATTTCCCCTCTTTT	CTG(4)
Xisep0225	GCAAGAACCCCTCACTCACT	CTTCTTCTCCTCCCCTCCTG	CTCA(3)
Xisep0226	TCGACTCCCTTCCTTCCATA	GCTCCAGTTCATCGCGTAG	GGC(6)
Xisep0227	TTCGTCAACGAGAACCCTCT	CTTGAGCGGCCTGATGTC	CGG(4)
Xisep0228	GACATGGCCAGCTAAGAGGA	CCATGCAGTGATCGTTGTGT	GAGG(3)
Xisep0229	TTGACCTACGGGACAAGGAG	AGCGGATATCAAGCACAACC	GGC(4)
Xisep0230	ATGCGTACCGGACACAGG	CAGCAGCAGCAGATTCCTC	CAG(5)
Xisep0231	GTACACGGAAAGTCGGAAGC	CTTGGACACGTCCCAGAAGT	GGC(5)
Xisep0232	GGAAGCTTCGCTTCACTCTG	TCGCAGAACTCCAAACACAC	CCG(4)
Xisep0233	AGGGCATACCATACCAGCAG	GCGGAATCGATGATGCTACT	TGTA(5)
Xisep0234	GCCTCCCTTCCCTTCCTT	CCTCTGCCTCTTCACGTTTC	CT(10)
Xisep0235	TCCAGAAGAATCCGGTGAAC	AGGCAATCAATCCAAAGGTG	GATT(3)
Xisep0236	GAGGCTCGCAACTAACTGCT	CGATGTCCTCTCCGATCTTC	CGC(4)
Xisep0237	GGCCTCAACCTCACTCCTCT	CTTGGTGCGCTCGAACTT	GCG(4)
Xisep0238	AACTCGCACAAGAAGGTGGT	GACGACGACTGATGAAGCAA	CGGT(3)
Xisep0239	GGCGAGTCTATCTGGACGTT	GTGTCCGGTACGCATTGAG	CGC(4)
Xisep0240	CAGCTACCTCGAGGACAAGG	CCTCGTACAGGCTGACCACT	GCC(4)
Xisep0241	GACGACCTCCTGACCAAGTG	TATATAAGGCGGACGGAGCA	ATCC(4)
Xisep0242	GCTGGAGAAGCTCAAGGAGA	TCGTTGAATGTTGGAGTGGA	TACC(3)
Xisep0243	ATTTTGCAGGGCATTGAGAT	CAAGAACCTCGCACACACAA	TG(12)
Xisep0244	AAGCCGGTGCTAACTGAATG	TCTCGGTGCCTACCTCTTGT	GC(5)
Xisep0245	GAGAGCTAGCGAGGTCAACG	TGGAGCTAGCCACATGATCTC	GAC(4)
Xisep0246	CTCAGCAGCAGCTAGGGTTT	TCCGAGACGGAGAACTCAAC	GGC(4)
Xisep0247	GGCCAGATCATGCACCTC	CAGACATCTCCGGCTCATCT	CGC(4)
Xisep0248	CTGGTGAGGGAGATGATGGT	GCAAACTCGATCTGCCAAC	GCAT(3)
Xisep0249	GGAGAGGAGAGAGGGAGAGG	AATTCCGAGGCTGATGTTTG	CGCCT(3)
Xisep0250	CGAGTGCTCCTGAGTTCCTT	CCTCGCTCGTACATTCTCCT	TAAT(3)
Xisep0301	ATTCATCGACGGGACGAC	CACTTGTTGAGCGGGATGA	GA(9)
Xisep0302	GAACGTGTTCCACGTCACC	GCCAGGTTCTTCTTCACGAG	GCG(4)
Xisep0303	GGTGCGTAGGGAGTACCAGA	GAGCCCGCGGTACTAGACT	GT(7)
Xisep0304	TATCTGGCAGAAGCAGCAGA	CCCCTGAATAATCCTTCCACT	AGA(5)
Xisep0305	GATGCTGCTGGTGGTGTG	GTTCCGCTCCAGGATGAAG	GTG(4)
Xisep0306	AGGCAAGAAGCGCAATAGAG	GCGGCAGTTGTAGTTGTAGGA	CGT(6)
Xisep0307	CACGAGGCTCATGTCTTCCT	AGGACACAAGGCGCTTAGG	CCG(5)
Xisep0308	GAGGGTTCATTCCTCATCCA	CATCGGGTACACCGTCTTG	GA(9)
Xisep0309	ATGAGCATGAACGAGGAAGG	CACCGTCAGGACATTGACTG	ATGG(3)
Xisep0310	TGCCTTGTGCCTTGTTTATCT	GGATCGATGCCTATCTCGTC	CCAAT(4)
Xisep0311	AACCTGAAGTGGGTGTCGAG	ATACGTACACGGGGCACACT	CGTGT(4)

Xisep0312	GCGATGACATGGTCAAGGT	GCCTCATCATGCTTCGTACA	GCG(4)
Xisep0313	CGTAGAATGGCAGCTTCCTC	CCTCTCCACCTCCTTCTCGT	CGC(4)
Xisep0314	GTTCGACGACGACGACCT	GTCCTCGAACCCGACCTT	GCC(4)
Xisep0315	CTGGAGGGACTACATCACCAA	TGGCAGTGGCATGTCATATAG	CGGC(5)
Xisep0316	CACGGACAGCATGACTCG	CGCCGTAGAAGATGGTCAG	CGC(4)
Xisep0317	AAGGTTATCCCGGGAAGGA	CAATAGGCAGCAACAGCAAA	CCG(4)
Xisep0318	CTGCGACGACTGGGCTAC	AGCGAGAGGGAGTGGTACTG	CGC(7)
Xisep0319	AAGCAGCTCGATCTGATCCT	TGTCGATGGGGAAGTAGAGG	GCC(5)
Xisep0320	GGCCACCATGAACTCCTACT	AGATGTCACCGACCATGGAG	CTC(6)
Xisep0321	GGAAACCGACGCCTGTACTA	TCCCAGTAATGGCACCTCTT	CGT(4)
Xisep0322	GGTGCTCAACAGGATCCAAG	CTTGGGCTCCTCCTTCTTCT	GCC(5)
Xisep0323	CGAGGCCTTGCTGTAATTGT	CTGATCAGATCGAGCAGTGG	TACA(5)
Xisep0324	TCTCCTTTCCCCTCCTCTTC	TCGAGTCAGGTCCAGCTCTT	GCT(5)
Xisep0325	GCCACACTACCTGCCTCTCT	TCCTTGAACCTCGCAGTCTT	GGC(6)
Xisep0326	GAGCTACGTGCTGCGTGA	GGACAAGAATGGAGGAATGG	CGT(4)
Xisep0327	CTGTTTGTGCTTGCAACTCC	TCATCGATGCAGAACTCACC	GTT(4)
Xisep0328	CATCTTCCTCCGTCAACCAT	ATCCTGCGACCCTTCTCAC	AAG(4)
Xisep0329	GTTGTCGTCGTCTGAGCATC	TCCAGGTGTTGGTGTTGAAG	GGTGA(5)
Xisep0330	CCACACAATCAGTTCCTCCA	AGAACATGAACGGCAAGGAG	GCC(5)
Xisep0331	ATGCTAATTGGCGTTGGTGT	CTGCCACTCCTTCAGCTTCT	GT(6)
Xisep0332	GCACAGGACACTAGGGAAGC	AGCAGCCTGGTGCTACTACTG	GGC(7)
Xisep0333	CTGATCGGCTTGTGAATGTG	ATGCAATTGCTGATGAAACG	CTG(4)
Xisep0334	TCCAAAAATCCAAAGCCATC	AAGGTGAGCAGCAGGAAGAG	GCT(4)
Xisep0335	AACTACACCCTCCGGGACTC	ACCCTCTCCTTCTCCTGCTC	CGA(5)
Xisep0336	CATTGCCGATCCATTCTTCT	CAGCCAGTCGGTGTAGTTGA	GAG(5)
Xisep0337	TCCACTTCTCGGTGGATTTC	ATCCTCGTCCTCGTCGTATG	GCA(4)
Xisep0338	GGGACAGATATGGTGGCAGA	TTTCATACCTGGATGGCACA	TGG(4)
Xisep0339	CAAGGAGCTGTGGAAGAAGG	CAATGGAATGCTCCCAATTT	GCA(7)
Xisep0340	CAAATCTCCCCTTCCTCACA	CTCCGCAGGAGCTAGCAG	AAG(5)
Xisep0341	GTCTCCGCCTCCTCTCCTT	GCTCTAGTGCTCTCCCCTGA	CTC(4)
Xisep0342	GTTCATTCGTTCCCCACCT	GGACCCAATTCCTCCAAGA	CGC(8)
Xisep0343	GAACTTCCTGGCCATGGTT	ACCTGTGGAACGGTGACTG	GCT(5)
Xisep0344	GAGGGAACCACCGAATCTC	TCACCTTGACGATCAGATGC	TC(12)
Xisep0345	ACCCATCCATCATCTTCGTC	GCTGGAGGTTTGCTGGAATA	AT(5)
Xisep0346	CGCTCCTCAGGCTCCTCT	TCCTCGAGCACCTGGTTG	CCT(4)
Xisep0347	GATCGGCCAACATCAACC	AACATGTCCCAGTGCTGCTT	GGC(6)
Xisep0348	AAGCTCAACTTCCCCTCCTC	GCTGCTCTTGTTCCTCTTGG	CCG(4)
Xisep0349	CGAGGCACACTACCATCAGA	CACACCACCAGCAGCATC	CGG(4)
Xisep0350	CCACTCCGCTACCTTCACTC	CTCCTCATGCTCCACGAAAT	GCC(4)
Xisep0401	TAGAGCCTCCGGTAGCACAG	CAAGTGCCTGATCGATTTGA	AACG(3)
Xisep0402	GCCTCAACATTGACGAGGAT	CACACGCAGAGACACACAAA	CGAT(3)
Xisep0403	GAAGAAGGCCATCGAGGTG	TTAGATCCGGGTTCTTGACG	CAC(10)
Xisep0404	GCTCTTAGTGCGCAACACAT	CATCCACACCAAACAAGCAC	TTCTC(3)
Xisep0405	TCGTTGGTTAGGAAGGTGGT	TCGACGACCGACATGATCT	CGG(4)
Xisep0406	CGTTGGTTAGGAAGGTGGTC	CAGAACCCGCTACCGTACA	CGG(4)
Xisep0407	ACCCTGCTGCAACCAAAG	AACTTGCGCCAACCACTT	AGGC(3)
Xisep0408	CAAGCAAGCAAGTCTCGTCA	GCCACCGTGATGTAGAGGA	GGC(5)
Xisep0409	GCGTACGGGTTCACCAAC	CTGAAGCCGGACTGGTAGAA	ACG(4)
Xisep0410	CGTCGACAAGAACACCATGT	CGTGCGCAGTACGTATTTGT	GCC(4)
Xisep0411	TTGGAAGGGAAGTTCTTGGA	ATAAGGGCCCTCTTCCTCTG	GCG(4)
Xisep0412	CACTCTGCCATGAGCTTTGA	TGAGACTGAGACACCCGTATCAT	TG(7)
Xisep0413	CGCTGTTGCTCTCCTCTGTT	GGTACAGCCGCTCGTTCTC	GCG(4)
Xisep0414	CGCGTACTTTGACGACGAC	CCTTTTTCACAGGTCGAGGA	GCG(4)
Xisep0415	GTCGAGGCCATGCTGTTC	GTGAGCGTGGTGCTGATG	GGC(4)
Xisep0416	CTCGGCCTATGATTTTGCAT	GGCAAGCTTGATCCATTGTT	ATCG(3)
Xisep0417	GAGGGAGCTGGTTGCGTA	GTACTTGACGCGCACCTTG	GCC(4)
Xisep0418	GGAAGCAGTGACGATGATGA	GGCTATGAGGACACGGTGAT	ACC(6)
Xisep0419	GCATCGACGCCCAGATAG	AAGCCATGACTGCTTCCATC	GCG(5)
Xisep0420	CTTCGTGGGTTATCGTCGTT	CGTCGGACCCATGGTAGTT	GGC(5)
Xisep0421	GCCAAAGGAATGAGATGGAG	GCCCTTGAGCAGCAGATTTA	TGGA(3)
Xisep0422	TGCCCGTAATTAAGCCCATA	CCCACTGCTCCAGGTAAGAA	GCAT(3)
Xisep0423	GCTACCACCTCTTCGTCACC	GCGAGGTTGATCCTCATCAT	ACG(4)
Xisep0424	GTCCGTGCCATTCAACTTCT	AAAGGTGCTTGCTGTCCTGT	ATCC(8)
Xisep0425	ACTACGAGCTGCTGGTGGAG	CAATCTGTGCTCGTCCTCTG	GCG(5)
Xisep0426	CCTCGATCTCGTCTCCTCCT	AGACGGCGAGGATAAGCAG	CGC(4)
Xisep0427	AAGCGGCGGAAAGAGAAG	GAGCGAGAGGCTGAGGACT	GA(6)
Xisep0428	CAGAGCGTGGAGGAGATCAT	ATTTGGAGCCTGCTCATGTC	GAC(5)
Xisep0429	GTCGTCTGGAAGCAACAGC	TGGGGGTAGTTGGTGGTG	GCG(4)
Xisep0430	GGTGGAGAAGACCATCCTGA	CCGCCAAATGGAAGTAGGA	GCG(5)

Xisep0431	CTACCCGTCCATCTCCATGT	ATTTGGAAAGACCGCCACTT	GGCG(4)
Xisep0432	GCATCTTCAACGCCTCGT	AGGCTGCAACCAATCTGTCT	CGC(4)
Xisep0433	TGAAAAGTCGCTGATTGGTG	CTCTCTCCTGCAAGCAAAGG	CCTGC(4)
Xisep0434	AAAGTTCGGCATCATCAAGG	CCTTGAGGTTTGGGAGCAC	GC(5)
Xisep0435	GAGGGAAGGCAGCTCTCAG	CCTAGCAGCCAGCTCTGC	GCCG(3)
Xisep0436	TTTCTGTGCGACGAGAACC	GTCGGCTAATGCCTTTGACT	CGC(6)
Xisep0437	GAGCGAGCGAGAGAGAGAGA	CTCCGCCTCCATCTTCAC	CAG(5)
Xisep0438	GAAGAAGCACGTCGTCGTTA	GAACTCCACCATGAGGTTGC	GCG(4)
Xisep0439	TAGTCGAAGCAGCAGTCGTG	GTGTTCAAGTTCGACGAGCA	GAC(4)
Xisep0440	GGGATGAGGACCGTCATGTA	TTTATTTCCATGCCACCACA	GAT(9)
Xisep0441	CCCAACTAGGCATCCGTTTA	TTGGGTGTCAGCAATGAAGA	GAT(9)
Xisep0442	AAACCCTAGCCTTGCTGCTT	TCTCCACATCCATAGCAGAGG	GCG(4)
Xisep0443	TCATGTACAGAGGCGACACG	AGGTCGCAACAGACACCTTC	GCA(7)
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Xisep0445	AGCTGCTGGAGGAGTACACG	CGAAGGACACAGACGAACAG	CCG(4)
Xisep0446	TTCGAGAAAGCTGCAGTGAA	AAATGCATTGTTGGAGCAAA	GCG(4)
Xisep0447	CATGGTGGTTACCGTTGAGA	GAAATCGGAATCGCTGGTAG	GCT(5)
Xisep0448	GTCTCGGTGGAGTCCGAGT	GTTGAGAGCAGGAGCACCAT	ACC(6)
Xisep0449	CCGCTCATCAGTCATCACAT	ACAAAATCCATCCCACAACG	TCA(7)
Xisep0450	AACGATCACCACGACAACG	CCTTGAGGAGCTCGCTTG	CAC(6)
Xisep0501	GAGCTGAAGCTGAGGGTGAC	CATTGCAACGGCAGAGACTA	AAAG(3)
Xisep0502	GTATACCCCATGCCATACGC	AAGCACAACAATGACTGACCA	GCC(4)
Xisep0503	TTGAAGGAAGCTGTGGAAGG	CGTAGGGGGACACGTAGAAG	CGT(4)
Xisep0504	GCTCAAGACCATCGAGAAGC	TGATTGTGAAATAACAGCAGGAG	CTGC(6)
Xisep0505	ACGAGGGACAAGGTAAGCAG	CAGCGTTGAAGTTGCTCTTG	CGC(4)
Xisep0506	CGTGCAAGTTTGGAATTTGTC	CGGGCAGGTATAAGGTGTTG	AACG(3)
Xisep0507	GACCAGGCCCAGATTGTATG	AATGAGCATGCCCAGAAAAG	GCAT(3)
Xisep0508	GCCTAAACCCTCGGTTTCC	GAGACACGCTTCTCTGCGTA	CGG(4)
Xisep0509	CTTTTCCCCCTTTCTTCCAA	ACTCCCTGTTCGACAGCATC	CGG(4)
Xisep0510	GCCCTCTCCAGTCTTCCTG	CCGACGCATTTGCTTACATA	GGA(4)
Xisep0511	CCTCGCCCAAAACCCTAC	GAGGATCACCTCATCGTGCT	CCG(5)
Xisep0512	CATCTCCCAAGCCTGCTG	ACATGTTGAGCAGCGAGTTC	CTAG(3)
Xisep0513	GAGGGAAGAAGAAAACCCAGA	AGCCTCTCCTCCTCCTCCT	GGC(5)
Xisep0514	CTCTAGCTCCAATCCTGCTCA	CGGCTTGGTCTTGCTCAC	GCG(4)
Xisep0515	AGCTCGAGGGAGAGGAAGAT	GTCCGAGCACTCCTCCAAG	AGG(4)
Xisep0516	GGGCTTTATCGGAGATGGAT	TAGCGACCCTGCTTGAGGTA	GGC(4)
Xisep0517	AGCAAAGGTGCCGAAGAAG	TCCGGTTTTTCTTGTTGTCC	GCG(4)
Xisep0518	ACGTGCTGTCCTCCATCG	AGACCGACGTCGTCACCTT	CGG(4)
Xisep0519	CACCACCACCACCACCTC	GTACATCTTGGGGTCGAGGA	GCG(4)
Xisep0520	GGAATATGGCGCTGTTCTTC	GGAAACAAGCCAGCCAAATA	AAAG(3)
Xisep0521	GAGGCTTGAACAGCTGAACC	ACGCGTGGGTTGAAGTAGAG	CCG(5)
Xisep0522	TCATGGACCGTGTCATCG	GCGTACTTGCTCCACCTCTC	CAG(8)
Xisep0523	ACGACATGGACGACATCAGA	AACAAAAACACACGGGAAGG	TGC(4)
Xisep0524	CCCTAAACCCTCGGTTTCC	GCGTCCTTCCACCTCTCC	CGG(4)
Xisep0525	CACGAGGTGATGGAGGAGAT	GGAGGAGGAGAGCAGATCG	CTGC(5)
Xisep0526	ACCACTTGTGTGTGCGTGAG	CGTAGGGGTTCTCGTCGTAG	GGC(4)
Xisep0527	CGGAGGAGAAACGTAACCAA	CCAGGGGTCGAACTTGTAGA	GGC(4)
Xisep0528	CGGACACGTGGAATGAGTTT	AGGTGAACCAGCAGCATAGG	CAG(5)
Xisep0529	GCAACAACGTCAACATGTCC	TCGGAGGTAGAGGTGTCGTC	AAG(5)
Xisep0530	GACTCAGCTGCCTCCACATC	GAAAGATCGAGGTGCAAGGT	GCG(6)
Xisep0531	GCTCCCCTACGAGCTGTTC	CTTCTGGTCGTCGGAGGTAG	AAG(5)
Xisep0532	GAGGCACAGACACACCAAAA	ACCAGGAACAGCACCAGAGA	CGAT(3)
Xisep0533	TTACCTTGCGAGGAAGTTGG	TCCTGCTCAAGGCAGAGACT	GCA(4)
Xisep0534	GCCACCATCAGGCTACCTC	CGTTGCTGCCACAGAAGAC	GGC(4)
Xisep0535	GCTCAAGACCAACATCACGA	GTTCTTCTCCAGCTCGTCCA	GCGG(4)
Xisep0536	CCAATGGTGTTGTTGACACAG	GCCCCATCTTTGTTACCTGA	TGA(4)
Xisep0537	CACGAGGGACCTGCACTC	TGAAGGCAAATCCTTTCAGC	CTG(4)
Xisep0538	CAAGGTGACCAGGGATAAGC	CCCGTGTAAAGTTCCCTTTTT	TGGTG(3)
Xisep0539	GACCCCATCTCTTCCTTTCC	AGACTGAGGCACCGCTTG	GCT(4)
Xisep0540	AGTCCATCGGGTCGATAGGT	CCCCTTGGCCAAAAATCT	TCGGA(4)
Xisep0541	TCCTCTGGGACACCGTCTAC	CATCTCGCAAAGTGAAGCTTAG	ATCC(5)
Xisep0542	CACCAGAGAGGGAGTGAAGC	GTCCACGCTGTAGCTCCTGT	GCC(4)
Xisep0543	CGAGGGTTTTTCTTCTGTGG	GACATCGGAGACCTTGAGGA	CGC(4)
Xisep0544	GAGAAGCCATCGGTATCTCG	CCTGCAGTTTCACATTTACAGC	AT(8)
Xisep0545	AGGACTGCATTGACCGCTAC	AGCCAGCTAGATGAGCCAGA	TCCA(3)
Xisep0546	AGACCGTTCCTCTGGGTTTT	AGCTCTCCAGCGTCGAGTT	GAC(6)
Xisep0547	CAAGGAAATCCCAGTCGTTC	ACGGACGGTAGTCCACCAG	CCG(5)
Xisep0548	CTACCTCCGACGACCAGAAG	AGATCGCCATGGATCACAC	GGA(4)
Xisep0549	TTCTCCTCCCCCACCAAT	AGCTTCATGAGGAGCGAGAG	AGCG(3)

Xisep0550	GCGGCGAGAGAGAGAGTTC	CGAGCTTGATCTTCTCGTTGA	GA(11)
Xisep0601	CTCCGACCTGTCCAAGAAAC	GAACGTCCAGATCGACTCGT	AGC(5)
Xisep0602	TCAACAAGTACGACCGCAAC	CACAGCAGGGAGGAACTAGG	ACG(4)
Xisep0603	GTTCTCGATCGGCTTCTCAG	GTGCCTTCCTTCACCTTCCT	CGG(6)
Xisep0604	GCACCTACGGCTTTTACTGC	ACGGTGGATAATCGAGGATG	CTC(15)
Xisep0605	GTTGCCTCCGATCCATCTC	AGGGAGGCTGGCCAATATAC	AGCT(3)
Xisep0606	AGGAAATAATTCCCGGATGG	TTTTCTGCCACAGGTCACTG	TTGG(3)
Xisep0607	CACGAGGATTTCACCAAACC	TGCACGTGTTCGAAATAGGA	AGA(4)
Xisep0608	TTTCACCAAACCAAGCTAAGG	GTAGAGGCAGCCCTTCTCCT	AGA(4)
Xisep0609	AGGTGAAGCAGAAGCTGAGG	CGTGAAGATGCATCCGTAGA	CCG(4)
Xisep0610	GCACGAGGGAGAGAACTAGG	CTTCGCGGCACAGATAGTTA	GA(9)
Xisep0611	GAGCCGTGCTGATGATCC	CTCTGCAGCGTGTTGGACT	GCG(5)
Xisep0612	CTCTCTGTCCTCCTCGTCGT	CCTGCTTCTTGGACACCTTC	GCT(4)
Xisep0613	ACCACTACCTGGGGTCTGC	CAACGTGCGTCAGACAGAAT	TC(12)
Xisep0614	CCCCCAACACATACAAGAGC	GTTCACCAGCAGCTTCGTC	CGA(5)
Xisep0615	TAGCTGCCGAGATCTTTCGT	GCATCAGGGTCAGAATCACA	CGAT(3)
Xisep0616	AGGCTCCCTCCTCGTCTC	CATCTTTTCTGGGCTTGAGG	CTCTC(3)
Xisep0617	GGCTGGGAGAGCTAGGAAGA	GACGGCTCGTCCATCATC	GATC(3)
Xisep0618	CTACTCCAGCCTGTGGAACG	GCTCCTGGTTGTACCAGTCC	CGG(7)
Xisep0619	GCACGAGGCAAGCAACTACT	CCCAGAACACCGTCACCT	GCAA(4)
Xisep0620	CTTCGACTCCTCCACTGCTC	GAGTCGCCGAAGTTGAAGAC	GGC(4)
Xisep0621	CAGTCGCGGTGGTAGACAT	GCCGAGTCGTCAGAAGAAGA	GCG(4)
Xisep0622	GAGGATCGGAGGAAGAGACC	TCTCCCATTCTCCCCTCTTT	TA(5)
Xisep0623	ACCTTGCCGACGATTCCT	TGCAATCAGAACAACGATGC	AGC(5)
Xisep0624	TCCTCCTCCTCCTTCTCCTC	TGTAAGCATGGTGCCAGAAC	CCG(4)
Xisep0625	CTAGCAGCAGCAGCAGTCAC	GCCTTTGCTTGCTTTGATTT	TCC(4)
Xisep0626	TGAAAGAGGTCATGCACCAG	TCACTACACCACGTGCACAA	ACG(6)
Xisep0627	CAGACCAACAGCCCCAAC	GCTTGGTCGTACGTGGATCT	CGA(8)
Xisep0628	CAGGCGTGTCAGTGTCGT	ACGATGTTCTCCAGCGAGTT	GGC(5)
Xisep0629	CCGTGCCTTGGGATATGTA	GACCTCGTTGAGGGTGTCC	CGC(4)
Xisep0630	GATCGAGTCGTTCGTCGAGT	AAATCCATCGACCAATCAGC	GTC(5)
Xisep0631	AATCCGAAGAGAGCGGAGAG	AGCTTGCCTAGCCAGAAACA	AG(7)
Xisep0632	AGAGAGGAGGTCCCAAATGC	TTAAGGCCCAAACAAACTGG	CATG(4)
Xisep0633	GCCTGCCTCTCATCTCAGTT	CAGCATAGCCACACATGCTT	CT(9)
Xisep0634	GCATAGCCACCAGATCTTCC	AATCATGCTTGCACACTTGC	CAG(5)
Xisep0635	CCTTCTCCGCCTCGTACC	ATCATGTACTTGCGCTGCAC	CGG(7)
Xisep0636	CTTCATCGTGCTCACTGCTC	CTGGGAAAGGGTGGTCAATA	CGG(4)
Xisep0637	TGCTCCAACTCTCCCAACTC	ACATGAACGCTTCCCTTGAG	GCG(4)
Xisep0638	CACCATGTCTGCGGTAGTGT	AGGTGATGGTGGAGCAGAAC	CCA(4)
Xisep0639	TCGGACGGAGTCATCAGATA	GCCTTCGTGTCTTCTGTCCT	TCT(6)
Xisep0640	CGTCGAGAGGCTGCTCAT	GAGATGATTGATGCGAAGCTAA	GCC(6)
Xisep0641	ATAACAAGGCCATTGCTGCT	ATGGTCCATCGTCTCAGAGC	AGG(5)
Xisep0642	TTTTACATCAACGGCACCAA	GTGAGCGGTGGTGAGCTT	ACC(4)
Xisep0643	CTCACCTTGGGAGCTGAATC	GGAGGACCTAGCAAGCAAGA	TC(7)
Xisep0644	ATGGAGTGGGACAGCGAGT	ACGTAGATGATGGGGCAGTC	GAG(6)
Xisep0645	AGGACATCCTGTCGGTGTTC	CTGCCTTTCTTCCTCGACTC	GGC(4)
Xisep0646	AGAGGAGGACGAGGAGGAAG	ACAGGGTGAGCTGGTTGGT	GGA(5)
Xisep0647	CGAAGGAGTGCACGAACAT	GGTAGAGCATCACCCAGTCG	GGA(4)
Xisep0648	GAGAAGTTGGAGCGGAGGA	AACACCCAGATCAGCGAAAC	GCC(4)
Xisep0649	CGTGCCTCTGCCAGTACA	GCGCCGGACTCGATAGTA	CGT(6)
Xisep0650	GTGGTCGAGGTCGAGATGAG	TGCACGATGTCGTTGGAG	GGC(5)
Xisep0701	CGGTGGGAGAGACAGAGAGA	CCAATCAATACCACTCCTGTGA	TTCTT(3)
Xisep0702	TCCTCCACCTCAACTCCAAC	TCCAATCAATACCACTCCTGTG	TTCTT(3)
Xisep0703	GAGCTATGTCCATTGGAACGA	GCTCGGGCTCAAGAACAC	GCG(4)
Xisep0704	CAAGTCCGTCGTGCTAGAGG	CCCTTTAATTAGCCCCAAACA	GT(5)
Xisep0705	ACTACCGTTCCCTCCCTACC	ACCTTGGCGAAGATGTGC	CGG(6)
Xisep0706	GTGCACGAAAGCACAGAAGA	CGTTGGTGATGAAGTTGAGG	GAC(4)
Xisep0707	GAGCCCTCGACCAGATCAT	GAGCTATGTCCATTGGAACGA	CGTG(3)
Xisep0708	AAAGAAACACTGGGCGAAGA	CTTGCACTGGATGTTCATGG	ACA(4)
Xisep0709	AACGTACTGCTTGGGAAGGA	TGGATAAAGCAGGTGACAACA	TA(5)
Xisep0710	ACCCGCAAGGGTTTCATAG	GCACCCCGAGAGAAGAATTA	TTTGT(3)
Xisep0711	CACGAGGCAGAGGCAGAG	GAGAAGGGGCCCAGGTACT	GCC(4)
Xisep0712	GGTCGGCAGGAAGAGGTC	GCCGATGATCTGGTCGAG	ACG(4)
Xisep0713	AGACAAGCACCTCGAGAAGG	GGTGTCTTCTCCGTCAGAGC	GGC(4)
Xisep0714	TACCGCAAAATTCGATGTGA	GAGATGAGCTTGAGCGAGGT	TGCA(3)
Xisep0715	GCCCTGCAGCTTCTTCTCTA	TCTCTGGTACCGGGATGCT	GCC(4)
Xisep0716	GAGCACGGGCACGTAGAC	CCTCTGCTCACCGATCTCAC	CCG(4)
Xisep0717	GAGACGGGGACAAGAATGG	AGGAACATGGACACGAGGAT	GCT(4)
Xisep0718	AACCACCACCTCCACATCAG	AGCACGTAGTAGCAGCAGCA	CT(5)

Xisep0719	CCTCGTTCTCCCTCTCCTCT	GAGCTGCACCTCCACGAC	AGC(4)
Xisep0720	AGGCGTGGAAGAGAGGGTA	CAAGTGTCAACACCCACCAG	GAG(9)
Xisep0721	AGCACCCATGGTCTCTCG	CTTCTCCTCCAGCACCTTGT	CTC(5)
Xisep0722	GCTACAACCCAGGCTACGAC	ATTGGGGTCCTCGCAGTAGT	GCG(5)
Xisep0723	GGCTGGGGCGTAATCTAATC	TTGACCAGCACTCAAACTTCA	GT(5)
Xisep0724	GAGGGCGTACAGGAAGAACA	CCGAGAAGGACTTGGTGAAG	GGC(6)
Xisep0725	GGACTGACTGACCCTCATGG	GGGTGGTAGACGGGGAAC	CCG(6)
Xisep0726	CTCTAGGCGAAGCGAAGTTG	GAGACCCGAGCACCTTGATA	GGC(5)
Xisep0727	CGACAAACTGAGCAACAACG	TGCATTTGGTTGCATTGAGT	AGCT(4)
Xisep0728	AGGAGGAGGAGAAGCACCAC	TGAAGAGCGCGTTCACCT	AGC(4)
Xisep0729	CCGACCTCTCGTCATCAGA	AAACTACGGCATGGAACTGC	CTC(5)
Xisep0730	ACCACCACCACCACAACTC	CTCTTGCCCTTGATGGTGAT	CGA(4)
Xisep0731	CTGTCAGAAAGGCACCACAA	GCACCAACTCGTTTCTTCCT	GAT(5)
Xisep0732	AACCTCAGCACACCAAAGGA	CGGTCAGAGGAGATCTTGGA	GAG(4)
Xisep0733	GTGATGCATCTCACGGACAG	GCAGCTACTGCATGCTTGTC	TGTAA(5)
Xisep0734	GTCCTCCCGTTCTTCAGGTT	AGGGCGTCCTTGAACTTCTT	ATGA(5)
Xisep0735	CTACTTCGGCAACCTGCTCT	AATTCACTCTCCGGCAGTTG	CGG(4)
Xisep0736	AGCAGGATGAAGACGCAGAT	GCACCGCATTTGATTGATTT	GGC(6)
Xisep0737	CGATCCCTACGGTTGTTCTT	TGACCTGGAATGGAATCTCA	CGTG(3)
Xisep0738	CACGAGGCTCCTCTCCTCT	GTTGGGTTAGGTGCTTGGAA	CTCCT(3)
Xisep0739	GCCCAAATCATCCAAATGAG	ATGAAACCGTCCATCCAGAG	GAA(5)
Xisep0740	AGAAGGAAGCCTGACAGCAG	TCGAATACATACAGCTGAGATCG	TTGTG(3)
Xisep0741	ATGGTAACCGTGCAATTCGT	CAAAGCAATAAACAGCAAACCA	TTGTG(3)
Xisep0742	GGGATTCATCAAGCTTCTGC	TCGTCTTTGCATTGGTTTCA	GT(5)
Xisep0743	GTTCGAGGACTTCGATCTGG	AGGACTCCTCGTTCCTCAGC	GGC(4)
Xisep0744	AGGCATCGAGCAGCATGTA	GGGTGTCTGCTGGATCTTCT	GGC(4)
Xisep0745	CTTAGCTTTGCTCGCCAGAC	GTCGTTGCCCATGGTGAT	GCC(4)
Xisep0746	GAGCTGCTGAGGAGGTGAAG	TCGCAAGGATTCTTCTTCGT	TTTG(4)
Xisep0747	AGGCAGCCTGCTTATCACAA	ACAAGCTCAGGTGGGTGGT	TCC(5)
Xisep0748	CTTTGGTCCTCCCCCATC	CCATATCCTCCGACATGAGC	GCC(5)
Xisep0749	CCTAGGGCTGTGCCTACTCA	ATCAGGCAAAAAGGTTGAGC	CAC(9)
Xisep0750	GTCGGGCAAGATCTTCAACT	AGGTTGGTGCTGCTCGTC	CCG(4)
Xisep0801	GGTGTGAGTGTGATCGCTGT	GGGAAATCATCATTGCCATC	GAT(5)
Xisep0802	CTCGATCGACACGCTCCT	AGTGCACGTCGTAGGTGTTG	GCG(4)
Xisep0803	GAGCAGAAGCAGAGCGAGAT	GCTTCACTGCCGAGGATAAT	GCG(4)
Xisep0804	ATGGTATGCGGATGTGACAA	CCAAGAAGAAGCTCCATTGC	CCG(5)
Xisep0805	CTCCCCCGTGATTTGATCT	TAAGCAAAAGCACCATCAGC	GT(8)
Xisep0806	GCATGCCCCTGGTACAGTAG	CTGCCAGCCAGCTTTTAATC	CAG(4)
Xisep0807	CCTCTTCTTCGCCTGTTCTG	GAACAATTCACCTGGGAGGA	CTCG(3)
Xisep0808	ACCTCTCTCGGCTCCTCTTC	CGCCTGCGAGGATATGAT	GCTC(3)
Xisep0809	GGAAACTCTTGTGGGTTGGA	TTGACCTCTCTACAAATGATCCAC	TATG(4)
Xisep0810	GCAAGTGCGTCAAGAGGAAT	CATGTTCTCCATGTCGTGCT	CCA(6)
Xisep0811	CGCCTCCTCTTGCTCATC	GAGAGGGAGAGGGTGTAGAGC	CCT(4)
Xisep0812	CCAGCATCTATCGTCAAGCA	AAATCAAATTTTGGCGGGTA	TGA(5)
Xisep0813	TCTTGGACAGCATAAGCGAAT	TCATCCTCTCCGTTGGATCT	GCA(4)
Xisep0814	TTGTTTGAATCCTGGATCTGG	CTCCTCATGCGCTTCTTCTT	CGC(6)
Xisep0815	GCATATTCACATCGACCAAGG	TTTTGGTAGCGCACAGACAG	TG(10)
Xisep0816	ACTCCCTCCCTCAGTGCAG	AGGATCTCCAGGATGTCGAA	CTCTC(3)
Xisep0817	ACCATTCCGAAGCTTCCAC	GCGAGCTCAGAGGAGTTGTT	AGC(7)
Xisep0818	CAATTGGTGTCCCTTCCTTG	TCTCCAATTGGCCACTATCA	TATT(3)
Xisep0819	GAGTACGACGTGGACGAGTG	GTAGGTGGCCGTCGACTC	CGG(4)
Xisep0820	ATCACTCGACCGCACATACA	ATCAGCGATCGAGACACCA	CTAG(3)
Xisep0821	AGTCCATCAGCTTGGACGAG	AGCTCCCCTGCTTTCGATAC	GCC(4)
Xisep0822	ACGGCAGCACAACTTCACTA	GCTTATTGCAGCTTCTCTCTCA	GA(5)
Xisep0823	TTACACGGTGACCACTTTCG	GGGAGGAGGAGAGGGAGAG	CCT(4)
Xisep0824	TCCTGAAAGAAACGCACACA	GAGGAGGGTGTGGAGGTGTA	CCG(4)
Xisep0825	ACGAGGGCACCTACCATTC	GGGAGATGGACGAATATGTGA	CCG(6)
Xisep0826	AAGTGGTGATGCTCCACGAT	TTTACTCCCCTTCGATCCCTA	CCG(5)
Xisep0827	GCAGTTTCCGACCAGATCC	TCAGCTCGTCGCTGATGAT	GGC(4)
Xisep0828	CTTTCACCGTCGTGCTCTTC	AATAGTCGCCGCCTCTAGGT	GAT(4)
Xisep0829	CGCTGCCAAAATCTAAGCTC	CACGGTGGTCACATCAGAAG	AG(6)
Xisep0830	GGCCTCTACCTCGTGCTCT	AGACGTTGTCGGTGGAGGT	CGG(4)
Xisep0831	TCCATGACCTTGAGGAGGAG	TTGAAGCAGGACAACACACC	AAAAG(3)
Xisep0832	GCAGCTTGCTCCTAGGAAAG	ACAGGTCTTGCATAGTGTGGTC	CATAT(3)
Xisep0833	CGGAGTAGCAGCCGTAGC	GAACCCACTCCCACCTTTC	GCG(4)
Xisep0834	CTCAAGGAGAGTGGGTCGTC	CCCCTAGCTAGCTGTTGACCT	GCA(5)
Xisep0835	GTCGATCGAGTGAGACTACTGC	CTTCTTCCTCCCTCCAGTCC	GCC(5)
Xisep0836	CGACTGCTGCTTCGACTACA	GACCGATCCACCGAATCTC	GCG(4)
Xisep0837	CACGTTGAGGACGGGTAGAC	CCTTACTAGAAACGACCGAGCTA	CCAT(4)

Xisep0838	TCGTGCCTAGCCAGTCTTCT	CCCAGAAGTGGGTCGTCTT	TCG(4)
Xisep0839	TACGCATAGCGCCTTTCAAT	ATTTCATTATGCCGGTCTCG	ATTAC(4)
Xisep0840	GCAAGACCATGATGAGTCCA	TCGCTGCTGGCTTCTTCT	CGC(4)
Xisep0841	TAGGAATGACGACACCACCA	CAAAGGCAAGGGTTTTGCTA	GCA(10)
Xisep0842	TCCGGAAAACCCTAACCCTA	CGTTGACGTCGTTGTAGAGG	GAC(4)
Xisep0843	CCCAAACATTCCCACGTAAC	GTGAACAGAGGAGGCAGAGG	AGCTG(3)
Xisep0844	GTGTTCAAGTTCGACGAGCA	TAGTCGAAGCAGCAGTCGTG	CGT(4)
Xisep0845	CAGCAAGCAACATCAACCAT	GAGCTCGAAGAACGACGAAC	CT(5)
Xisep0846	TGTTATTAGTCCCCAAAAGGTCTC	ATAGCTGCCCACTTCCACAC	CGG(6)
Xisep0847	CTCCCCTGTTTGCTATCTCG	TCCATGGAATATGAGCACCA	CCT(7)
Xisep0848	GCTCGACCTTTCTGAATTGG	TTCCTCTTGTTGTCGGAAGG	CGC(7)
Xisep0849	TTCGGCTCTTCCCACAAGTA	ACGTTGGCACTCGAGAAAAC	TG(10)
Xisep0850	TTTGAATTGGCTGGCATGTA	AGCAAGCAGCTGTGTGATGA	AG(24)
Xisep0901	ACCGTCTCTCCTGCTCCAC	ATCTCCGCCGTACCAAAAG	GGC(4)
Xisep0902	TCGGAGTTCCTGCTGATGAT	GCGATTCCTTCCTGATCTTG	CAG(4)
Xisep0903	ATGTGGACTCGGAGACCTTG	AGCACCTTGCTTCTGCTGTT	CAG(4)
Xisep0904	CCAACCGAAGGATCAACAAC	GCTCCCTCCCTTTCTCTCTC	GAGCA(3)
Xisep0905	GCACGAGGCACATACACAAC	GAGAACGGACCCAGGTACAG	GCC(4)
Xisep0906	CAGCTTGACTCCGACAGTGA	GAGGCCACCTTTTTCCTACC	ATACA(4)
Xisep0907	TTTCAGCAGTTGCTGCACTC	CTGCCAAGGGTTCAAAGAAG	CAT(4)
Xisep0908	AAGAGGCACTCGGACTTCG	GGAGGTGGCAGCTGTAGTTC	GGC(8)
Xisep0909	CATGCCTGTCGTCGTACCT	TCCTCCTCCTCTTCCTCCTC	GCC(4)
Xisep0910	TTCCTTCTCGCGATCTCACT	GAACCGCAGCTTACCGAAC	GGC(7)
Xisep0911	ACGAGGCAACACAGCAATAA	AGCACCGGGATCTTCTTGT	GGC(5)
Xisep0912	GGCAATGCATTCACTTCAAA	CCGAGATCCCAGACATGC	GTA(4)
Xisep0913	CAATGGACACGACACTCCTG	GAAGCCGAGGAAGAAGAAGG	CAG(4)
Xisep0914	CGCCTCAACTCCATCTTCA	TGTTGAAAGCAGCCCTATGTC	CGC(4)
Xisep0915	AGCTTCTTCCGCCACAAGT	TGCACCAAGGACTAACACGA	CCG(6)
Xisep0916	ATCGGCCGCAGTTGTAGATA	GAGCATGCTATGCTTGCTGAT	TAGCA(3)
Xisep0917	CGCTAGGGACCGGAATAGA	ACTTCGATCTGGAAGCTGGA	GCG(5)
Xisep0918	CTGGAGCTGTCAGGCTGTG	GTGCCGTTCCGTTTCACT	AGC(5)
Xisep0919	AAGTAAGCGGAGGCAGAGG	CTGGACTCACTCGTCGGACT	GAG(5)
Xisep0920	TTCAATGGACAGCGACTACG	CTTGCCCAAGCAGGTCTC	GCG(5)
Xisep0921	AGCTCCAAACCTTCCAAACC	CGGAAACCACCACAAGTAGC	TGG(4)
Xisep0922	ATGAGTTCCTCCACGTCCA	GGATGAGCAGGTCGGTTATC	GTA(4)
Xisep0923	CCCATGTCAGGCATCTCTC	TCTAGAGCAGTATCCCGCTGA	CCG(5)
Xisep0924	GCACGAGGATTTCGACTGTT	TGCGTTGTTTAAACGCACTT	TCAA(3)
Xisep0925	GCTAGGCAGCTGACAACCTT	GGAGTCCTCGTCGAAGTCC	GCG(5)
Xisep0926	CGTCCAGTGGTTCATCGAC	CCCTTGCCGAAGAAGTTGTA	GCC(5)
Xisep0927	GCCTGGTGTTCTACGAGCTG	ATGCTTGTGCGTCTTGGAC	GCC(5)
Xisep0928	CCTCTGCCTCTGCCTATCAC	CCTCCTACTACCGGGACGAT	CG(5)
Xisep0929	AATCCGGATGGTGATGGTTA	AGCTTGTTCTCCACCTCGAA	GGC(4)
Xisep0930	CGCAGTCCGGCGTAGTAT	CGCCATTGACATCAACCA	GGT(5)
Xisep0931	AACCCAAGCAACTTCCTTCC	CTCCATCGTGTCGGTCCT	GCC(5)
Xisep0932	GAGAGCAGCCGGTGTACG	GCACACAGGCAGGAAGCTA	GGC(4)
Xisep0933	ACCCACCACCTTTCTTCCTT	CAGCTGGTACGTCTTGGTGA	CGG(4)
Xisep0934	GTCACCAAGCCCAACCTCT	TGAAGCTGAAGCAACACGTC	GCC(4)
Xisep0935	CAGAATACTGGCAGGGAACG	CGGCTTCTGCTGCTACTTCT	GCC(4)
Xisep0936	GTGGTGAACGCGATGATG	TGTAGCGGAGCACCATGTAG	GGC(4)
Xisep0937	ACGAGGCACCATGTACACCT	GGGGAGGAAGAAAAGGTACG	CCG(4)
Xisep0938	TGCTGTTCTTGAACGTGTTTG	TTTTGCACAAAGTTGCGTGT	TGGGT(6)
Xisep0939	GTGAGCAGACGACGACTACG	GGGCTCAGCTCAGCAGTAGA	CCG(4)
Xisep0940	GAGATAGAGAGAGGGGGAGAGC	AGACACTACCCAGGCCTCAA	CGG(4)
Xisep0941	TCACCATCATCACCATGGAC	CTAGCCGCATGCATAAATCC	GCG(4)
Xisep0942	CAACAAGGATGGGCAGATG	TTACACAATTGCAGCGAAGG	GCC(4)
Xisep0943	AGTGCGACTGGTGCTTCC	TACCCAACCAAATGCAAACA	GCC(4)
Xisep0944	CCCGTTACCCGTGATGTCT	TGCGCTTCTTCTCCTTCTTC	CCG(5)
Xisep0945	CTTGCCGTCTATGCTGTGTC	CCATCTGCAGAGTCATCGTC	AAG(7)
Xisep0946	GCTCCACCTATTCGGAGTGA	GTACAGAACCGATGGCGAAG	GTGC(3)
Xisep0947	GGTTTTGGCTCCTGATCG	ACATAAGCACGCCAACGTC	GCC(4)
Xisep0948	AGGCCGAATCACAATAATGG	AGTGCATGAACAGGGCATC	TA(5)
Xisep0949	CAGTGCCAATAAGCTCGTCTC	CATCGATCTCTGCTTCTGCTT	GCA(5)
Xisep0950	TCGTCTCCCACTAGGGTTTG	AGGAGGATCGTCTCCTTGG	CGG(6)
Xisep1001	GGTAGGCTGGTGGACGACTA	ATGAGGGCCAAGCATCACT	GAT(4)
Xisep1002	TCTTGATCCCACAACCACAA	TTTGCTCTTGGCTGATGATG	CCG(4)
Xisep1003	CGTACATCGACGTGCTCCT	GCATGTACTCGGGCTTACG	CCG(4)
Xisep1004	AGCAGCAGCTCCAACAGAAC	GTGCCTGCTGTAACGGAGAT	GCA(4)
Xisep1005	GGAGAATCTGGTGGGTCTGA	CATGCTCTCGTCGCTGAAC	GCG(6)
Xisep1006	CGCAACCTGAGAAGCAAGTT	GTGTTCACGGGGCACTTT	CCG(6)

Xisep1007	GCACGAGGCAATAAACAAAAG	AACTGACGCAGCACCTTTCT	TCC(5)
Xisep1008	GATGCGCAAGCAGAACAAG	CAGCAATGGAAATAGCTCAGG	CAG(7)
Xisep1009	CCCCTTCTGCTAATCCTCGT	GGGATGGCCAAAGTAGGTCT	CGC(4)
Xisep1010	GTCCCTCCTCCAGAACAGC	GCCCTCATGAATCCGAGATA	CCG(6)
Xisep1011	GGAGAAGGAGGTGCAGGAG	CACTGACTGACCACGAGCTT	GT(5)
Xisep1012	TAGCAAGCAGAAATCGACCA	ACCATTGTCCCTCACTCCTG	TC(40)
Xisep1013	CGGTTACGGCGGATTATTAC	ATGGTGGCGATGCAGACTA	CGG(7)
Xisep1014	ACCGCCGACGTCATAGTAAG	GGCAGTAACATAGCATCCATCA	GT(5)
Xisep1015	CGGGTGCTGAGAAGAAAGAT	ACAGTGTCCTTGCGCTTCTT	AAG(5)
Xisep1016	GCACGAGGGCTAACAGAGTC	CAGGCAGTTGGTGAAGTACG	GCG(4)
Xisep1017	GAGGGGAGGACATGCAGAT	GTCCAGAGCTGGTTCACGTC	CGG(5)
Xisep1018	AGATAAGGCGGAGGTTGTCA	TGATGATCAAGGCCCATACA	GGC(5)
Xisep1019	ACAACGAAGCCTCTGACCAT	GGCATCCCTTGTCTCAACTT	GGC(5)
Xisep1020	CCGATCCCTCTCTCCTTTCT	ATAAGGTTCGCCCGATCTGT	CGC(4)
Xisep1021	GAGGGTTCCAACTCTCTCTGC	CGCCATCGTATAGTGCAGACT	CCG(6)
Xisep1022	ACCTTCGGTGAGCATACGAC	GCGGGTTATTACACCTCAGC	GAC(5)
Xisep1023	CGGTGATCATCAGCATCAAT	AGAGAGACGTCGCAAGAAGC	GAT(6)
Xisep1024	CTTCCATCTTCCAGCTTCCA	GCTGCTTGATGGAGAAGAGG	CGC(5)
Xisep1025	ACCTTCTCGTCCTCGTCCTC	AGAACATGACCGGATCGAAG	GCG(5)
Xisep1026	CAATGAGGTGTCGGACCTGT	GTGCAGAGGAAGCAGAGCA	CCG(4)
Xisep1027	GCAAGTCATGGTTGTGATCG	GAACGCCTCCTCCTCTTCTT	GCC(5)
Xisep1028	CAGCGACCATGAGGATGAC	TGGCATGCATCAAACAAGAT	GCA(4)
Xisep1029	GACCCTCCTCCTCAACCACT	CATGCATGCACAAGCAGATT	GCAT(3)
Xisep1030	AGCCTGGAGGAGGAGATAGC	GTCCTCGAAGCCCCAGAT	CGG(5)
Xisep1031	TGCTCCTGCCTCGTTCTC	TAGTCCTCGGTCGACTCCAT	CGG(6)
Xisep1032	GCAAGCTCTACGGGATCTTC	GCAGCTGGAAAATAATCGAAA	TTCAG(3)
Xisep1033	GCGCGACAAGATCTACTTCA	AACTCGCAGGACGACGAC	GAA(4)
Xisep1034	TGGACTGAAGCTGTTCTTCG	TCTTCAATTGTCTTGGGCAAC	GCT(4)
Xisep1035	CACTTTCTACCGCTCCTTCG	AGTGATGATGATGACCGAACC	TGAT(5)
Xisep1036	GGGCATTGTCAAGGAGGAG	CCAGACGACGAAGCTGTTG	AGC(4)
Xisep1037	ACGAGGCTCCTCTCCTCATC	TTTTCAGGGTGCTCTGAAGTC	CCG(6)
Xisep1038	GGGCTCTAATCCTCCTCAGC	GCTACCACTGCCTCCATTGT	GCT(4)
Xisep1039	GTGGATTCAAATCCGCTGAC	GGCAATTTGGCAAGCAAT	CCTG(5)
Xisep1040	GCGCGCTCTATCTCTTGTCT	ACTCGAGTAGGAACCGCTGA	CCG(5)
Xisep1041	GCGATGCTGATCCTGGAC	CATGATGCCCATGGTATGAA	GCC(4)
Xisep1042	GGAGGCAAGTTCAGGAAGTG	TGTGTGCAGTGCATGCTTAG	CGTA(5)
Xisep1043	GCTCCAAAATCGAATTCCTTC	TTCCCAGTGTTGGTGATGTC	CGC(4)
Xisep1044	ATGTGGGCCCTCAACAAC	GAAGACGACGCCTTGCTATC	GGC(5)
Xisep1045	GTTTCGCCGTCTCGTCTC	TGTTTAGCAGCACGAGTGGA	CCCG(3)
Xisep1046	CGCAATGGAAGAGGACTGAT	CTACATCCTTTGCCCCAAAC	GCTC(4)
Xisep1047	TCTTTGCCCTCCCGCTAT	TCCATGAAATGAGCAAACGA	TGCGT(4)
Xisep1048	ACTCCTTCCTCGGACGCTAC	GGTACAGGGCCAGGTACATC	GC(5)
Xisep1049	GACGAGAGCTGCCACGAC	GCGAGCAGGTAGAAGAGCAC	CGG(5)
Xisep1050	AGGACCGCCTCCTCTTAGC	CTGCTGCTGGAACTGGAAC	GCG(4)
Xisep1101	ACGAGGACAAAACAAAACAGC	TGCTTCTCCCATGGTGGT	AG(9)
Xisep1102	CAAGTTCACCTGGGAAGGAC	AACACCAACCCTGCTCTCAG	GGA(6)
Xisep1103	CTCTTCGAGGACACCAACCT	AAGGCAAAGCACAAAGCCTA	TCG(7)
Xisep1104	CTTCTCTTCTCCAGCGATGC	GGCAACAGCTTGAACCACTT	CGG(4)
Xisep1105	GCGCTCACCTTTGATATCGT	GGATTGTTGGCACCATACCT	ATC(4)
Xisep1106	TCGATCGATGATCCATTTCC	TTGACGTACACGCTACACAGG	ATG(4)
Xisep1107	GGATAATCTGCAGGCGACTT	CCATCTGCTGCTCTGACTTG	GCA(6)
Xisep1108	GCACGAGGCACTTCAGAATTA	AAGGCACAAGCACAACAGC	TTCA(3)
Xisep1109	CACAAGATCACGGAGGAGGT	AGGTCCGGAAAAGGGACTTA	CGG(5)
Xisep1110	CCCGAGCATACTCCTCTCAT	CCCTCCTTGAACTTCACCAG	AGTG(3)
Xisep1111	CCTCCTCTCCTCATCCCTCT	ATGGGTAGCGGGTTTCTTG	CGAG(3)
Xisep1112	GCACGTACTCCGATCCATCT	GAGCCATCTCGAAACATGC	AT(5)
Xisep1113	AGCTCGTGATTTCCCATGAC	GTTTCCGTTGTCGAGGAGAG	CCA(9)
Xisep1114	GGTGATGGGAGCAGATCAGT	GAAGAGCTCGGAACTGCAAG	GGA(4)
Xisep1115	GCCATGTTCCTCAACAGGAT	TGGATTAGACTGACGCAGCA	GCC(4)
Xisep1116	ATATCCTCGCTCGTCAGTCG	CGCTTAACTTCAGAAGCATCC	CCG(4)
Xisep1117	CCGCGTCTCAGTCTCTCACT	GGGAGCGGGAAGGAGTAGTA	CCA(4)
Xisep1118	GAGCACATGACCGAACTCAA	TCAACCGACGTGAATGAAAC	CGT(4)
Xisep1119	CGAGAAGCACTGCACAGAAA	GGCTCTTGAACACGTAGCAGT	GGC(6)
Xisep1120	TGAAAACGGCATCAGTAGCA	TAACGCCTTCAAGGGTCAAG	CGC(4)
Xisep1121	CACCACGGTCGACCTCTC	CAAATCTGGGTTTTCGAGGT	GCC(4)
Xisep1122	GACGACCTCCCAGCAGAG	GTTTTCGAGGTCGAGCACTT	GCC(4)
Xisep1123	GGACATCGACCTCAACCTGT	GGTACCCGAGGCTGTTGAG	CGG(4)
Xisep1124	CGCGTTCACTAGCCTCCT	TGTAGTCGTAGATGCTCTTGTCG	CCG(4)
Xisep1125	GGCCACTGTTGCGTGTACTA	ACGTCGGCACGTAGTTCTTC	CGA(4)

Xisep1126	CAGGAGAGGAGGAGGAGGAG	AAGTCGTCGTCGGTCAGG	GCA(4)
Xisep1127	GCTGGAGGAGGAGTTCAAGA	CCATCCGTCCAGATTGTCTC	GCG(4)
Xisep1128	GGCGGGAAAAAGTTCCTTTA	CGCACACCCATTTCAATTC	AT(6)
Xisep1129	CCTCCAGCCTACAACTCTGC	TGCCTTATTGGCTTTCTGCT	GGCC(4)
Xisep1130	GCATGACGAGGAGAAGAAGG	CCACGAGGAAGACGAAGG	CG(6)
Xisep1131	CGGAACCTGACCAAGAAGAG	CGTCGGTCTTGATCCAGTG	ACG(7)
Xisep1132	CGTGTACAGCTTCGGCATC	AGCAGGAACTCCTCCCACTC	GGA(4)
Xisep1133	CGATGCAGCTCCAACTCATA	GTGTATGTCGCCGAAGTGG	CCA(5)
Xisep1134	ATCAGCAGCAGCGAGCTT	CTTGCCCCTAGGCGTAGAC	CGG(6)
Xisep1135	GAAACCCTAGCCCGCTACA	GTAGCTGTCGCAGACGTTGA	CGC(6)
Xisep1136	GCTCCGAAGCTCCGTTCTA	TTCCAGGAGGTCGATAGGTG	GCC(4)
Xisep1137	ATCGCCCTCTCCGCTACTAT	GGATGGTGGTAGTCGTCGTT	CCG(5)
Xisep1138	GCGTGCTCTAGCTTTCTGCT	ACAGCAACGACCCAAGAAGT	CGA(7)
Xisep1139	CACGACTTCCTCGGCTTC	GGCAGGTGAGCACCAGAG	CGG(5)
Xisep1140	TGGGAGTACTACCCGGAGGT	CGCACGTACACCCTTAATCTT	GAC(4)
Xisep1141	GCGTGCTAGCCAAGATCAA	GACGCAGGTGGAGTAGGAGT	GGC(5)
Xisep1142	CGGTTAGTCGGGTTCCAAG	GCGAATCCTCAATCCTCATC	TGA(4)
Xisep1143	ATGGAGGAGGCCAAGAAGTT	CTGCTTCCCCCAAATATTGA	AGG(4)
Xisep1144	AACTAGCCCCGAAAATGGAT	CACCACCGCCGATCTTATTA	AAG(5)
Xisep1145	GAGGACGAGTGCATGATGAG	GGACGGGAACAGAGAAAGAA	AT(8)
Xisep1146	CCTCCTCCTCCTGTCTCTCC	AGAAAGCACTGGGCACTGAC	CT(5)
Xisep1147	AGATCAGGTGATGAGCCAAGA	GCGACTCCTTGGTCTCTGAA	ATG(7)
Xisep1148	CCTTGACGCAAAAGAACCTG	TTCCTCCTCCTCCTCCTGAT	GCG(5)
Xisep1149	ACATGCAAAGCCAGTTTGGT	TGCTCTCAAGCTGCTGAATG	CAG(7)
Xisep1150	GTATTGTACGGCGCCCCTTT	ATGCACTAACCGGGGACATA	TCTA(15)
Xisep1201	TACAGGCGTCATGGTGAGAG	TGGTCCACTGAGTGACGGTA	CCG(7)
Xisep1202	CTACCTCGTGCACCAAATGA	CGCAAACAGATCCTTGCTTT	ATA(6)
Xisep1203	TGCCTGGTGATTCAAGACAG	ATCACCAGCTTCACCCTGAC	CGG(4)
Xisep1204	AGCCAGCCAGAAGAAGACCT	GCACAAGACACGTTCCTTCA	AT(5)
Xisep1205	CGAAAAGGAGGAAGCAATGA	CGCAGTTCAAGGAGTCGTC	CCT(6)
Xisep1206	TGCTGGTGTTACTGCTGTCTG	CAAACCAGCTAATGAGACGATG	TTC(7)
Xisep1207	AACCCACCTTCCCTTTCCT	CCCATGCATGAGAAGACGA	GCC(4)
Xisep1208	TCCAAACACACAGACCGTTT	TCCGATGGTTGAGAGCTTGT	TCGAA(4)
Xisep1209	TGTTTCGTTCACAACCTCCA	AGCATCCCCTTCCGAGTAGT	CGG(4)
Xisep1210	GAGATCCTCCGACCTGGAC	ACCAAACCCAAACCCTGACT	GGT(5)
Xisep1211	GAGAAGAAGAGCCGATCGAA	GGTTCTGTTGACCAGGTGCT	CGG(4)
Xisep1212	TGTAGGCAGCAACTCTTGGA	ACAACCCAACCGAGGAACTT	CGAT(3)
Xisep1213	AGGTCAGCGTCTTGCAATCT	ACAAATTGAAAGGGCGAGAG	GAA(5)
Xisep1214	CCGTCACCCTTCTTGTCG	CACCTCGTCCTCCACCAG	GCG(4)
Xisep1215	ACCTTGCTCCCACAGAAATC	ATGCCACCATAGTCGAGAGG	GGC(6)
Xisep1216	TCTCACCCCGAGAGTAAACC	GCTTTGCCGGATTCAACTT	CACC(3)
Xisep1217	CGTGATTTGCCACGTATTCA	AATGAGCTTGCATGAGCAGA	AAG(4)
Xisep1218	TGCTCTGGGCTTACTTCCTC	TACACGGTGCTCATCACTGC	TA(8)
Xisep1219	GGGGATCGAGGGAGTGAT	GATGTAAATGGCCACCTCGT	CGG(4)
Xisep1220	CGTCGTCGCTGGAGAGAT	CACCATGACCGATCCTTTTT	GGT(4)
Xisep1221	ACCTCCTCCTCCCACTGAAG	AGCAGGTTACCCAGCAACTG	CGT(9)
Xisep1222	GGAGAGGACGAAACCCTAGC	CATTGAACGCAGTTTCTGGA	GGC(4)
Xisep1223	CAAGACAGCGTCGTGAAGTC	GGGAGATGCCTCACCAGA	CAC(5)
Xisep1224	GGGGGTGATGACAAAGACAA	TGCTGCTCTCTCGTTGCTAA	AGGC(3)
Xisep1225	AATTCCAGTTGCTCGCTCTC	CCTCCCTCCCCCTACTACAC	CTC(8)
Xisep1226	ATCGATCCATGGAGGGTGT	CAACCACCACCGCTACAATA	AGG(4)
Xisep1227	CCATCGTGGCGGTGTACT	ATGTAGCCGAAGCCCTGAT	GCC(4)
Xisep1228	GCACGAGGTATGCACGAGTA	CGCGAAGAAGTCGATGAAC	CGC(4)
Xisep1229	CCTCATCCTCCTCTCCCTCT	GACGGCTTCTTCTGCCAGT	AGCA(3)
Xisep1230	CCTCGCTCCACCACTCTCT	GTACCCGCACTCGATGATGT	CCAA(4)
Xisep1231	CTGCTTATGCGCTTCGATTT	CATAATGGGTGCACTCTAGCC	GT(11)
Xisep1232	AGACCACGTCCACGATGC	CGAGTACACCGCCACGAT	TGC(5)
Xisep1233	CAACCTTCCATTCCGTCATC	GCAATCTCGCTTCTGATGTTC	AGC(6)
Xisep1234	GCTCAGGCATCAAGGAAATC	CCTCCTGAGCTCCACAGTCT	GCT(4)
Xisep1235	ATCAGGGCTTCGGCTACAT	AAAGATCAGTAGGAGGCTGGTG	CGG(5)
Xisep1236	GGTGACCACTGACGAGATGA	AAACACCAGCTGCTCCAAGT	CGG(6)
Xisep1237	AATCATGCCAACGAGAGGAC	CACCAACACCACCACCATAG	GGT(4)
Xisep1238	GGCGAGAACCCTAACCCTAC	TCCCCCTGGTAGGTCATGT	GCC(4)
Xisep1239	GTGGACTAGCCACCACCAGT	TCCCAACCAAAATTGCCTAC	GT(5)
Xisep1240	AGAGGGAGCAAGGGAGAGAG	ACACCTCCCACGGATTCAC	GCG(4)
Xisep1241	GAGGGCGAGACAGAGGAGAT	CTACCTTTGAGCCCACCGTA	AGCTG(5)
Xisep1242	CTCCTCAGGTTTGGAACGAG	TCACCGTCACACACACACAC	GGC(9)
Xisep1243	CGAGACAAGCAAGCAGCA	AGCCAGAGCTCCGGAAAG	GA(7)
Xisep1244	CGTAGCCACCACCACCTC	TTCGGCTTCGTCACCTTCT	GCC(5)

Xisep1245	CAACAGCCTCCTGTGGAGA	CCTCGTCTACCATCCAGCTC	GAG(4)
Xisep1246	CGGACAACGAGGTCAAGAAC	CGGCTGTAGCTGTTGCTGTA	GCC(4)
Xisep1247	ACGAGGGGAACACTCACCTA	CTTCTTGTTCTTGGCGCAGT	CCT(4)
Xisep1248	AGCAAAAGGCAGCAGGAAT	CCGTCTAGCTCGCAGGTCT	GAG(6)
Xisep1249	GTTACGGAGGCGGTGGTTA	AGGATAACTTGGCCGAAACC	GGC(4)
Xisep1250	AGCCATCTCCTCTCCTCCTC	GGTGGTGCTCCTCCTCCT	GCG(5)

Special Project Funding:
Syngenta Foundation for Sustainable Agriculture, Department of Biotechnology (Govt. of India)

RK Varshney, T Mahender, RK Aggarwal, CT Hash, T Nepolean, S Senthilvel, V Rajaram, V Vadez, DA Hoisington, P Ramu and B Jayashree

Molecular genetic maps and consensus maps based on SSRs, DArTs and EST-based markers developed for chickpea, pigeonpea and groundnut (2011)

1. Chickpea: For developing the reference genetic map of chickpea, an international reference mapping population (*C. arietinum* ICC 4958 × *C. reticulatum* PI 489777) is being used to integrate newly developed markers along with already mapped markers. Screening of parental genotypes of this population with 1344 CaM (derived from BES) and 311 ICCM (derived from enriched libraries) markers, as mentioned in Milestone 2.4.8.1 showed polymorphism with 253 CaM and 52 ICCM markers. In addition, screening of another set of 233 SSR markers (H-series), with these parental genotypes, showed polymorphism with 52 H markers. All these polymorphic markers were screened on 131 recombinant inbred lines (RILs) of this mapping population. Marker genotyping data generated by other research groups such as University of Frankfurt (Germany) / University of California- Davis (USA) on this population have also been assembled. Thus in total, the genotyping data available for >1000 markers on this population are being analyzed for developing the reference genetic map of chickpea.

Special Project Fund:
Generation Challenge Programme, National Fund of ICAR (Govt of India), Department of Biotechnology (Govt. of India)

RK Varshney, SN Nayak, N Varghese, G Srivani, PM Gaur, DA Hoisington and DR Cook

2. Pigeonpea: An interspecific mapping population (*Cajanus cajan* ICP 28 × *C. scrabaeoides* ICPW 94) is being targeted for developing the reference map. The parental genotypes are being used to screen for polymorphism with larger set of SSR markers. In parallel, high density DArT arrays are being developed at DArT Pty/ Ltd in Australia that will be used to genotype this mapping population.

Special Project Fund:
Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Govt of India)

RK Varshney, A Dubey, HD Upadhyaya, A Killian and DR Cook

3. Groundnut: The RIL mapping population of groundnut (ICGV 86031 × TAG 24) is being used for developing the genetic map for cultivated groundnut. A total of 1145 SSR markers available in public domain as well as unpublished markers from different sources were screened on the parents ICGV 86031 and TAG24, a total of 144 (12.6%) markers were identified polymorphic in these parents. Of the 144 polymorphic markers identified, 135 SSR loci were mapped into 22 linkage groups with genome coverage 1,270.5 cM. Two linkage groups of the developed genetic map were aligned with available genetic maps of AA diploid genome of groundnut and *Lotus* and *Medicago,* which exhibited syntenic relationships. This work has been reported in a recent paper authored by Varshney et al. in Theoretical Applied Genetics (DOI 10.1007/s00122-008-0933-x)

Special Project Funding:
National Fund of ICAR (Govt. of India), Generation Challenge Programme

RK Varshney, V Vadez, DA Hoisington, R Aruna, SN Nigam, D Bertioli, G He and SJ Knapp

Molecular genetic maps and consensus maps based on SSRs, DArTs and EST-based markers developed for pearl millet (2010)

As reported in 2007, upon screening a total of 627 markers (100 genomic SSRs, 60 EST-SSRs, 100 pearl millet SSCP-SNPs, 57 wheat SSCP-SNPs, 310 CISP-SNPs) on 24 pearl millet inbred genotypes including parents of 11 mapping populations and two other inbred lines (Tift 383 and Tift 186), the 100 markers showed polymorphism in. These polymorphic markers (27 gSSRs, 22 pearl millet SSCP-SNPs, 51 CISPs) were used to genotype 150 RILs of mapping population ICMB 841-P3 × 863-P2. Apart from this, a set of 50 newly developed polymorphic SSR markers (see above) were also used to genotype the mapping population ICMB 841-P3 × 863-P2. In total 150 polymorphic markers have been genotyped and the segregation data for this mapping population were recorded. In order to integrate these markers on to the genetic linkage map for pearl millet calculation of the map distance using MAPMAKER V3/EXP is currently underway. In parallel, high density DArT arrays are being developed at ICRISAT and DArT Pty/ Ltd in Australia that will be used to genotype this mapping population.

In addition, genotyping of 141 F7 RILs from the (H 77/833-2 x PRLT 2/89-33)-based pearl millet mapping population with 32 pearl millet SSR primer pairs (21 gSSRs and 11 EST-SSRs) was completed. One of the gSSR loci (*Xpsmp2081*) exhibited severely distorted segregation. Segregation data for the remaining 31 SSR marker loci were used to produce a skeleton linkage map across the seven linkage groups (3 to 6 loci per linkage group). This skeleton map had a total length of 753 cM (Haldane), compared to 352 cM for the earlier F_2 skeleton linkage map of this cross based on 50 RFLP markers.

Special Project Funds:
Syngenta Foundation for Sustainable Agriculture, Department of Biotechnology (Govt of India)

RK Varshney, T Mahendar, S Senthilvel, T Nepolean, B Ramana Kumari, CT Hash, A Kilian and DA Hoisington

NARS partners trained to uptake molecular breeding activities (Annual)

Achievement of Output Target (%):
100%

Countries Involved:
India; Malaysia; Pakistan; Philippines; Thailand,

Partners Involved:
ICRISAT Patancheru

Progress/Results:
The Center of Excellence in Genomics (CEG) recently launched at ICRISAT, Patancheru offers courses and workshops to provide scientists and students training in the use of genomic technology in crop research and breeding with a final objective to strengthen and enhance the capacity of NARS from India. These courses are specifically designed to address the requirements to use the CEG's high-throughput Genotyping Service Lab. These courses include experimental design, sample submission and data analysis. Genomic application exercises/demonstrations cover a range of activities e.g. molecular diversity assessments to gene/trait mapping and marker-assisted breeding. Courses are offered twice a year for around 20 scientists and students each. Course lectures are given by ICRISAT/CEG scientists as well as invited scientists from India and abroad.

The course is open mainly to Indian students and scientists who have a demonstrable ability to use the techniques taught and the CEG marker services. Transport to/from ICRISAT, room and board, and all training costs are provided to the selected participants from India through funds provided by the DBT, Government of India. The course also trains a few participants outside of India, although all transportation costs to/from ICRISAT are borne by the participant or their sponsor(s).

Training courses offered:
The CEG offered four training courses during the year 2008. Two courses exclusively for ICAR scientists during March (for two weeks) and October 2008 (for three weeks), and other two for the CEG applicants those submitted their applications directly to CEG through on-line/hard copies. These courses were designed, organized and offered by a group of ICRISAT/CEG scientists with help of Dr. B.M. Prasanna, IARI, New Delhi, India. The courses were announced through CEG website and DBT Newsletter.

The first CEG training course entitled "*Molecular Marker Applications in Crop Genetics and Breeding*" was held at ICRISAT during 31 March to 11 April 2008. We received about 500 applications submitted on-line and through hard copies for this course. The selection committee selected 20 candidates including 2 Asian participants who were self-supported. The course provided the participants a hands-on opportunity to gain expertise in the use of molecular markers (SSRs, SNPs and DArTs) in diversity analysis, gene/QTL mapping and marker-assisted breeding. The course focused on the experimental design and data analysis components of molecular markers, rather than the actual marker data generation technology. The participants were given lectures on marker technology and were able to see how the various marker data is generated. Special attention was given on the requirements for scientists to utilize a high-throughput marker service facility such as the one at the CEG (e.g., DNA extraction and quality control). In addition to ICRISAT/CEG scientists we have two resource persons Dr. Jorge Franco Durán, Department of Biometrics, Statistics and Computation, Faculty of Agronomy, Universidad de la República, Paysandú, Uruguay, and a former Monsanto Consultant Dr Xavier Delanay, a MARS specialist from USA and Prasanna, ICAR National Fellow, IARI, New Delhi.

The second CEG training course entitled "*Molecular Methodologies for Assessing and Applying Genetic Diversity in Crop Breeding*" during 17-28 November 2008. This time, we received more than 500 applications submitted on-line and through hard copies. The Selection Committee selected twenty-six participants from ICAR centers, State Agricultural Universities, Private Sector, Research Foundations and Governmental Organizations including 5 overseas participants who are self-supported from Kenya, Malaysia, Pakistan, Philippines, and Thailand. The main thrust of this course was to expose the participants to the analysis and interpretation of molecular marker data that can now be supplied by a Genotyping Servicing Lab, such as the one housed at the CEG. The two-week training course included laboratory practicals, lectures (by genomic scientists, bioinformatics specialist, crop physiologist and biometrician and invited speakers), computer and biometrics classes using the specialized computer software for diversity analysis, association mapping and field visits. In addition to ICRISAT/CEG scientists four resource persons namely Professor PK Gupta, Honorary Emeritus Professor and INSA Honorary Scientist, Meerut University; Dr BM Prasanna, ICAR National Fellow, IARI, New Delhi; Professor EA Siddiq, National Professor and Distinguished Chair, CDFD; Dr Joy K Roy, Department of Plant Pathology, University of Minnesota, USA shared their expertise with the participants.

In addition to the above courses, the CEG also hosted two other training courses at the request of Dr Mangala Rai, Director General of Indian Council for Agricultural Research (ICAR), who plans to see that the majority of the ICAR breeders receive training in the application of molecular tools in breeding.

The first batch of ICAR scientists was trained during 17 to 28 March 2008 in the area of "*Molecular Marker Applications in Crop Genetics and Breeding*". The course was offered to fifteen scientists from various ICAR institutes, State Agricultural Universities, and researchers from the ICAR supported Regional Research Stations participated in this first training course. The training course exposed the participants to the analysis and interpretation of molecular marker data that can now be supplied by a Genotyping Service Lab, such as the one housed in the CEG. The two weeks consisted of lectures, laboratory practicals, field visits and practice sessions using the specialized computer software for data analysis. During the graduation ceremony on 28 March 2008, each participant was presented a certificate by Drs William Dar, Director General, ICRISAT; N Seetharama, Director, National Research Center for Sorghum, Hyderabad; and Dave Hoisington, Global Theme Leader-Biotechnology. ICAR provided the travel cost for the participants. Apart from ICRISAT/CEG scientists, Dr. Jorge Franco Durán, Department of Biometrics, Statistics and Computation, Faculty of Agronomy, Universidad de la República, Paysandú, Uruguay, was the guest faculty for this course.

Second batch of ICAR scientists participated in the training course, *Molecular marker applications in crop genetics and breeding* during 6-24 October 2008. Twenty-two scientists from various ICAR institutes, state agricultural universities and ICAR-supported regional research stations participated in this course. The course provided the participants a hands-on opportunity to gain expertise in the use of molecular markers in crop breeding, gene/QTL mapping and marker-assisted breeding. The course focussed on the experimental design and data analysis components of molecular markers, rather than the actual marker data generation technology. The participants were given lectures on marker technology and were able to see how the various marker data is generated. Special attention was given on the requirements for scientists to utilize a high-throughput marker service facility such as the one at the CEG (e.g., DNA extraction and quality control). In addition to ICRISAT/CEG scientists we had two resource persons Dr. Jorge Franco Durán, Department of Biometrics, Statistics and Computation, Faculty of Agronomy, Universidad de la República, Paysandú, Uruguay, and Dr Michel Ragot, Head, Genetic Information Management, Syngenta Seeds, France.

The feedback on training courses from the participants was received requesting participants to fill-in a questionnaire consisting of two parts – topic specific and general. Most of the participants for all four courses cited the content and design as the strength of the course and commented that these courses are well structured and very educative courses. The comments received from the participants for all four courses indicated their great appreciation for the CEG in offering the courses, and one person commented that this was the first course where he was able to learn that he could actually "use" molecular markers in his program without having to "do" the marker technology.

The CEG considered the feedback from each course and implemented suggestions in the next course so that the participants of new courses are benefited and courses can be made more informative and enjoyable.

Out-line of the training course(s)
Introduction to molecular markers (SSR/SNP/DArT), laboratory techniques, laboratory practicals DNA extraction, DNA quality assessment, Polymerase chain reaction, gel electrophoresis including PAGE, introduction to molecular diversity, application of molecular diversity, Software ware for diversity analysis PowerMarker, DARWin, Structure, introduction to experimental design and phenotyping, introduction to decision support software for breeders iMAS (molecular assisted selection), phenotype analysis, linkage map construction, introduction to QTL analysis, PlabQTL practicals, introduction to marker-assisted breeding, bioinformatics in crop improvement, high performance computing, writing successful project proposals, introduction to genotyping laboratory, using CEG's genotyping laboratory, LD mapping, introduction to MABC, MARS strategies, TILLING and Eco-TILLING, association mapping, software for association mapping TASSEL, EMLD, Haploview, other invited lectures.

Details about participants trained are given in Table 17.

Special Project Funds: Department of Biotechnology (Government of India)

Table 17: Details of Training Course Participants offered by the Center of Excellence in Genomics, supported by the Department of Biotechnology, Government of India, during 2008

Type of organization	First Training (17- 28 Mar 2008)	Second Training (31 Mar-11 Apr2008)	Third Training (6-24 Oct 2008)	Fourth Training (17-28 Nov 2008)	Total
ICAR Centers	8	7	6	5	26
State Agricultural Universities	4	9	7	10	30
Regional Agricultural Research Stations	4	1	9		14
Private Sector/ Research Foundations		1		4	5
Government Organizations				2	2
Overseas		2		5	7
Sub Total	16	20	22	26	84
Overall : Gender	Male		61		
	Female		23		

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Output target 2.4.9: Data management infrastructure development (2010)

Evaluation of database by users and data submission (2008)

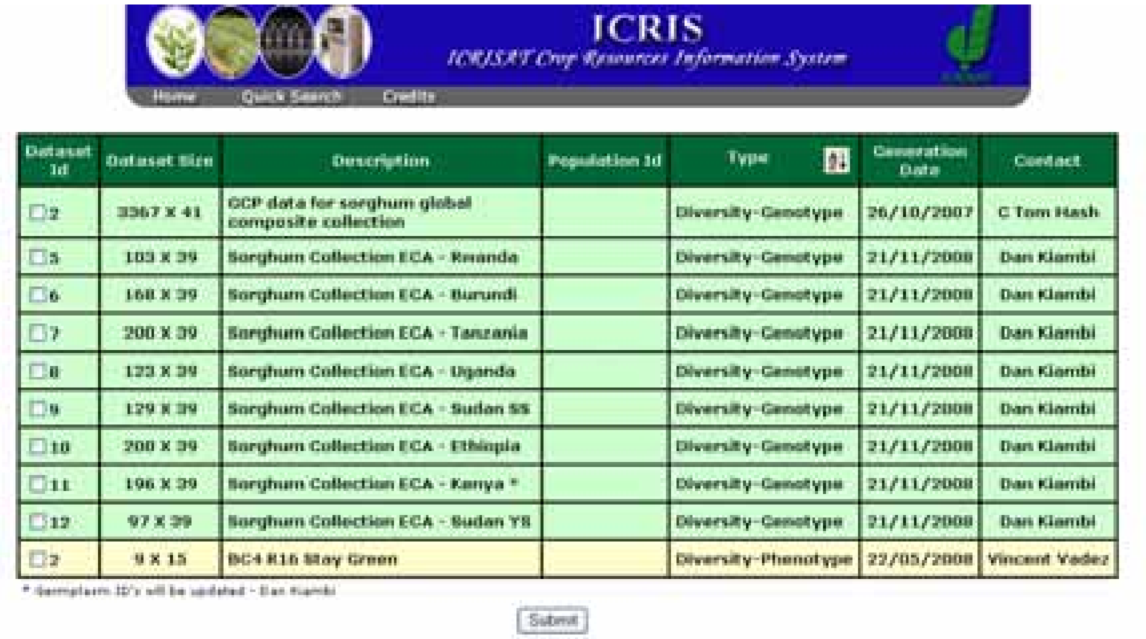
Achievement of Output Target (%):
>50%

Countries involved:
India; ESA; Peru; WCA

Partners Involved:
GT-BT staff, students, technicians in Patancheru; DK and Santie DeVilliers in Nairobi. Reinhard Simon from CIP, Guy Davenport from CRIL-CIMMYT.

Progress/Results:
LIMS: The LIMS (Laboratory Information Management System) for the capture of SSR genotyping data has been expanded to provide data capture support for information generated during parental screening and genotyping of mapping populations besides genotyping of germplasm collections. Additional functional modules include one for job scheduling that allows users to book time slots on the genotyping instrument and another for run-plate design besides providing better query and report generation options. The central LIMS installation is on the server and is accessed by users through their browsers; data generated on the ABI machine is uploaded by the ABI-operator onto the LIMS database located on the server. This arrangement allows central storage of all genotyping information generated. Data on germplasm screened, DNA extraction and PCR plates and marker information is input by the user. Marker datasets are also being curated by data generators voluntarily. The LIMS interfaces with laboratory instruments through file exchange, keeping track of the sample from its source to the final output data along with its versions. A quality control module for database content is currently being designed. A modality for sustained support for the maintenance of the LIMS at ICRISAT-Nairobi is also being worked out.

ICRIS: It is available on the intranet (http://10.3.1.159/ICRIS) and can be accessed through the GT-Biotechnology web pages. The database currently stores genotype, marker and phenotype information and the database schema will soon be expanded to accommodate transcript data also. A suite of web pages allow the user to both browse and query the database, and retrieve results as germplasm x marker or germplasm x trait matrices depending upon the type of data to be retrieved. The database and web pages have been demonstrated to staff at Patancheru, Nairobi and Niamey and their suggestions to improve usefulness have been incorporated. This includes expanding the number of data export formats that will allow downloaded data to be immediately used with relevant analysis tools. Submission of data to the database by data generators is enabled through templates. Templates are available for the upload of data from SSR genotyping experiments for composite collections as well as mapping populations, genotyping experiments using RFLP markers, phenotyping data, marker information besides relevant meta-data about germplasm. The database currently contains the chickpea and sorghum composite collection genotyping datasets besides seven of the eight country sorghum diversity analysis datasets from ESA generated during 2005-2008 (Rwanda, Tanzania, Burundi, Sudan (2), Ethiopia, Kenya and Uganda). Phenotyping datasets include the minicore germplasm evaluation from chickpea and stay-green evaluation in sorghum. Crop-specific trait ontology development using the chickpea and sorghum datasets has been initiated (Figure 6).



Dataset Id	Dataset Size	Description	Population Id	Type	Generation Date	Contact
2	3367 X 41	GCP data for sorghum global composite collection		Diversity-Genotype	26/10/2007	C Tom Hash
5	103 X 39	Sorghum Collection ECA - Rwanda		Diversity-Genotype	21/11/2008	Dan Kiambi
6	168 X 39	Sorghum Collection ECA - Burundi		Diversity-Genotype	21/11/2008	Dan Kiambi
7	200 X 39	Sorghum Collection ECA - Tanzania		Diversity-Genotype	21/11/2008	Dan Kiambi
8	123 X 39	Sorghum Collection ECA - Uganda		Diversity-Genotype	21/11/2008	Dan Kiambi
9	129 X 39	Sorghum Collection ECA - Sudan SS		Diversity-Genotype	21/11/2008	Dan Kiambi
10	200 X 39	Sorghum Collection ECA - Ethiopia		Diversity-Genotype	21/11/2008	Dan Kiambi
11	196 X 39	Sorghum Collection ECA - Kenya *		Diversity-Genotype	21/11/2008	Dan Kiambi
12	97 X 39	Sorghum Collection ECA - Sudan YS		Diversity-Genotype	21/11/2008	Dan Kiambi
2	9 X 15	BC4 R16 Stay Green		Diversity-Phenotype	22/05/2008	Vincent Vadez

* Germplasm ID's will be updated - Dan Kiambi

Submit

Figure 6. Summary of sorghum genotyping data set available in ICRIS database.

Prototype of the information system for MAB developed (2008)

ISMAB: Information System for MAB (ISMAB) is a standalone system being developed for the management of information generated during the course of a marker assisted breeding programme. The system allows the integration of information relevant to the breeding programme that may come from local and/or external databases. Based on user requirements and developer discussions the system has been designed to consist of four basic components. These include a Molecular Breeding Design Tool (MBDT) that will assist breeders in selecting parental germplasm based on phenotypic data, check availability of genotyping data for potential recipients and donors, display graphical genotypes, allow user to choose markers and design crosses and the target genotype. The second component interfaces with the LIMS, providing the LIMS with the list of germplasm and markers for which they need to be screened which carries out the sample tracking for germplasm. The third component is the MOlecular Selection Tool (MOSEL) that facilitates the selection of the most promising lines in terms of closeness to the target genotype, filter sort and scroll graphical genotypes for proximity to target and parental lines, choose lines and crossing schemes for further development. The fourth component is the loading of data into the central database, for future use and dissemination.

In the first year of its development, the first component of the system has been designed and is being developed. All system components are being developed as plug-ins meaning that each component is a self-contained programme that can easily be installed and used as an independent application, besides being used as a collection of plug-ins. Being developed as a rich client application, when deployed they will allow the user to experience richer user interfaces, work offline as well as integrate content. The MBDT module currently allows the import of files consisting of genotype data, linkage maps or QTL data through a file import wizard. The files are read to display a list of germplasm; the user is allowed to create sublists, view graphical genotypes, and view them against the linkage maps. The user can choose colors to display allele information in the graphical genotypes, select foreground markers based on a segment of interest. The module allows the selection of donor and recurrent and design of the desired genotype.

Special Project Funding:
DBT, Government of India, and Generation Challenge Program.

B Jayashree, DA Hoisington, CT Hash, V Vadez, S Senthilvel,
T Nepolean, D Kiambi, RK Varshney and P Ramu

Data submission, curation and fulfilling database interoperability requirements (2009)

Report not available

Information system for MAB tested and user comments incorporated (2009)

Report not available

Data availability through GUI, web services and ongoing curation (2010)

Report not available

Information system for MAB testing and release (2010)

Report not available

Output target 2.4.10 Development of data analysis tools (2011)

Enhancement of the iMAS tool (2009)

Report not available

Pipeline of open source tools for sequence analysis, marker development and annotation (2009)

Achievement of Output Target (%):
<50%

Countries Involved:
India

Partners Involved:
NA

Progress/Results:
Modules and scripts that facilitate sequence diversity analysis have been developed and are being made available along with source code. The module *divest.pm* is a diversity estimator module that reads an input file derived from sequence assembly programmes like cap3 or the alignment file output from multiple sequence alignment programmes like ClustalW or BioEdit, and returns calculated diversity statistics. This module improves upon existing nucleotide diversity analysis software in that it provides diversity statistics for user defined groups and considers the presence of heterozygous loci in the calculation. The process of SNP diversity analysis and marker identification from sequence data involves pipelining of data from one software to another, format conversion scripts to convert output of one program to input of another especially when there is a need to pipeline several tools and automate analysis. Several workflow/pipelining environments are available in the public domain and one such environment has been implemented on the Paracel HPC at ICRISAT. The PISE (Pasteur Institute Software Environment) allows integration of in house scripts/tools along with external tools that a user may need for his analysis. Ease of use is achieved through the creation of a graphical user interface (GUI) for all of the programmes/scripts available in the environment and the chaining together of scripts to facilitate automation and analysis. Over 40 analysis tools which include both in-house developed programmes as well as third party tools are currently available for sequence analysis through this environment.

Special Project Funding:
Generation Challenge Program

B Jayashree, RK Varshney and N Spurthi

Output target 2.4.11 RILs and mapping populations of staple crops assembled for utilization (2010)
Suitable contrasting parental lines for salinity tolerance in groundnut for the development of RILs provided (2008)

Achievement of output target (%):
100%
Countries Involved:
India

Partners Involved:
CRRI Cuttack and CSSRI Karnal

Progress/Results:
We reported that 31 genotypes (14 tolerant and 17 sensitive) were identified from two repeated trials across two different seasons. These genotypes were screened with 21 SSR markers to detect the genetic distance among these. The dendrogram (Figure 7) reflects the genetic contrast between lines and guides the choice of parental combinations to be used by breeders to develop population, i.e. using genotypes that contrast both genotypically and phenotypically.

Special Project Fundings:
NA

V Vadez and L Krishnamurthy

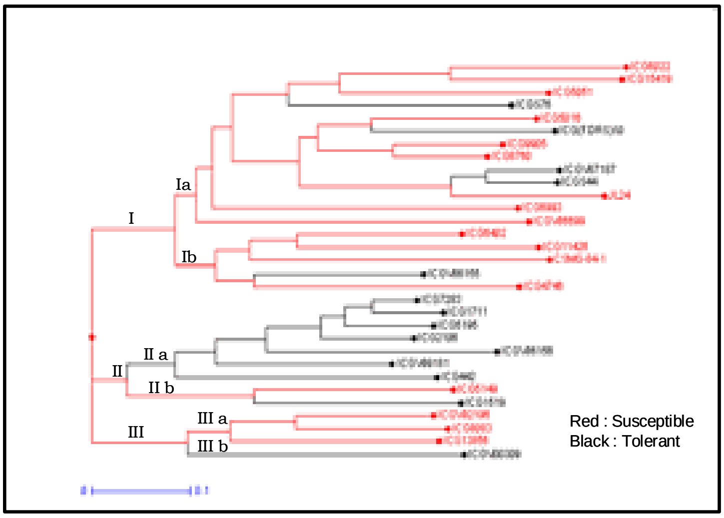


Figure 7. Dendogram of salinity tolerant and susceptible groundnut accessions.

Seed multiplied for RILs populations for different crops (2009)

Achievement of Output Target (%):
>75%

Countries Involved:
NA

Partners Involved:
ICRISAT Patancheru

Progress/Results:
Sorghum and pearl millet RILs: As reported previously, seed samples of parents and progeny of four ICRISAT sorghum RIL populations and three ICRISAT pearl millet RIL populations were produced during the 2006/07 postrainy season and contributed to the ICRISAT gene bank in 2007. The sorghum RIL populations thus assembled include two targeting stem borer resistance and midge resistance [359 F10 RILs based on cross (ICSV 745 x PB 15881-3)-1 (ICSL 72 and 266 F10 RILs based on cross (ICSV 745 x PB 15220-1) (ICSL 71001 to ICSL 71266] and two targeting *Striga* resistance and the stay-green component of terminal drought tolerance [219 F8 RILS based on cross (N13 x E 36-1) (ICSL 73001 to ICSL 73219) and 221 F8 RILs based on cross (IS 9830 x E 36-1) (ICSL 74001 to ICSL 74221). The pearl millet RIL populations thus assembled included the World Reference Mapping Population for pearl millet [166 F7 RILS based on cross (81B-P6 x ICMP 451-P8)-1 (ICML 72001 to ICML 72167), which is segregating for rust and downy mildew resistance as well as several morphological markers including d_2 dwarf plant height, *Br* long panicle bristles, and *hl* hairy leaf blade]; a second population segregating for seedling heat tolerance, terminal drought tolerance and downy mildew resistance [121 F7 RILs based on cross (H 77/833-2 x PRLT 2/89-33) (ICML 71001 to ICML 71149)]; and a third population segregating for terminal drought tolerance, downy mildew resistance, and stover ruminant nutritional value [144 F7 RILs based on cross (ICMB 841-P3 x 863B-P2)-1 (ICML 61001 to ICMP 61149)].

Special Project Funding:
NA

CT Hash, SP Deshpande, T Nepolean, HD Upadhyaya, BVS Reddy and HC Sharma

TILLING populations of pearl millet developed (2009)

2. Pearl millet TILLING population: As reported in 2007, DNA has previously been isolated from 4,655 mutant lines generated from pearl millet inbred line “P1449-2-P1”. Assuming a population size of 10000 M2 lines to be ideal for mining allelic variants in drought-responsive candidate genes, another set of 15000 seeds of inbred line “P1449-2-P1” were mutagenized using 7.5 mM EMS. The mutagenized seeds were initially sown in pots and surviving seedlings then transplanted to the field. In total, 64% (9600) of M1 plants from these 15,000 mutagenized seeds were selfed and harvested.

In 2008 rainy season, an additional set of 3000 M1 lines were advanced to M2 generation and DNA from 2,858 of these have been isolated. To date, DNA from 7513 M_2 TILLING lines is available. To accomplish the target population of 10,000 TILLING lines, additional M1 lines (5,000) will be sown for advancement to M_2 generation during Feb 2009. DNA isolation and pooling for these additional lines will be done early next year.

In order to increase the throughput during allele mining, eight-fold pooling of normalized genomic DNA from a set of 4655 (2581 mutant lines generated in 2006 and 2074 lines in 2007) M^2 lines was accomplished. The strategy of DNA pooling is as depicted in Figure 5. For instance the DNA from each source plate well (8 source plates) bearing the well ID A01 are being pooled into destination plate well bearing the well ID A01 (Figure 8). Thus a total of 7 pooled plates, 4 plates from the DNA isolated from the initial set of mutagenesis experiments and 3 pooled plated from mutant lines generated during 2007 were prepared. Further, all the plate records were uploaded into LIMS (Laboratory Information Management

System) followed at ICRISAT for data storage and retrieval. Thus the pools of DNA from mutant population will be made available for international pearl millet community for allelic mining candidate genes.

Further, efforts are underway to mine allelic variants for drought responsive candidate genes (*viz*, DREB 2A) in the mutant DNA pools prepared.

Special Project Funding:
Department of Biotechnology (Govt. of India)

RK Varshney, T Mahendar, YP Khedikar, CT Hash and DA Hoisington

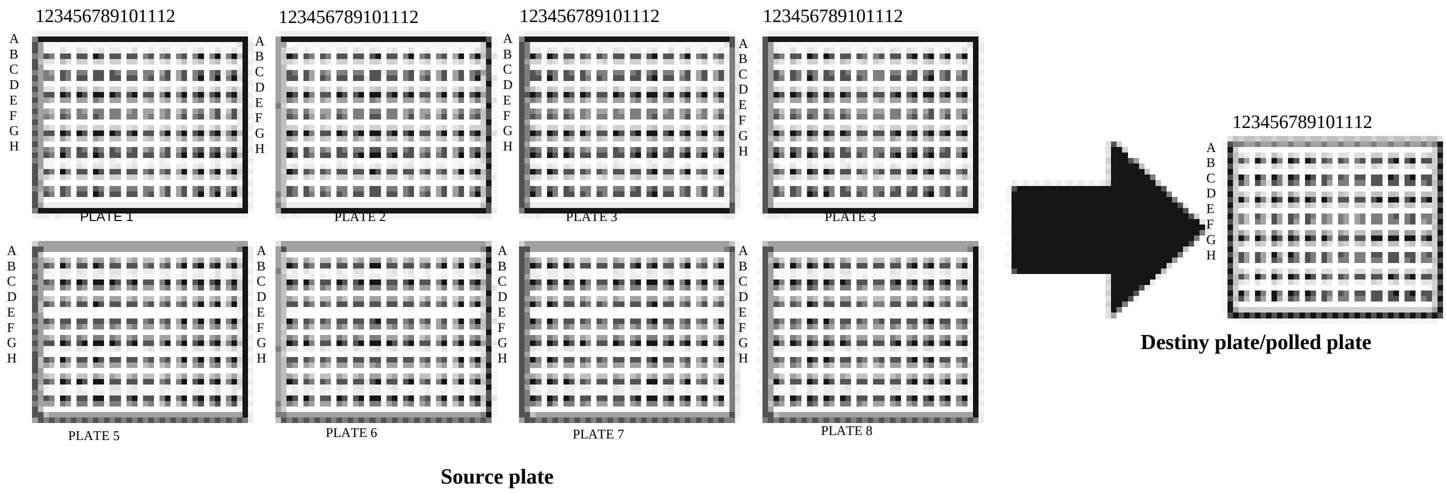


Fig 8. Schematic representation of 8-fold pooling of genomic DNA of M2 lines of TILLING population of pearl millet

DNA of different RIL populations isolated (2010)

Report not available

Marker and phenotype databases for the available RIL mapping populations curated (2010)

Report not available

Out put target 2.4.12: Agriculturally beneficial micro-organisms assembled for utilization with associated capacity development (2010)

Agriculturally beneficial microorganisms from diverse environments accessed and characterized for 6 different traits – P-solublization, antagonism to disease-causing fungi, pathogenicity to insect-pest, siderophore production (Annual)

Achievement of Output Target (%):
<50%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
A total of 164 actinomycete isolates were accessed from soil samples of various districts of Karnataka, obtained from GT- Agro Eco System team of ICRISAT. All were characterized for their morphological characteristics. Further, another 151 isolates from our collection were studied for agriculturally important beneficial traits such as pathogenicity to insects, antagonism to disease causing fungi, P solublization and siderophore production. Of the 151 isolates, 7 (BCA 508, 656, 658, 659, 678, 690 and 698) were entompathogens, 11 (BCA 546, 655, 657, 660, 667, 671, 679, 689, 696, SRI 521C and 638f) were antagonistic to phytopathogens, and 2 (SRA 997 and 998), were siderophore producers. None of the isolates solubilized P, indicating that such isolates were not very common in the soil samples, or did not stand the conditions of storage of few days, until analyzed.

Existing collection of agriculturally beneficial organisms conserved for medium and long-term storage system and annually 20% germplasm attended (Annual)

Achievement of Output Target (%):
<50%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
All the new and promising isolates (164 actinomycete isolates) were preserved in paraffin oil for medium term preservation.

Requested agriculturally beneficial microorganisms distributed to bonafide users for utilization (Annual)

Achievement of Output Target (%):
<50%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
Eight units (one unit is sufficient to cover one acre of land) of carrier based different chickpea rhizobial inoculants and 17 rhizobial strains of chickpea, pigeonpea and groundnut (in slopes) were supplied on request, from NARS, BRC partners, and peer scientists at ICRISAT. Further, ten units of carrier based and 4 slopes of entomopathogens (*Bacillus subtilis* [BCB 19] and *Metarhizium anisopliae* in particular), and 15 units of carrier based bacterial isolates of multiple plant growth promotion traits (*Pseudomonas fluorescens*, *P. aeroginosa* [CDB 35] and one actinomycete [CDA 19]) were also supplied on request.

Special Project Funding:
Funded by National Bureau of Agriculturally Important Microorganisms and WWF.

OP Rupela and S Gopalkrishnan

MTP Project 3: Producing more and better food of the staple cereals and legumes of the west and Centra; African (WCA) SAT (sorghum, pearl millet and groundnut) through genetic improvement

Project Coordinator: **Eva Weltzien Rattunde**

Highlights for 2008

The crop improvement team in West-Africa was strengthened during 2008 by the recruitment of Dr. Falalou Hamidou, as Regional scientist in groundnut physiology, the secondement of CIRAD entomologist, Dr. Alain Ratnadass to ICRISAT- Niamey and the CIRAD Sorghum breeder, Kirsten vom Brocke, to ICRISAT-Bamako, the transfer of Dr. Farid Waliyar as Regional Director and Plant Pathologist to the West-Africa region, the recruitment of Dr. Tom van Mourik as Regional Scientist (Agronomy) after his assignment as Associate Professional Officer ended.
The project achieved two major regional milestones:

1. The proceedings of the regional training program and workshop on hybrid breeding of Sorghum and Pearl millet in West Africa, in collaboration with CORAF, University of Hohenheim and INTSORMIL, and a participant from Pioneer –International Seed company. Pearl millet and sorghum breeders from Nigeria, Niger, Ghana, Burkina Faso, Mali and Senegal participated and contributed to the proceedings, based on their experiences with the evaluations of experiments with sets of factorial crosses among different groups of pearl millet populations, or through the evaluation of regional sorghum trials and nurseries. The team is thus making rapid progress towards the identification of heterotic groupings of pearl millet and sorghum breeding material and germplasm that are practical and relevant for effective hybrid breeding in the region. With support from the Genetic Marker Facilities in Nairobi (BECA) and at Patancheru, India we have also achieved the marker analysis for genetic diversity, and differentiation among a representative subset of regional germplasm and breeding materials for both crops.

2. The proceedings of a regional colloquium on the use of regional agricultural diversity for locally effective crop improvement, conducted in collaboration with CIRAD, IER, AMEDD, INERA and Bioversity was produced in collaboration with CIRAD. These proceedings provide the opportunity to take stock of the previous years of sorghum focused research at IER, ICRISAT and CIRAD on issues related to the local management of genetic diversity, seed system assessment and development, as well as participatory methods for variety development and evaluation. The proceedings also document contributions from non-project scientists from the region, and as well as a summary of the lively fora for discussion with a wide range of stakeholders of sorghum genetic diversity management in West Africa, including farmer organizations, seed producers and local development practitioners.

Major outcomes of these projects were related to increased production and marketing of seed of sorghum, pearl millet and groundnut of the project, as well as other crops, primarily by local farmer associations and seed cooperatives. It appears that one reason for the increased sale of seeds was farmers' decision to increase significantly the area planted to sorghum pearl millet and groundnut. In Mali the area under cotton was tremendously reduced in 2008, and farmers have increasingly invested in groundnut and cereals also as a source of income, possibly in view of the high prices resulting from the food crisis of the past 12 months.

Another outcome is that NGO partners involved in agricultural development projects increasingly include components for farmer training in variety testing, seed production, and improved crop management into their project proposals. Regularly ICRISAT scientists are invited to present training courses to farmers, project personnel and extension workers on approaches to facilitate improvements in farm productivity, food security as well as income generation.

In addition we are starting to observe the first outcomes in terms of child nutrition. Women trained in the use of soybean and cereal malts have in all cases formed village level organizations, and it appears that most of these groups continue to interact and use the new techniques for the preparation of weaning foods. These initiatives will need to be monitored, and possibly supported in a targeted manner for achieving sustainable improvements.

Achievements in 2008

Output 1: Heterotic relationships identified within sorghum and pearl millet germplasm adapted to WCA conditions and appropriate broad-based breeding populations and hybrid parents and knowledge made available to NARS and other partners in order to maximise genetic gain from selection

Output Target 2008 3.1.1 Enhanced access and capacity development of NARS to new, characterized diversity of sorghum and millet germplasm in adapted backgrounds

Achievement of Output Target (%):
100%

NARS partners in five countries have been involved in multi-location characterization of a total of 424 pearl millet landrace accessions and breeding materials from all over WCA, divided into three maturity groups: extra-early, early to medium and late maturing materials targeting the Northern Sahelian, Southern Sahelian, and Soudanean zones, respectively. Superior accessions selected from 2006 and 2007 trials have been tested for a third year to derive information about yield stability and genotype × environment interaction patterns, and to identify most stable and adapted entries for variety development and release. Characterization data will be included in the ICRIS database in 2009.

A regional initiative for enhancing access to sorghum germplasm was implemented by enabling NARS at 21 sites in five countries in WCA to obtain and characterize geographically diverse sorghum germplasm as replicated initial observation trials. The capacity for evaluating the genetic diversity was strengthened by including farmers' assessments of panicle-, grain-, and overall-appreciation to complement traditional agronomic observations and training of NARS partners for statistical analysis of multi-environment trial data.

Countries Involved:
Burkina Faso; Ghana; Mali; Niger; Nigeria; Senegal

Partners Involved:
IER, INERA, SARI, IAR, LCRI, CBARDP, INRAN, ISRA, University of Hohenheim

Progress/Results:
Sorghum germplasm observation trials for the drier Northern Sudanian zone were conducted at 6 and 9 sites in 2007 and 2008, and similarly for the Southern Sudanian/Northern Guinean zones in 9 and 12 sites, respectively. Two Regional Germplasm Sets were prepared and dispatched, one of 55 accessions of intermediate to early maturity for 9 sites of the drier Northern-Sudanian zone (Mali, Burkina Faso, Ghana, Niger and Nigeria), and the second of 80 accessions for 10 sites in the wetter Southern-Sudanian/Northern-Guinea zone (Mali, Burkina Faso, Ghana, Niger, Nigeria). The number of accessions was increased in 2008 by 50% over 2007, with varieties from Nigeria (34), Ghana (24), Burkina Faso (8), Mali (12) and two local checks).

These evaluations have led to identification of certain accessions for direct use, such as Ribdahu with midge resistance, or as parents for pedigree breeding or hybrid development (Beninga Zabilla, Berko Manga, Nwagu, Yashemori, Yalfalgori, Zabuwa, Shuka, CGM 19/9-1-1, KL1).

Pearl millet: In 2008, 49 elite early to medium pearl millet accessions selected from trials conducted in 2006 (360 entries) and 2007 (72 entries), and originating from eight different WCA countries have been evaluated for the third year in a total of 7 sites (including one low-input site). Twenty-four (24) extra early accessions or population crosses selected as superior from 2007 trials have been tested for the 2nd year in the Northern Sahel. And 24 superior late accessions (selected out of 64 tested in 2006 and 32 tested in 2007) have been re-evaluated for the 3rd year at four locations in the Sudanian zone. In each country, promising entries have been identified as new experimental cultivars or breeding populations for recurrent selection. Another set of 32 highly diverse cultivars was tested at 4 sites across a climatic gradient in Niger, Burkina Faso, Mali and Ghana to derive information about the materials adaptability to variable climates. Two students from the region were trained at Master level to characterize and understand pearl millet diversity. All partners highly appreciated the enhanced access to pearl millet genetic diversity.

Although we have enabled greater regional access to germplasm with involvement of all major pearl millet and sorghum NARS Programs, a continued exchange of germplasm is necessary. The future germplasm exchanges will focus on gathering more diversity of specifically interesting types of germplasm discovered during this round of experimentation, and the exchange of breeding materials created by suing the germplasm in new crosses, or populations. Key experiences and lessons learned that will be vital for enhancing future genetic-base broadening for NARS sorghum programs include:

- Stronger linkages between evaluation of diversity and germplasm utilization are needed, particularly designing characterization work to address specific traits or breeding objectives.
- There is need to enhance NARS' capacity to efficiently use the discovered diversity in cultivar development and delivery, i.e., to strengthen the application of recurrent full-sib selection cycles to further improve promising pearl millet populations; and to enable off-season seed production of best entries in each country for enhanced on-farm testing activities in the following year, which would require the development of irrigation facilities.
- Effective targeting of germplasm must extend beyond consideration of rainfall isohytes to include major soil types (sandy- versus heavier-soils) and biotic constraints (for example sorghum midge pressures in the triangle Fada N'Gourma, Burkina Faso east to Maradi, Niger, and south through Kebbi State Nigeria and Upper East Ghana, and stem borer pressure in Zamfara and Kaduna states, Nigeria).
- Dedicated efforts to enhance access to wider diversity of germplasm for NARS are highly appropriate in WCA as the region possesses such rich genetic diversity but germplasm from other countries or zones has not been readily accessed by researchers in the past, and the opportunity to enlarge the germplasm base of NARS breeding programs is highly appreciated and provides high long-term impact.

BIG Hausmann, F Rattunde and E Weltzien

Special Project Funding:
IFAD TAG Promiso project for regional sorghum and pearl millet germplasm trials
BMZ "Mobilizing regional diversity..."; BMZ - CODE-WA
McKnight for statistical training

Output Target 2008 3.1.2 Guinea race sorghum hybrid parents made available to NARS and PS breeders for developing hybrid cultivars

Achievement of Output Target (%):
100% (Sorghum)

To facilitate production of experimental hybrids by NARS a total of 8 sets of hybrid parent sets were prepared and dispatched to NARS in five countries. Descriptions of the male parents and suggested sowing plans were also provided. This provision of hybrid parents and supporting information enabled NARS to produce a significant number of experimental hybrids.

Countries Involved:
Burkina Faso, Mali, Senegal, Ghana, Nigeria

Partners Involved:
INERA, IER, ISRA, SARI, IAR

Progress/Results:
The sets of hybrid parents provided to NARS and the number of experimental hybrids produced in the crossing blocks established with these parents and additional local germplasm are summarized in the two Tables below.

Hybrid Parents provided to NARS in five countries of WCA for hybrid crossing blocks

SARI (Tamale Ghana), IAR (Kano and Samaru Nigeria)	INERA (FarakoBa and Saria Burkina Faso) ISRA (Bambey Senegal)	IER (Cinzana Mali	IER (Sotuba Mali)
Male Parents			
Bahu Banza(3)	GPN01 267-9-1	GPN01 267-9-1	CSM-63E
Gizo(15)	Bibalaweli Tioribougou	Bibalaweli Tioribougou	CSM-388
Yarshemori(25)	Kenikeje	Kenikeje	SEGUETANA Cz 24/25
Yarfalgori(23)	IS 27564bf	IS 27564bf	IS 6731
Sambalma(4)	IS6745bf	IS6745bf	GPN01 S01 267-9-3-3v
Fara-fara(12)	Kapelga	Kapelga	CGM-19/9-1-1
Sambalma(1)	Sariasso10	Sariasso10	
Jardawa(9)	Sariasso14	Sariasso14	
Fara(22)	S1-4	S1-4	
Jardawa(21)	B2-1	B2-1	
Zabuwa(17)	Pougyalmbangdo	Pougyalmbangdo	
El-Yarba Zangu(7)	S35	S35	
Mace da Kunya(11)		00-KO-F5DT-19	
IS7509		02-SB-F4DT-298	
IS14732		02-SB-F5DT-189	
IS30804		02-SB-F5DT-169	
IS15629		CSM63E	
CSM485		Seguetana	
DIO-I			
IS 26320			
Buhu Banza			
Male-Sterile Female Parents			
FambeA	ICS38A	02-PR3009A	FambeA
GP271-20A	FambeA	02 SB-F5DT-12A	GP271-20A
IS3534A	GP99 271-20A	ICS38A	
ICS38A		97 SB-F5DT-150A	
97 SB-F5DT-150A		FambeA	

Number of experimental hybrids produced by WCA NARS from hybrid parent nurseries, 2007

Institute	Location	Country	Number of Experimental Hybrids Created in 2007
IER	Cinzana	Mali	33
IER	Sotuba	Mali	approx. 100
SARI	Tamale	Ghana	60
IAR	Kano	Nigeria	23
IAR	Samaru	Nigeria	99
INERA	Saria	Burkina Faso	36

BIG Hausmann, F Rattunde and E Weltzien

Special Project Funding:
USAID funded West African Sorghum Research Network (prior to 2008)

Output Target 2009 3.1.1 Initial heterotic groupings for sorghum and pearl millet hybrid breeding for WCA established and published

Achievement of Output Target (%):
50% (Sorghum); 75% (Pearl millet)

Molecular marker diversity assessments of sets of approximately 200 sorghum and millet germplasm accessions pertinent for hybrid breeding in WCA have been conducted. Further analysis and interpretation of these results is necessary. Assessments of combining ability are progressing through evaluation of diallel and factorial population crosses in pearl millet and a structured set of putative intra- and inter-pool sorghum hybrids with parents of Guinea-race, Guinea/Caudatum inter-racial, or caudatum parentage

Countries Involved:
Burkina Faso; Mali; Niger; Nigeria; Senegal

Partners Involved:
ISRA, IER, INERA, INRAN, LCRI, IAR, University of Hohenheim

Progress/Results:
The identification of groups of breeding material thath express heteorsis when crossed with each other is being pursued in WCA for sorghum and pearl millet using both marker information, as well as combining ability data, derived from crossing materials of diverse genetic origins, or with divergent characteristics. With genetic markers, easily a large set of materials cam be characterized for its diversity, and thus groups of similar materials can be established, that are relatively distant from each other. The actual heterosis between, and also within these groups can then be tested by evaluating crosses between materials representing different groups. In sorghum this step is more complicated, as crosses can only be made once male-sterile lines are available from the groups in question.

Sorghum: The second year of combining-ability evaluations were conducted at four environments in Mali with 70 entries, four replicate trials at Sotuba,-IER, Cinzana-IER, Samanko Low-P and Samanko High-P at ICRISAT.

Pearl millet: SSR marker diversity differentiated a set of about 200 accessions largely according to geographic origin. Genetically distinct materials were found especially between accessions from Senegal versus Niger and Nigeria, while accessions from Mali and Burkina Faso lied in between these two clusters. Results from the 2006 factorial and the 2007 diallel crosses evaluations confirmed outstanding performance of certain, putative inter-pool crosses between landraces from Senegal and Niger. But hybrid superiority also depended on the particular parental combination. Also there seems to be an optimal genetic distance between the parental populations beyond which performance/adaptation of the population hybrid goes down. For example, crosses of West African materials with a genetically distinct landrace from Sudan revealed lower hybrid performance and partially lack of adaptation. In 2008, another 5 sets (4 early to medium, one late maturing) of 5x5 factorial crosses, representing putative inter- and intra-pool crosses were evaluated in multi-location trials to further validate heterotic groups. For all 50 parental populations involved in these crosses, SSR marker data are available so that pairwise genetic distances can be computed and correlated with the hybrid vigor. Data collection for these trials is still underway.

BIG Haussmann, F Rattunde, CT Hash and E Weltzien

Special Project Funding:
BMZ Mobilizing Regional Diversity…
Rockefeller Foundation Sorghum Hybrids for WCA

Output Target 2010 3.1.1 Ten new pearl millet and sorghum inbred lines with good combining ability and quantitative trait characterization made available to partners with associated capacity development for developing hybrid cultivars

Achievement of Output Target (%):
25% (Sorghum); 50% (pearl millet)

Ca 150 West African inbred lines in S6 developed at ICRISAT-Niger will be tested for combining ability in 2009 to identify and multiply the best.

Sorghum: Structured combining ability trials have been initiated to assess combining ability of twelve male- and five female-parents. Initial Hybrid Observation Nurseries are being conducted to identify restorer and maintainer lines that warrant further study.

Countries Involved:
Burkina Faso; Ghana; Mali; Niger; Nigeria; Senegal

Partners Involved:
IER, IAR, INERA, LCRI, INRAN, ISRA, SARI

Progress/Results:
Sorghum: Analysis of the 2007 combining ability trial indicated that GPN01 S01 267-9-3-3v "Lata 3 (Balla Berthe)" , a restorer line derived from the Dwarf Guinea Population, had consistently high combining ability over a range of environmental conditions.

Pearl millet: More than 150 inbred lines had been successfully advanced at ICRISAT-Niger to S6 in the offseason (planting end of January 2008) and will be crossed to three testers (2 populations, 1 male sterile line) in the off-season 2008/09. Generally, it can be noted that the genetic load of West African landraces (that have never been inbred before) is quite high, resulting in severe inbreeding depression and loss of 30 to 40% of the initial lines with increasing inbreeding generation. To avoid these losses, we tried to do sibbing within each inbred line but this was not always feasible due to lack of enough plants to do the sibbing.

BIG Hausmann, F Rattunde and E Weltzien
Special Project Funding:
BMZ Mobilizing Regional Diversity

Output Target 2011 3.1.1 Two superior pearl millet topcross hybrids and 6 guinea hybrids for at least two countries in West Africa identified, release relevant information as well as parental seed made available to partners

Achievement of Output Target (%):
25% (Sorghum); 25% (pearl millet)

Pearl millet: Inbred lines in S6 available at ICRISAT-Niger and landrace populations with high GCA identified in each partner country

Sorghum: Yield testing of experimental hybrids is being conducted with WCA NARS collaboration (Table) to identify the first series of commercially viable hybrids. The hybrid "Fadda" (97 SB F5DT-12A x GPN01 S01 267-9-3-3v) has been submitted for registration in Mali.

Countries Involved:
Burkina Faso; Ghana; Mali; Niger; Nigeria; Senegal

Partners Involved:
IER, IAR, LCRI, INERA, INRAN, ISRA, SARI

Progress/Results:
Sorghum: Two replicate Initial Hybrid Observation Nurseries with more than 100 hybrids were prepared in 2008, composed of hybrids produced by ICRISAT, IER, INERA and IAR. These nurseries were provided to NARS in six countries (9 sites) for identification of promising hybrids that warrant further evaluation. Collaborative Regional Hybrid Yield Trials are being conducted to identify commercially viable hybrids for each of the three major agro-ecological zones in WCA.

Number of Sorghum Hybrids undergoing yield testing by WCA NARS 2005-2008

Zone	N. Sudanian		S. Sudanian					Guinean
Year	Bambey Senegal	Saria Burkina Faso	Bengou Niger	Samanko 1st Date Mali	Samanko 2nd Date Mali	Sotuba Mali	Sinthiou Senegal	Samaru Nigeria
2005	8	24	41	66	82	48	20	8
2006	12	12	16	18	55	55	16	18
2007	15	15	20	20	30	25	20	35
2008	0	28	0	34	34	28	28	28

Pearl millet: Inbred line development in WCA genetic background is underway at ICRISAT-Niger; S6 lines are currently available in low seed quantities. Good general combiners in the female genepool still need to be converted into male sterile versions. Good restorer genotypes still need to be identified or developed in the male pool. Fifty (50) WCA landrace populations have been characterized for general combining ability (GCA) in 2008 ; including previous trials conducted in 2006 and 2007, combining ability information is now available for around 100 landrace populations (= potential hybrid parents).

Yield potential of hybrids and reduced height OPVs of sorghum. Relationships with plant density and yield components.
In 2007, 3 trials with 3 hybrids and 2 OPVs at 3 plant densities (67, 133 and 200 000 pl/ha) with 3 reps have been planted together with IER in 3 locations (Samanko, Cinzana and Sotuba), under high fertilization rate. The average grain yields have been high in Samanko and Cinzana (3.3 and 3.8 t/ha) and low in Sotuba (1.1 t/ha) with no significant effect of the plant density neither of the variety except in Samanko where the grain yields of the varieties has been related with their flowering date so no effect of density there either.

Relationship between the sowing date and the development and growth of one hybrid and one landrace of sorghum
The landrace CSM 335 and the hybrid Fambe x CSM 388 have been tested in a trial in Samanko with 2 sowing dates, 5 June and 3 July, of and 3 reps under high fertilization rate. The soil water potential was daily recorded every 25 cm until 2m in one plot of the hybrid sown in July. The average grain yields have been only 1.0 and 1.2 t/ha without any significant difference, for the June and July sowings, respectively. These low grain yields have been caused by the low water reserve accessible to roots since it appeared after this experiment that the arable soil depth in the plot was only 1m, as there is a layer of impermeable clay underneath. Panicles of the plants sown in July had a significant larger number of branches than for the June sowing.

F Rattunde, B Clerget, BIG Hausmann and E Weltzien

Special Project Funding:
BMZ “Mobilizing Regional Diversity, ...”; McKnight Foundation participatory pearl millet improvement

Output 3.2: Improved methodologies developed for integrating breeding of groundnut, sorghum and pearl millet populations and varieties with crop management strategies to overcome key environmental and socio- economic constraints and making them available with new knowledge to partners

Output Target 2008 3.2.1 At least two diversified dwarf Guinea-race sorghum populations and broad based pearl millet populations with farmer preferred traits made available with associated capacity development to partners for the first time for at least two different SAT agro-ecologies in WCA (partly associated with SLP SWEP).

Achievement of Output Target (%):
100%

Twelve diversified pearl millet populations targeting the Southern Sahel and two populations targeting the Northern Sahel available and improved by one cycle of recurrent population improvement. Two broad-based dwarf sorghum populations with Guinea-race grain and glume characteristics were created. These populations have been provided to the NARS in Mali and Burkina Faso for use as source materials for deriving novel dwarf varieties and further population improvement.

Countries Involved:
Burkina Faso; Mali; Niger; Nigeria; Senegal

Partners Involved:
ISRA, IER, IAR, INERA, INRAN, LCRI

Progress/Results:
In 2006 a specifically targeted training course for pearl millet and sorghum breeders from the region was conducted on methods for recurrent selection, and options for sharing responsibilities among different partners. Theoretical training for scientists and research technicians was included in the annual cereal breeders’ meetings held during the past three years. In addition field visits and the ensuing discussion helped to discuss specific methodological issues, and clarify key points for future collaboration.

Superior pearl millet population crosses identified by ICRISAT and partners in 2006 have been recombined in 2007 and undergone one cycle of recurrent population improvement in 2008, targeting the Southern Sahelian (N=12 populations) and the Northern Sahelian (N=2 populations) zones. The recurrent population improvement was partially done on-station, partially on-farm with farmer participation. In 2008, another 125 new population crosses (=potential diversified populations) were evaluated together with partners in Senegal, Mali, Burkina Faso, Niger and Nigeria

Sorghum: Two dwarf Guinea-race sorghum broad-based populations were created. The "Dwarf Guinea Population C2", produced by recombining 20 superior lines selected from multi-environment progeny testing for grain yield, provides source material for higher grain yield with desirable Guinea-race grain and glume characteristics. The "Diversified Dwarf Population" was produced by crossing the 20 superior lines from the first cycle of the Dwarf-Guinea Population with 14 Guinea-Caudatum inter-racial pedigree lines from IER. This second population provides source material with greater diversity for panicle and peduncle length, and increased variability dwarfing genes with a high frequency of stem internode lengths less than 10cm. The respective crosses were conducted in 2006 rainy- season, the F1s sown in the 2006-07 off-season, the F2 bulks sown in the 2007 rain-season, and the Dwarf-Guinea C2 and Diversified Dwarf broad-base populations were constituted in 2008 from a total of 57 and 248 dwarf sterile plants, respectively.

Analysis of the Dwarf Guinea Population F1s and Diversified Guinea Population F1s show that the grain yield of the new populations is equal or superior to that the best dwarf check varieties currently available (Tables below). A set of four new genetically narrower-based dwarf populations were created in 2008 by bulking four to five selected F2 bulks from the superior Dwarf Guinea Population F1s (ICSP 0710 "Fati" and ICSP 0706 "Roni") and the Diversified Dwarf Population F1s (ICSP 0709 "Fatido" and ICSP 0707 "Ronido"), using replicated yield trial results of F1 performances and applying greater selection pressure for dwarf (reduced stem internode) plant type (Fatido and Fati) versus relaxed selection pressure for internode length but higher pressure for grain yield (Ronido and Roni). Progeny based (S1) selection has been initiated in the broad based populations as well as the four narrower based populations for deriving lines for variety development, and for continued population improvement in the broad based populations.

Mean and range of yield and plant heights for Dwarf Guinea Population cross F1s and check dwarf varieties, 2007 Samanko

		Plant Height (cm)			Panicle Yield (g/m2)		
	No. of entries	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Population F1 crosses	37	239	283	323	259	304	336
Dwarf Check Varieties	4	236	259	289	235	260	276

Entry Mean std error Plant Height (11), Panicle yield (24)

Mean and range of yield and plant heights for Diversified Guinea Population F1s, Samanko 2007

		Plant Height (cm)			Grain Yield (g/m2)		
	No. of entries	Minimum	Mean	Maximum	Minimum	Mean	Maximum
Population F1 crosses	35	247	298	337	204	303	364
Dwarf Check Varieties	3	170	226	287	173	203	369

Entry Mean std error Plant Height (13), Grain yield (23)

F Rattunde, BIG Hausmann and E Weltzien

Special Project Funding:
McKnight Dynamic Gene Pool, BMZ "Mobilizing regional diversity..."; IFAD – PROMISO;

Output Target 2008 3.2.2 Tools for effective integrated Striga management for different agro- ecologies made available to partners in at least two countries.

Achievement of Output Target (%):
100%
Training workshops have been given to scientists, technicians, and lead farmers in Mali and Nigeria in order to effectively install, manage and evaluate CBFFS (Cluster-based Farmer Field Schools) on ISM. A guide and field book to streamline the approach and data collection has been made available in French and English to partners in Mali and Nigeria.

Countries Involved:
Mali; Nigeria; Niger

Partners Involved:
Institut d'Economie Rurale (IER), Cinzana, Mali
Institute for Agricultural Research (IAR), Zaria, Nigeria
Lake Chad Research Institute (LCRI), Maiduguri, Nigeria
Institut National de Recherches Agronomiques du Niger (INRAN), Niamey, Niger
Community Based Agricultural and Rural Development Programme (CBARDP), Katsina, Nigeria
Union des Agriculteurs de Cercle de Tominian (UACT), Tominian, Mali

Progress/Results:
In 2006, 2 CBFFS (Cluster-based Farmer Field Schools) have been installed in 12 villages in the Mopti region in Mali in 2006 and were run for 2 consecutive years. In 2007, 2 more CBFFS were installed in Segou region in Mali and 12 more CBFFS were installed in Kebbi, Zamfara, Katsina, Sokoto, Jigawa, Borno and Yobe state in Nigeria. The CBFFS activities were scaled up from 12 Training of trainer (TOT) sites with 195 farmer trainers, 39 secondary sites with 585 farmer participants in 2007 to 21 TOT sites with 365 farmer trainers, 73 secondary sites with 1095 farmer participants in 2008 in Nigeria. In Mali, activities were scaled up from 2 TOT sites with 30 farmer trainers, 6 secondary sites with 120 farmer participants in 2007 to 4 TOT sites with 75 farmer trainers, 15 secondary sites with 300 farmer participants in 2008. Currently, agronomic (Striga reduction and yield components of crops) and economic data are being gathered from all sites. Results are promising especially in the millet based cropping systems in Mali and Nigeria. The combination of micro-dosing NPK or DAP (at 30-60kg/ha), Urea (at 30 kg/ha) to millet, intercropping groundnut or cowpea with millet, increased crop density, and pulling of *Striga* plants by hand at 70-90 DAS reduces *Striga* plant and seed density considerably and increases yield of millet and the intercrop as well as revenues. Sorghum cropping systems in Nigeria showed more variability in the effectiveness of the ISM strategy for two reasons. First, the sorghum variety used was an improved variety that was not always adapted to the environment and not always *Striga* resistant. Second, the sorghum based systems already have a higher degree of intensification (i.e. farmer practices are often giving higher doses of fertilizer and systems include intercrops and/or relay crops with sorghum, millet, groundnut and cowpea). It is more difficult to optimize these systems in terms of *Striga* control and yield. When considering agronomic (*Striga* reduction and yield) and economic performance of ISSFM (Integrated *Striga* and Soil Fertility Management) in comparison to farmer practice, improvements are more often obtained when changing from pure cereal based cropping to intercropping of cereal and a legume (cowpea and/or groundnut). Very encouraging results were obtained in Yobe state in 2007, where the number of CBFFS increased from 1 to 8 and the number of trials from 7 to 41. The micro-dosing technique was adapted (mixing millet seeds with fertilizer) so that it could be used for dry sowing, a common practice of farmers in the region. Results were also highly promising in Mali and the number of CBFFS has also doubled.

A *Striga* seed bank population model for forecasting *Striga* seed bank development under different cropping regimes has been developed and made available to the scientific public (see publication). This model can be used by others to forecast *Striga* seed bank development, providing they have estimated a number of *Striga* population parameters in experiments.

Three years of on-station trials on effectiveness of single and combined control options for *Striga* have been executed successfully in Mali and Niger in 2006, 2007 and 2008. Data is currently being analyzed and a manuscript is drafted with data from Mali. These data will be used in the *Striga* seed bank population model to forecast the effects of single and combined control options on the long term (>15 years).

Striga soil seed densities and field histories have been determined in over 40 fields throughout Mali. This data will allow for analyses of factors and agronomic practices that (de)favor increased *Striga* population densities and will provide insight into the agro-ecology of the parasite. Furthermore, interviews and interventions have shown that there are three potential reasons for persistence of *Striga* infestations in farmers' fields. First, the control options that exist for *Striga* are rarely 100% efficient and so farmers who apply one control option often do not succeed in reducing the parasite. Second, the options that are available are not always affordable or feasible for farmers (such as high fertilizer doses and laborious, extensive late weeding). Third, farmers often are not aware of (1) *Striga* biology and reproduction, (2) the wide variety of available control options and their effect on *Striga* and the host and (3) the concept of integrated *Striga* and soil fertility management. There is a need for research into which of these three components is limiting *Striga* control in different agro-ecological and socio-economical regions in order to efficiently disseminate large scale ISM and tackle the *Striga* problem in West Africa. It is also necessary to develop a strategy and methods to cost-effectively up-scale from CBFFS to a whole region, as the CBFFS approach is a good initial tool for participatory research and dissemination of technologies, but not applicable on a very large scale.

Number of Training of trainers (TOT) and Farmer Field School (FFS) trials, trainer farmers and participating farmers conducting experimentation in Mali and Nigeria in 2008.

Country	State / Region	TOT 2007	FFS 2007	Trainer farmers 2007	Participant farmers 2007	TOT 2008	FFS 2008	Trainer farmers 2008	Participant farmers 2008
Nigeria	Kebbi	3	12	60	180	4	12	60	180
Nigeria	Katsina	2	12	60	180	3	12	60	180
Nigeria	Zamfara	2	3	15	45	2	6	30	90
Nigeria	Sokoto	2	1	5	15	2	4	20	60
Nigeria	Yobe	1	6	30	90	8	33	165	495
Nigeria	Borno	1	3	15	45	0	0	0	0
Nigeria	Jigawa	1	2	10	30	2	6	30	90
Mali	Segou	2	6	30	120	4	15	75	300
Total		**14**	**45**	**225**	**705**	**25**	**88**	**440**	**1395**

Tom van Mourik

Special Project Funding:
IFAD-PROMISO

Output Target 2009 3.2.1 First availability of allele-specific molecular markers for genes controlling photoperiod sensitivity of flowering time in pearl millet and sorghum

Achievement of Output Target (%):
75%

The following components of the association study have been completed: Phenotyping of photoperiodic response in WCA sorghum and pearl millet germplasm samples; SSR diversity analysis to understand population structure; Sequencing of six candidate genes in sorghum and four candidate genes in pearl millet for the complete sets of accessions. Final data analysis and publication are underway.

Countries Involved:
No NARS, but genetic materials from all over WCA

Partners Involved:
ICRISAT-Niger and Mali , University of Hohenheim

Progress/Results:
For pearl millet, results from both phenotyping photoperiodic response of 200 WCA inbred lines (≥S4 generation) using two planting dates and analysis of the inherent population structure were summarized in the M.Sc. thesis of Raj Kishore Pasam, entitled "Evaluation of photoperiodic response and characterization of population structure of pearl millet germplasm from West and Central Africa". Fifty-seven percent (57%) of the inbred lines showed photoperiod-sensitive flowering with the extent of photo-sensitive reaction varying in a quantitative manner and showing a large range of values for the photoperiod response index (PRI). Strong photoperiod-sensitive flowering was correlated to late flowering in the first planting, confirming previous results obtained with the parental populations of the inbred lines. Genotyping of the 200 inbred lines with 22 SSR markers detected 347 alleles, with an average of 16 alleles per locus. The selected markers were proven to be highly informative, i.e., showing Polymorphic Information Content (PIC) values between 0.44 and 0.92 (mean PIC = 0.70). The inbreeding coefficients obtained for the various markers ranged from 0.88 to 1.0 (mean f=0.95) and the values for the observed heterozygosity from 0 to 0.07 (mean Ho = 0.04), thereby confirming the high degree of homozygosity, but also the remnant heterozygosity of the examined ≥S4 lines. There was high diversity among the inbred lines across WCA and also within their countries of origin. Principle Coordinate analysis of 173 inbred lines based on a simple matching dissimilarity matrix derived from allelic data of 22 SSR loci was performed. The *ad hoc* criterion described to estimate the number of subpopulations as five (k=5). There was no clear grouping obvious in the germplasm. The first axis explained 4.64 % of the variance, and second axis explained 4.34 % of the variance amounting to total of 8.98 % of total variance. The differentiation of the materials appears to be linked to the geographic distance of the origin of the materials. Further analysis of this data is required.

In sorghum, about 88% of the inbred lines showed photoperiod-sensitive flowering to a variable extent, with 68% of the lines being classified as highly photoperiod sensitive (PRI classes 4 and 5). The number of accessions which were mildly photoperiod sensitive or insensitive was lower in sorghum compared to the tested set of pearl millet lines. Genotyping of 219 sorghum inbred lines with 27 SSR markers detected 523 alleles, with an average of 19 alleles per locus. PIC values ranged from 0.13 to 0.94 (mean PIC = 0.70). The model-based approach of STRUCTURE subdivided the sorghum panel into two subgroups consisting of 64 and 109 individuals. 46 accessions had for both subgroups membership probabilities of less than 0.80, and, thus were assigned to a mixed group. The *ad hoc* criterion to estimate the number of subpopulations was two (k=2).

Six candidate genes for sorghum [PhytochromeA (PhyA), Early flowering3 (Elf3), Heading date 6 (Hd6), Crytochrome1 (Cry1), Crytochrome2 (Cry2), GIGANTEA (GI)] and four candidate genes for pearl millet [PhyA, PhyB, PhyC, Dwarf 8 (D8-3)] have been sequenced for the complete set of accessions. The number of detected single nucleotid polymorphisms (SNPs) ranged from 2 (Hd6) to 84 (Elf3) in sorghum, and from 1 (PhyC) to 40 (Phy A) in pearl millet. In additions to these genes, Phytochrome B (PhyB) and Dwarf 8 (D8) are currently sequenced for the complete set of sorghum. Our next goal is to identify Heading date 1 (Hd1) and Heading date 3a (Hd3a) in sorghum and pearl millet. Final association mapping still needs to be done.

A model-based cluster analysis assigned the inbred lines to five distinct groups based on their inferred ancestry with 41% of the accessions being identified as admixtures.

Multi-latitudinal trials with sorghum varieties were conducted from the equator to temperate latitudes with sorghum varieties characterized previously at one latitude only. 10 varieties from Kenya, Tanzania, Mozambique, Mali and Burkina Faso have been sown monthly in Samanko (Mali) from November 2006 to November 2008, Kiboko (Kenya) from July 2007 to June 2008 and in Mozambique from January to December 2008.

Characterization of the development and yield of a collection of photoperiod sensitive sorghums
A collection of sorghum 32 varieties coming from Northern Nigeria (16) and a BMZ genotyping project (16), plus 6 reference varieties have been cultivated in α-desing lattices with 3 reps in 3 locations (Samanko, Cinzana and Bougouni). Sowing dates have been very close but the dates of flag-leaf exertion and flowering have been later in Cinzana and Bougouni than in Samanko, in spite of the very close daily mean temperatures in the 3 locations. For each variety, the total number of leaves has been greater in Cinzana than in Samanko, which is in agreement with the longer vegetative phase observed in Cinzana. On the contrary, the total number of leaves has been lower in Bougouni than in Samanko, which disagrees with the longer vegetative phase observed but is coherent with the longer phyllochron recorded (see below). For each variety, initial phyllochrons have been similar in Samanko and Cinzana but longer in Bougouni, probably in relationship with the low soil fertility which has delayed the onset of the plant development by about 15 days. Secondary phyllochrons of late varieties have been significantly different between varieties in the 3 locations and positively correlated with duration of the vegetative phase. For each variety, secondary phyllochrons have been longer in Cinzana than in Samanko.

Yield potential of the early photoperiod sensitive landrace derivative: CSM 63E
This sorghum variety has been cultivated at 4 plant densities (67, 133, 200 and 267 000 pl/ha) and 2 sowing dates distant by a 2 weeks at 3 reps in 2 locations (Samanko and Cinzana) under a high fertilization rate. The average grain yield has been much higher in Cinzana (3.2 t/ha) than in Samanko (1.6 t/ha) with a significant effect of the sowing date but not of the plant density. Flowering dates have been delayed by 6 days in Cinzana compared with Samanko for sowings done on 16 and 17 July and by 3 days for the 1-2 August sowings. Consequently at 67 000 pl/ha the total number of leaves on the main stem has been 16.4±0.6 in Samanko against 19.2±0.4 in Cinzana. This difference of 3 leaves has induced a difference of about 1:2 of the leaf area indexes (LAI) and of the photosynthetic capacity at flowering date between both locations.

BIG Hausmann, F Rattunde, B Clerget, M Mgonja, E Weltzien, C Hash and P Ramu

Special Project Funding:
BMZ "Mobilizing regional diversity..." ; The Eiselen Foundation , IFAD - PROMISO

Output Target 2009 3.2.2 One new genepool of pearl millet with reduced *Striga* susceptibility available for testing in West African breeding programs

Achievement of Output Target (%):
75%

Third cycle of recurrent full-sib and S1 selection for reduced Striga emergence and high panicle yield completed in a pearl millet diversified, trait-specific population; extraction of two experimental cultivars (one short panicle, one long panicle) from the genepool underway in off-season 2008/09.

Countries Involved:
Mali; Niger

Partners Involved:
ICRISAT-Niger, IER, Wageningen University

Progress/Results:
A third cycle of recurrent full-sib and S1 selection for below-average Striga emergence and above-average head yield was successfully undertaken in 2008. The full-sib families were evaluated under field conditions in Sadore, Niger (N=210) and Cinzana, Mali (N=78), the S1s (N=100) only in Niger. 2008 was an excellent Striga year in Niger, while Striga emergence was less strong in Mali, partially due to late planting. In the full-sib trial conducted at Sadore, the mean number of emerged striga/m² (averaged across three striga counts) amounted to 10, with a range from 0 to 81 for individual entries, and a repeatability of the plot values of 65%. Selection was done according to an index of below-average Striga emergence, above-average grain yield, and low downy mildew susceptibility. Two sets of 8 to 10 best full-sib families (5% selected fraction) with specific panicle characteristics were selected for creation of two new experimental cultivars (one shorter panicle, one longer panicle); the recombination of these entries is ongoing in the off-season 2008/09; the Striga resistance genepool improvement is being continued with lower selection intensity (60 best full-sib families = 30% selected fraction) for further enhancement of Striga resistance allele frequencies in 2009. The S1 trial and Malian data gained in 2008 still need to be analyzed. Effective gains from selection will be tested in 2009.

BIG Haussmann

Special Project Funding:
McKnight Participatory sorghum and pearl millet improvement project.

Output Target 2009 3.2.3 Knowledge of adaptation and initial regional adaptation maps for 5 sorghum and pearl millet varieties each made available and disseminated with associated capacity development to WCA partners

Achievement of Output Target (%):
50%

Pearl millet: data set on 49 WCA landrace accessions and experimental varieties evaluated across seven sites and three years will be complete with the data gained in the rainy season 2008, and will, in combination with the climatic data from the test sites, allow for an initial genotype × environment interaction-based adaptation mapping.

Sorghum: The regional germplasm trials as reported under output 3.1 will serve as the basis for mapping the adaptation of different groups of sorghum materials, especially of specific susceptibilities to biotic constraints, such a midge, headbugs or stemborers.

Countries Involved:
Burkina Faso; Mali; Niger; Nigeria; Senegal

Partners Involved:
ISRA, IER, INERA, INRAN, LCRI, University of Hohenheim

Progress/Results:
Genotype x environment interaction-based adaptation mapping requires evaluation of a set of diverse genotypes across several locations and years, to enable separation of genotype x location, genotype x year, and three-fold interactions, and to derive conclusions about potential specific adaptation to certain experimental sites and about yield stability of the entries. With the rainy season 2008, such a data set has been created for pearl millet: 49 entries evaluated across six sites (more precisely: 7 site/fertilizer treatment combinations) across 3 years (2006, 2007 and 2008). These data must now enter detailed analysis.

BIG Haussmann, F Rattunde, PS Traore, B Clerget and E Weltzien

Special Project Funding:
BMZ “Mobilizing regional diversity...”, BMZ-CODE-WA, IFAD- PROMISO

Output Target 2010 3.2.1 Tools for farmer participatory recurrent selection tested for pearl millet and sorghum with partners with associated capacity development in different agro- ecologies. (associated with PRGA SWEP)

Achievement of Output Target (%):
75%

For pearl millet different methods of farmer-participatory recurrent population improvement were used at a total of six contrasting sites in Niger and Mali in the rainy season 2008. The methods included: simple mass selection; mass selection with parental control; full-sib selection on-farm, and full-sib selection on-station. For sorghum farmers in 3 areas in Mali an d3 in Burkina Faso used 3 different methods for single plant selection in population bulks with different t structure. After a specific training course on participatory recurrent selection, partners started trying out different methods for recurrent selection. Annually during the activity planning meetings with national partners training sessions were conducted to address specific issues and areas on knowledge and experience. Courses on participatory breeding tools were conducted with new partner as well, During the joint field visits t farmers trials, as well as to research station trials, specific questions were addressed.

Countries Involved:
Burkina Faso; Mali; Niger

Partners Involved:
IER, INRAN, INERA, Fuma Gaskiya, Mooriben, German Agro Action

Progress/Results:
Pearl millet: up to three different methods of farmer-participatory recurrent population improvement were implemented on-farm at five sites in Niger (Southern Sahelian zone; Tera, Falwel, Serkinhaoussa, Doga, Aguie) and at one site in Mali (Northern Sahel: Dioura) in the rainy season 2008. The methods comprised: simple mass selection; mass selection with parental control; and progeny-based full-sib selection. Full-sib families from selected populations were also evaluated on-station at ICRISAT-Sadore. Entries selected through the different methods are currently recombined to produce enough seed for a thorough comparison of selection gains on-farm and on-station in 2009. Experimental varieties developed through these different methods will be evaluated on-station and on-farm with farmers in 2009 to estimate selection gains and derive conclusion about the most efficient and feasible methods

For sorghum new population bulks using local varieties from 3 areas in Mali, and 3 in Burkina Faso were made available to farmers interested to conduct plant selections. The methods they used differed by the type of population structure in the farmers grow-out: a population bulk versus a progeny based structure. The selection farmer did was with or without the identification of pollen fertility or sterility. Individual farmers used very different selection intensities.

The different selected population bulks, combined from selections made in 2007, were tested in a replicate trials at Samanko station. From two farmers' selection, the initial, intermediate and final selected bulks were compared at Samanko station, as well in with the concerned farmers in 2007, and 2008. Combined analysis remains to be conducted.

E Weltzien, BIG Haussmann, F Rattunde and K vom Brocke

Special Project Funding:
IFAD – PROMISO, McKnight Participatory sorghum and pearl millet improvement (dynamic genepool)

Output Target 2010 3.2.1 Two NARS empowered to breed groundnut varieties with multiple attributes especially drought tolerance.

Achievement of Output Target (%):
50%

A wide range of diverse genetic resources has been supplied to the NARS in Mali, Niger and Nigeria to enrich genetic diversity of their breeding programs. Facilities for phenotyping and hybridization are being upgraded and the skills of staff to manage the programs are being trained in priority skills.

Countries Involved:
Mali; Niger; Nigeria

Partners Involved:
Institut d'Economie Rural (IER) Mali, Institut National de Recherches Agronomiques du Niger (INRAN) Niger and Institute for Agricultural Research (IAR), Nigeria

Progress/Results:
Hybridization (crossing) and phenotyping facilities were assessed for adequacy/improvements as well as staff to manage these facilities in Mali, Niger and Nigeria. Overall these facilities are either lacking or in disuse. In Mali the phenotyping facilities needed are for drought and foliar disease screening, in Niger mainly drought and in Nigeria, phenotyping facility for groundnut rosette disease and the aphid vector need rehabilitation. Efforts are underway to backstop each program with the minimum facility to be able to improve these capacities, especially irrigation to ensure multiple generation advances within a year and nucleus seed production and good drought trials during the off-season or late during the season.

In order to reinforce human capacity, two students, one each from Mali and Niger were nominated by their institutions to pursue an Msc program in groundnut breeding. Arrangements are underway to get them registered at Bamako and Ouagadougou universities, respectively in December 2008. Further, we conducted 2-day in-country training workshops in Mali, Niger and Nigeria in participatory variety selection methodologies, and data capture.

We made available 300 new advanced breeding groundnut lines with multiple traits to the NARS for them to enrich their breeding resources. Additional F_5-F_8 lines were supplied for in situ selection at their locations.

IER in Mali received 77 advanced breeding lines for replicated variety trials and 288 lines as observation nurseries. The replicated variety trials consisted of a drought tolerant variety trial (15 entries); medium maturity variety trial (15 entries); short duration variety trial (15 entries) and rosette resistant variety trial (32 entries). Observation nurseries consisted of advanced breeding lines with various attributes (resistance to rosette disease and the vector aphid, resistance to early leaf spots and earliness and limited fresh seed dormancy). These were successfully conducted at the IER research station in Kayes.

INRAN Niger, received 45 advanced breeding for replicated trials including, drought tolerant trial (15 entries); medium duration rosette resistant trial (15 entries) and short duration rosette resistant trial (15 entries). The trials were successfully conducted at the Maradi station of INRAN

IAR Nigeria received 74 advanced breeding lines (F_8 +) as observation nurseries grouped into early, medium and late maturing. They all have enhanced resistance to groundnut rosette disease. Additionally, five breeding nurseries consisting of 104 progenies derived from F6/F7 populations with enhanced resistance to the groundnut diseases and the vector aphid were supplied for local evaluation and selection of promising material. The current policy in Nigeria is only to promote varieties that have resistance to the groundnut rosette disease and the aphid vector. These lines were evaluated for local adaptation, as well as for resistance to the predominant diseases in northern Nigeria.

At ICRISAT- Bamako, three replicated variety trials were conducted. These included a short duration, medium and drought tolerant variety trials. In each of these trials 15 advanced breeding lines along with a local check were evaluated. Harvesting has been completed and post harvest data is being collected.

In addition to the replicated variety trials, 12 breeding nurseries consisting of 253 F_6-F_8 progenies derived from populations with enhance resistance/tolerance to foliar disease, rosette and the vector aphid as well as having fresh seed dormancy and confectionary attributes were evaluated for agronomic performance at Samanko in a non replicated augmented design. The lines were derived from segregating populations obtained from ICRISAT- Lilongwe Malawi in 2007. These included 70 lines resistance to rosette, 41 lines combining rosette disease and aphid resistance, 40 lines combining rosette disease resistance and fresh seed dormancy, 54 lines combining rosette disease resistance and good oil quality, 81 lines with resistance to foliar diseases and the vector aphid, and 15 lines combining aphid resistance and confectionary traits. These materials will be shared with NARS in 2009.

R Ntare, ES Monyo and SN Nigam

Special Project Funding:
Tropical Legumes I & II funded by Bill and Melinda gates Foundation

Output Target 2010 3.2.3 Three high yielding, well adapted sorghum varieties with at least one trait adding value to the harvest (stover quality, brewing quality) identified for dissemination to farmers in two countries in WCA.

Achievement of Output Target (%):
25%

Novel varieties with short stem internodes that are promising for grain/fodder dual-purpose use are being developed.

Countries Involved:
Mali; Nigeria

Partners Involved:
IER, IAR

Progress/Results:
A total of 1050 S1 progenies were assessed in replicated evaluations at ICRISAT-Samanko and 250 S1 progenies at IER-Sotuba stations. Selection among and within progenies has been conducted. Evaluation of short-internode progenies derived from landrace accessions was conducted in Nigeria.

The dwarf variety Nafalen 6, a short guinea type variety was registered in the Malian National Variety catalogue in 2008. The dwarf variety Weli is undergoing mass selection by a farmer to identify types with better glume and grain characteristics, so that the higher grain yield, and stover quality become available to other farmers.

HFW Rattunde and E Weltzien

Special Project Funding:
McKnight Seeds Project. IFAD-PROMISO

Output Target 2011 3.2.1 At least two new breeding populations of groundnut with enhanced multiple attributes available for testing and selection by NARS

Achievement of Output Target (%):
50%

Segregating population was advanced to the next generation and a hybridization program initiated at Samanko to generate new crosses.

Countries involved:
Mali; Niger; Nigeria

Partners Involved:
IER, INRAN, IAR

Progress/Results:
The major objective is to improve the disease and drought tolerance in farmer-preferred groundnut varieties using modern molecular tools. Several major activities lead to this objective: (1) An exploration of the diversity available in the reference collection of groundnut germplasm, and compared to locally adapted varieties, identify important new sources of resistance to diseases and drought and other traits of economic importance; (2) develop the necessary tools needed to identify the genetic basis of tolerance and to introgress these into farmer-preferred varieties; (3) use molecular markers to identify genes and QTLs involved in disease resistance and drought tolerance; and (4) introgress resistance/tolerance into farmer preferred varieties.

Identification of new sources of resistance to foliar diseases, and drought related traits: In order to identify new sources of resistance to foliar diseases and drought related traits, we evaluated accessions a reference set of 268 accessions for resistance to early leafspot. The accessions were scored for early leaf spot (ELS) symptoms at 80 days after planting on a severity scale of 1 (resistant) to 9 (susceptible). Development of ELS was uniform on susceptible checks. Highly significant differences were observed among accessions. Of the 268 accessions tested, 30 were resistant to early leaf spot disease with a core of $\leq$ 5. The lines with a score of 4 were ICG 11219, ICG 10384, ICG 6703 and ICG 10036. These were comparable to the resistant check ICG 7878. The rest were classified as susceptible (severity rating of 6-9). Of those classified as resistant to ELS, 17 were Spanish bunch types and 13 Virginia. The same number of accession (the 268 accessions of the reference groundnut collection) will be planted in early December 2008 under two water treatments (watered and stressed) to measure harvest index and yield under drought stress.

In addition to the germplasm accessions, a total of 51 advanced breeding lines were evaluated for their reaction to ELS and LLS. For ELS, ICGV 01276 and ICGV 99029 were the most resistant with a score of 3; followed by ICGV 00068 and ICGV 0064 with scores of 4 and 5 compared to the susceptible checks (Fleur 11 and ICGS 11) with a score of 9. Te lines resistant to LLS were ICGV-IS 08837, ICGV 08831, ICGV 08832 and ICGV –IS 08835. These had a score of 4-5 and were comparable to the resistant checks (ICG 7878 and ICG (FDRS) 4 with similar scores. The collection of post harvest data has been completed and the data still needs to be analyzed .

F Waliyar and BR Ntare

Early generation populations: Sixty-nine (69) F_3 and 28 F_5 bulk populations with various attributes were grown at ICRISAT Bamako, Mali for generation advance. In both populations over 1000 single plant selections were made based on plant type, pod load, and tolerance to foliar diseases. These progenies will be advanced to higher generations in 2009.

Fifty three new crosses (30 for foliar diseases resistance, 12 for productivity, 10 for aflatoxin contamination tolerance, and 1 for limited fresh seed dormancy were made during 2008 rainy season to generate populations for the target traits in desirable agronomic backgrounds. New parents used in the hybridization included the most popular varieties in West Africa and high yielding foliar diseases resistant lines ICG nos. 7878, 7, 6222, 4440, and ICG (FDRS) 4. In the productivity crosses, the new parental lines were ICGV 00350 and ICGV 91114. For aflatoxin, the sources of resistance/tolerance are 55-437 and J11. The most popular varieties were also sent off to ICRISAT- Lilongwe, Malawi to incorporate resistance to groundnut rosette diseases and the vector aphid.

BR Ntare and ES Monyo

Special Project Funding:
Tropical Legumes I and II funded by Bill and Melinda Gates Foundation

Output Target 2011 3.2.2 At least 2 downy mildew resistant open-pollinated varieties of pearl millet

Achievement of Output Target (%):
25% first cycle of recurrent selection for downy mildew resistance done in 2008.

Countries Involved:
Niger

Partners Involved:
None

Progress/Results:
A total of 600 Half-sib families derived from two farmer-preferred ICRISAT cultivars and 306 full-sib families derived from a new diversified population (Niger × Senegal cross) were evaluated at Sadore under artificial downy mildew infestation using infester rows and late planting, to identify resistant progenies for recombination and new experimental variety creation. Harvesting has just been completed and data still need to be analyzed.

BIG Haussmann

Special Project Funding:
None

Output Target 2011 3.2.3 Refined adaptation maps for at least 10 sorghum and pearl millet varieties available for use by partners

Achievement of Output Target (%):
50%

For pearl millet: data set on 49 WCA landrace accessions and experimental varieties evaluated across seven sites and three years will be complete with the data gained in the rainy season 2008, and will, in combination with the climatic data from the test sites, allow for genotype × environment interaction-based adaptation mapping. More targeted adaptation trials are planned for 2009 and 2010.

Countries Involved:
Burkina Faso; Mali; Niger; Nigeria; Senegal

Partners Involved:
ISRA, IER, INERA, INRAN, LCRI

Progress/Results:
Genotype x environment interaction-based adaptation mapping requires the evaluation of a set of diverse genotypes across several locations and years, to enable the separation of genotype x location, genotype x year, and three-way interactions, and to derive conclusions about potential specific adaptation to certain experimental sites and about yield stability of the entries. With the rainy season 2008, such a data set has been created for pearl millet: 49 entries evaluated across 7site/fertilizer treatment combinations. These entries have been tested across 3 years (2006, 2007 and 2008) in these 7 site/fertilizer treatment combinations These data must now enter detailed analysis.

BIG Haussmann, B Clerget and PS Traore

Special Project Funding:
BMZ “Mobilizing regional diversity...”, BMZ-CODE-WA

Output Target 2011 3.2.4 Understanding of dry land cereal pest dynamics enhanced for at least two priority species across WCA, and used in adaptive IGNRM research targeting at least two countries.

Achievement of Output Target (%):
25%

Most of the achievement of the output target for sorghum & pearl millet is in Niger and only to a limited extent in Mali: Major targets pests & study sites for further studies were identified (e.g Konni, Niger, for agroecological management of sorghum head-bug). One additional promising trap crop for sorghum head-bug management was identified (Crotalaria pallida) and another one confirmed (pigeon pea), and field trial design for "push-pull studies" partially validated.

Andropogon grass was dismissed as a potential trap crop for millet stem borer, Coniesta ssp. management.
Tests are underway on the assessment of crop residue management options for pearl millet pest management, using
Neem & Jatropha and the use of potential trap crop species. Seeds of Cirad 441, a sorghum cultivar with dual resistance to sorghum midge & head-bugs, were multiplied for onward tests.

Countries Involved:
Niger & to a limited extent Mali

Partners Involved:
(Cirad); Inran (Hame Abdou Kadi Kadi; Issoufou Abdoulsalam; Habou Kano); University Abdou Moumouni (Zakari-Moussa Ousmane+ students); IER (Niamoye Diarisso); Intsormil (Bonnie Pendleton)

Progress/Results:
Direct observations of sorghum pest incidence were made at Samanko, Sadore & Konni stations, and in farmers' fields at Konni. Direct observations of pearl millet pest incidence were also made at Sadore. Identification of major pest problems and most relevant study sites for the same also included discussions with ICRISAT, Nars & Intsormil scientists in Niger & Mali (particularly sorghum midge in eastern Burkina & southern Niger, sorghum head-bugs in southern Niger, sorghum & millet stem borers in northern Nigeria). This interaction took place mainly as part of the effort for developing an entomology component to the Cereals for the Drylands BMGF project proposal.

In view of future collaborative trials with NARS partners in the region relating to the deployment of sorghum midge resistance, we multiplied seeds of sorghum cultivar Cirad 441 (=CCAL 1/13), with dual resistance to sorghum midge & sorghum head-bugs, in the joint Inran-Icrisat demonstration plot of the open-field day planted at Sadore, and in Inran sorghum midge nursery at Konni. The seeds were provided by Icrisat-Bamako. Part of the harvested seeds were planted for off-season multiplication at Sadore.

Tests on trap cropping as a sorghum head-bug management option were conducted at Konni (Inran station) & Sadore (Icrisat station), in partnership with Inran & UAM. At both sites, millet pest population dynamics were also monitored by light trapping. Coniesta ignefusalis & Rhinyptia infuscata were the 2 major pests trapped. Millet pest incidence and damage was also recorded at Sadore. Sorghum & pearl millet pest studies were part of the internship topic of 2 students of UAM, Mr Moussa Akourki at Sadore, and Mr Abdoulaziz Maâzou at Konni.

The sorghum experiment conducted at Konni was in a RCBD with 5 treatments & 2 reps. It aimed at assessing the potential of pigeon pea (cv. ICPL 87: treatment SG3), rattle box (Crotalaria pallida: treatment SG4) and castor bean (local semi-naturalized: treatment SG5) as perimeter trap crops for managing sorghum head-bug Eurystylus oldi, in comparison with 2 sorghum-bordered treatments: SG1 (unsprayed control) & SG2 (insecticide sprayed control). Plots were 159 m² -large and interspersed with cowpea "fillings" of the same size. Probably due to late sowing, sorghum (cv. SEPON 82) sustained both high sorghum midge and long smut incidence. This, combined problems of rattle box & castor bean establishment and late insecticide spraying on SG2, was probably the cause for the lack of significant differences between treatments in terms of head-bug population per 5 panicles, damage rating (on a 1-9 scale), and grain yield. Still, head-bug infestation & damage were high (mean score of 6.5 for both head-bugs and midge on SG1). Relatively high populations of head-bugs were found on pigeon pea and some on rattle box. High predation was observed on rattle box (qualitative observations). There is scope for repeating the trial with more thought on relative phenologies & timeliness of sowing or sorghum vs trap crops, timeliness of insecticide spraying on sorghum, and with a higher number of replications (probably 4 instead of 2). This trial will involve only pigeon pea & rattle box as trap crops, but additional "assisted push-pull" using extracts from Neem & Jatropha seeds collected at Sadore during this 2009 cropping season.

The sorghum experiment conducted at Sadore was in a RCBD design with 5 treatments & 2 reps also aimed at assessing the potential of pigeon pea (cv. ICPL 87: treatment SG3), rattle box (Crotalaria pallida: treatment SG4) and castor bean (local semi-naturalized: treatment SG5) as perimeter trap crops for managing sorghum head-bug Eurystylus oldi, in comparison with 2 sorghum-bordered treatments: SG1 (unsprayed control) & SG2 (insecticide sprayed control). As compared to Konni, an additional castor bean treatment was added (SG6) which was supposed to involve "assisted push-pull" management, using neem seed extract as a repellent sprayed on sorghum, and Jatropha seed extract as an insecticide sprayed on the castor border. However, treatments SG2 & SG6 were not applied, Plots were only 52 m²-large and not interspersed but separated with mere 0.60m alleys. Sorghum development was generally good, but head-bug infestation was medium as compared with high infestation by Pachnoda. Establishment/development of pigeonpea & rattle box was poor before sorghum flowering, and no Eurystylus found on these hedges. Some Eurystylus (3 per 5 plants) were found on castor bean (vs 86 per 5 panicles on sorghum). More head-bugs were found in castor bean-bordered plots (110 per 5 panicles) compared to controls (81), but differences not significant. All the same for damage rating (2.8 vs 2.4). Follow-up experiments are planned for 2009.

On the other hand, Andropogon grass was dismissed as a potential trap crop for millet stem borer Coniesta management, since bored stem incidence in a hedge bordering millet plots was only 22%, with no Coniesta larva recovered (actually a mean of 0.67 larvae per 100 stems!), compared with 82% bored stems and 1.8 larvae per stem (all Coniesta) recovered in neighbouring millet plots.

An experiment was started at Sadore, on eight 159 m²_large millet plots interspersing a test on okra pest agroecological management, in completely randomized design with 4 treatments & 2 reps. It aims at determining the effect on soil macrofauna, more specifically soil-dwelling instars & conservation forms of millet head-pests (Heliocheilus, Rhinyptia, Pachnoda, Meloidae) and their antagonists (termites, ants, predators like ground beetles), along with various crop residue management options.

A Ratnadass

Special Project Funding:
[list special projects that contributed to the 2008 research]

The sorghum trial at Konni was made possible thanks to a Cirad core budget-funded project (Oméga3) which financed a trial on okra pest management on the same station and backstopping mission to the student posted there.
Similarly, the trip to Mali was financed under this Cirad's Oméga3 project.
Continuation of this trial is pending to funding by Cereals for the Drylands BMGF project.

Output 3: Crop management, Aspergillus flavus resistant groundnut varieties and post-harvest technologies to reduce aflatoxin contamination in food and feedproducts, as well as micronutrient rich cereal varieties and processing techniques to improve bio- availability developed, tested and made available to partners with new knowledge in the SAT of WCA

Output Target 2008 3.3.1 Early adoption of crop management practices to reduce Aflatoxin contamination in Mali documented

Achievement of Output Target (%):
25%

Output Target 2008 3.3.1 Early adoption of crop management practices to reduce Aflatoxin contamination in Mali documented

Achievement of Output Target (%):
cancelled
Validation of crop management technologies to minimize aflatoxin contamination completed in Mali and extended to Nigeria and Senegal under a previous project that ended in 2007. A synthesis report is available and the results were disseminated through a regional workshop. Household structure of the farmers involved in the trials was determined in a survey in 2007 regarding early adoption of improved groundnut varieties. A survey questionnaire specific for crop management techniques to minimize aflatoxin contamination was prepared but lacked funds to execute it. As it is not assured that funds will be available in the near future, this output target is cancelled for the time being.
B Ntare, J Ndjeunga and F Waliyar

Countries Involved:
Mali

Partners Involved:
IER

Output Target 2009 3.3.1 2-3 farmer-and market preferred groundnut varieties tolerant to aflatoxin contamination identified for dissemination by at least three NARS in WCA

Achievement of Output Target (%):
25% Limited seed availability to conduct to conduct planned on-farm variety trials.

Countries Involved:
Mali

Partners Involved:
IER

Progress/Results:
A set of 36 advanced breeding lines with enhanced tolerance to Aflatoxin contamination has been assembled from ICRISAT- Patancheru. Fifteen of these were evaluated in a replicated trial at Samanko for agronomic performance and aflatoxin contamination?. The aflatoxin contents of the harvested pods will soon be determined. Pod yields varied from 0.52 to 2.79 tons/ha. The highest yielding lines in this trial were ICGV 93305 (2.79 t/ha) followed by ICGV 94379 (2.69 t/ha), ICGV 94434 (2.49 t/ha) were above the local check 55-437 with a yield of 1.69 t/ha). The remaining 21 were multiplied to obtain enough seed for on-station and on-farm testing for agronomic performance, aflatoxin, and farmer / market preferences.
F Waliyar and BR Ntare

Special Project Funding:
TLII: BMGF

Output Target 2010 3.3.1 Effectiveness of integrated management techniques, including new preferred varieties resistant to aflatoxin contamination, assessed and knowledge shared with associated capacity development with partners is this output the same as Output Target 2011: 3.3.1 Crop management practices for reduced Aflatoxin contamination out-scaled, and impact assessment initiated in at least two countries below?

Achievement of Output Target (%):
This output target has been cancelled due to unavailability of funds

Countries Involved:
N/A

Partners Involved:
N/A

Progress/Results:
The funds to conduct this work are not available as anticipated. This output target thus is cancelled.

Special Project Funding:

Output Target 2010 3.3.2 ELISA testing lab set up in at least 2 countries in WCA

Achievement of Target (%):
0%

Countries Involved:
Mali; Niger

Partners Involved:
IER and INRAN

Progress/Results:
Yet to start work on this

Special Project Funding:

Output Target 2011 3.3.1 Crop management practices for reduced Aflatoxin contamination out-scaled, and impact assessment initiated in at least two countries

Achievement of Output Target (%):
50%

Validation of crop management technologies to minimize aflatoxin contamination completed in Mali and extended to Nigeria and Senegal under a previous project that ended in 2007. A synthesis report is available and the results were disseminated through a regional workshop.

Countries Involved:
Mali; Niger; Nigeria; Senegal

Partners Involved:
IER, NRAN, IAR and ISRA

Progress/Results:
A report summarizing results from on-farm management of aflatoxin contamination of groundnut in West Africa was published in 2007. The technologies included tolerant varieties, soil amendments and best-bet harvesting and drying techniques. Applying these technologies resulted in aflatoxin reduction ranging from 70-84%. More than 50% of the farmers applying the technologies are producing groundnut with tolerable levels of Aflatoxin contamination. These technologies were expended to Nigeria and Senegal under the CFC funded project that ended in June 2007. A paper on management of aflatoxin contamination in Niger is under review. Follow-up work in Nigeria and Senegal is essential. As funds to continue this work are not available, this output target is cancelled.

BR Ntare, F Waliyar, O Kodio and B Diarra

Output Target 2011 3.3.2 Two sorghum and pearl millet varieties with increased iron and zinc content, and low content of anti- nutritional factors available for cultivation in at least two countries in WCA

Achievement of Output Target (%):
25%

Countries Involved:
Mali; Niger

Partners Involved:
ETH Zuerich, Switzerland, Wageningen University, The Netherlands, University of Copenhagen, Denmark

Progress/Results**:**
The prevalence of anemia and zinc deficiency among women and children in Mali is extremely high. Sorghum and millet are the main staple foods in most of the regions in Mali. Therefore, improving the Fe and Zn content of these staple foods can contribute to the reduction of malnutrition. However, the uptake of Fe and Zn by the human body is significantly reduced by the presence of phytates.

In Mali, sorghum grains are decorticated before consumption. The analysis of 5 sorghum varieties tested in 9 villages showed that mechanical decortication (3 minutes) reduced Fe content of sorghum by 39%, whilst manual decortication caused a reduction of 47% in Fe content. The phytate content is reduced as well by 47% after manual decortication. The bioavailability of iron and zinc can be estimated using the [Phy]/[Fe] and the [Phy]/[Zn] molar ratio. The [Phy]/[Fe] molar ratio ranged from 33 – 51 depending on variety with an average of 44, whilst the [Phy]/[Zn] molar ratio ranged from 58 to 74 with an average of 71. The molar ratio did not change significantly after decortication indicating that the bioavailability of Fe and Zn remained the same. Literature suggest that Fe absorption is only increased if the molar ratio is below 1, whilst zinc absorption is greatly reduced when [Phy]/[Zn] molar ratios is higher than 10-15. Therefore these ratios remained very high and would likely limit Zn and Fe absorption.

Farmers from 8 villages were managing 32 variety trials. Samples have been collected and manually decorticated (32 varieties, 2 reps, 8 villages). In Mali, sorghum grains are decorticated before consumption and therefore, manually decorticated gains were analyzed for Fe and Zn content. The results are expected in December 2008 and will allow estimating the genetic, environmental and G x E interaction of Fe and Zn content. A sub-sample of 5 varieties is analyzed for phytate content as well.

From 2006 onwards, 70 varieties of sorghum were cultivated on high and low phosphorus fields at Samanko station and Kolombada station in Mali. The samples were mechanically decorticated for 4 minutes and washed with distilled water in order to reduce Fe contamination from soil. The Fe content of decorticated sorghum grains cultivated on low P fields ranged from 12.7 to 36.7 with a mean of 22.3 ppm, whilst Zn content ranged from 9.2 to 35.5ppm with an average of 18.0 ppm. While AOV indicates significant GxE interactions, no crossovers are apparent. A sub-sample of 20 varieties of sorghum and 5 varieties of millet is currently being analyzed for phytate and phytase content. The 4 best varieties with respect to Fe/Zn content and agronomic characteristics (Tieble, Segetana, Bobodjé and Doua G) were selected and used in 17 women trials in several villages.

In pearl millet, the extra-early, high Fe/Zn cultivar GB8735 has entered farmer seed production at Dioura (Mali) and Keita (Niger). Two other high Fe cultivars have been included in on-farm participatory variety evaluation trails: the cultivar Moro in 6 tests in Dioura (Mali), and the variety Faringuero in 3 tests at Falwel (Niger).

A diversified population derived from the cross of two extra early, high Fe/Zn cultivars, GB8735 x Moro, has undergone one cycle of recurrent full-sib selection for yield performance and panicle traits at Sadore (Niger) and Koporo (Mali). The improved cultivar resulting from this effort will again be tested for Fe/Zn contents.

The search for further high Fe/Zn sources in pearl millet included evaluation of 72 pearl millet accessions tested in Niger in 2007 at Sadore under two fertilizer treatments (Sadore no-input, Sadore fertilized) for grain mineral contents (Fe, Zn, and other minerals). Analysis of the samples of a third location (Maradi, high-input) is still underway. Initial results indicate significant differences for grain Fe and Zn content among the 72 accessions tested under the two fertilizer treatments in Sadore. Entry means across the two treatments at Sadore ranged from 24 ppm to 48 ppm for Fe and from 20 to 46 ppm for Zn. Fe contents were significantly correlated to Zn contents with a coefficient of correlation of r= 0.61 (P=0.01). However, genotype x fertilizer treatment interaction was highly significant for both Fe and Zn contents, with the GxE interaction component of variance being threefold (Fe) respectively two-fold (Zn) higher than the genetic variance among the tested entries. This means that Fe and Zn contents were not very stable across the treatments. Results from Maradi (data not yet available) still have to be integrated in the analysis to validate these results and to identify those accessions that will show stable grain mineral contents across different sites and fertilizer treatments.

To transfer high Fe/Zn contents from the extra-early, short-panicle cultivar GB8735 into later flowering, longer panicle varieties, recurrent selection trials involving full-sib (FS) families created from BC1 or F1 progenies of the crosses (1) ICMV 99001 x GB8735; (2) ICMV IS 92222 x GB8735, and (3) ICMV IS 89305 x GB8735 were planted at Sadore and Lossa (both Niger) in the rainy season 2008, with two replications per experiment. The number of FS families per cross and test location are as follows: Cross (1): 312 FS at Sadore, 228 FS at Lossa; cross (2): 252 FS at Sadore and 174 FS at Lossa; Cross (3): 330 FS at Sadore and 240 FS at Lossa. Having part of the FS being tested at the second site Lossa (N of FS depending on seed availability) will allow for a better selection both for stable agronomic traits and grain mineral contents. Only those full-sib families with superior agronomic performance will be tested for Fe/Zn contents.

In cooperation with University of Copenhagen, Denmark, decorticated grain of 24 pearl millet accessions evaluated in the rainy season 2007 at three site/fertilizer treatments (Maradi_fertilized, Sadore_fertilized, Sadore_no input) in Niger have been analyzed for mineral contents. Results revealed significant differences among the tested entries for mineral content of the decorticated grain. Mean Fe = 30.1 ppm (range 19.4 to 44.1 ppm); mean Zn = 28.8 (range 18.1 to 38.3); heritability estimates: Fe: 83.5%; Zn: 79.4%. Only across the two Sadore fertilizer treatments (data from whole grains at Maradi not yet available), decorticated grains contained 75% of the Fe of the whole grain (range 66 to 109%) and 79% of the Zn content of the whole grain (range (68 to 123%). Therefore decortication, on the average reduces Fe and Zn contents by 25 and 21%, respectively.

M Smit, F Rattunde, BIG Hausmann and E Weltzien

Special Project Funding:
Harvest Plus, INSTAPA, McKnight Foundation AnbeJigi

Output Target 2012 3.3.1. Cereal processing techniques characterized for improving bioavailability of iron and zinc in young children diets in Mali

Achievement of Output Target (%):
10%

Countries Involved:
Mali

Partners Involved:
Helen Keller International (HKI – Mali); Laboratoire de Technologie Alimentaire (LTA)

Progress/Results
The uptake of Fe and Zn by the human body is significantly reduced by the presence of phytates. Food processing techniques can reduce the amount of phytates and make a significant contribution to improved nutritional status and health. A study is currently being conducted to better understand traditional food processing practices such as soaking, fermentation and germination.

The use of germinated flour (malt) for infant feeding has two advantages; the phytate content in malt is reduced, which increases the bioavailability of Fe and Zn and in addition; nutrient density can be increased by adding small quantities of malt, which reduces the viscosity of the porridge. Culinary demonstrations were given to women in 6 villages to demonstrate the use of malt in order to improve weaning foods.

M Smit and E Weltzien

Special Project Funding:
McKnight Foundation AnbeJigi

Output 4: Sustainable breeder, foundation and certified seed systems in partnership with NARES and private seed entrepreneurs developed through marketing of high quality seed of adapted released varieties of sorghum, millet groundnut, etc. accessible and affordable to resource poor farmers through network of agro- input dealers in an enabling agricultural environment

Output Target 2010 3.4.1 Improved agricultural enabling environment established for marketing high quality seed of sorghum, millet groundnut, etc. between West African countries

Achievement of Output Target (%):
25%

During 2008 the establishment of an improved enabling environment for marketing quality seed between West African countries was improved by 1.) Release of a Regional Variety Catalogue, and 2.) The approval at the regional level of a variety release and registration system as well as seed quality control and seed certification systems and 3.) The establishment of Science base seed quarantine pests list for inter-regional trade among West and Central African countries.

Countries Involved:
Although WASA current funding levels have been restricted to selected five countries in the region, the enabling environment interventions involved 17 countries which are Benin, Burkina Faso, Cape Verde, Chad, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Partners Involved:
Many partner institutions were involved at the initial stage of this process. The ones directly involved for achieving the above results are: AVRDC; CILSS/INSAH; IITA; WARDA; CORAF/WECARD; CNFA, SSC/ISU, USAID Mali; African Union and other ICRISAT projects.

Progress/Results:
Following, the approval of the regulation C/REG.4/05/2008 on 'Harmonization of the Rules Governing Quality Control, Certification and Marketing of Plant Seeds and Seedlings by the Council of Ministers of the Economic Community of West African States (ECOWAS), national variety registrars and delegates of national seed trade associations from ECOWAS member countries plus Mauritania and Chad participated in a five-day regional workshop on variety release and registration in the regional catalogue for crop species and varieties including capacity strengthening and exposure on practical procedures and conditions for testing of distinctness, uniformity and stability (DUS) and values for cultivation and use (VCU) for candidate varieties of 11 crops species.

Delegates shared information provided about the status of National Variety Catalogues. With this system a variety released and registered in a national catalogue will be automatically registered in the regional catalogue then it can be officially marketed in all the 17 countries. This means that the existing and new private and public sectors varieties will be available to all seed users (farmers) in the region and not just at a national level. National legislations and regulations now need to be adapted to this regional regulation.

An initial regional quarantine pest list has also been developed during a workshop held in November 26-29, 2007 in Bamako, Mali together with the national Plant Health services / departments of all 17 ECOWAS countries. Based on the expertise and knowledge of the Plant Health Departments, the group achieved a dramatic reduction of quarantine pests for intra- and extra- regional seed trade in comparison with the initial INSAH/CILSS list (extrait from Olembo 1999) and UEMOA list (UEMOA & FAO 2006)). During the pest analysis, some countries realized that information provided by the 2005 Edition of CABI Crop Protection Compendium (ISSN 1365 9065 ISBN 0 851 99 086 X) were conflicting with the information available at the countries levels for the presence or not of a specific pest. It was then recommended that each country should organize a national workshop of the plant protection and plant health experts to provide more information with respect to the country wise details for the presence and/or absence of specific pests and diseases for the agricultural crop species with reference to the 2005 Edition of CABI Crop Protection Compendium. An original copy was given to each delegate.

Out of the 145 pests analysed from the present countries lists, two types of quarantine pest were identified and accepted, 32 pests as quarantine pest list for seed trade within the West Africa region and 61 pests for the extra regional seed trade. These first regional draft lists of seed quarantine pest list based on science were used to establish seed import/export requirements with a manual of procedures for West Africa region
Norbert Maroya, R R Hanchinal and Richard Jones

Special Project Funding:
The enabling environment improvement activities were fully funded by USAID through the West Africa Seed Alliance (WASA) and the Sustainable Commercialization of Seeds in Africa (SCOSA)

Output Target 2011 3.4.2 Enhanced businesses of foundation seed production to satisfy requests from certified seed producers/seed companies linked to product markets in Mali and Nigeria

Achievement of Output Target (%):
25%

The present seed systems in Nigeria and Mali are dominated by the public sector. Breeders' and Foundation seed availability is thus usually the responsibility of the National program breeders. In Mali foundation seed purchased from public sector breeders and was used to produce a total 14 ha of foundation seed with seed producers' cooperatives in Sikasso region. In Nigeria breeder seed purchased from ICRISAT, IITA and NARS and foundation seed stage-I purchased from NARS and National Agricultural Council (NASC) was used to facilitate foundation seed (Stage-I/Stage-II) production on a total of 76.5 ha with WASA facilitated seed producers associations/groups with a buy back arrangement from WASA facilitated private seed companies. WASA also facilitated the establishment of new seed producers' groups/companies in remote rural area of Kano state in Nigeria. With nuclear seed received from WARDA (rice), ICRISAT Bamako (groundnut), ICRISAT Niamey (millet) and IITA (cowpea), WASA initiated in both countries foundation seed production.

We ensured that farmer have access to seed of improved varieties of groundnuts through farmer participatory variety selection and availability of nucleus, breeder and foundation seed of preferred varieties.

Countries Involved:
Mali; Nigeria

Partners Involved:
IAR, NASC, AGRA, USAID MARKETS, SASAKAWA GLOBAL 2000, Prop Com and IFDC, WARDA, IER, USB, DNA, ASPM,INSAH/CILSS, IICEM, ASSEMA, SEEDAN, Comptoir 2000, Faso, Kaba, Premier Seed Ltd, Alheri Seed Ltd, Da-all green Seeds Ltd Mashala Seeds Ltd ., , AOPP, EUCORD INRAN, Niger, ADPs

Progress/Results:
In both countries a fairly good numbers of small scale unregistered seed companies exist (e. g. in Mali 40 seed producers' cooperatives were surveyed together with 329agrodealers in the region of Sikasso). A georeferenced data base of agro-dealers, seed companies and seed producers

associations was established in Mali (Sikasso region) and the survey started in Nigeria. Based on the regional training of trainers held in February 2008 in Accra, Ghana on seed business plan development including private sector participants from Mali and Nigeria, business plans will be developed with interested seed companies/enterprises in Mali. In Nigeria, business plan has been developed looking to the need and size of the company /association and made available to two newly established seed companies Sahara Savana Seed Company and Maina Seed Company and two seed producers' associations namely wheat seed producers' association Bunkure, Kano and Fadama seed growers' association

To encourage increased demand for both foundation and certified seeds WASA with assistance from ICRISAT Bamako initiated on-farm demonstrations with nine varieties and hybrids of sorghum and eight varieties of groundnut with respectively 19 farmers (6 villages) and 22 farmers (7 villages) in the region of Sikasso. In addition hybrids varieties were introduced from the private sector in India (MAHYCO) and evaluated in on-farm demonstrations in Mali and Nigeria. The crops involved are namely maize (4 hybrids), sorghum (4 hybrids), millet (4 hybrids), okra (4 hybrids), tomato (3 hybrids), egg plant (4 hybrids) and pepper (2 hybrids). The evaluation of these on farm demonstrations were organized through many field days involving hundreds of participants

In Mali foundation seed production has been organized on a total 14 ha in the region of Sikasso with 5 seed producers associations for released varieties for crops including sorghum (one variety on 8 ha); cowpea (3 varieties on 5ha) and millet (on variety on 1 ha). Purification of certified seed production was undertaken for rice (Nerica 4 on 7ha) and maize (Sotubaka 1ha and Dembagnuman 2ha).

In Nigeria foundation seed production has been organized on a total 76.5 ha in five local government areas Muntsra, Kwa, Danhasan, Maramara and Kadawa) in Kano state for released varieties for crops including sorghum (6.25 ha), cowpea (7.5 ha) and millet (13.5 ha), maize (9.25 ha), rice (25.1 ha), soybean (11ha); and Groundnut (2.95 ha). The numbers of varieties involved varied with from one for millet and soybean, two for sorghum, three for maize, four for cowpea and rice and six for groundnut.

Norbert Maroya, RR Hanchinal and Richard Jones

Farmer Participatory Varietal Selection (FPVS): The demand for varieties by farmers and processors is a result of plant, seed and other desirable traits that are embodied in the varieties. Knowledge of such traits is valuable for crop improvement programs and good market signals for processors. With the objective to select farmer-preferred varieties, 40 mothers and 180 baby trials involving 5-8 released/pre released and advanced breeding along with local controls were conducted across Mali, Niger and Nigeria. Data from the above trials is being collected and the results will be available later. Selected varieties will be multiplied to contribute to the development of a sustainable seed delivery system in the target countries.

BR Ntare, J Ndjeunga and F Waliyar

Nucleus and breeder seed production: ICRISAT in Mali and Niger produced nucleus, breeder and in some cases foundation seed of 20 varieties and elite lines during 2007 rainy and 2008 offseason. This provided the seed stock for the FPVS trials in partner countries. Seed quantities ranged from 3 to 400 kg. Nucleus seed and breeder seed of 99 advanced breeding lines was produced at ICRISAT Mali to support seed system activities. Seed quantities ranged from 1 to 10 kg.

Foundation seed production: ICRISAT Mali supplied 640 kg of breeder and foundation seed to partners in Mali, 540 Kg in Niger and 45 kg in Nigeria for the FPVS trials. A total of 4 t of seed was purchased from seed producers trained by ICRISAT in Mali was made available to public and private beneficiaries. During 2008 rainy season, 440 kg of nucleus seed of 84 breeding lines and about 4 tones of foundation seed of 12 varieties were produced to support seed systems.

Empowering farmers in seed production: Prior to the installation of the on-farm trials participating farmers were trained in best practices of crop management and the characteristics of the new varieties to be tested. Other information pathways used included on-farm and on station fields days, radio and television coverage and farmer-too farmer visits. User friendly brochures on variety characteristics and crop management are in preparation. More than 500 farmers and 11 extension agents in Mali received training in seed production and crop management. ICRISAT–Mali provided a training module for this purpose.

ICRISAT- Bamako and Niamey organized 2-3 day in-country workshops in Mali, Niger and Nigeria to sensitize key actors along the along the groundnut value chain, including researchers, farmers and farmers' organizations, traders, groundnut processors, private seed companies and journalists. In Mali, 47 participants of whom 6 were female attended the workshop. In Niger, 37 participants attended of whom 12 were female. In Nigeria, 45 participants attended and all were male.

BR Ntare and J Ndjeunga

For sorghum and pearl millet breeder seed of all varieties under on-farm testing was produced, either in isolation, during off-season, or using selfing/ sibbing techniques. Foundation of sorghum female hybrid parents was produced, one in isolation, and 2 by hand pollination. besides seed production through sibbing of new experimental varieties, the pearl millet breeding program produces in large isolation plots (in the rainy season and in two off-season plantings) a total of around 6 tons of breeders seed of the following popular cultivars: GB8735; Sosat-C88; ICMV IS 99001; ICMV IS 92222; ICMV IS 89305; and ICMV IS 94206. While this seed is preferably sold to seed producers (farmer associations, private sector, WASA), large parts are also sold directly to individual farmers or to development partners in Niger to enhance on-farm testing and increase the future demand for seed of these cultivars.

A set of sorghum hybrids were produced at Samanko with one pollinator with good combining ability. We assisted IER with the first efforts at hybrid seed multiplication on –farm. Certified seed of eight open-pollinated varieties was produced by two farmer cooperatives. Partner Farmer seed cooperatives sold a total of 28 tons of certified seed of sorghum pearl millet and some legume crops, during the 2008 cropping season, in Niger, Burkina Faso and Mali.

Farmer managed variety selection trials with sorghum and pearl millet were conducted in 32 different rural areas, with at least 4 villages per area, and 4 farmers per village in Mali, Burkina Faso, Niger and Nigeria.

E Weltzien, BIG Haussmann and F Rattunde

Special Project Funding:
These activities were funded by the West Africa Seed Alliance (WASA), TLII project (BMGF), McKnight Foundation Seed project, IFAD - PROMISO

MTP Project 4: Producing more and better food from staple cereals (sorghum and millets) and legumes (groundnuts, chickpea and pigeonpea) at lower cost in the eastern and southern African (ESA) SAT through genetic improvement

Project Coordinator: **Mary A Mgonja**

Highlights for 2008

1.0 Project summary

Project 4 contributes to the overall **goal** of achieving sustainable food, nutrition and income security of farm families in ESA and is responding to CGIAR System Priorities i) 2A to increase yield and considering pro- poor traits (pests, diseases and Striga), ii) 2B abiotic stresses (drought) and (iii) 2C on nutritional quality of sorghum, pearl and finger millet through bio-fortification; and on food safety issues associated with aflatoxins in groundnut. The project has five outputs designed around the 3 Science Council Priority areas but linked with other SP and projects. Highlight of 2008 progress by outputs, key IPGs, outcomes, impacts are highlighted:

Output: 4.1 Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented.

This output emphasizes on strengthening the efficiency of breeding and cultivar evaluation while conserving and making maximum use of the natural genetic resource base (linked to project 2). Regionally-based task networks integrate farmer participation and include the regional i)highland sorghum evaluation team for Kenya, Tanzania, Rwanda and Uganda that identified 8 superior sorghum varieties, ii) pigeon pea team in Tanzania and Malawi that was supplied with high yielding early, medium and long duration genotypes for evaluation and seed increase. iii) Desi and Kabuli chickpea genotypes with resistance to Fusarium wilt for further evaluation in Kenya and Tanzania. Groundnut improvement teams in Malawi and Tanzania supported by smallholder farmer associations and farmer research groups to identify promote and disseminate new varieties and technologies. Breeding networks emerge from collaborative development and implementation of regionally oriented projects such as Tropical Legume II and the upcoming HOPE for dryland cereals, both funded by and in review at the Bill & Melinda Gates Foundation.

Output 4.2 Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences.

Genetically diverse breeding populations were developed and advanced for sharing with partners for further selection e.g sorghum lines that are resistant to striga (developed using MAS) midge, stem borers and leaf diseases; pigeon peas with resistance to fusarium wilt, groundnuts that resist early and late leaf spots, rosette and aflatoxin contamination. Improved sweet sorghum for bio-ethanol production and dual purpose sorghum were identified and disseminated to partners. Hybrids and OPV were tested to provide farmers with more options. Capacity building was provided on need basis e.g on seed production to support dissemination of released varieties and seed of various categories were shared through signing of SMTA

Output 4.3 New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, specific abiotic stress tolerant varieties and associated knowledge and capacity development.

Drought is considered to be the primary cause of yield reductions for crops in Sub-Saharan Africa. Early maturing varieties that escape terminal drought have been developed and introgression of Stay-green (Sg) into farmer varieties is going on as a mechanism thought to confer drought tolerance. Stay-green QTL from two donor parents (B35 and E36-1) note: B35 has not been bred by ICRISAT and E36-1 originates I think from the Maldandi landraces were introgressed through MABC into 4 farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale and will be advanced BC3S2 in 2009. F6 and F7 progenies from crosses between B35 and 6 improved lines and two farmer varieties will be in preliminary evaluations to establish advantage conferred by the stay green trait QTL on yield and other agronomic traits

Output 4.4 Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified germplasm with enhanced micronutrient levels available for evaluation.

The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment. Studies confirmed evidence of gene flow in major sorghum growing areas of Kenya. Farmers' environmental and socio economic conditions should be considered as part of the gene flow process and in the biosafety policy establishment.

Output: 4.5 Technological options and knowledge to reduce groundnut aflatoxin contamination

Aflatoxins contaminate groundnut and other agricultural commodities. Management is difficulty due to lack of awareness, environmental conditions and farming practices. A protocol was used for isolation of atoxigenic strains of A. flavus and 84% of samples met the Kenya Bureau of standards while only 70 % meet the EU standards. I think it would be good to know the purpose of these atoxigenic strain. Was it to over-populate the toxigenic strains? Improved groundnut varieties had a significantly lower level of contamination than local varieties.

IPGs: Genetically diverse and improved germplasm, parental lines and varieties, breeding networks, new tools e.g. for aflatoxin siagnostics, traits discoveries and strengthened capacity.

Outcome: Partners in breeding networks i) share responsibilities and products ii) Have capacity to use and integrate new and more precise tools iii) access to quality seed of improved high yielding and nutritions germplasm for further testing iv)have access to mycotoxin diagnostic tools and v) improved knowledge on gene flow and GM deployment these outcome are actually outputs

Impact: Improved efficiency in breeding, better access to quality seed, nutritious and safe to use food, increased productivity and profitability and informed decision on environment management and biosafety policy

Output 4.1: Sustainable regional breeding networks that integrate conventional and biotechnology tools established and associated capacity building implemented

Summary:

The concept of regionalized crop improvement is being deployed in ESA through funded projects to regionally address common constraints cutting across national borders and also by encouraging sharing of germplasm To implement the strategy regional trials were composed and distributed to collaborators. The highland sorghum improvement has been initiated and evaluation of highland materials in high altitude Karatu Tanzania indicated that cold tolerant varieties originating from Rwanda (BM 5, IS 25570, BM 21, S 79, Urukaraza, BM 27 and Ikinyaruka) had grain yields ranging from 2.056 to 2.500 t ha-1 compared to the local check with yields of 0.889 t ha-1. An additional site-Njoro in the Rift Valley of Kenya was included in collaboration with Egerton University Seed increases were done in 2008 for materials that performed well in Tanzania and those initially identified in Uganda, Kenya and Rwanda for composing future regional highland sorghum evaluation targeting the four countries.

National Groundnut Performance Trials (NPTs) in Tanzania have identified two short duration varieties ICGV-SMs 99557 and 99555, (Spanish) and three medium duration (Virginia) ICGV-SM 01711, ICGV-SM 01721 and CG7 for release recommendation. The NPTs are being conducted by the Tanzania Official Seed Certification Institute (TOSCI). TOSCI established trials in five sites (Nachingwea, Naliendele, Masasi, Kilosa and Makutopora). Any new release in Tanzania for groundnut will be the first since 1998. To accelerate germplasm exchange and support seed system efforts, Groundnut nuclear seed ranging from 3.8 -71.7 kg and over 9 tons of breeder seed were produced in Malawi and Tanzania. Over 90 elite lines and varieties, which included international trials sets were distributed from Chitedze Agricultural Research Station to various NARS programs. To improve capacity in seed production and maintenance and on aflatoxin management, training courses were conducted in Tanzania and Malawi. Participants included four research technicians, 20 extension officers, 11 farmer research group leaders, and 273 farmers . Two candidates one each from Malawi and Tanzania were identified for higher degree training.

Both desi and kabuli chickpea types are important in ESA. The program completed a regional field trial evaluation of 30 high yielding advanced chickpea lines for potential release in ESA. Eleven, each of desi and kabuli genotypes were evaluated in Tanzania and test genotypes showed good resistance to Fusarium wilt, early-medium maturity (3-3.5 months) and higher yield potential up to 2833 kg /ha in desi (ICCV 97107) and 2042 kg/ha in kabuli varieties (ICCV 97406) . Same genotypes will be re-evaluated in 2009, to select best lines for Farmer Participatory Variety Selection (FPVS). In Kenya, 3 kabuli (ICCVs 00302, 97304, 92311) and 2 desi genotypes (ICCVs 92944 and 97126) have potential and the same have been submitted to KEPHIS for National Performance Trials for possible release

High yielding long duration pigeon peas genotypes have been developed at ICRISAT-Nairobi and the same were supplied to the NARS in Tanzanian and Malawian NARS for evaluation. In Tanzania, Northern region the focus was on long duration late materials and in the Eastern region it was on long duration materials it would be good to know the difference between long duration late and long duration. Long duration genotypes were evaluated in southern Malawi. In Kenya, the best long duration performers were ICEAPs 01500, 01204, and 01381, which perfomed better than the checks by 32.2%, 25.5%, and 13.5% respectively. The best medium performers were ICEAPs 01528, 01547 and 01530 as promising genotypes with pest tolerance-cum-high yield potential. In Tanzania the long duration varieties ICEAPs 01196 and 01192 were better than the checks by 13.6% and 12.7% respectively. The combined analysis of performance of the medium duration at two sites in Kenya and one site in Tanzania revealed that ICEAPs 01170, 01179 and 01147 were the best performers. In Malawi and Mozambique, ICEAPs 01143/8, 01487/16, 01162/21 and 01485/9 were the most superior genotypes. The long duration ICEAPs 00926, 00576-1, 01499/7 and 00557 had high yields in Malawi coupled with fusarium wilt resistance.

The project produced 1.455 t of 10 varieties of pigeonpea seed on station in Kenya and distributed 8.58 t of seed on-farm in Tanzania. ICEAP 00040 was planted on a 17 ha area in Malawi and 2244 kg seed of 9 chickpea varieties produced in Kenya and 1200 kg seed was distributed to farmers for seed production in Tanzania.

Most of the legumes work in project 4 is done under the support of the of a global legume project on "Enhancing grain legumes' productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia" –Tropical Legume II which is coordinated and Managed from ICRISAT Nairobi. The focus is on germplasm management, enhancement and evaluation for adaptation and resistance to identified key biotic and abiotic stresses. To catalyze adoption a seed system objective is also in place coupled with an objective on situation analyses and outlook. Capacity building is an integral component of the Legume II targeting short courses on specific topics for project implementation and post graduate training for future sustainability of project activities

IPGs:

- Improved cereal and legume germplasm available for evaluation by collaborators ,
- A platform with clear rules and regulations (SMTA) developed for germplasm exchange among the breeders in the collaborating countries

Outcome:

- Collaborator including farming communities participating in short term trainings (crop management, seed production, field experimentation) are capable to implement project activities better and therefore can produce reliable information on the technologies being developed and evaluated
- Partners are able to increase efficiency in breeding from use of biotechnology tools
- Breeders can access new materials from peers and thus enhance the diversity of the materials in their national programs and therefore increase chances to identify better genotypes

Impact:

- Participatory approaches in verification of varieties, use of alternative seed delivery models and integration of private partners will increase chances for better variety identification, improve seed access for adoption and links to markets will result in improved food security, nutrition and income

Output target 2008 4.1.1 A regional highland sorghum improvement program initiated with at least two NARS in ESA

Achievement of Output Target (%):
Fully Achieved

Countries involved:
Kenya; Tanzania

Partners involved:
[ICRISAT Nairobi, Selian Agricultural Research Institute – Northern zone Tanzania and Kenya Agricultural research Institute KARI Katumani, Tanzania National Genetic Resources, TPRI Arusha, NGO- Network for Ecological Education and Practice-Sustainable energy project Karatu Tanzania]

Comments/Explanations:
Highland sorghum work is now going on in Kenya and Tanzania.

Progress/Results:
Sorghums occupy a unique ecological niche in highlands and require some level of cold tolerance especially to maintain viability of the pollen because flowering coincides with the onset of the cool season. In Eastern Africa, highland sorghums are grown in the Rift Valley of Kenya, Northern zone of Tanzania, Ethiopia, Eritrea, Rwanda, Burundi and South western Uganda. Breeding and selection of sorghums for highlands has been left to each national program. However there is merit in pursuing a regional highland crop improvement program that will facilitate sharing of materials and information for this specific breeding target.

One set of a cold tolerant sorghum trial was constituted with 48 entries and sent to Karatu Tanzania in January 2007 for evaluation by Bjarne Lausten of the Network for Ecological Education and Practice-Sustainable energy project, Uganda and the Rift valley of Kenya. The cold tolerant varieties originating from Rwanda (BM 5, IS 25570, BM 21, S 79, Urukaraza, BM 27 and Ikinyaruka) had grain yields ranging from 2.056 to 2.500 t ha^{-1} compared to the local check with yields of 0.889 t ha^{-1}. The mean days to 50% flowering was 86 days, however, the high yielding lines flowered in about 83 to 85 days and also attained a plant height of more than 2.10 m and a mean seed set of 89%. The newly (July/ August 2008) collected highland sorghum materials (reported in Project 2) have been acquired from the Tanzanian curator and will be planted in Kabete Nairobi in 2009 for characterization together with other highland germplasm that ICRISAT had collected and conserved earlier on. The objective is to determine materials that are adaptable to cool temperatures and use these in determining varieties and hybrid parents (restorers) for future hybrid development work targeting this agro-ecology in ESA

Special Project Funding:
Nil

MA Mgonja, E O Manyasa, Henry Ojulong, J Kibuka and P Sheunda

Output target 2008 4.1.2 Completion of regional field trial evaluation of 30 high yielding advanced chickpea lines for potential release in ESA

Achievement of Output Targe (%):
Fully Achieved

Countries Involved:
Kenya; Tanzania; Mozambique

Partners Involved:
ICRISAT-Nairobi, Lake Zone Agricultural Research and Development Institute-Tanzania, Egerton University-Kenya, ICRISAT-Mozambique

Comments/Explanations:
100 % targets achieved, completed field evaluation of desi and kabuli genotypes in Tanzania, Kenya and Mozambique.

Progress/Results:
Both desi and kabuli types are important in ESA chickpea growing countries. Ethiopia released 12 varieties suitable to its agro-climatic situations. Presently, Tanzanian and Kenyan farmers grows only local genotypes available with them. Nine desi and eight kabuli genotypes were evaluated at Chokwe, Chindeke and Tsangano in Mozambique. Based on the mean performance across locations, 2 desi varieties ICCVs 00108 and 97031 with grain yield of > 2700 kg/ha had shown superior performance and ICCVs 00305(2535 kg/ha) and 97306 (2277kg/ha) were the best genotypes among kabuli types. Eleven, each of desi and kabuli genotypes were evaluated at Salawe and Ukiriguru in Tanzania and test genotypes showed good resistance to Fusarium wilt, early-medium maturity (3-3.5 months) and higher yield potential up to 2833 kg /ha in desi (ICCV 97107) and 2042 kg/ha in kabuli varieties(ICCV 97406) . Same genotypes will be re-evaluated in 2009, to select best lines for Farmer Participatory Variety Selection (FPVS).

In Kenya, 7 each of desi and kabuli types were evaluated at Njoro, Bomet and Mgotio locations and found that 3 kabuli (ICCVs 00302, 97304, 92311) and 2 desi genotypes (ICCV 92944 and ICCV97126) have potential and the same have been submitted to KEPHIS for National Performance Trials for possible release.

Special Project Funding:
Partly by Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output target 2008 4.1.3: At least 4 high-yielding long duration pigeonpea cultivars adapted to ESA cropping systems developed and available with associated capacity development to NARS partners

Achievement of Output Target:
Fully Achieved

Countries Involved:
Kenya;Tanzania; Malawi

Partners Involved:
ICRISAT-Nairobi, Selian agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe

Comments/Explanations:

Progress/Results:
ICRISAT-Nairobi, evaluated 182 long duration genotypes (under three maturity groups i.e. long duration early materials, long duration and long duration / late materials) at Kiboko (wilt sick plot), Kampi ya Mawe (rainfed site) and Kabete (high altitude site).).This maturity grouping of long duration genotypes is based on relative maturity with respect to check varieties, which facilitates the identification of genotypes suitable to different long duration growing areas across ESA. Genotypes maturing at same time as ICEAP 00932 and earlier than ICEAP 00040 were classified as long duration early materials. Genotypes maturing at same time as ICEAP 00040 but mature earlier than ICEAP 00053 were classified as long duration normal materials. Genotypes maturing at same time as ICEAP 00053 were classified as long duration late materials. Among the 33 new long duration late materials tested, 10 out performed the best check ICEAP 00053(1916 kg/ha) and best performer was ICEAP 01534 with 34.5% yield improvement coupled with bold and cream colored grains (20g / 100 seed mass). 104 new genotypes tested in 3 long duration material trials, 19 genotypes recorded better yield than the best checks in respective trials. The top most genotype identified in each trial were ICEAPs 01500 (32.2%) yield increase over best check), 01204(25.5%) and 01381(13.5%). Selian and Ilonga Research Stations representing northern and eastern Tanzania, respectively evaluated 56 long duration late genotypes and found ICEAPs 01196(13.6%) and 01192(12.7%) as superior genotypes at Ilonga. The results from SARI will be reported in 2009. Multilocational evaluation of 7 genotypes, for yield and fusarium wilt resistance at Makoka, Chitala, Bvumbwe, Chitedze in Malawi showed ICEAPs 00926, 00576-1, 01499/7 and 00557 as high yielding genotypes coupled with fusarium wilt resistance.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, M Somo, D Ojwang and P Kaloki,

Output target 2008 4.1.4 At least 30 medium duration pigeonpea materials evaluated in at least two ESA countries

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Kenya; Malawi; Mozambique; Tanzania

Partners Involved:
ICRISAT-Nairobi, Selian Agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe, ICRISAT-Mozambique

Comments/Explanations:
Achieved 100 % targets and evaluated medium duration genotypes in 4 ESA countries.

Progress/Results:
Traditional medium duration varieties are photo and thermo-sensitive, i.e. when they are grown away from equator (Malawi and Mozambique), their phenology is delayed. Photo and thermo-insensitive varieties developed at ICRISAT-Nairobi were evaluated for high yield potential and adaptation.

In Kenya, 71 genotypes (in three trials) were evaluated at Kiboko and Kampi ya Mawe, and 27 high yielding genotypes were identified with better yield than best check under rainfed situations. Pest tolerance screening at two sites showed that ICEAPs 01528, 01547 and 01530 as promising genotypes with pest tolerance-cum-high yield potential.

In Eastern Tanzania, 44 MD genotypes were evaluated for superior yield, grain traits and fusarium wilt resistance and found that 21 genotypes were superior to the best check. The combined analysis of performance at two sites in Kenya and one site in Tanzania revealed that I CEAPs 01170, 01179 and 01147 were the best performers.

Evaluation of 22 genotypes in Malawi and Mozambique showed that ICEAPs 01143/8, 01487/16, 01162/21 and 01485/9 were the best genotypes.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, D Ojwang, P Kaloki and M Somo

Output target 2008 4.1.5 Groundnut variety adaptation trials including on farm variety tests conducted and monitored in ESA countries

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Malawi; Mozambique; Tanzania

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, CARE Malawi, Naliendele Agricultural Research Institute Tanzania, Hombolo Research Station Tanzania, Makutopora Research Station Tanzania, Diocese of Central Tanganyika, Masasi District Council Tanzania, Dodoma District Council Tanzania, Chamwino District Council Tanzania, Institute of Agricultural Research – Nampula Research Station Mozambique, Inhambane and Nampula District Councils Mozambique, ICRISAT Mozambique.

Progress/Results:
Farmer Participatory Variety Selection approach was used to evaluate elite varieties for local adaptation and farmer preference in Malawi, Mozambique and Tanzania. All together, 62 varieties (26, in Malawi, 22 in Tanzania 14 in Mozambique) were evaluated.

In Malawi, a total of 36 mother trials (each for Spanish and Virginia) were evaluated across 6 districts namely Salima (4), Dowa (12), Phalombe (4), Balaka (4), Thyolo (6) and Chiradzulu (6) representing four main Agricultural Development Divisions (ADD) of Blantyre, Kasungu, Machinga and Salima. In all sites a farmer-managed baby trial comprised a subset of 2 varieties and local checks making a total of 120 baby trials. Results have revealed three high yielding Spanish varieties that were better than the current best check ICGV-SM 99568. These are ICGV-SMs 03572, 99566 and 01514 which yielded up to 6 % higher than the check (2306 vs 2447 kg ha^{-1}). For the Virginia, results revealed up to 13% superiority over standard check with ICGV-SMs 01728, 99772, 98712 giving higher pod yields than CG 7 in Malawi (2899 vs 3269 kg ha^{-1})..

In Mozambique 36 mother trials (24 Spanish and 12 Virginia) and 132 baby trials were distributed to be evaluated under Nampula and Inhambane provinces. Results have not been provided to date due to lack of human capacity (there is only one scientist for all legumes/oilseed crops). Visual assessments revealed the following as potential for further assessment: ICGV-SM 99541, ICGV-SM 01513, ICGV-SM 01514, ICGV-SM 99568 and JL 24. ICGV-SM 99541 showed outstanding performance and varietal descriptors in support of its release have been prepared and submitted to the NARS. All the five fore-mentioned varieties have a short duration (Spanish) background. In addition, however, ICGV-SM 01514 and ICGV-SM 99568 are resistant to the groundnut rosette disease. ICRISAT will work with technical officers in Mozambique to improve data collection and analysis.

In Tanzania variety trials were conducted in 10 villages representing groundnut growing areas across 4 districts Masasi, Nanyumbu, Dodoma and Chamwino. Mean pod yield of Spanish varieties across sites indicated high performance of ICGV-SM-99557 (1294 kg ha^{-1}), ICGV-SM-99555 (1270 kg ha^{-1}) and ICGV-SM-00530 (1268 kg ha^{-1}). However, no statistical differences were detected between varieties. Although the disease scores were low which indicated low disease pressure as a result of prolonged dry spells that was not favourable for fungal disease, varieties differed significantly (P=0.01) in their reaction to rust disease. For the Virginia varieties, differences for mean pod yield across sites for four varieties (ICGV-SM 90704, ICGV-SM 95342, ICGV-SM 01711, and ICGV-SM-1721 were highly significant (P=0.01). Variety ICGV-SM-90704 significantly out-yielded recommended variety Johari (1775 vs 1217 kg ha^{-1}) a 45% advantage and was superior to the recommended check Red Mwitunde by over 63% (1092 kg ha^{-1}) while almost doubling the yield of the local checks Manguru and Kanyomwa (879 and 963). The above Elite lines are under National Performance Trials (NPT) and DUS Tests by the Tanzania Official Seed Certification Institute (TOSCI) for release consideration.

Special Project Funding:
Tropical Legume II Bill and Melinda Gates Foundation and McKnight Foundation

E S Monyo, M Osiru, O Mponda and H Charlie

Output target 2008 4.1.6 At least 5 t of improved seed each of pigeonpea and chickpea cultivars produced for participatory variety evaluation and demonstration

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Ethiopia, Kenya; Malawi; Tanzania

Partners Involved:
ICRISAT-Nairobi, Selian Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, Lake Zone Agricultural Research and Development Institute-Tanzania, Debre Zeit Agricultural Research Center-Ethiopia

Progress/Results:
Pigeonpea: 1455 kg of seed of 7 long duration varieties viz., ICEAPs 00040(667 kg), 00053(225 kg), 00020(75kg), 00932(42kg), 00933(42 kg), 00576-1(35kg), 00936(19) and three medium duration varieties namely 00557(173kg), 00554(162kg) and 00850(15kg) were produced at ICRISAT-Nairobi for PVS evaluation and demonstrations. Selian Agricultural Research Institute-Tanzania was given 3.58t and of 5.0 t of ICEAPs 00053 and 00040 seed, respectively to farmers in 8 districts for seed multiplication and supply back twice the quantity of seed for re-distribution under revolving seed scheme.

Chickpea: 2244 kg chickpea seed of five kabuli (ICCVs 97306, 95423, 00305, 96329, and 92318) and four desi (ICCVs 97126, 00108, 92944 and 97105) varieties were produced at ICRISAT-Nairobi. 1200 kg seeds of ICCVs 92318 and 95423 were distributed to farmers in Ilalambogo, Salawe, Maswa, Misungwi, Mbarika, Iteja, Ukiriguru and Shinyanga in Tanzania, for multiplication and plan to buy back 15 tons to redistribute to farmers. In Ethiopia, 900 kg breeder seed of the FPVS varieties (Ejerie, Teji, Shasho, Haburu, Areti and Natoli) were multiplied at Debre Zeit Agricultural Research Center.

Special Project Funding:
Tropical Legumes-II, BMGF; Treasure legumes-IFAD

SN Silim, NVPR Ganga Rao, D Ojwang, P Kaloki and M Somo

Output target 2008 4.1.7 Coordination and management of a global legume project on "Enhancing grain legumes' productivity, and production and the incomes of poor farmers in drought-prone areas of sub-Saharan Africa and South Asia" –Tropical Legume II.

Achievement of Output Target (%):
Achieved 100 % targets that were planned for year 1 including aligning collaborators for capacity building, articulated feedbacks and drawing lessons to inform future strategies for project implementation

Countries Involved:
Ethiopia; India; Kenya; Malawi; Mali, Mozambique; Niger; Nigeria; Tanzania

Partners Involved:
ICRISAT, CIAT, IITA, NARS of the respective countries,

Progress/Results:
Progress made during the first year of TL II (a Bill and Melinda Gates Foundation-funded project) was reviewed at the First Annual Review and Planning Meeting held in Addis Ababa on 29 September – 03 October in Addis Ababa, Ethiopia. Major achievements for the first year are highlighted as follows:

- A Programme Management Team consisting of Objective Coordinators, Principal Investigators, and the Project Manager was put in place. An Advisory Board comprising the Deputy Directors General for Research of the three partner centers (ICRISAT, IITA & CIAT), an internationally renowned legumes expert, one reputed legumes expert each from Sub-Saharan Africa and South Asia, and Project Managers of TL I and TL II has also been constituted.
- All objectives have conducted their national and regional stakeholders' workshops where partners have been exposed to the project objectives and the roles and responsibilities of each party have been defined.
- The socio-economics group (Objective 1) has generated baseline data. Situation have revealed the existence of "ruling varieties", such as 'TMV2' (groundnut), 'Annigeri' (chickpea), and 'Maruthi' and 'Asha' (pigeonpea) in India. These varieties are still in use in spite of a large number of varieties that have been released. Detailed analyses need to be done to establish the cause for the persistence of such varieties and characterization of common bean should include other factors i.e. in addition to drought.
- The crops groups (Objectives 2 to 7) have assembled large numbers of existing national, regional and international germplasm and screened in nurseries for drought tolerance and other desirable traits; established farmer participatory variety selection trials and demonstrations; and generated new breeding lines.
- The Seed Systems objective (Objective 8) produced a total of 861.9 tons of foundation, certified, or truthfully labeled seed of TL II crops, which were produced during the 2007/08 crop season in different countries. Depending on the existing condition of the countries, the seeds were produced at research centers or at private seed growers and selected small-scale farmers' fields.
- A total of 34 students (27 MSc & 7 PhD) have been identified and nominated by their national programs for training. Twenty nine of the students (22 MSc & 7 PhD) have been registered at various African universities. NARS scientists and technicians have been given short-term training ranging from 2 weeks to 3 months. Irrigation facilities for crops research have been installed or upgraded for the NARS of Ethiopia, Kenya, Malawi, Mozambique, Niger and Nigeria.
- Observations and lessons learned include: lack of critical mass in some NARS, the need for including post-harvest (including processing) and management aspects, and the need for more interaction with other projects.

Special Project Funding:
Tropical Legumes-II, BMGF

Tsedeke Abate

Output target 2009 4.1.1 At least 3 high- yielding medium duration pigeon pea cultivars adapted to southern African cropping systems developed and available with associated capacity development to NARS partners in Tanzania and Malawi

Achievement of Output Target (%):
Achieved 100% targets by supplying medium duration trials to NARS partners in Tanzania, Malawi, Kenya and Mozambique.

Countries Involved:
Kenya; Malawi; Mozambique; Tanzania

Partners Involved:
CRISAT-Nairobi, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural Research Station-Malawi, ICRISAT-Lilongwe, Kenyan Agricultural Research Institute (Katumani)-Kenya, ICRISAT-Mozambique

Progress/Results:
One medium duration yield trial (6 new genotypes) and one medium duration fusarium wilt resistance screening trial were supplied to Ilonga Agricultural Research station. Two medium duration trials (7 and 17 new entries, respectively) were supplied to three locations in Malawi. Also, one trial for wilt screening was supplied to Malawi. Two medium duration trials consisting of 14 and 31 genotypes were supplied to KARI-Katumani in Kenya. MD trial with 17 genotypes was supplied to Mozambique. ICRISAT-Nairobi, also planted 3 medium duration trials and 3 observation nurseries at Kiboko and Kampi ya Mawe.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, M Somo, D Ojwang and P Kaloki

Output target 2009 4.1.3 At least 3 high-yielding chickpea cultivars adapted to ESA cropping systems tested by NARS in Ethiopia, Kenya and Tanzania

Achievement of Output Target (%):
Achieved 75% targets, conducted FPVS trials and demonstrations in Ethiopia, Tanzania and Kenya. Evaluated 61 new desi and 62 new kabuli genotypes in two locations of Kenya, for heat tolerance coupled with high yield and good grain traits.

Countries Involved:
Ethiopia; Kenya; Tanzania

Partners Involved:
ICRISAT-Nairobi, Lake Zone Agricultural Research and Development Institute-Tanzania, Kenya Agricultural Research Institute (Njoro) - Kenya, Debre Zeit Agricultural Research Center- Ethiopia

Progress/Results:
In Tanzania**,** two desi (ICCVs 97105, 00108) and three kabuli (ICCVs 00305, 97306, 96329) genotypes were evaluated through FPVS at 19 farmers' fields in Iteja, Ukiriguru, Ilalambogo and Mwasenge villages and ICCVs 97105, 00108 and 00305 were selected as farmer and market preferred varieties.

In Ethiopia, five kabuli (Ejerie, Teji, Shasho, Haburu, Areti) and one desi (Natoli) varieties were planted in 38 PVS sites in Minjar (10), Shenkora (8), Lume/Ejere (10) and Gimbuchu (10) districts along with 190 demonstrations.

In Kenya, four kabuli (ICCVs 96329, 00305, 95423, 97306) and two desi varieties (ICCVs 00108, 97105) were planted in 12 PVS sites each in two rift valley districts (Bomet and Nakuru). FPVS were organized in Bomet during November and ICCVs 95423 and 97105 were found as farmer preferred varieties.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output target 2010 4.1.3 At least one medium and one long duration pigeonpea variety released in two countries of ESA

Achievement of Output Target (%):
Achieved 25% targets by means of identifying high yielding genotypes and processing them for National performance Trials (NPT) in Tanzania, Kenya and Malawi

Countries Involved:
Kenya; Malawi; Tanzania

Partners Involved:
ICRISAT-Nairobi, Selian Agricultural Research Institute-Tanzania, Ilonga Agricultural Research Institute-Tanzania, Chitedze Agricultural research Station-Malawi, Kenyan Agricultural Research Institute (Katumani) - Kenya, LELDET Seed Company-Kenya

Progress/Results:
ICRISAT-Nairobi, Kenyan NARS and Leldet Seed Company collaboratively conducted NPT in Kenya involving four medium duration (ICEAPs 00554, 00557, 00850, 00540) and three long duration varieties(ICEAPs 00932, 00933, 00936) at Katumani, Kiboko, Kampi ya Mawe, Kitui and Mbeere. In Tanzania, SARI identified through PVS, ICEAPs 00053, 00932 and 00936 as potential ones for release. Malawian NARS identified 2 long duration and 2 medium duration varieties for potential release.

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output 2010 4.1.4 At least 2 M.Sc students from ESA trained in pigeonpea and chickpea breeding and 2000 farmers trained in their production and management

Achievement of Output Target (%):
Achieved 50%: Trained/demonstrated pigeonpea and chickpea production technologies to 4500 and 165 farmers respectively and by identified students to work on chickpea and pigeonpea breeding.

Countries Involved:
Ethiopia; Kenya; Tanzania

Partners Involved:
ICRISAT-Nairobi, ICRISAT-Patancheru, Lake Zone Agricultural Research and Development Institute-Tanzania, Debre Zeit Agricultural Research Centre-Ethiopia

Progress/Results:
One student from Kenya working on heat tolerance in chickpea using 123 genotypes and another student from Ethiopia working on molecular characterization of Ethiopian chickpea cultivars were trained. One student from Tanzania was identified to work on Pigeonpea breeding.

4500 farmers (40% women) were trained to pigeonpea management, seed multiplication, processing and utilization in Tanzania and Malawi. In Ethiopia (38 farmers) and Tanzania (127 farmers and 18 extension staff) farmers and extension staff were trained on improved chickpea production technologies.

Special Project Funding:
Tropical Legumes-II, BMGF

SN Silim and NVPR Ganga Rao

Output target 2010 4.1.5 At least 500 kg of breeder seed and 10 t of seed of pigeonpea and chickpea produced to support on farm trial and demonstrations in 4 ESA countries

Achievement of Output Target (%):
Achieved 25% targets, by producing breeder seed of all PVS entries of pigeonpea (medium and long duration varieties) and chickpea (desi and kabuli), to attain the target of 10 t seed by 2010.

Countries Involved:
Ethiopia; Kenya; Malawi; Tanzania

Partners Involved:
ICRISAT-Nairobi, Debre Zeit Agricultural Research Center-Ethiopia, Lake Zone Agricultural Research and Development Institute-Tanzania, Kenya Agricultural Research Institute (Njoro)-Kenya, Selian Agricultural Research Institute-Tanzania, Chitedze Research Station-Malawi

Progress/Results:
ICRISAT-Nairobi produced 90.4 kgs of pigeonpea breeder seed (ICEAPs 00040, 00053, 00932, 00933, 00936, 00020, 00576-1, 00554, 00557) under strict isolation to meet requirements for large scale seed production targets by 2010. Breeder seed multiplication of pigeonpea varieties namely ICEAPs 00053, 00554, 00576-1, 00933, 00557 and 00936 was taken up at SARI-Tanzania in 2007/08. In Malawi, 2.7 ha area was planted with ICEAPs 00040, 00020, 00932, 00557, 00576-1, 01514/15, 01480/32, 01162/21 and 01167/11 and produced pure breeder seed.

Breeder seed of chickpea PVS entries namely ICCVs 96329, 95423, 00305, 97306, 00108 and 97105 were produced at ICRISAT-Nairobi. In addition, ICRISAT-Nairobi provided 20 kg seed each of the 5 FPVS chickpea varieties to Tanzanian NARS and 4 kg seed of each of 6 FPVS to Kenyan NARS for multiplication.

Special Project Funding:
Tropical Legumes-II, BMGF; Treasure Legumes project - IFAD

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output 4.2: Improved germplasm and parental lines of adaptable sorghum, pearl millet, pigeon pea, chickpea and groundnut that are resistant to chronic biotic stresses and meet end user preferences developed and disseminated with new knowledge to partners

Fusarium wilt is one of the major disease, constraint for pigeon pea productivity in ESA. Land races collected from Tanzania, Mozambique, Kenya and Malawi were evaluated in wilt sick plot at Kiboko over the years using prevalent pathotypes / virulence of fusarium wilt existing in ESA. Germplasm accessions namely Acc 128, 125, 130, 74 and 135(Tanzania), Acc 72(Mozambique) and Mthwajuni (Malawi) had less wilt incidence coupled with high yield. Accordingly they are potential donors in wilt resistance breeding. Locally adapted pigeon pea varieties were evaluated for genetic transformation using marker genes and different promoters. Two short duration (ICPV87039, ICPV86012), one medium duration (ICPV00554) and one long duration (ICPV00040) along with the control variety ICPV88039 are being transformed with different Agrobacterium tumefaciens strains and the GUS reporter gene and one scientist has been trained on the technique

To develop genetically diverse groundnut lines resistant to Groundnut rosette and ELS diseases, thirty one (31) rosette segregating nurseries comprising 1074 progenies and six ELS nurseries comprising 331 progenies were evaluated for resistance using the infector row technique. Fifty seven rosette free progenies and 9 combining rosette and ELS resistance were identified from the F7 populations. Results from a 25 entry aflatoxin resistance trial revealed 10 potential sources of resistance to aflatoxin with aflatoxin contamination levels of less than 1 ppb compared to over 1000ppb for the control.

Southern Madagascar presents many crop production challenges, from geographical isolation to threats from frequent cyclones and short seasons thereafter. Sorghum has been considered an optional crop to be planted after a cyclone. The NARS Madagascar (FOFIFA) in collaboration with NGOs have tested 25 varieties for three years and released a sorghum variety Kuyuma in 2007. Through the emergency relief program, Madagascar imported 60 tons seed of Kuyuma from Zambia and distributed to farmers in South Madagascar. ICRISAT has also provided 100kgs breeder seed of IRAT204 in 2008 for further multiplication in Southern Madagascar

Striga, midge and leaf diseases are among the most serious biotic stresses of sorghum in many parts of SSA. Molecular markers tightly linked to Striga resistance Quantitative Trait Loci (QTL) were identified. Striga resistance from resistant donor (N13) has been moved to susceptible Farmer Preferred Sorghum Varieties (FPSV) from Eritrea, Kenya and Sudan and resistant lines identified using MAS. Field trials have been conducted in Kenya, Sudan and Mali to evaluate FPV introgressed with 1-3 striga resistance QTL. Preliminary results show that several introgressed lines have resistance similar to that of the donor parent. Other biotic challenges to sorghum production are midge, leaf diseases and stem borers especially in the SH environments Host plant midge resistance and time of planting are some of the important components for integrated management of the pest. Several sources of resistance to midge have been identified in the previous years and these have been evaluated for midge and leaf disease resistance. Three lines IS8884, IESVs 95005/3-SH and IESV94114SH had low midge, leaf blight and anthracnose scores (1.0 and 3.0) and also had grain yields between 1.2-1.8t /ha. 41 lines with low midge scores ($\leq$3.0), tolerance to leaf diseases and with good yield potential were selected for further testing by NARS targeting Uganda, Tanzania and Southern Sudan.

Sorghum improvement in ESA is targeting four agro-ecologies and production systems, the Dry Lowlands (DL) which is the most predominant, the Sub Humid (Around Lake Victoria) the high altitudes (highland sorghum together) “away from the equator photoperiod sensitive sorghums”. Over the time, the program has identified sources of resistance to the key biotic and abiotic stresses. Genetically diverse breeding populations were and continue to be developed and advanced for sharing with national partners for further selection and adaptation. Sorghum hybrids development and evaluation is a continuous work to determine agronomic performance, adaptability and stability of promising hybrids across the region. Across the Kenya, Malawi and Tanzania, the best hybrids under dryland conditions were IESH22002, IESH22019, IESH2202, IESH 22010, SDSH 90003 IESH22005, IESH22011, SDSH94011, SDSH409, SDSH94011 and SDSH90003. Improved drought tolerant sorghums varieties were evaluated under the dry lowland and sub humid environments of Malawi, Kenya and Tanzania. The lines IESV23010DL, IESV23008DL, IESV23007DL, IESV23005DL, IESV23006DL, performed best across 2 seasons in Kenya and across the three countries in 2008. There was variation in flowering dates. All the varieties were late in flowering at Chitala (81 mean number of days to flower) than at Kiboko (62 mean number of days to flower). The same trial has been sent to more sites for regional evaluation regional in 2008/9 whereas a few have been marked for National Performance Trial in Kenya. The best performing varieties under the Sub Humid environment (Alupe for Lake zone were Wagita, IS8187, AF 28 and IS25434. Regional pearl millet evaluation in Kenya, Tanzania and Uganda identified ICMV221 as the best performer in Uganda and the breeder has been provided with information and seed to facilitate releases and seed production respectively.

New issues, demands and opportunities related to health and nutrition are becoming important components of food security, whereas concerns about climate change, energy and environmental safety are in the mainstream of global concerns. On energy, the dual-purpose nature of sweet sorghum, producing both grain and sugar-rich stalk offers new market opportunities for smallholder farmers’ integration in production of bio-ethanol as an alternative to fossil fuel. Sweet sorghum cultivars were evaluated in multi-location environments in Mozambique and Kenya. The varieties IS2331, IESV91104 DL, IESV92008 DL, IS92028 DL, SPV1411, SPV422 and IS93046 have shown consistent performance in terms of traits required for bio-ethanol production and grain yield. It is appropriate to propose the sorghum variety IS2331as a sorghum variety for fast tracking as a feedstock in bioethanol production

Demand for livestock products (mainly milk and meat) in SSA is expected to double by 2020 and this requires increased availability of feed and fodder for livestock. Sorghum has the potential to meet most of this demand especially in the SAT. Local and improved varieties with varying end users attributes, eg,, food, feed, forage and fodder were identified. Improved lines SDSL 90162-2, IESV 92007 DL, IESV 990006 DL, IESV 92165 DL, and IESV99091DL and 2 local lines Makueni local and Kiboko-Local 2 exhibited suitability for dual purpose use giving high biomass and good grain yield (2.702-3.955 t ha^{-1}). The materials have been given to an MSc student at the University of Nairobi to evaluate the nutritive attributes. Partners are provided with seed as requested through the signing an SMTA. The seeds were at different levels of development- from segregating materials for selection in the respective environments to breeder and nuclear seed of released and elite materials.

Capacity building of partners is an integral part of this project to ensure continuity and sustainability of all research and development activities; and this was provided on need base. In Mozambique training was provided to four (4) MIA's technicians on experiment design, data entry and computation using Genstat for windows. It focused on 2 experimental designs namely the Randomized block and lattice designs. In Madagascar 40 participants from the NARS (FOFIFA) and NGOs operational in southern Madagascar were trained on sorghum crop (Origin, Biology, Taxonomy), husbandry, cultivar development and evaluation, and on seed production, quality control and dissemination methods including international regulations of seed export and import

IPGs:

- Improved cereal and legume germplasm available for evaluation by collaborators,
- A platform with clear rules and regulations (SMTA) developed for germplasm exchange among the breeders in the collaborating countries
- Molecular markers: 10 SSR foreground and 20 SSR background markers for MAS for striga resistance
- 103 sorghum lines introgressed with 1 to 3 striga resistance QTLs

Outcome:

- The deployment of acquired skills and their active participation in the project activities has led to increased awareness and started implementing MAB
- Private and public sector partners throughout ESA gain access to materials with diversified genetic bases and use these for further selection and evaluation under targeted agro environments
- The activity had the spill-over affects of attracting and securing funds for other related projects and exposing NARS partners to other regional and international partnerships
- Farmers growing lines/varieties reported above of ICRISAT mandate crops have experienced increased productivity and enterprise profitability.
- Food quality has been improved due to enhanced nutritional value and reduced aflatoxin contamination in groundnuts
- Increased awareness of the potential benefits and growing acceptance for the use of GMOs throughout the ESA region and policy level discussion on biosafety issues

Impacts:

- Improvement of biotechnology facilities in participating national programs and demonstrated the utility of inter-institutional research collaboration (at both regional and international levels)
- Enhanced breeding capacity in NARS
- Policy support for biotechnology
- Farmers production and productivity will increase especially if the project links to project 1 on markets policy and institutions

Output target 2008 4.2.1 Pigeonpea landraces from Tanzania and Mozambique fully screened for Fusarium wilt resistance

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Kenya

Partners Involved:
ICRISAT-Nairobi

Comments/Explanations:
Achieved 100 % targets, screened land races of Tanzania, Kenya, Malawi and Mozambique at wilt sick plot developed at Kiboko using prevalent pathotypes / virulence of fusarium wilt existing in ESA.

Progress/Results:
Fusarium wilt is one of the major diseases, constraining pigeon pea productivity in ESA. The virulence pattern existing in ESA is entirely different from that of Asia. Further, it is believed that land races in ESA co-evolved with virulent wilt races of ESA. Hence, the land races collected from Tanzania, Mozambique, Kenya and Malawi were evaluated in wilt sick plot at Kiboko over the years. Wilt progression was recorded, by data collection at 10-15 day intervals. Data on days to 50% flowering, days to 75% maturity, plant height, seed yield and 100 seed mass were also collected to identify wilt resistance coupled with high/low yield potentials. Germplasm accessions namely Acc 128, 125, 130, 74 and 135(Tanzania), Acc 72(Mozambique) and Mthwajuni (Malawi) were recorded with less wilt incidence coupled with high yield, accordingly they are more potential donors in wilt resistance breeding. Acc 132, 68 and 59 had good wilt resistance but low yields and need to follow introgressive breeding approach in utilizing them.

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, M Somo, D Ojwang and P Kaloki

Output target 2008 4.2.2. At least one improved sorghum or pearl millet cultivar released in an ESA country.

Achievement of Output Target (%):
Fully Achieved

Countries involved:
Madagascar; Zambia

Partners involved:
ICRISAT – Nairobi, FOFIFA Madagascar, Catholic Relief Service (CRS), World Food Program (WFP), FAO Madagascar, Zambia National Program and the Adventists Development and Relief Agency (ADRA)

Comments/Explanations:
The Madagascar National Agricultural Research System (FOFIFA) in collaboration with some NGOs, tested a number of sorghum varieties since 2004/05 and in 2007 released Kuyuma and ZSV15 for production in southern Madagascar –Tulear province.

Progress /Results:
Southern Madagascar presents many crop production challenges, from the very old traditional low-yielding crop varieties being used to the strong cultural set up with many ‘do’s and ‘don’t’s in the predominantly livestock based farming system. The interest on sorghum traces back to 2004 when Madagascar faced a serious cyclone. The emergency and relief providing organizations in addition to meeting the immediate food and shelter needs, desired to put together a more sustainable strategy and hence contacted ICRISAT to assist in that endeavor and hence the visit in 2004 by ICRISAT cereal breeder to the southern zone of Madagascar- the Tulear province. The main recommendation was a re-introduction of drought tolerant crops that could be planted after a cyclone as a strategy of coping with the frequent cyclones. Although the proposal was not funded immediately, ICRISAT- Nairobi provided the national research institute FOFIFA with a set consisting of 25 early maturing sorghum varieties that were evaluated in Microessai station during the 2004/05 season. Nine varieties had yields ranging from 1.185t/ha to 2.911t/ha. Some of the highest yielders were ZSV15 (2.911t/ha), SP993529 (1.560t/ha), SDSL89420 (1.512t/ha), SP993531 (1.464t/ha) and SDSL98018 (1.423t/ha). During the 2005/06 season only 12 varieties were evaluated and 7 varieties namely ZSV15, Kuyuma , Chokwe, IRAT204, Macia, ICSV89117, and Larsvyt 58-85 were identified for further evaluation and demonstration to farming communities. The 2005/06 season identified two early sorghum varieties – Kuyuma and ZSV 15 with superior performance and appeal that was exciting to farmers that could reach maturity earlier than their local materials, although they planted later after a cyclone in 2006 they. This was in addition to previous evaluations, where IRAT204 had also been tested in Madagascar and found to be of interest to farmers. The government granted release for Kuyuma in 2007 and through the emergency relief program imported 60 tons seed of Kuyuma sorghum variety from Zambia which was distributed to farmers in South Madagascar. ICRISAT has also provided 100kgs breeder seed of IRAT204 in 2008 for further increase and distribution to farmers. Two additional sets of 15 varieties each were provided for further evaluation and identification of superior and stable varieties

Special Project Funding:
Nil

M A Mgonja, EO Manyasa, P Sheunda and J Kibuka

Output target 2008 4.2.3 Training of trainers for local seed production techniques for improved groundnuts completed

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Ethiopia, Malawi and Tanzania

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, Naliendele Agricultural Research Institute Tanzania, Diocese of Central Tanganyika and Debre Zeit Agricultural Research Institute Ethiopia.

Comments/Explanations:
100% of targets achieved. Seed production training programs were conducted for researchers, extension officers, farmers and NGO personnel and others involved in training farmers.

Progress/Results:
A joint training in collaboration with a SADC ICART EU funded sesame project in Tanzania facilitated the training of 35 farmers, 25 extension officers, 2 NGO personnel, 4 Ministry of Agriculture Training Institute tutors, 2 primary school teachers and 3 research technicians (16 women the rest men) on 12-13 September 2008 on techniques for seed production with a focus on groundnuts and sesame. This was followed in November 2008 by a training of 80 farmers (27 men and 53 women) from 16 villages of Chamwino District in Dodoma region with a focus on quality seed production of the groundnut variety Pendo. In Malawi, 238 farmers (110 women and 128 men) from 9 villages representing 5 popular groundnut districts in Malawi were trained on how to conduct farmer participatory variety trials from 4 – 14 Nov 2008. In Ethiopia, the first short (one-week) training course on chickpea seed production was given to 25 research technicians at Debre Zeit Agricultural Research Center in July 2008. In all these training programs, success hinges on use of three strategies - production of quality breeder seed on research stations, use of revolving fund system with contract to growers to produce basic seed for further multiplication and use of trained farmer community groups under supervision.

ES Monyo, O Mponda, T Kapewa, A Kbebew and H Charlie

Special Project Funding:
Bill and Melinda Gates Foundation, McKnight Foundation and EU

Output target 20084.2.4 Infector row technique for screening of GRD resistance in groundnut operational in at least one ESA NARS

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Tanzania

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Agricultural Research Institute Tanzania.

Comments/Explanations:
100% of targets achieved. Two research Technicians from Tanzania trained on the use of infector row technique for rosette resistance screening.

Progress/Results:
Use of the infector row technique was initiated in Tanzania following a one-month training course on its use in Malawi and on-site backstopping support. The Course was conducted from December 17, 2007 to January 13 2008 and two technicians (Mrs. Joana Kasuga and Mr. Joseph Nzunda) from NARI, Tanzania participated in the training. The training was focused on maintenance of viruliferous and non-viruliferous aphids in the greenhouse, in addition to improved groundnut production practices. Practical sessions on field screening for GRD using the infector row technique were also conducted. On return to Tanzania, the two technicians began using the Infector Row technique in Tanzania. However, their work has been hampered by slow progress on establishment of the greenhouse, required for rearing viruliferous aphids for use of the Infector Row Technique. Work on greenhouse establishment in Tanzania commenced in 2007 but has not been successfully completed due to logistical problems in procurement of materials. In the meantime, stopgap measures (a small room with gauze is being used within NARI) are being undertaken to ensure that GRD field screening activities continue.

Special Project Funding:
McKnight Foundation

ES Monyo, M Osiru and H Charlie

Output target 2008 4.2.5 GRAV CP transgenic groundnuts evaluated in a confined greenhouse trial for resistance to Groundnut Rosette Disease

Achievement of Output Target (%):
>75% Achieved

Countries Involved:
India; Kenya; South Africa

Partners Involved:
ICRISAT- Nairobi, ICRISAT-India, Agricultural Research Council, South Africa

Comments/Explanations:
80%. Two plantings were done during the course of 2008 in a contained greenhouse. Due to inefficient infection in the first planting, results could only be obtained from the second experiment and one more planting is planned for early 2009 to confirm the trends of GRD tolerance observed during the second planting. Countries Involved: Kenya, India and South Africa.

Progress/Results:
Two plantings were done in a contained greenhouse in South Africa, one in February and a subsequent one in May to evaluate 35 T2/T3 transgenic events containing the GRAV-CP gene. For each control and transgenic event, 4 seeds were planted, two seeds per pot. Plants were infected by feeding aphids on infector plants and transferring at least 5-7 aphids to young test seedlings 8 days post emergence. However, during the first planting, adequate GRD infection was not achieved as 25% of control plants did not develop GRD and therefore survival of transgenic plants could not be ascribed to resistance or tolerance to GRD. A second planting was done in May 2008, where 15 aphids were placed on each plant and efficient infection was achieved in all control plants as well as the majority of transgenic plants. For two transgenic events, 50 % (2 plants each) showed some resistance in that they did not develop GRD symptoms or disease throughout the growth season. Another four lines showed varying degrees of recovery from GRD post infection, manifesting in new emerging leaves that did not show GRD resistance. These results will now be confirmed in another planting planned for early 2009.

Special Project Funding:
Nil

S de Villiers

Output target 2008 4.2.6 Locally adapted pigeon pea varieties evaluated for genetic transformation using marker genes and different promoters and at least one scientist trained

Achievement of Output Target (%):
>75% Achieved

Countries Involved:
India; Kenya

Partners Involved:
ICRISAT, KARI, Kenyatta University

Comments/Explanations:
Transformation facilities at KARI, where this work was being done, were not improved to BL2 standards as planned and required by the Kenyan NBC. By mid-2008, the pigeonpea tissue culture technology was transferred to Kenyatta University (KU), the only certified BL2 plant transformation facility in Kenya and a scientist has been trained in pigeonpea tissue culture and transformation. Due to lost time and transfer of techniques, this work has progressed only to the point where several locally adapted lines have been subjected to transformation but transgene insertion has not been confirmed.

Progress/Results:
In 2007, the tissue culture evaluation of locally adapted pigeonpea varieties at the KARI-Biotechnology laboratory was completed and published. However, the BL2 transformation laboratory at this KARI facility has not been completed as planned since 2006, so it was not possible to continue with transformation activities at this location. Subsequently, the tissue culture technology was transferred to Kenyatta University where the only appropriate facilities in Kenya are in place. An M.Sc student has been trained in tissue culture regeneration and transformation of locally adapted pigeonpea varieties using the *Agrobacterium tumefaciens* mediated protocol developed at ICRISAT-India. Four of these varieties, including two short duration (ICPV87039, ICPV86012), one medium duration (ICPV00554) and one long duration (ICPV00040) along with the control variety ICPV88039 are being transformed with four different *Agrobacterium tumefaciens* strains (LBA 4404, EHA 105, AGL0 and C58C1, all harbouring an identical plasmid) and the GUS reporter and Km resistance selectable genes.

Special Project Funding:
N/A

S de Villiers

Output target 2008 4.2.7 At least 5 locally adapted groundnut varieties evaluated in tissue culture for regeneration response and one scientist trained in the technique

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India; Kenya,

Partners Involved:
KARI, Kenyatta University

Comments/Explanations:
Six locally adapted groundnut varieties, JL24 (control) Chalimbana, ICG-2, ICGV-12991, ICGV-90704 and ICGV-99568 were successfully regenerated using the tissue culture regeneration protocol.

Progress/Results:
Six locally adapted groundnut varieties, JL24 (control) Chalimbana, ICG-2, ICGV-12991, ICGV-90704 and ICGV-99568 were successfully regenerated using the tissue culture regeneration protocol from cotyledon explants developed for groundnut transformation by ICRISAT. JL24 performed on average only slightly better than ICGV-90704 (43 and 39 rooted plants from 35 explants, respectively), followed by Chalimbana (36 plants), ICGV-12991 (31 plants), ICG-2 (25 plants) and ICGV-99568 (24 plants). Of these, ICGV-90704 and ICGV 12991 are GRD resistant. Two sterilizing agents, $HgCl_2$ and NaOCl (commercial bleach) were compared as bleach is a safer and more accessible chemical for use in tissue culture in developing countries. However, $HgCl_2$ seems to be less toxic to the explants and its application resulted in substantially larger numbers of explants surviving the sterilization procedure and producing rooted plants through regeneration. Between 16 and 33% of explants that survived treatment with $HgCl_2$ formed multiple rooted plants compared to 7 to 16% of explants treated with NaOCl. An M.Sc student was trained in this technology at the KARI-Biotechnology laboratories and a publication of the results is being prepared.

Special Project Funding:
N/A

S de Villiers

Output target 2008 4.2.8 20 interspecific derivative lines of groundnut evaluated for Rosette and ELS disease in ESA and promising new sources of resistance comprising interspecific sources identified

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Malawi – for ESA

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, ICRISAT India – Molecular Biology Section.

Comments/Explanations:
100% of targets achieved. Two nurseries with a combined treatment combination of 61 entries were evaluated under high disease pressure at the ESA regional testing site – Chitedze Research Station near Lilongwe in Malawi.

Progress/Results:
Two wild Arachis spp. nurseries (one consisting of wild arachis spp with 33 entries from the ICRISAT genebank and the second consisting of 28 hypogeae by arachis interspecific crosses developed by the ICRISAT Cell Biology Team) were screened for resistance to GRD and ELS using the infector row technique at Chitedze Agricultural Research Station. Of the 28 Hypogaea by Arachis materials in the rosette high disease pressure nursery, ten (10) plants were selected for generation advance and none from wild *Arachis* spp. was selected. None showed immune reaction to rosette. More over, in the *Arachis* spp., the whole nursery succumbed to rosette infestation and none of the plants produced a pod. This is indicative of the rare occurrence of resistance even from the wild spp. These nurseries were also evaluated under high ELS disease pressure and the results are reported through Project 2.

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

ES Monyo, M Osiru, N Mallikarjuna and H Charlie

Output target 2008 4.2.9 At least 5 kg groundnut nuclear seed of each of 15 varieties in Regional Trials produced annually from 2008 to 2011 as source for breeder seed and entries for collaborative trials with NARS in ESA

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Malawi – for ESA

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi.

Comments/Explanations:
100% of targets achieved. Groundnut nuclear seed ranging from 3.8 -71.7 kg have been produced for use in breeder seed production and as sources of seed for regional collaborative trials and on-farm trials for all countries in ESA.

Progress/Results:
Groundnut nuclear seed ranging from 3.8 -71.7 kg have been produced for use in breeder seed production and as sources of seed for regional collaborative trials and on-farm trials for all countries in ESA. A total of 83 lines from elite trials were multiplied. Breeder seed production is only for the 15 varieties that are lraedy released. The remaining varieties were increased for multilocation testing and on farm trials.

ES Monyo, M Osiru and H Charlie

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

Output target 2008 4.2.10 At least 1 ton groundnut breeder seed of 3 released farmer/market preferred varieties in ESA produced annually from 2008 to 2011 as source for foundation seed for collaborating NARS and other partners

Achievement of Output Target (%):
100% of targets achieved.

Countries Involved:
Malawi – for ESA

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi.

Progress/Results:
Breeder seed was produced in Malawi various quantities for each variety in support of seed systems activities in ESA as follows: 2.37 tons of GRD resistant variety ICGV-SM 90704; 3.06 tons of early maturing GRD resistant variety ICGV-SM 99568; 1.4 tons of CG 7, 380kg of JL 24, 1.02 tons of ICGV 12991; 335kg of Chalimbana 2005, a recently released cultivar and 560kg of variety Chalimbana. All these varieties are multiple country releases (2 – 4 ESA countries) except Chalimbana which is only for Malawi.

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

ES Monyo, M Osiru and H Charlie

Output target 2008 4.2.10 Sorghum lines with resistance to midge, stem borer and leaf disease evaluated in advanced trials for yield and adaptability

Achievement of Output Target (%):
100% This is a continuous work of identifying and selecting sorghum lines from a pool of germplasm developed by the program for resistance to key biotic stresses namely midge, anthracnose and leaf blight

Countries involved:
Kenya

Partners involved:
IC RISAT Nairobi, KARI –Alupe Kenya

Progress/Results:

Sorghum midge [*Stenodiplosis sorghicola]* is the most widely distributed of all sorghum insect pests followed by stem borers (*Chilo partellus and Busseola fusca*-) and shoot fly (*Atherigona socccata*). Of the leaf diseases, the most prevalent is Anthracnose caused by *Colletotrichum graminicola* and leaf blight (*Exserohilum*-). Host plant resistance and time of planting are some of the important components for integrated management of the pest. Several sources of resistance to midge have been identified in the previous years. However the levels of resistance vary from one location to another. This calls for location specific breeding and testing of resistance to midge of sorghum progenies derived from the midge resistance improvement program. During 2008 long rains, two sorghum midge resistance evaluation trials were grown at Alupe in Kenya. The advanced midge trial had 80 lines selected from the preliminary midge resistant trial (IESV series) and the other had 49 entries -selections from the advanced midge trial (AF 28 x IS 8163 derivatives). From the advanced midge trials three lines IS8884, IESVs 95005/3-SH and IESV94114SH had low midge, leaf blight and anthracnose scores (1.0 and 3.0) and also had grain yields between 1.2-1.8t /ha. Yields from the Elite trial ranged from 0.528t/ha to 2.287t/ha and this highest yield was from the line IESV94086SH# 35 which also had a low (1.7) midge score. The other lines IS21185# 36 and IS8884#22 had yields of 1.935 t/ha and 2.199t/ha and all had a low midge score of 1.7 and 1.3 respectively. Sixteen lines from the advanced trial and 25 lines from the elite trial had low midge scores ($\leq$3.0), tolerance to leaf diseases and with good yield potential were selected and will be further tested and also availed to NARS in the region targeting evaluation in Uganda, Tanzania and Southern Sudan where midge, leaf diseases and stem borers are the major problems to sorghum production

Special Project Funding:
Nil

MA Mgonja, E.Manyasa, J Kibuka and P Sheunda

Output target 2008 4.2.11 Sorghum hybrids evaluated for agronomic performance, adaptability and stability across the Kenya, Tanzania and Malawi

Achievement of Output Target (%):
100% This is a continuous work of developing and evaluating new hybrids across multi environments to determine their stability in performance across countries in the region. There is annual replacement of poor performing hybrids, however a set of reference or probe genotypes are maintained in each of the three years to allow GxE analysis

Countries involved:
Kenya, Tanzania and Malawi

Partners involved:
ICRISAT Nairobi, KARI –Kenya, Department of Agricultural Research (DAR) – Malawi, Department of Research and Training-Hombolo Tanzania

Progress/Results:
The Regional Sorghum Hybrid Trial (RSHT) was conducted at Kiboko during the 2007/8 short rains and one set each was sent to Malawi and Tanzania. At Kiboko, although hybrids IESH 22002, IESH 22019, IESH 22011, IESH 22010 and SDSH 409 had consistently performed better during the last 2 seasons, (2006/7 SR and 2007 LR), only IESH 22019 maintained a stable performance and was the second best in grain yield performance (5.026 t ha^{-1}). The best yielding hybrid IESH 22021 had mean grain yield of 5.779 t ha^{-1}. Overall, 6 hybrids yielded better (4.645-5.779 t ha^{-1}) than the check varieties (3.86-4.608 t ha^{-1}). In Malawi, the RSHT was grown at Chitedze station, Lilongwe. Five hybrids IESH 22010 (6.947 t ha^{-1}), SDSH 90003 (6.586 t ha^{-1}), IESH 22005 (5.764 t ha^{-1}), IESH 22011 (5.542 t ha^{-1}) and SDSH 94011 (5.369 t ha^{-1}) out performed the best check parent Macia (3.600 t ha^{-1}). The hybrids matured late (mean days to flower was 74) and were shorter (mean plant height 114.3cm) in Malawi than at Kiboko (mean days to flower 64 and mean plat height 160.3cm). In Tanzania the trial was grown at Hombolo research station. There was significant headbug damage hence the lower yields realized (0.667-2.264 t ha^{-1}) relative to Kiboko and Chitala. The best performing hybrids were SDSH 409 (2.264 t ha^{-1}), SDSH 94011 (2.181 t ha^{-1}) and SDSH 90003 (2.125 t ha^{-1}). The check variety, Macia had mean grain yield of 0.931 t ha^{-1}. An advanced sorghum hybrid trial comprising of selections made in Preliminary hybrid trial in 2007 long rainy season was grown at Kiboko. The trial had 10 test hybrids, 2 check hybrids (IESH 22002 and IESH 22019) and 4 parental checks (Macia, Kari Mtama 1, ICSR 160 and ICSR 108). Four test hybrids (ICSR 276 x ICSR 38, ICSA 90001 x ICSR 172, ICSA 376 x ICSR 160 and ICSA 90001 x ICSR 162), 2 check hybrids (IESH 22002 and IESH 22019) and 2 parental checks (ICSR 160 and ICSR 108) had grain yields between 4.970 and 6.415 t ha^{-1} which were above the trial mean (4.870 t ha^{-1}). After realizing the hybrid potential in Malawi, the breeder has requested for and received the parent lines to use in his breeding program while continuing with the hybrid evaluation.

Special Project Funding:
Nil

MA Mgonja, E. Manyasa, A. Chamango, J Kibuka and P Sheunda

Output target 2008 4.2.12 Improved drought tolerant sorghum varieties evaluated in advanced trials in Kenya, Malawi and Tanzania to determine agronomic, adaptation, grain yield and resistance to diseases

Achievement of Output Target (%):
100% The trials were managed well and collaborators have provided information for identification of better materials for further evaluation in more counties with similar agro ecologies and production systems identification of most disease resistant

Countries involved:
Kenya; Malawi; Tanzania

Partners involved:
ICRISAT Nairobi, Department of Agricultural Research (DAR) – Chitala Malawi, Department of Research and Training-Agricultural Research Institute Ukiriguru Mwanza -Tanzania

Progress/Results:
The trial consisted of 16 selections made from the preliminary drought tolerance sorghum trial and 3 parental lines and 1 local checks. The trial was grown at Kiboko (Kenya) and Chitala (Malawi). Higher grain yields were obtained at Chitala than at Kiboko. At Kiboko, IESV 23010 DL, IESV 23008 DL, IESV 23007 DL, IESV 230005 DL, IESV 23006 DL, performed best across the 2 seasons attaining grain yields above 2.900 t ha^{-1} (mean 2.599 t ha^{-1}). At Chitala, IESV 23008 DL, Kari Mtama 1, IESV 23005 DL, IESV 23006 DL, IESV 23007 DL, IESV 23004 DL, IESV 23010 DL, IESV 92170 DL and IESV 23011 gave grain yields between 2.989 and 4.542 t ha^{-1} (trial mean 2.894 t ha^{-1}). The best variety at Kiboko, IESV 23010 DL (3.282 t ha^{-1}) had a 59% yield advantage over local check (2.053 t ha^{-1}) whereas at Chitala, the best variety, IESV 23008 DL (4.542 t ha^{-1}) had 86% yield advantage over local check (2.442 t ha^{-1}). All the varieties were later flowering at Chitala (81 mean days to flower) than at Kiboko (62 mean days to flower). The same trial has been sent to more sites for regional evaluation regional in 2008/9.

Sub-humid Lake Zone sorghum evaluation in Tanzania
An advanced sorghum trial comprising of 17 elite sorghum lines adapted to sub-humid Lake Victoria zone and 1 local check was grown at Ukiriguru in Tanzania during the first season (Jan-Feb) 2008. Ten of the varieties performed better than the local check (Mwanagudungu). Grain yield ranged from 0.889 t ha^{-1} in IESV 94025 SH to 2.656 t ha^{-1} in Wagita with overall mean of 1.738 t ha^{-1} with local check giving a yield of 1.267 t ha^{-1}. The best performing varieties were Wagita, IS8187, AF 28 and IS 25434. The trial will be repeated in 2008/9 season.

Special Project Funding:
Nil

MA Mgonja, E. Manyasa, A. Chamango, J Kibuka and P Sheunda

2008 4.2.13 Diversifying sorghum end-uses to feed and fodder to enhance the livestock industry in Eastern and Central Africa

Achievement of Output Target (%):
75% The field work has been completed and the materials provided to the University of Nairobi MSc student for laboratory analyses of the nutritive attributes of the different varieties. It is anticipated that the work will be completed and reported in 2009

Countries involved:
Kenya

Partners involved:
ICRISAT Nairobi, University of Nairobi, KARI-Kenya

Progress/Results:
Demand for livestock products (mainly milk and meat) in SSA is expected to double by 2020 and this requires increased availability of feed and fodder for livestock. Sorghum has the potential to meet most of this demand especially in the SAT. Being a C_4 crop, sorghum has tremendous potential for biomass production, most of which is accumulated in the vegetative parts. In most of Africa and in the semi-arid regions of Kenya, in which most of the livestock is raised, high productive dual-purpose types of sorghum, resistant to dry conditions are not in use. The objective of the study was to identify dual purpose sorghum varieties with grain, forage productivity and quality attributes that can be adapted to the semi arid drought prone lowland areas of Kenya.

Based on 3 seasons data (1 season at Kampi ya Mawe and 2 at Kiboko) 11 sorghum lines showed potential for use as either pure forage or dual purpose with biomass yield of 19.21 – 42.36 t ha^{-1}. Three farmer lines namely Nguugu, Muthiriku and Mugana from Meru/Embu in Kenya gave the highest biomass of 45.28, 40.00 and 38.06 t ha-1 respectively. These lines were however very late hence subjected to terminal drought stress and either failing to form grain or giving poor grain yield (0.948-1.422 t ha^{-1}). They would therefore be suitable for pure forage production or in areas with a longer season. These local materials can also be used in improving sorghum for dual purposes by tapping their potentials for biomass and potentials for grain from varieties that have been selected for higher grains. Improved lines SDSL 90162-2, IESV 92007 DL, IESV 990006 DL, IESV 92165 DL, AND IESV 99091 DL and 2 local lines Makueni local and Kiboko-Local 2 exhibited suitability for dual purpose use giving high biomass and good grain yield (2.702-3.955 t ha^{-1}). The materials have been given to an MSc student at the University of Nairobi to evaluate the nutritive attributes

Special Project Funding:
ICRISAT-Israel

MA Mgonja, E. Manyasa, J Kibuka and P Sheunda

Output target 2008 4.2.14 Sweet sorghum varieties and hybrids evaluated in multi environments to determine their suitability industrial testing of ethanol production

Achievement of Output Target (%):
100%

Countries involved:
Kenya; Mozambique; Namibia

Partners involved:
ICRISAT - Nairobi, Sekab-Eco-Energia, Moçfer Indústrias Alimentares (MIA), Instituto de Investigação Agrária de Moçambique NARS Mozambique (IIAM), ICRISAT Mozambique, Creative Entrepreneurs Solutions- Ondangwa Namibia

Progress/Results:

Sweet sorghum cultivar evaluations started in 2007. Selections made from all the sweet sorghum variety trials were constituted into an advanced sweet stalk sorghum trial. This trial consisted of 24 varieties and 1 local check

Kenya: In Kenya the trial was planted at Kiboko in the seasons 2007/8 short rains (SR) and 2008 Long rains (LR) and at Alupe during 2008LR. In 2007/8 season at Kiboko, varieties SPV 1411, IS 2331, SPV 422, ICSV 700 and IS 93046 had the highest brix% (13.5-15.5) and stalk juice volumes (2.6-5.0Kl/ha). These varieties also had good grain yields (2.091-3.749 t ha^{-1}). In 2008LR varieties SPV 1411, SPV 422, ICSV 700, IS 93046, IESV 92008 DL, IESV 92001 DL and ICSB 324 had the best performance in terms if brix% (11.6-17.3) and stalk juice volume (1.935 - 3.778 KL/ha) with grain yields of 0.995-3.571 t ha^{-1} at Kiboko. At Alupe, stalk juice volumes obtained were lower than those at Kiboko due to a delay in crushing as the crusher was not delivered on time. However, most of the varieties that performed well at Kiboko were still the best at Alupe. High brix% (11.2-15.6%) and stalk juice volumes (1.111-1.732 KL/ha) were obtained from IS 2331, IESV 91104 DL, IESV 92008 DL, IS 92028 DL, SPV 1411, SPV 422, and IS 93046. IS 2331 has shown consistent performance in sweetness traits and grain yield and it is to be promoted for commercial utilization

Mozambique: The evaluations of the twenty five open pollinated genotypes were conducted at four research stations during the rainy season 2007/08. These locations comprise four agro-ecological regions situated in 5 districts, namely, Namialo, Nampula province; Chiúrre and Balama in Delgado Province, Sussundenga in Manica Province and Chókwè, Gaza Province. Data was taken on agronomic traits including grain yield as well as on traits determining suitability for in bio-ethanol production. The one cropping season evaluation in three environments indicated that the twenty five genotypes differed significantly for all traits assessed. The %brix varied from 7.7 to 18.3 and grain yield from 0.14 to 5.7 ton ha^{-1}. The stability analysis revealed variation among the top-performers genotypes and relatively superior performance were achieved in Cabo Delgado Province. The trial aimed to identify suitable genotypes mainly for ethanol and grain production and five varieties showed outstanding performance for the key attributes. The varieties that had promising results had juice volumes ranges between 8.928Kl/ha to 12.000Kl/ha for IS 2331; 4.667Kl/ha to 7.803Kl/ha for S35; 9.050Kl/ha to 13.308Kl/ha for ICSV 93046, 5.446Kl/ha to 8.875Kl/ha for IESV 92008 DL and 7.433Kl/ha to 8.979Kl/ha for IESV 92001 DL. The corresponding mean sugar contents (Brix%) across the three sites in Mozambique ranged from 13.7% for S35 to 16.0% for IESV92008. The genotype IESV 92008 DL was top-performer in Katapua and Ocua for stalk yield, juice volume, sugar content and grain weight The stability analysis revealed variation among the top-performer genotypes. For instance, the genotype IS 2331 performed very well in Ocua, Chipembe and Katapua for stalk yield, juice volume and grain weight. However, for the sugar content trait the results were higher only in Ocua. The genotype S 35 showed good results in Ocua and Chipembe for stalk yield, juice volume, sugar content and grain weight. But results were poor in Katapua, especially for the soluble solid concentrations (%brix). The genotype ICSV 93046 revealed good performance for stalk yield, juice volume, sugar content and grain weight in Ocua, but not in Chipembe and Katapua. Overall, for many agronomic traits the crop performance was much better in Ocua, followed by Katapua.

Namibia: A preliminary evaluation in Namibia was done during the summer of 2008. The varieties IESV92001DL, IESV92008 DL, MR22X IS 8613/2/3-1-3, IESV92038/3SH, IESV92036 SH and IS2331 were superior among the ten varieties tested in terms of biomass, juice volume and sugar content in the stalk juice

On the overall, and consistently across the three countries of Kenya, Mozambique and Namibia that the varieties IESV92001DL, IESV92008 DL and IS2331 have the most initial key attributes and can be fast tracked for potential use in bio-ethanol production from sweet sorghum. There are plans to increase seed of the best performers for evaluation in additional countries as may be requested by collaborating investors and researchers for pilot production and demonstrations

Special Project Funding:
Nil

MA Mgonja, E Manyasa, W Leonardo, C Dominguez, P Sheunda and J Kibuka

Output target 2008 4.2.15 Regional Pearl millet cultivars evaluation to establish adaptability and stability of performance

Achievement of Output Target (%):
75% Reason for incomplete fulfillment is that the work on pearl millet has been declining after the closure of the ASARECA projects which was aimed at revamping the pearl millet hybrid breeding

Countries involved:
Kenya; Tanzania
Partners involved:
ICRISAT Nairobi, Department of Research and Development Tanzania

Progress/Results:
A reconstituted regional pearl millet trial consisting of 25 entries was planted at Kiboko Kenya and Dodoma Tanzania in 2007/8SR and 2008 respectively. Higher grains yields were obtained at Kiboko (1.284-2.364 t ha^{-1}) than at Dodoma (0.319-1.178 t ha^{-1}). The varieties SDMV 95009, SDMV 92038 and Okashana performed best at Kiboko with grain yields of over 2.0 t ha^{-1}. At Dodoma the best varieties were SDMV 96603 and SDMV 92038 with grain yields of 1.178 t ha^{-1} and 1.075 t ha^{-1} respectively against local check yield of 0.922 t ha^{-1}. In Uganda, ICMV221 performed well and the breeder has been provided with seed and information to facilitate releases and seed increases. Twelve selections from the test cross hybrids evaluation of 2007/8 season and 4 parental checks (ICMV 221, Okoa, Shibe and Okashana 1) were evaluated in a preliminary yield trial. Only 3 hybrids (ICMA 00888 x Kat PM 1, ICMA 00888 x PMV 3 and ICMA 00888 x Okashana 1) attained seed set above 70% but had grain yield not significantly different from the parent checks (2.2-2.5 t ha^{-1}). However in 2008 long rains season, all the hybrids had seed set below 65%. There is need to revamp the pearl millet hybrid program by test more parents for suitability for top cross hybrids development.

Special Project Funding:
Nil

MA Mgonja, E Manyasa, J Kibuka, P Sheunda and H Ojulong

Output target 2008 4.2.16 Training on statistical methods in agriculture, experimental design and seed production

Achievement of Output Target (%):
100% The expected number of participants was achieved as well as the key topics for the training were well covered

Countries involved:
Madagascar; Mozambique

Partners involved:
ICRISAT Mozambique, Moçfer Indústrias Alimentares (MIA), FOFIFA, FAO, WVI, CRS Concern International

Progress/Results:
Mozambique:
One of the limitations faced by recently graduated agronomists is the capacity to plan, implement, collect and analyses of field experiments, data and be able to make inferences from the analyzed data. The objective was to improve MIA's staff capacity on statistical methods and data analyses. This training follows up one such training held in India from June to August 2008. The two days training was attended by four (4) MIA's technicians and was organized at MIA's office located in Chókwè district. The training encompassed experiment design, data entry and computation using Genstat for windows. It focused on the Randomized block and lattice designs.

In Madagascar
The training was conducted in Tulear, 1000km South of Antananarivo from 2nd to 5th June 2008. A total of 40 participants, which included senior staff from the Ministry of Agriculture such as the Madagascar Director of Agriculture, Director of Quarantine and a newly appointed Sorghum Coordinator; National Center for Agricultural Research and Rural Development (FOFIFA), Adventists Development and Relief Agency (ADRA), Regional Director for Rural Development (DRDR), FAO (including Head of FAO operations in Madagascar and Head of Emergency Coordination) Field staff from MAEP, FOFIFA, DRDR, FAO, TAFA, CARE, GRET , CRS ALT. The training started with a general understanding of the sorghum crop (Origin, Biology, Taxonomy) sorghum crop husbandry, cultivar development and evaluation, and dwelt more on seed production, quality control and dissemination methods including international regulations of seed export and import. At the end of training, a meeting was held with representatives of the participating stakeholder groups to chart a road map and way forward and the discussions were led by the sorghum coordinator and advisor to the Minister for Agriculture and FAO emergency program coordinator to plan way forward for emergency seed organization and research needs.
The suggested areas of focus for the future research and Development program for dry land cereals include:
1) Research:

- Need to evaluate cultivars to identify better suited types for different agro-ecologies.
- Post harvest handling- better decorticating technologies to minimize loses (50% loss in IRAT 204 and 25% in Kuyuma)
- Utilization- Diversified food products, feed, industrial use
- Training at various levels – research, extension and farmers
- Germplasm collection and evaluation
- Crop productivity enhancing technologies

2) Development: Alternative seed delivery models to be proposed and tested and also linking to end users
3) Capacity Building aimed for agricultural service providers as well as graduate and post graduate studies

Special Project Funding:
Nil

W Leonardo and C Dominguez (Mozambique), MA Mgonja and E Manyasa (Madagascar)

Output target 2008 4.2.17 At least 6 NARS are annually provided with breeding materials for further evaluation

Achievement of Output Target (%):
100% A total of 9 NARS and 12 organizations were serviced and all seed requests were met and each recipient signed and returned an SMTA before seed was shipped

Countries involved:
Kenya, Lesotho, Malawi, Mauritius, Mozambique, Somalia, Southern Sudan, RSA, Tanzania, Uganda and Zimbabwe,

Partners involved:
NARES of the respective countries; Seed companies (Leldet, Agricultural Seed Agency -Tanzania, Progene Seeds-Zimbabwe); NGOs and Biofuel Private Companies (FAO, CINS-Somalia, Bio-diesels East Africa, SEKAB, AFC – Mohoroni); Universities (ACCI Kwa Zulu Natal South Africa, Moi, Egerton and Nairobi); Advanced Research Institutes (CSIR- South Africa)

Progress/Results:
The sorghum and millet improvement program in ESA has resumed regional cultivar evaluation as a platform for germplasm exchange, improve efficiency in identification of suitable varieties and sharing data to support cultivar releases. The regional trials are composed based on agreed breeding zones and end uses, while others are targeting broader adaptability. In addition to regional trials, ICRISAT ESA provides nucleus and breeder seeds to partners in the public and privates sector organizations. A total of 189 kgs of seed was availed as nucleus seed in quantities ranging from 100gms to 8kgs as requested by the individual recipients. The largest quantity of breeder seed of IRAT204 (100Kgs) was given to FAO/Madagascar for multiplication and further distribution to farmers. In addition regional trials for sorghum varieties and hybrids and pearl millet varieties were given to Kenya, Tanzania, Malawi, Mozambique and South Africa. These included sweet sorghum materials whose demand is increasing exponentially.

Special Project Funding:
Nil

MA Mgonja, E Manyasa, J Kibuka, P Sheunda and H Ojulong

Output target 2008 4.2.18 Nurseries of genetically diverse breeding populations developed and advanced for sharing with national partners for further selection and adaptation

Countries involved:
Kenya, Tanzania

Partners involved:
ICRISAT Kenya, KARI Katumani/Kakamega, DRD Naliendele/Ukiriguru

Progress/Results:
The sorghum improvement in ESA is targeting four agro-ecologies and production systems, the Dry Lowlands (DL) which is the most important, the Sub Humid (Around Lake Victoria) the high altitudes (highland sorghum together) with the "away from the equator photoperiod sensitive sorghums". Over time the program has identified sources of resistance to the key biotic and abiotic stresses as well as adaptation traits. The following nurseries were managed during the short and long rain season of the 2008 year.

- Crosses made to develop early brown grain sorghum types targeting the drier Lake Zone (SH/DL) were advanced to F2 at Alupe during 2008LR season. 27 selections were made and will be advanced to F3 in 2009LR season.
- 98 F4 stay green progenies (B-35 x Elite drought tolerant lines) selected for advancing in 2009 at Kiboko
- Individual F7 progenies from Mugeta/Kaguru (early drought tolerant) x Macia/ZSV3 were bulked for preliminary yield trials in 2009 at Kiboko.
- Breeding for sweetness : 56 sorghum F1s (8 parents half diallel) developed in 2008 LR season for the 2008/9 planting in Kiboko
- F2 generation of photosensitive sorghum populations for planting and selection in southern Tanzania
- F2 generation of high lysine sorghum lines crossed to wild sorghums from western Kenya for gene flow studies
- F2 generation of crosses between wild sorghums from western Kenya and elite /cultivated sorghum varieties for hybrid fitness for gene flow studies
- Maintenance breeding for hybrid parents and open pollinated varieties for sorghum, pearl millet and finger millet

The segregating populations are for selecting suitable materials for the specific production zones materials and others are for studies that will provide data and information to assist in biosafety policy framework in two ESA countries

Special Project Funding:
Nil

MA Mgonja, E Manyasa, H Ojulong, P Sheunda and J Kibuka

Output target 2009 4.2.1 Three elite farmer varieties of sorghum from three countries carrying 1 to 3 striga resistance QTLs evaluated through a participatory approach

Achievement of Output Target (%):
75% Field trials have been conducted in Kenya, Sudan and Mali to evaluate farmer varieties introgressed with 1-3 *Striga* resistance QTLs. Preliminary results show that several lines derived from three farmer varieties have resistance similar to that of the donor parent. Preparations for farmer participatory field trials are advanced in the three countries.

Countries Involved**:**
Kenya, Eritrea, Mali; Sudan

Partners Involved**:**
Kenya Agricultural Research Institute (KARI) Kenya: National Agricultural Research Institute (NARI)–Eritrea; Institut d'Economie Rurale (IER) and Université de Bamako (UB), Laboratoire de Biologie Moléculaire Appliquée –Mali ; Agricultural Research and Technology Cooperation (ARTC) Sudan: Universität Hohenheim-Germany

Progress/Results:
In the recent past, the ability to develop markers and transfer target genomic regions has resulted in their extensive use in quantitative trait loci (QTL) mapping and marker assisted backcrossing (MABC). With time, molecular markers have proven to be a powerful complementary tool to conventional breeding in genetic analysis and introgression of complex polygenic traits conferring resistance to both biotic and abiotic stresses. In the recent past, ICRISAT and the University of Hohenheim have made significant progress in identifying molecular markers for *Striga* resistance in sorghum. During this period, five genomic regions associated with stable *Striga* resistance from resistant line N13 were identified across a range of 10 field trials in Mali and Kenya. The QTLs were identified on different chromosomes and each of these QTLs explains between 14 and 44% of the total phenotypic variation observed for *Striga* resistance in the sample used (Haussman *et al*, 2004). Flanking SSR markers to the QTLs are now available for use in marker assisted backcrossing and they are vital in transferring *Striga* resistance from the donor N13 to susceptible farmer preferred sorghum varieties (FPSVs). The application of marker-assisted backcrossing (MABC) in *Striga* resistance breeding has therefore been used in order to accelerate progress in the development of *Striga*-resistance into locally adapted farmer-preferred sorghum varieties.

ICRISAT, in collaboration with four African NARs (Kenya, Eritrea, Sudan and Mali) has been developing *Striga* resistant farmer varieties through Marker Assisted Backcrossing (MABC). In these four countries, the NARS are being assisted to strengthen *Striga* resistance of farmer-preferred sorghum varieties (FPSVs) by combining Marker Assisted Backcrossing (MAB) and farmer-participatory selection to develop near-isogenic lines carrying one to three *Striga* resistance QTLs. In order to ensure the effective integration of *Striga*-resistant FPSVs into farming systems in the target countries, studies in population genetics, socio-economics and seed supply systems are being undertaken. Four of the mapped *Striga* resistant QTLs with interval lengths of 20-50 cM were introgressed into 5 farmer preferred sorghum varieties in collaborating countries through two generations of backcrossing followed two selfing cycles to fix the QTLs. Results from on-station trials in Kenya, Mali and Sudan under artificial infestation are promising, with 102 derivatives introgressed with one to three QTL showing resistance and different levels of tolerance against *Striga* based on *Striga* counts (#m^2) and Area Under *Striga* Number Progressive Curve (AUSNPC). From these trials, several lines have shown resistance as good as that of donor parent N13 and with agronomic qualities that are similar to the recurrent parents based on grain yield (g/m^2), farmers' appreciation of grain quality and assessment of trait recovery. Field screening is hampered by heterogeneous natural infestations, high variability of soils and large environmental effects on *Striga* emergence. It is therefore imperative that the QTLs be tested for stability and effectiveness against *Striga* in farmers' fields across a wide range of environments where sorghum is grown. In addition, varying genetic backgrounds for introgressing *Striga* resistance are needed as farmer trait preferences are different and the environments where sorghum is grown are diverse.

Special Project Funding:
BMZ/GTZ

D Kiambi, CT Hash and D Hoisington

Output target 2009 4.2.3 6 newly improved pigeonpea cultivars disseminated through participatory methods in ESA

Achievement of Output Target (%):
75% Identified both medium and long duration varieties suitable for PVS evaluation, conducted PVS in target countries and regions, zeroed on farmer preferred varieties and taken steps to multiply seed of selected genotypes.

Countries Involved:
Kenya; Malawi; Mozambique; Tanzania

Partners Involved:
ICRISAT-Nairobi, Kenya Agricultural Research Institute (Katumani)-Kenya, Selian Agricultural Research Institute-Tanzania, ICRISAT-Lilongwe, Chitedze Agricultural Research Station-Malawi, ICRISAT-Mozambique

Progress/Results:
A majority of pigeonpea farmers in ESA, are still growing traditional low yielding, wilt susceptible, photo and thermo-sensitive varieties, in spite of availability of superior pigeonpea varieties developed by ICRISAT-Nairobi. The farmers' participatory evaluation with direct involvement of farmers in choosing preferred varieties based on high yield, cream seed color and bold seeds offer a greater scope for varietal dissemination. Participatory evaluation approach is being adopted in Mbere and Makueni districts of Kenya; Babati, Arumeru, Kondoa and Karatu districts of Tanzania; central and southern Malawi and Mozambique.

In Makueni and Mbere districts of Kenya, three medium (ICEAPs 000 557, 00554, 00850) and two long duration varieties (ICEAPs 00040, 00932) were evaluated. Farmers preferred varieties in Makueni and Mbere were ICEAPs 00554 and 00557, respectively.

In Tanzania, 47 PVS conducted in Babati, Karatu, Kondoa and Arumeru districts using genotypes from six long duration (ICEAPs 00040, 00053, 00932, 00933, 00936, 00576-1), two medium duration varieties (ICEAPs 00557, 00554) depending upon the crop growth duration available in respective districts. After PVS evaluation farmers preferred long duration varieties (ICEAPs 00040, 00053, 00932, 00936) in Babati, Karatu and Kondoa districts and medium duration varieties (ICEAPs 00554 and 00557) in Arumeru.

Medium duration varieties are suitable in central Malawi and northern Malawi when compared to long duration varieties in southern Malawi, and PVS evaluation was done accordingly using suitable genotypes. The most preferred genotypes were ICEAPs 00557 and 00040 in southern Malawi, ICEAPs 01514/15, 00557 in central Malawi and ICEAPs 01514/14, 00557 and 01480/32 in northern Malawi based on high yield, cream colored bold seeds, tolerance to drought and fusarium wilt resistance.

In Mozambique PVS with both long and medium duration varieties were organized in three districts namely Angonia, Chimoio and Chokwe districts, and farmers preferred variety was ICEAP 01480/32 being early, cream bold seeds, tolerance to drought and diseases.

Special Project Funding:
Tropical Legumes-II, BMGF; Treasure legumes-IFAD; Kellogg's fund

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output target 2010 4.2.5 Segregating long duration pigeonpea populations with large grain and resistance to fusarium wilt developed

Achievement of Output Target (%):
25% targets by making crosses between parents with large grains and resistance to fusarium wilt.

Countries Involved:
Kenya

Partners Involved:
ICRISAT-Nairobi

Progress/Results:
Crosses were made between ICEAPs 00040 (fusarium wilt resistant) and 00048 (large round grains and extra long duration) and F_2 populations are planted at Kabete (select for large grain) and Kiboko (wilt sick location) in 2008/09, to select for long duration and fusarium resistant single plants. The best plants selected in Kabete with large grains will be planted in next season at Kiboko for selecting bold grain types possessing wilt resistance. Conversely, the fusarium wilt resistant genotypes selected at Kiboko will be planted in Kabete for selection of large grain types. The best selections from both Kabete and Kiboko will be stabilized for agronomical and morphological traits in subsequent generations.

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, M Somo, D Ojwang and P Kaloki

Output target 2010 4.2.7 Segregating medium duration pigeonpea populations with large round grains and traits associated with insect pest tolerance developed

Achievement of Output Target (%):
25% targets by making crosses between pest tolerant lines and growing segregating populations. Planned to make new crosses involving best parent for round grains (ICEAP 00048) and best medium duration genotypes (ICEAPs 00554, 00557) during 2008/09 crop season.

Countries Involved:
Kenya

Partners Involved:
ICRISAT-Nairobi

Progress/Results:
Crosses were made between ICEAP 00040 and Mthwajuni, Acc 88 and ICEAP 00576-1 to incorporate pest tolerance from Mthwajuni (Tanzanian germplasm) and Acc 88 (Mozambique germplasm) to incorporate pest tolerance.

Special Project Funding:
Nil

SN Silim, NVPR Ganga Rao, P Kaloki, D Ojwang and M Somo

Output 4.3: New knowledge of the QTLs for the stay green and drought tolerance traits confirmed, and marker assisted selection efficiency improved, and specific abiotic stress tolerant varieties and associated knowledge for sorghum, pearl millet and groundnuts developed and disseminated in ESA with associated capacity development

Drought is considered to be the primary cause of yield reductions for crops in sub-Saharan Africa. Intra- and inter-seasonal variations in timing and intensity of rainfall result in drought stresses of various intensities and durations during crop growth. There are various approaches to address drought with one approach being the development of early maturing varieties that escape terminal drought. Stay-green, characterized bymaintenance of green stems and upper leaves under terminal drought stress, occuring during grain filling is a mechanism of drought tolerance. Two sorghum inbred lines (B35 and E36-1) are being used as donor parents for transferring the major stay-green QTL into four farmer preferred local sorghum varieties. Stay-green QTL from two ICRISAT donor parents (B35 and E36-1) were introgressed through marker assisted back-crossing into four farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale). During 2008, BC2F1 of all four varieties were advanced through BC3F1 to BC3S1 and have been planted for genotyping analyses and advance to BC3S2 in 2009. The donor parent B35 has also been crossed with 6 improved and elite lines and two farmer varieties. F6 and F7 progenies will be included in the preliminary evaluations to determine the extent of yield advantage from the stay green and other agronomic traits

As a basis for a marker-assisted breeding program a groundnut working collection of farmer- and market-preferred varieties have been identified (by trait) from Sub-Saharan Africa as recurrent parents for introgression of resistances to leaf diseases into farmer / market preferred varieties. These include ICGV-IS 96894 (Nigeria), ICG 12991 (Malawi), ICGV-SM95714 (Malawi), ICGV7878 (Mali), ICGV91114 (Patancheru), ICG FDRS 4 (Mali) and ICG FDRS 10 (Mali). In addition, nine elite lines from the ESA program have been identified as good candidates for MAB. Development of twenty eight (28) new breeding populations was also initiated using these lines. These include twelve (12) incorporating rosette resistance, eight (8) incorporating ELS resistance and eight (8) incorporating rust resistance. Phenotyping of these populations at F2's will be done during the 2008/09 growing season while F2:F3 populations will also be produced.

IPGs:

- Improved drought tolerant lines available for evaluation by collaborators ,
- Stay green products that can be used to improve fodder quality and benefit crop livestock system
- 35 farmer/market preferred groundnut varieties assembled from all across SSA and a program for marker assisted introgression of resistance to biotic constraints initiated at ICRISAT Malawi

Outcome:

- Collaborator participating are capable to improve their efficiency from use of biotechnology tools
- Breeders use existing staygreen and striga resistance QTL in their breeding program".

Impact:

- The potential of the materials under development in this output will benefit from integration of biotechnology and conventional breeding methods
- The products from this output will be beneficial to crop livestock farming systems

Output target 2008 4.3.1 Eefficiency and effectiveness of MAS for stay-green in sorghum determined

Achievement of output target (%):
Fully Achieved

Countries involved:
Kenya and Ethiopia

Partners involved:
ICRISAT –Nairobi, Melkassa Agricultural Research Center

Progress/Results:
Stay-green QTL from two ICRISAT donor parents (B35 and E36-1) were introgressed through marker assisted back-crossing into four farmer-preferred Ethiopian sorghum varieties (76T1#23, Meko, Gambella and Teshale). Each generation was analyzed by DNA genotyping at the foreground (to identify individuals with the stay green QTLs introgressed) and background (to identify the individuals with staygreen QTL that had the most recurrent background recovered from the backcrossing) level to determine which individuals to advance to each subsequent generation. During 2008, BC2F1 of all four varieties were advanced through BC3F1 to BC3S1 and have been planted for genotyping analyses and advance to BC3S2 in 2009. The number of BC_3F_1s advanced across all four recurrent parents to BC_3S_1s was 34 from donor parent B35 and 22 from the donor

parent E36-1. Each advanced line contained 1 or 2 target QTLs. In the previous generation, some BC_2F_1 individuals contained up to 4 QTLs but these were not captured in the BC_3F_1 individuals genotyped. In most cases very few progeny of the individuals with multiple QTLs survived after planting for genotyping and we were not able to capture more than 2 QTLs per individual to advance to BC_3S_1. The selected BC_3S_1 seeds were planted in December and leaf samples for genotyping will be collected and sent to BecA in January 2009.

Special Project Funding:

Syngenta Foundation for Sustainable Agriculture project: Harnessing modern science in Africa to sustain sorghum and millet production for resource-poor farmers

Kassa Semagne and S de Villiers

Output target 2008 4.3.2 A groundnut working collection of at least 15 farmer- and market-preferred varieties, as the basis of a marker- assisted breeding program by 2008

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Malawi; Mali; Mozambique; Niger; Senegal (WCA); Tanzania (ESA)

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Agricultural Research Institute Tanzania, Institute of Agricultural Research – Nampula Research Station Mozambique, ICRISAT Mozambique, ICRISAT WCA Mali.

Progress/Results:
The following elite varieties have been identified (by trait) as recurrent parents for introgression of resistances into farmer / market preferred varieties.

- **Rosette virus resistant** ICGV-SM 90704 (Malawi) and ICGV-IS 96894 (Nigeria),
- **Aphid Resistance** ICG 12991 (Malawi),
- **ELS Resistance** ICGV-SM 95714 (Malawi)
- **ELS and LLS resistance** ICG 7878 (Mali)
- **Rust Resistance** ICGV 94114 (Patancheru), ICG FDRS 4 (Mali) and ICG FDRS 10 (Mali).

In addition to the above, field experimentation at the ICRISAT Chitedze Research Station under managed high disease pressure for ELS and GRD, coupled with farmer participatory variety selection have identified the following Elite varieties as good candidates for MAB.

- Rosette resistance in early maturity background: ICGV-SM 99555, ICGV-SM 99557, ICGV-SM 99541, ICGV-SM 01514, ICGV-SM 01515, ICGV-SM 99529
- Rosette resistance in confectionary large seeded background; ICGV-SM 01711, ICGV-SM 01731, ICGV-SM 01708

The following are candidate farmer / market preferred varieties: from Tanzania; Red Mwitunde, ICGMS 33 (Pendo), Robut-33 (Johari), Spancros (Nyota), and ICGMS 46 (Sawia). From Malawi; CG7, Chalimbana, JL24, Chalimbana 2005. ICRISAT Mali provided the following popular varieties from Mali, Senegal and Niger; 55-437, 47-10, Fleur 11 and ICGV 86124. Seed increase of the above germplasm took place in Malawi and was completed in June. The crossing program to develop the good x good population and the backcrossing program involving the preferred varieties and the resistance sources began in July 2008.

ES Monyo, M Osiru, B Ntare, O Mponda, H Charlie and E Sichone

Special Project Funding:
Bill and Melinda Gates Foundation and McKnight Foundation

Output target 2008 4.3.3 Progenies of crosses between stay green donor parent and elite dryland sorghum advanced for selection under drought conditions

Achievement of Output Target (%):
100%
The materials have been advanced and are ready for preliminary evaluations

Countries Involved:
Kenya

Partners Involved:
ICRISAT Kenya, KARI Katumani

Progress/Results:
The stay green donor parent B35 has been crossed with six elite lines (IESV91111DL, IS 8193, Seredo, KARI Mtama , Mexico R-LINE#5 and Tegemeo) to transfer stay green trait to the elite lines. The objective was to introgress staygreen QTL into these elite varieties as an attempt to improve their drought tolerance. In the 2007/08 Short rain season, 35 progenies were planted together with their parents. A total 98 F4 selections were made and will be planted as head rows in the 2008/09 season for further selection. In addition F6 generation of crosses between Mugeta and Kaguru (Local sorghum varieties) with Macia and ZSV3 were advanced. During 2007/08 short rains season, six lines which were uniformly stable based on plant height and grain yield potential were selected and advanced to F7 in 2008 long rains season. Each of the progenies was supplied with limited moisture and 20 heads were selected for advancement in 2008/09 short rains season.

Special Project Funding:
Nil

MA Mgonja, E Manyasa, H Ojulong, P Sheunda and J Kibuka

Output target 2009 4.3.4 At least one new breeding population each for GRD, ELS and rust resistance for ESA by 2009

Achievement of Output Target (%):
50% Hybridization completed, hybridity confirmed, F1:F2's produced

Countries Involved:
Malawi for the entire ESA

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, Naliendele Agricultural Research Institute Tanzania.

Progress/Results:
A total of fifty six (28) breeding populations were generated during the 2007/08 growing season. These include: twenty four (12) incorporating rosette resistance, sixteen (8) incorporating ELS resistance and sixteen (8) incorporating rust resistance. Phenotyping at F2's of these breeding populations will be done during the 2008/09 growing season. Some remnant seed will be planted to advance the populations as F3 bulks as a backstop measure.

From previous populations, thirty one (31) nurseries comprising 1074 progeny rows ranging from F2 through F7, were evaluated under high rosette disease pressure. The objective was to combine two or more important production traits (grain yield, aphid resistance and GRD resistance). A total of 379 single plant selections were made for generation advance- 213 plants derived from F_2-F_6 progeny rows were identified for generation advance through single plant selections; 84 F7 progeny rows were advanced to check row yield observation trials, while 72 check row populations were advanced to preliminary trials. Fifty nine (59) progeny rows from F7 and Check row populations had 0% rosette incidence

Special Project Funding:
McKnight Foundation, Bill and Melinda Gates Foundation

E Monyo, M Osiru and H Charlie

Output 4.4: Progress in knowledge and/or improved germplasm of nutritionally enhanced transgenic sorghum and biofortified transgenic events and non- transgenic germplasm with enhanced micronutrient levels available for evaluation and studies on risk assessment conducted

Summary:
Environmental Risk Assessment is an important pre-requisite for deploying genetically engineered crops. The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment; leading to loss of biodiversity and destabilization of the ecosystem. The study finds evidence of gene flow in the major sorghum growing areas of Kenya. Agro-ecology, household income and farmers' education and crop handling practices can either promote, or minimize the flow of genes from wild to cultivated sorghum varieties and vice versa. Farmers' environmental and socio economic conditions should be considered as part of the gene flow process, however, the biosafety perspectives ought to focus on the effects and impacts. Gene flow studies (hybrid fitness and out crossing rates between wild and cultivated sorghum) were completed in South Africa and Kenya and continuing in Burkina Faso for populating each country's biosafety file for application of permits to conduct research with transgenics.

Output target 2008 4.4.1 Farmers' knowledge on wild and weedy sorghum and implications for cultivated sorghum documented with associated capacity development for at least 2 ESA countries

Achievement of Output Target (%):
>75%

Countries Involved:
Burkina Faso; Kenya

Partners Involved:
Pioneer seed, Council for Science and Industrial Research (CSIR-South Africa), Agricultural Research Council (ARC-South Africa), African Agriculture Technology Foundation (AATF), Africa Harvest, KARI-Kenya, and INERA-Burkina Faso]

Comments/Explanations:
80% achieved: The study has been completed in Kenya; an abstract was accepted by the Journal of Food Agriculture and Environment (JFAE). Data has been collected in Burkina Faso and awaits analyses and synthesis. Burkina Faso was considered a target country 2 years after the project was initiated and the originally planned target country -0South Africa could not allow studies with their germplasm.

Progress/Results:
Sorghum (*Sorghum bicolour L*) is one of the most important cereal crops in Africa with wide ranges of races, varieties and feral relatives that are sympatric and sexually compatible. Transgenic technology is among scientific innovations with potential to improve sorghum productivity and nutrition. The deployment of transgenic sorghum is likely to be met by trepidation that gene flow will negatively impact the environment; leading to loss of biodiversity and destabilization of the ecosystem. A study was conducted in eastern and western Kenya regions between July 2006 and March 2007 using settings intentionally selected to capture variations in culture, agro-climatic and socio-economic conditions. Data was obtained through primary surveys and personal interviews with 881 randomly sampled smallholder sorghum farmers. Descriptive statistics and probit analyses were used on the qualitative and quantitative data respectively, to identify drivers of pollen and seed mediated gene flow.

The study finds that wild/weedy sorghums are widespread in the two regions. More than 91% and 36% of the respondents in western and eastern Kenya respectively are aware of the existence of wild/weedy sorghums. Farmers identify off-types by grain size, maturity stage, shape of the panicle and grain colour. Respondents in western Kenya identified a higher number of sorghum varieties than in eastern Kenya. Agro-ecology of the farms ($p=<0.01$), cultural practices [presence of wild sorghum ($p=< 0.05$) and off types ($p=<0.01$)] and household wealth ($p=0.089$) drive farmers' ability to maintain variety purity. The three factors were negatively related to variety purity maintenance. Farmers maintain variety purity by rouging, removal of off-type panicles after harvest, spatial separation of sorghum fields, selection of seeds prior to planting, and weeding out off-types. The study finds evidence of gene flow in the major sorghum growing areas of Kenya. Agro-ecology, household income and farmers' education and crop handling practices can either promote, or minimize the flow of genes from wild to cultivated sorghum varieties and vice versa. Farmers' environmental and socio economic conditions should be considered as part of the gene flow process, however, the biosafety perspectives ought to focus on the effects and impacts.

Special Project Funding:
Africa Biofortified Sorghum (ABS)

MA Mgonja, E Manyasa, J Kibuka, H Ojulong and P Sheunda

Output target 2008 4.4.2 Out crossing rates between sorghum and wild species determined

Achievement of Output Target (%):
>75%

Countries Involved:
Burkina Faso; Egypt; Kenya; Nigeria; South Africa,

Partners Involved:
Pioneer seed, Council for Science and Industrial Research (CSIR-South Africa), Agricultural Research Council (ARC-South Africa), African Agriculture Technology Foundation (AATF), University of Pretoria, Africa Harvest, KARI-Kenya, and INERA-Burkina Faso]

Comments/Explanations:
75% achieved: All that was planned for the fitness experiment was achieved. However due to failure in synchronizing of flowering dates in the case of Burkina Faso trial and choosing of appropriate parents in the case of South Africa the pollen flow experiment was not finalized during the course of the year. The strategy was to resort to assessing grain color of the progeny plants instead of seedling plant.
Progress/Results:
In light of the future deployment of GM sorghum in the region, scientific risk assessment of transgenic crops and its impact on conventionally bred crops and crop wild relatives need to be done to establish adequate biosafety regulations. For estimation of hybrid fitness and rate of hybrid formation, two sets of populations developed between cultivated and wild or weedy sorghum were used. The first set consists of 10 crosses from four cultivated varieties (Zerazera 308, Seredo, N13 and Ochuti) and four wild/weedy sorghums (Busia wild 4, 5, 10 and 12). F2 and parents were planted in November 2007 and data recorded on plant height, above ground biomass, grain characteristics and yield per plant. A second set consists of crosses between three high lysine lines (IS 11167, IS 11758 and 21116) and five wild sorghums (Busia wild 2 and 5 and Siaya wild 1, 2 and 3), F2 were evaluated during the long rains of 2008.. A third set of populations between six cultivated varieties and new collections of wild varieties has been planted for evaluation.

Differences between the crossing types (Cult x Cult (selfed cultivated); Cult x Wild; Wild x Wild (selfed wild) and Wild x Cult) were tested by one way ANOVA. Analysis of the first set revealed highly significant differences for all the traits among the crossing types. Differences were noted between the cultivated parents (Cult x Cult) and the hybrids (Cult x Wild and Wild x Cult) and wild parents (Wild xWild). No significant differences were however noted between the wild parents; and the Wild x Cult hydrids, implying that at F_2 hybrids were not superior to the wild parents. Comparing the F_1data from previous season with F_2 data showed sharp reductions in differences of relative fitness in traits between the F_1 and F_2 hybrids.

Results from the cross between the high lysine and the wild showed crossing type affecting all evaluated characters. Hybrids generally performed better than the selfed maternal parents, except in stem girth, panicle width and number of seeds per panicle. In the Wild x Cult hybrids, the differences where more marked in the vegetative traits as opposed to the reproductive traits suggesting that the hybrids have a stronger capacity for clonal propagation compared to the parents (Song *et al*., 2003). Reciprocal differences were detected between Cult x Wild and Wild x Cult for all the characters and is in agreement with earlier findings (Hauser *et al*., 1998).

Data from the gene-flow experiments (without pollen competition) collected from the previous season was analysed. The sorghum crop had an average of 2115.7 female flowers per panicle. On the basis of the amount of female flowers per plant and the average amount of seeds produced per plant and distance class, the hybridization rate of pollinated flowers per plant was calculated. The hybridization rate was relatively low, 5.57% at 0.75 m distance to the central field in South Africa. At 5 m from the centre, hybridization was 3.28% and 2.53% in South Africa and Kenya respectively. The rate fell to below 1% at 30m and less than 0.1% at 70m for both countries. Hybridization rate was affected by wind direction and speed. The findings are in agreement with earlier work on sorghum and other crops (Song *et al*., 2003; 2004; Schmidt and Bothma, 2006). Collection of data on gene flow experiment with pollen competition is yet to be completed for South Africa and Burkina Faso.

Special Project Funding:
Africa Biofortified Sorghum ABS of the BMGF

MA Mgonja, H Ojulong, E Manyasa, J Kibuka and P Sheunda

Output target 2008 4.4.3 Understand the in situ dynamics of crop-to-wild and crop-to-weed genetic introgression in Kenya at the country scale

Achievement of Output Target (%):
100% All project activities have been completed as agreed with the donor and final report and journal publications are being prepared.

Countries Involved:
Kenya

Partners Involved:
CIRAD, KARI, University of the Free State, University of Hohenheim

Progress/Results:
Germplasm collected in 2006 and 2007 of cultivated land races, cultivated-wild hybrids and wild sorghums from Turkana, Western, Coastal and parts of Eastern provinces of Kenya comprised a total of 329 cultivated and 110 wild/weedy samples. This included samples acquired from ex-situ collections at the national gene bank of Kenya to cover Rift valley and North Eastern region of the country. All of these were submitted to DNA genotyping for diversity assessment with 24 SSR markers at the ILRI/BecA hub. The resulting data was analyzed to estimate the crop-wild geneflow and the results are being incorporated in a PhD thesis. Various population genetics software have been used to analyze the extent and structure of diversity within and among cultivated and wild sorghum and to make inferences on the genetic and evolutionary relationships (e.g level of historical gene flow) among the two at different spatial scales. In total 295 alleles were detected for the 24 SSR markers in the 439 cultivated and wild sorghum genotypes. Cultivated sorghum harbors significantly lower allelic richness and gene diversity than the wild sorghum (Wilcoxon's signed-rank test: $P \leq 0.05$ and $P<0.001$, respectively), a suggestion of reduced diversity in the cultivated gene pool due to population bottlenecks during domestication. In cultivated sorghum genetic diversity is highest in Eastern region and least in Turkana, whereas in wild sorghum it is highest in the Coast and least in Western and Nyanza. There is a very moderate degree of differentiation among cultivated and wild sorghum (as estimated by Fst (0.062), principle coordinate analysis (PCO), neighbour joining (NJ) cluster analysis, Bayesian model-based cluster analysis and AMOVA (only 6.4% variation among the congeners), which suggests important historical gene flow between the two congeners. This is further supported by the general finding that the level of differentiation among cultivated and wild was lower within than among regions. Most significantly, genetic differentiation among cultivated and wild sorghum (and through inference therefore, historical gene flow) was observed to vary among regions, with Turkana having the highest (e.g Fst=0.18) and Western/Nyanza the least (Fst=0.03). These differences could be attributed to variations in farmer practices such as wild/weedy sorghum management and sorghum variety selection, but also due to differences in the wild sorghum types among regions.

Special Project Funding:
Environmental Risk Assessment of Genetically Engineered Sorghums in Kenya and Mali, funded by US AID-BBI

Fabrice Sagnard, Santie de Villiers and Kassa Semagn

Output target 2008 4.4.4 Determine gene flow and out crossing rates between cultivated, wild and weedy sorghum types and assess hybrid fitness in diverse ecologies using conventional and molecular markers

Achievement of Output Target (%):
95% All experimental work has been completed and the results are being analyzed and assimilated in two Ph.D dissertations and publications in peer reviewed journals that will be submitted in early 2009.

Countries Involved:
Kenya

Partners Involved:
CIRAD, KARI, University of the Free State, University of Hohenheim

Progress/Results:
In 2006, a Ph.D student was recruited in this project. He conducted a preliminary assessment of a chosen 8 x 8 km intensive study site (ISS). The aim was to identify the optimum number of farms that have to be sampled in order to acquire all the sorghum varieties grown in a particular target region and also to obtain some preliminary information on crop diversity and wild sorghum ecological distribution and identification criteria. This was done along an altitudinal gradient of 750 to 1200 masl and across 4 different language groups. Farmer-level interviews were conducted in 372 households across the ISS. Information on among other geographical coordinates, elevation, varieties of all crops grown and on presence and abundance of wild/weedy populations was collected. Multivariate statistical analysis of the ensuing data on farm-level crop and variety diversity information was used to select 44 representative households. The selected households were visited for quantitative categorization data and sample collection. In total 17 wild/weedy populations made up of 25 panicles each and 22 populations of at least 12 farmer-named varieties of cultivated sorghum, each made up of 5 panicles were collected and genotyped using 10 SSR markers at the ILRI/BecA hub. The Bayesian model-based method implemented in the software STRUCTURE was used to analyze the SSR data for the extent and direction of gene flow among cultivated and wild sorghum by answering three questions: (i) Is there gene flow between cultivated and wild sorghum, (ii) If so, what is the direction of gene flow and (iii) Are there varietal differences in cultivated-wild gene flow. Overall, the results are consistent with previous observations and conclude that gene flow between cultivated and wild sorghum is a common occurrence wherever the two co-occur. Most notably, the work found an almost 9-fold more introgression from cultivated sorghum to its wild congener. This apparent asymmetrical gene flow from cultivated to wild sorghum could lead to genetic assimilation of wild sorghum within and around sorghum agro-systems and is thus a source of biosafety concern due to the potential for escape and persistence of transgenes. Finally the work observed significant differences in the extent of crop-to-wild gene flow among varieties, even though the differences seemed to vary among farmer fields. These differences may be due to a combination of different factors including, flowering synchrony, flower structures, plant growth habit and farmer practices such as weeding regimen, varietal combination etc.

Pollen competition between wild and cultivated sorghums
Controlled field pollination experiments were conducted during October 2007 – March 2008 at Kiambere field station, Kenya to test the competitiveness of wild x cultivated sorghum pollen using male-sterile and male fertile bait plants. Two male sterile lines (ATX623 and ICSA88006), 2 wild sorghums (accession number 126 and 213), and 2 cultivated sorghums (accession number 173 and 209) were used as treatment factors. Two-component pollen mixtures were made by mixing equal amounts of pollen from the two pollen donor parents (a wild and a cultivated) on a 50%:50% volume basis. The resulting pollen bulk was divided into 4 equal portions; one was used to pollinate 3 cultivated plants, a second to pollinate 3 wild plants and the third and fourth portions were used to pollinate each of 2 male sterile lines BTX623 and ICSA088006. At maturity all seeds from experimental plants were harvested separately. A random sample of 100 seeds (progenies) for each experimental plant per treatment was screened with a panel of 2 diagnostic genomic SSR markers per treatment. The genotyping work had been completed and data is being analysed in order to determine if pollen from cultivated and wild plants contribute equally to fertilization or not.

Special Project Funding:
Environmental Risk Assessment of Genetically Engineered Sorghums in Kenya and Mali, funded by US AID-BBI

Fabrice Sagnard, Santie de Villiers and Kassa Semagn, KARI, University of the Free State, University of Hohenheim

Output 4.5: Technological options and knowledge to reduce aflatoxin contamination at different stages of the groundnut crop cycle developed and disseminated to partner NARES, traders and processors in ESA with associated capacity building for enhanced food and feed quality

Summary:
Several mycotoxins contaminate food crops of the poor in the SAT. Among these, aflatoxins, which are toxic, carcinogenic, and immuno-suppressive substances, contaminate groundnut, maize, cotton, chilies, and many other agricultural commodities. Management of contamination of food and food products by mycotoxins has proven to be a difficult challenge in developing countries. This is due to a lack of awareness, stringent food safety regulations and their implementation, environmental conditions and farming practices that are conducive for the contamination. An existing protocol was used for isolation of atoxigenic strains of A. flavus. As this worked well no new protocol was developed. The extent of mycotoxin contamination of groundnut in Kenya was determined and it indicated that 84% of samples met the Kenya Bureau of standards while only 70 % meet the EU standards. Improved groundnut varieties had a significantly lower level of contamination than local varieties. Business plans have been developed for mycotoxin testing facilities in Kenya and Malawi; and also for seed company development with training manuals. To improve aflatoxin contamination awareness among farming communities, aflatoxin management packages are being introduced in Malawi through the Farmer Field Schools concept. As farmers learn about the potential dangers of aflatoxin contamination of their produce, they also learn management principals to avoid the problem.

Output target 2008 4.5.1 Protocol for isolation of atoxigenic strains of A. flavus developed in ESA

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Kenya and Malawi

Partners Involved:
University of Georgia, CABI, National Smallholder Farmers' Association of Malawi, and KARI

Comments/Explanations:
An existing protocol was used for isolation of atoxigenic strains. As this worked well no new protocol was developed. Countries Involved: Kenya and Malawi.

Progress/Results:
We screened over 250 A. flavus isolates and obtained 11 atoxigenic strains from Makueni District in Kenya, that have been saved in agar slants. These are strains that were double screened for 5 toxins which we considered good candidates for future commercialization. Otherwise the frequency of atoxigenic strains was higher than that but varied across regions.

Special Project Funding:
USAID Linkage Grant and Borlaug Fellowship

RB Jones

Output target 2008 4.5.2 IPG knowledge on the extent of mycotoxin contamination of groundnut in Kenya and Malawi with appropriate capacity development disseminated regionally

Achievement of Output Target (%):
>50%

Countries Involve:
Kenya
Partners Involved:
University of Georgia, CABI, and KARI

Comments/Explanations:
This work was only completed in Kenya and not Malawi as the special project funding was restricted to Kenya only.

Progress/Results:
A survey of 764 households in Homa Bay and Busia Districts of Kenya was conducted to establish groundnut management practices and the prevalence of aflatoxin in groundnut samples collected from grain stores. Samples were analyzed using the indirect competitive ELISA technique and total aflatoxin levels determined.

At least 84% of collected samples met the Kenya Bureau of Standards limit for human consumption of 20 parts per billion, but only 70% met the higher European Union standard of 4 parts per billion. A significantly higher number of samples from Busia were contaminated and this was related to higher rainfall and humidity in agro-ecological zones LM1 and LM2 that predominate in this district. Improved groundnut varieties had a significantly lower level of contamination than local varieties across both districts.

Special Project Funding:
Lucrative Legumes Project and Borlaug Fellowship

RB Jones

Output target 2009 4.5.3 Farmer Field School concept used with participatory farmer variety selection in adaptive trials to provide input into groundnut breeding and promote aflatoxin control practices in 2 ESA countries from 2009

Achievement of Output Target (%):
50% of targets achieved. Activities were successfully established and running with some farmers in one district. Efforts under way to scale up and out to remaining districts and communities.

Countries Involved:
Malawi

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi, CARE Malawi.

Progress/Results:

The farmer field school concept is currently in use in Kasungu district. A total of 15 farmer field schools were established during the 07/08 growing season. Each FFS has a membership of 30 farmers from 15 group village heads (a group of villages). Besides several agricultural interventions being demonstrated, farmers are being trained on water management issues as one way of escaping end of season drought to minimize aflatoxin contamination. Similar aflatoxin intervention measures have been introduced in Mchinji and Nkhotakota districts. The main objective is to validate and promote options for management of Aflatoxin contamination of Groundnut through use of time of planting (early versus late) and water management (box versus open ridges) while introducing the concept of farmer learning by doing. A total of twenty farmers were involved in the running of the Aflatoxin trials for the three Districts. Analysis for aflatoxin levels undertaken using ICRISAT's ELISA technology revealed the potential of these simple technologies in the reduction of aflatoxin contamination by more than 10 fold (40.3 vs 401 ppb) through use of simple technologies such as plot water harvesting (box ridging) and early planting to alleviate onset of end of season drought stress. The potential for reducing this further by combining crop management technologies and resistant genotypes will be explored.

Special Project Funding:
McKnight Foundation, Bill and Melinda Gates Foundation, EU Food Security Program for Malawi

E Monyo, M Osiru and H Charlie

Output target 2010 4.5.2 Pre-harvest and post harvest aflatoxin control measures implemented in at least 2 countries in an annual basis by 2010

Achievement of Output Target (%):
25% Aflatoxin sick plot have been established. Screening have been initiated; control agronomic packages ready for on-farm verification. Stakeholder workshop to assess occurrence and distribution of the problem at national level has been implemented.

Countries Involved:
Malawi

Partners involved:
ICRISAT Malawi, Chitedze Agricultural Research Station Malawi, National Smallholders Farmers Association (NASFAM) Malawi Ministry of Health Malawi. ICRISAT WCA Niger.

Progress/Results:
Results from Elite Aflatoxin Groundnut Variety Trial conducted on-station demonstrated significant differences for aflatoxin contamination between genotypes under imposed water stress. The levels of aflatoxin in stressed trial ranged from 0 – 1545.8 ppb compared to 0 – 12.7 ppb for the irrigated trial. Ten potential sources of resistance to aflatoxin were identified. These are ICGV-SM 01503, AH 7223, Faizpur, ICGV 91284, ICGV 91322, ICGV 95456, J 11, U 4-47-7, U 4-7-5 and Var 27 which all revealed aflatoxin contamination levels of less than 1 ppb under imposed stress. These are very significant findings with implications for groundnut improvement for aflatoxin resistance. On post harvest control, a post-harvest training on drying methods for groundnuts was undertaken in April 2008. The training which involved thirty-five (35) farmers (20 men and 15 women) emphasized on methods of reducing postharvest aflatoxin contamination through use of the ventilated stacking method which is a slow drying procedure aimed at reducing the moisture content of groundnuts post harvest to the required level of 8 %. In addition to farmers, the training also benefited partners from the Millenium Village Project who will continue to train more farmers in Zomba District Malawi.

A new project to assess aflatoxin occurrence and distribution in Malawi began in September 2008. A one day workshop involving 22 participants from key stakeholders (representatives of farmer organizations, agric researchers, medical doctors, traders, processors, and policy makers was held at the ICRISAT Lilongwe site on 5th December 2008 to Solicit 'buy-in' and other input from key stakeholders, streamline project strategies and activities; Identify project stakeholders; Identify issues for project implementation; and, Explore and initiate linkages between the Agricultural and Health sectors in Malawi. Progress and current knowledge on aflatoxins was presented by ICRISAT complimented by health related aflatoxin effects as observed by the medical fraternity in Malawi presented by a Surgeon from the Kamuzu Central Hospital in Lilongwe. Effects of aflatoxin contamination on groundnut trade from Malawi was also highlighted by the representatives of traders and processors who participated. The major outcome of the workshop was commitment of the stakeholders to contribute their knowledge in management of the aflatoxin problem in Malawi.

Special Project Funding:

McKnight Foundation, Bill and Melinda Gates Foundation

E Monyo, M Osiru, F Waliyar, B Chinyamunyamu,
H Charlie, W Munthali and E Sichone.

Output target 2009 4.5.4 Business plan developed for mycotoxin testing facility with associated training manuals

Achievement of Output Target (%):
50% Business plans were completed for mycotoxin testing facilities in Kenya and Malawi but the associated training manuals are still to be developed.

Countries Involved:
Kenya; Malawi

Partners Involved:
CABI, ICRAF, and the National Smallholder Farmers' Association of Malawi

Progress/Results:
Business plans have been developed for mycotoxin testing facilities in Kenya and Malawi. These business plans have been used to establish a pricing schedule to calculate the cost of various analyses that are being undertaken by these laboratories.

Special Project Funding:
Lucrative Legumes Project and program for the Sustainable Commercialization of Seeds in Africa

RB Jones and M Van Den Berg

Output target 2009 4.2.8 Format for seed company business plan developed with training manual using the Malawi case study

Achievement of Output Target (%):
100% This work was completed ahead of time using information collected by ICRISAT since 1999 in the operation of a seed revolving fund.

Countries Involved:
Malawi

Partners Involved:
National Smallholder Farmers' Association of Malawi

Progress/Results:
Data were collected from 1999-2006 on the production and sales of groundnut and pigeonpea breeder and foundation seed. The analysis showed that the seed revolving fund has been sustained in real terms. This information is now being used to set future prices, and as an example on how maintenance breeding can be established in a sustainable way in other countries including Ethiopia, Tanzania and Mozambique.

Special Project Funding:
USAID Seed Revolving Fund and the program for the Sustainable Commercialization of Seeds in Africa

RB Jones

MTP Project 5: Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (sorghum, pearl millet and pigeonpea) through genetic improvement

Project Coordinator: KN Rai

Highlights for 2008

- Molded grains of sorghum were found to have higher levels of Flavon-4 Oils than the non-molded grains, indicating that the expression of this phenol compound in the biosynthetic pathway is enhanced in response to the pathogen attack, and hence its concentration can be used to assess the expected reaction of sorghum cultivars to mold.
- Based on the comparison of isonuclear hybrids with six diverse CMS systems for grain yield, shoot fly resistance and grain mold in sorghum, it was found that the A_2 CMS system was comparable to the widely used A1 CMS system, which enhances the prospects of cytoplasm diversification of sorghum seed parents and hybrids.
- A preliminary evaluation of sweet sorghum hybrids identified five hybrids that has 50% more sugar yields than the best performing check hybrid SCH22 SS (4.45 t ha^{-1}) with grain yields comparable to the check (3.44 t ha^{-1}).
- Effective greenhouse and laboratory screening techniques for resistance to sugarcane aphid (*Melanaphis sacchari*) in sorghum were developed with the identification of antibiosis component of resistance in the laboratory method using detached leaf assay. Several moderately resistant lines with damage rating < 4 on 1-9 scale were identified
- A comprehensive pearl millet study comparing the efficiency of three diverse CMS systems in terms of stability of male sterility, maintainer frequency in the breeding materials and grain yield association showed the A_5 CMS system most useful, followed by the A_4 CMS system , and the currently commercial A_1 CMS system in that order.
- Effective greenhouse and field screening techniques for resistance to blast (*Pyricularia grisea*) in pearl millet were developed and several designated seed and restorer parents resistant to blast (leaf area infection score <2 on 1-5 scale) were identified.
- Four short-duration pigeon pea hybrids that had outyielded the early-maturing control UPAS 120 by about 20% in the multilocation trials were shared with NARS and consortium seed companies in India for further evaluation and possible release/adoption.
- In search for cytoplasmic diversification of CMS systems in pigeonpea, one accession each of three wild species *(C. lineatus, C. acutifolius and C. platycarpus*) were identified that could be donors of the sterility-inducing cytoplasm.
- Based on a comparison of pearl millet lines tolerant and susceptible to terminal drought stress and near-isogenic lines (NILs) with a QTL for drought tolerance in the genetic background of the susceptible genotype, it was observed that transpiration rate (TR) was lower in the tolerant lines and NILs than in the susceptible line. TR response to increasing vapor pressure above a threshold slowed down in the tolerant line and NILs whereas it had a continued linear response in the susceptible line. This showed that TR and TR response may be the key mechanisms for terminal drought tolerance in pearl millet.
- Evaluation of 52 commercial and pipeline hybrids of pearl millet in Alfisols at Patancheru showed that 11 hybrids had >70 ppm grain iron (Fe) and >50 ppm zinc (Zn) contents. Two hybrids had 80-85 ppm Fe and 70 ppm Zn, which are far higher than those reported in improved cultivars of other major cereals.
- A diallel study showed that both Fe and Zn are predominantly under additive genetic control and no hybrid was found to exceed the Fe and Zn levels of the better parents for these micronutrients. This showed that while genetic improvement of populations to breed open-pollinated varieties with high Fe and Zn levels will be highly effective, the breeding of hybrids with high Fe and Zn levels would require incorporating these traits in both parental lines of the hybrids.

Output 5A: Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite backgrounds, for specific target markets, production environments and research application made available biennially (from 2008) to defined partners with associated knowledge and capacity building in the Asian SAT

Sorghum

Output target 2008 5.1.1 SO Comparison of A_1, A_2, A_3 and A_4 CMS systems in hybrid combinations for key constraints in sorghum completed

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India

Comments/Explanations:
Studies on comparison of different cytoplasms conducted for two years and concluded. Countries Involved: India; Partners Involved: Indian NARS (Public and Private Sector).

Partners Involved**:**
Indian NARS (Public and Private Sector)

Progress/Results:
Isonuclear allo-plasmic A-lines with A_1, A_2, A_3, A_4 (M), A_4 (G) and A_4 (VZM) cytoplasms each in six nuclear genetic backgrounds (ICSA 11, ICSA 37, ICSA 38, ICSA 42, ICSA 88001 and ICSA 88004) were crossed with two varieties; IS 33844-5 and M 35-1-19 to generate 72 hybrids. The trial included 84 entries including 72 hybrids, 8 parents (ICSB 11, ICSB 37, ICSB 38, ICSB 42, ICSB 88001, ICSB 88004, IS 33844-5, M 35-1-19) and 4 checks [(296B, RS 29, CSH 16 and trait standard checks (CSV 15 for grain yield trial evaluated in 2006 and 2007 rainy and postrainy seasons, IS 14384 for grain mold resistance screening trial evaluated in 2006 and 2007 rainy seasons and IS 18551 for shoot fly resistance screening trial evaluated in 2006 and 2007 rainy and postrainy seasons)]. The number of fertile plants and sterile plants were counted on the F_1s (hybrids), F_2 population and BC_1F_1 population of 26 crosses, that showed complete fertility restoration on selfing. The data are being analyzed.

Grain yield: The significant mean squares due to cytoplasms *per se* and their first-order interaction with A-line and second-order interaction with A-line and R-line for grain yield suggested the overall influence of cytoplasm on the responses of hybrids on grain yield. A_1 followed by A_2 cytoplasm seemed to be better combiners for grain yield as they were significantly superior over other cytoplasms in majority of nuclear backgrounds. For overall mean performance for grain yield, A_1 and A_2-based hybrids were comparable to each other and superior to A_3, $A_{4\,(M)}$, $A_{4\,(G)}$ and $A_{4\,(VZM)}$ cytoplasms. The cytoplasms A_3 and $A_{4\,(M)}$ were comparable to each other and superior to $A_{4\,(G)}$ and $A_{4\,(VZM)}$ cytoplasms. Although significant cytoplasm influence on sca effects were evident in some of the nuclear genetic backgrounds for grain yield, no definite pattern of association with a particular cytoplasm was observed. The A_1 cytoplasm based hybrids were more heterotic compared to the hybrids based on A_3, $A_{4\,(G)}$, $A_{4\,(VZM)}$ cytoplasms; A_2 cytoplasm-based hybrids were more heterotic compared to the hybrids based on $A_{4\,(VZM)}$ and $A_{4\,(G)}$ cytoplasms and A_3 and $A_{4\,(M)}$ cytoplasm-based hybrids were more heterotic compared to the hybrids based on $A_{4\,(VZM)}$ cytoplasm.

Shoot fly resistance: During the 2006 and the 2007 rainy seasons, it was observed that cytoplasm did not have any significant influence on the shoot fly resistance of hybrids. The A_1, A_3, $A_{4\,(M)}$, $A_{4\,(G)}$ and $A_{4\,(VZM)}$ cytoplasms-based hybrids were comparable for resistance to shoot fly (for both leaf glossiness score and deadhearts %). But comparison of the cytoplasms in individual genetic backgrounds indicated that A_3 and $A_{4\,(M)}$ cytoplasms in few genetic backgrounds were tolerant to shoot fly during the 2006 rainy season, and $A_{4\,(M)}$ and $A_{4\,(G)}$ cytoplasms were superior to A_2 cytoplasm during the 2007 rainy season. The A_1, A_2, A_3, $A_{4\,(M)}$, $A_{4\,(G)}$ and $A_{4\,(VZM)}$ cytoplasms-based hybrids were equally comparable for resistance to shoot fly and no particular cytoplasm seemed to influence the resistance to shoot fly during the 2006 and 2007 post rainy seasons.

Grain mold resistance: During the 2006 rainy season, $A_{4\,(M)}$ followed by A_3 cytoplasm and $A_{4\,(M)}$ cytoplasm during the 2007 rainy season seemed to be better combiners for panicle grain mold rating (PGMR). During the 2006 rainy season, although no definite pattern of association of PGMR scores with a particular cytoplasm was observed, the hybrids based on A_1 and A_2 cytoplasms were comparable to each other and were superior to A_3, $A_{4\,(M)}$, $A_{4\,(G)}$ and $A_{4\,(VZM)}$ cytoplasm backgrounds for mean PGMR scores during the 2007 rainy season. During the 2006 rainy season, the six cytoplasms-based hybrids were comparable among themselves for heterotic responses to grain mold resistance. During the 2007 rainy season, A_1-cytoplasm based hybrids were more heterotic than hybrids based on A_3, $A_{4\,(M)}$, and $A4_{(G)}$ cytoplasms; and A_2 cytoplasm-based hybrids over hybrids based on $A_{4\,(M)}$ and $A_{4\,(G)}$ cytoplasms.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Output target 2009 5.1.1 SO Insect-host genotype-natural enemy interactions and mechanisms of resistance clarified (associated with the SP-IPM SWEP)

Achievement of Output Target (%):
25% Germplasm and improved lines have been evaluated for multiple insect resistance, studies on resistance mechanisms and genotyping are in progress.

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad

Progress/Results:
Identify sorghum lines with multiple resistance to insect pests. To identify sorghum lines with multiple resistance to insect pests, and to understand the mechanisms and diversity among the lines that have been identified earlier to be resistant to different insect pests (sorghum shoot fly - *Atherigona soccata*, spotted stem borer - *Chilo partellus*, sorghum midge - *Stenodiplosis sorghicola*, and head bugs - *Calocoris angustatus* and *Eurystylus oldi*), over 300 lines were evaluated for resistance to shoot fly, stem borer, midge, and head bugs during the 2007/08 postrainy season. The lines showing high levels of resistance to different insect pests or having high to moderate levels of resistance to 2 to 3 insect pests and better agronomic desirability were selected for further testing for resistance to all the four insect species during the rainy season. The material was divided into three groups; early-, medium-, and long-duration.

One hundred lines with resistance to individual or multiple insect species were selected for detailed studies on stability of resistance, resistance mechanisms, and molecular diversity. The test material was planted in 2 row plots, 2 m long, and there were three replications in a randomized complete block design. Data were recorded on leaf glossy score (1 = glossy, and 9 = non-glossy), shoot fly deadhearts (%), recovery resistance and overall resistance scores (1 = good, and 5 = poor), and agronomic performance (1 = good, and 5 = poor) in the shoot fly nursery. For stem borer resistance, the material was screened under artificial infestation, and the data were recorded on leaf feeding (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), deadheart formation (%), recovery and overall resistance scores (1= good, and 9 = poor), stem tunneling (%), and agronomic desirability (1 = good, and 5 = poor). In the midge nursery, the material was evaluated for midge resistance on a 1 – 9 scale (1= <10 spikelets damaged by midge, and 9 = >80% spikelets damaged by midge). Data were also recorded on plant height and other morphological traits.

In the shoot fly screening nursery, the leaf glossiness score ranged from 1 to 5, seedling vigor from 1 to 3, pigmentation from 1 to 3, overall resistance score from 3.3 to 9.0, plants with eggs from 40.6 – 100%, and plants with deadhearts from 8.4 to 100%. The genotypes ICSV 702, ICSV 705, ICSV 707, ICSV 708, ICSV 2502, ICSV 9308, IS 2122, IS 2146, IS 2312, IS 5469, IS 5566, IS 5604, IS 5622, IS 6566, IS 8549, IS 18368, IS 18551, IS 18579, IS 18662, IS 2205, IS 1054 and PS 35805 exhibited leaf glossiness, high seedling vigor and plant pigmentation, and high to moderate levels of resistance to shoot fly. The genotypes ICSV 705, ICSV 707, ICSV 708, ICSV 2500, ICSV 2501, ICSV 2503, ICSV 2511, ICSV 9304, ICSV 9308, IS 2122, IS 2146, IS 2312, IS 3461, IS 5470, IS 5566, IS 18368, IS 18551, IS 18579, PS 35805, IS 2205, and IS 1054 suffered 20% lower deadhearts than the plants with eggs in Swarna, suggesting that antibiosis is one of the mechanisms of resistance to shoot fly in these lines, in addition to the principal component - antixenosis for oviposition.

In the stem borer screening nursery under artificial infestation, the leaf damage scores ranged from 5.7 to 7.7, indicating very high levels of infestation. The deadheart percentage ranged from 6.8 to 93.5%. The genotypes ICSV 705, ICSV 2511, ICSV 9603, IS 1104, IS 2122, IS 2123, IS 2312, IS 4646, IS 5469, IS 5470, IS 5604, IS 5622, IS 12308, IS 13100, IS 14108, IS 14334, IS 18579, IS 18677, and IS 20024 suffered <20% deadhearts compared to 7.8% deadhearts in IS 2205 – resistant check, and 65.7% deadhearts in ICSV 1 – the susceptible check. Data recording on stem tunneling and other morphological traits is in progress.

In the short-duration lines midge screening nursery (25 lines), the midge damage scores ranged from 2.0 to 9.0, and the genotypes ICSV 88032, IS 21881, and TAM 2566 showed high levels of resistance to sorghum midge, *S. sorghicola* (damage rating 2.0 to 2.3) as compared to the susceptible check, Swarna (damage rating 9.0). In the medium-duration midge screening nursery (45 lines), the midge damage scores ranged from 2.7 to 9.0, and the genotypes ICSV 9508, ICSV 9603, IS 8671, IS 10712, and IS 21879, exhibited high levels of resistance to sorghum midge (damage rating 2.7 to 3.0) as compared to the susceptible check, Swarna (damage rating 9.0). In the long-duration lines nursery (35 lines), the midge damage scores ranged from 1.3 to 9.0, and the genotypes ICSV 197, ICSV 386, ICSV 391, ICSN 730, ICSV 745, ICSV 89036, ICSV 95071, ICSV 95077, ICSV

96011, IS 7005, IS 8891, IS 9807, IS 15107, IS 18698, IS 19512, and DJ 6514 showed high levels of resistance to sorghum midge (damage rating 1.3 to 3.0) as compared to the susceptible check, Swarna (damage rating 9.0).

Physico-chemical mechanisms of resistance to sorghum shoot fly, *Atherigona soccata:* We studied the expression of resistance to shoot fly in relation to biochemical constituents of the leaves during the seedling stage in a diverse array of 15 sorghum genotypes with different levels of resistance/susceptibility to this insect. The sorghum genotypes IS 1054, IS 1057, IS 2146, IS4664, IS 2312, IS 2205, SFCR 125, SFCR 151, ICSV 700, and IS 18551 exhibited low levels of resistance. Compounds decane 5- methyl, decane 4- methyl, hexane 2, 4- methyl, pentadecane 8- hexyl, and dodecane 2, 6, 11- trimethyl, present on the leaf surface of sorghum seedlings were associated with susceptibility to shoot fly; while 4, 4-dimethyl cyclooctene was associated with resistance to shoot fly. Phenolic compounds p-hydroxy benzaldehyde, p-hydroxy benzoic acid, luteolin, and the compounds at retention times (RTs) 24.38 and 3.70 min in the HPLC column were associated with susceptibility, whereas cinnamic acid and apigenin were associated with resistance to shoot fly, *A. soccata*. The amounts of p-hydroxy benzoic acid and p-hydroxy benzaldehyde were greater in the shoot fly susceptible genotypes, but their concentrations declined in the shoot fly damaged seedlings. This may be one of the reasons for non-preference of damaged seedlings for oviposition by the shoot fly females. The compounds associated with resistance/susceptibility to *A. soccata* can be monitored in germplasm or mapping populations to develop cultivars with diverse mechanisms of resistance to this pest.

Special Project Funding**:**
Sehgal Endowment Fund (SSF) Project on Multiple Resistance to Insects in Sorghum

Output target 2009 5.1.2. SO Dual-purpose foliar disease resistant forage/sweet sorghum hybrid parents developed (associated with SLP)

Achievement of Output Target (%):
50% Based on the evaluation of the improved sweet sorghum material developed, some promising dual purpose restorers/varieties, hybrids and hybrid parents were identified for sugar yield (a function of stalk yield, juice Brix and juice volume) and grain yield

Countries Involved:
India; The Philippines; Mali

Partners Involved**:**
NARS (Public and Private sector) in India, The Philippines and Mali

Progress/Results:
Sweet sorghum elite varieties/restorer line trial: Twenty-two varieties previously selected were evaluated along with the sweet sorghum varietal checks SSV 84 and RSSV 9 during the 2008 rainy season. Compared to the best performing check SSV 84 for sugar yield (5.01 t ha^{-1}), three lines SP 4487-3 (7.13 t ha^{-1}), SP 4484-3 (7.07 t ha^{-1}) and SPV 422 (6.88 t ha^{-1}) were significantly superior for sugar yield. In these three varieties, grain yield varied from 1.56 to 2.24
t ha^{-1} (SSV 84: 1.67 t ha^{-1}) and Brix from 14.7 to 17.8% (SSV 84: 18.0%).

Sweet sorghum hybrid parental line trial: The parental lines of hybrids in elite hybrid trials that include 43 B-lines and 24 R-lines were evaluated in a hybrid parental lines trial along with the checks SSV 74, SSV 84 and CSH 22SS during the 2008 rainy season. Compared to the best performing check SSV 74 (7.0 t ha^{-1}), R-line SP 4487-3 (9.53 t
ha^{-1}) was significantly superior for sugar yield, and other R-lines, SP 4482-1, SP 4484-1, SPV 422, SP 4487-1 and IS 3556 with sugar yield ranging from 7.20 to 7.93 t ha^{-1} were on par with SSV 74. Among these six R-lines, grain yield ranged from 0.7 to 3.13 t ha^{-1} (SSV 74: 1.53 t ha^{-1}) and Brix from 15.2 to 16.8 (SSV 74: 15.5). In the B-lines, ICSB 474, ICSB 25001 and ICSB 479 with sugar yield ranging from 3.5 to 3.87 t ha^{-1} were comparable to the check SSV 84 (4.67 t ha^{-1}). The grain yield in these lines ranged from 1.72 to 3.33 t ha^{-1} and Brix from 15.3 to 18.2.

Sweet sorghum advanced hybrid trial: Forty two selected hybrids were evaluated in SSAHT during the 2008 rainy season along with the checks SSV 84, CSH 22SS and CSH 25. Compared to the best performing check SSV 84 for sugar yield (4.60 t ha^{-1}), four hybrids [ICSA 675 × SP 4484-1 (7.79 t ha^{-1}), ICSA 502 × SP 4481-1 (7.17 t ha^{-1}), ICSA 475 × AKSV 22 (6.90 t ha^{-1}) and ICSA 95 × SP 4511-2 (6.87 t ha^{-1})] were significantly superior for sugar yield. Among these four hybrids, the grain yield varied from 3.47 to 4.48 t ha^{-1} (SSV 84: 1.47 t ha^{-1}) and Brix from 13.3 to 15.3 (SSV 84: 16.4).

Sweet sorghum elite hybrid trial: A total 53 hybrids selected previously were evaluated in SSEHT during the 2008 rainy season along with the checks SSV 84, CSH 22SS and CSH 25. Compared to the best performing check CSH 22SS for sugar yield (4.45 t ha^{-1}), five hybrids ICSA 285 × SSV 74 (6.89 t ha^{-1}), ICSA 95 × SSV 74 (6.69 t ha^{-1}), ICSA 324 × SSV 74 (6.47 t ha^{-1}), ICSA 474 × NTJ 2 (6.15 t ha^{-1}) and ICSA 474 × SSV 74 (6.11 t ha^{-1}) were significantly superior. Among these five hybrids, grain yield ranged from 3.99 to 5.37 t ha^{-1} (CSH 22SS: 3.44 t ha^{-1}) and Brix from 13.9 to 16.0 (CSH 22SS: 12.3).

Special Project Funding:
Sorghum Hybrid Parents Research Consortium and IFAD Biofuels Project

Output target 2009 5.1.3 SO More than 25 scientists and technicians trained in sorghum improvement through an international training course

Achievement of Output Target (%):
25% An international training program on sorghum improvement is proposed in 2009. From the presentations of the previous training course, a book on 'Sorghum improvement in the new millennium' has been published in 2008. This book will be very handy in organizing such training courses in future.

Countries Involved:
Open to all countries

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
An International learning program on "Sorghum hybrid parents and hybrid research and development" was organized from 6th to 17th February, 2007 jointly by ICRISAT-Patancheru and National Research Center for Sorghum, Hyderabad, India. There were 18 participants from both public and private sectors in India, Philippines and Sudan. Based on the lectures delivered by the resource persons, a boon on "Sorghum improvement in the new millennium" has been published in 2008. An international training program is proposed in 2009.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Output Target 2009 5.1.4 SO Two major putative QTL for stem borer resistance identified

Achievement of Output Target (%):
50% Mapping population for stem borer resistance has been phenotyped. Genotyping and data analysis are in progress.

Countries Involved:
India

Partners Involved**:**
Tamil Nadu Agricultural University, Coimbatore

Progress/Results:
Evaluation of mapping population for resistance to spotted stem borer, *Chilo partellus*: To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population based on ICSV 745 × PB 15220 was evaluated for stem borer resistance under artificial infestation in the field. The mapping population (270 lines), along with the resistant (IS 2205) and susceptible checks (ICSV 1), and the parents (PB 15220 and ICSV 745) were planted in a balanced alpha design in three replications. Data were recorded on leaf feeding (1=<10% leaf area damaged, and 9=>80% leaf area damaged), deadheart formation (%), leaf sheath and plumule pigmentation (1 = highly pigmented, and 5 = Non-pigmented – green colored), stem tunneling (%), days to panicle initiation, recovery resistance (1 = good recovery, 5 = poor), and agronomic score (1 = good, and 5 = poor). There was a significant variation in the traits studied in the mapping population. Leaf damage rating (DR) was 4.63 in PB 15220 and 6.65 in ICSV 745 compared to 4.72 in the resistant check, IS 2205 and 7.92 in the susceptible check, ICSV 1. The RIL population mean was 6.03. Deadheart formation was 45.01% in PB 15220 and 81.48% in ICSV 745 compared to 19.36% in the resistant check - IS 2205, and 83.30% in the susceptible check ICSV 1. Overall resistance score was 5.44 in the PB 15220 and 7.00 in ICSV 745 compared to 4.83 in the resistant check, IS 2205; and 7.92 in the susceptible check, ICSV 1, the population mean being 6.19.data analysis is in progress to identify QTLs associated with resistance to *C. partellus*.

Special Project Funding:
SEF Project on QTL Mapping for Stem Borer Resistance

Output Target 2009 5.1.5 SO Techniques to screen for resistance to aphids and shoot bug standardized

Achievement of Output Target (%)**:**
75% Greenhouse and field screening techniques have been developed, and are being validated.

Countries Involved:
India

Partners Involved**:**
National Research Center for Sorghum, Hyderabad

Progress/Results:
Development of a technique to screen sorghums for resistance to sugarcane aphid, *Melanaphis sacchari*. Nine genotypes, along with the susceptible check Swarna, were evaluated for resistance to *M. sacchari* under greenhouse conditions using artificial infestation, and under laboratory conditions using detached leaf assay. The plants were raised in the greenhouse in pots (30 cm diameter) using a mixture of black soil, sand, and farm yard manure (2:1:1). The plants at the boot leaf stage were infested artificially with aphid infested leaves (2×2 cm aphid colony) or with 0.5 ml of aphids per plant (collected from the field) resulted in very high level of infestation of the aphid. Aphid damage rating (1=<10% leaf area damaged, and 9=>80% leaf area damaged) in the plants infested with aphid colonies on leaves ranged from 3.4 to 8.0, and the lines 61523, 61592, and IS 40616 exhibited a leaf damage rating of 3.4 to 4.4 compared to 7.8 in Swarna, and 8.8 in CK 60B. In the plants infested with 0.5 ml aphids, the leaf damage rating ranged from 4.4 to 8.8, and the lines 61523, 61592, IS 40615, and IS 40618 exhibited a leaf damage rating of <4.8 compared to 8.8 in Swarna and 8.0 in CK 60B. Both the infestation techniques resulted in high levels of infestation in the test material, and can be used to screen sorghums for aphid resistance.

Under laboratory conditions, the test material was evaluated using detached leaf assay. Fifteen cm leaf sections from the middle portion of 5th leaf were inserted in 3% agar-agar in a 1 L plastic jar. Each leaf was infested with 10 gravid females. Numbers of aphids were counted 7 days after infestation. Total numbers of aphids varied from 44.3 on IS 40416 to 215.4 on ICSV 745. Aphid multiplication was lower (44.3 to 88.7 aphids) on lines 61592, IS 40618, and IS 40416 compared to that on Swarna (215.4 aphids). Numbers of adult aphids were more on IS 21808, IS 40615, and Swarna (21.8 to 26.1) than on 61592, IS 40616, ansd IS 40618 (6.9 to 11.8). Production of winged adults was greater on 61523, IS 21808, and Swarna (3.9 to 4.3) as compared to that on IS 40616, IS 40618, and ICSV 745 (0.1 to 1.5). The detached leaf assay not only provided information on genotypic susceptibility to aphids, but also gave an indication of antibiosis component of resistance to *M. sacchari*.

Identification of sources of resistance to sugarcane aphid, *Melanaphis sacchari*: Thirty-one sorghum lines comprising of improved breeding lines and germplasm accessions were screened for resistance to sugarcane aphid, *M. sacchari* during the 2008 rainy season. There were three replications in a RCBD, and observations were recorded at physiological maturity on aphid damage (1=<10% leaf area damaged, and 9=>80% leaf area damaged). There were two sets of this experiment, one inoculated with a 10 cm leaf portion with aphid colonies (attached to each plant in the middle); while the other set was left un-infested. In the trial infested with aphids artificially, the aphid damage scores ranged from 3.0 to 6.7, and the lines 61582, 61588, 61592, IS 40615, IS 40620, SLR 8, SLR 27, SLR 28, SLR 35, SLR 39, SLV 25, IS 33722, EC 8-2, PU 10-1, DJ 6514, and ISV 745 exhibited a leaf damage rating of <4.0 compared to 6.7 in the susceptible check, Swarna. In the uninfested trial, the aphid damage scores ranged from 3.0 to 6.7, and the lines 61582, 61588, 61592, IS 40615, IS 40620, SLR 27, SLR 28, SLR 35, SLV 25, IS 33722, EC 8-2, PU 10-1, DJ 6514, and ISV 745 exhibited a leaf damage rating of <4.0 compared to 6.7 in the susceptible check, Swarna. Infestation of plants with aphids from other fields did not result in greater aphid severity under field conditions. Heavy rains towards the end of rainy season washed out the aphid colonies, and hence, no differences were observed in aphid damage between the infested and un-infested plots.

During the postrainy season 2007/08 in the cooperative trial with the All India Coordinated Sorghum Improvement Project, 45 genotypes were screened for resistance to sugarcane aphid under natural infestation in the field. The material was evaluated for aphid damage at the physiological maturity. There were three replications in a RCBD, and observations were recorded at physiological maturity on aphid damage (1=<10% leaf area damaged, and 9=>80% leaf area damaged). Nine genotypes (S 102, S 122, S 128, S 129, S 132, S 135, S 136, M 35-1, and Y 75) suffered an aphid damage rating of <2.5 compared to 4.7 in 296B, and 5.3 in the susceptible check, Swarna.

Special Project Funding:
SEF Project on Multiple Resistance to Insects in Sorghum

Output target 2010 5.1.1 SO At least six high-yielding and large-seeded male-sterile lines with resistance to shoot fly and grain mold (3 each) developed

Achievement of Output Target:
60% For shoot fly resistance, the resistance levels in the advanced lines (BC_7s and BC_9s) are encouraging with 9 to 25% less shoot deadhearts% compared to the check 296 B (59% SFDH) and significantly higher grain yield (up to 10%) compared to 296 B (4.11 t ha^{-1}). For grain mold, ICSB 384 (PGMR score 4.0) was found moderately resistant compared to the check 296 B (PGMR score 9.0).

Countries Involved:
India

Partners Involved**:**
Indian NARS (Public and Private sector)

Progress/Results:
a. Shoot fly resistance
Shoot fly (*Atherigona soccata)* is a major pest limiting grain yield especially when sowings are delayed in rainy season. .Efforts have been underway to develop new hybrid seed parents with shoot fly resistance (SFR) as the available hybrid seed parents possess limited resistance.

1. Advanced B-line Trial: A trial consisting of nine advanced B-line progenies (6 BC_7s on A_1; 2 BC_9s and 1 BC_7s on A_2) and with three controls (296B, high yielding B-line; IS 18551, shoot fly resistant control and Swarna, shoot fly susceptible control) was conducted for evaluation of shoot fly tolerance in a screening block and agronomic traits evaluation in a breeding block during the 2008 rainy season. In the screening block, 296B had 59% shoot fly deadhearts (SFDH), whereas IS 18551 and Swarna had 31% and 45% shoot fly deadhearts, respectively. Four B-lines had SFDH ranging from 33 to 40%, significantly less (by 9 to 25%) than 296B (59% SFDH); and two of them were significantly superior for grain yield (4.50 and 4.52 t ha^{-1}) compared to 296B (4.11 t ha^{-1}) in the breeding block.

2. Hybrids and Parents Trial: A trial consisting of 15 hybrids along with their parents (8 B-lines and 7 R-lines) and four controls (296B, high yielding B-line; CSH 16, commercial hybrid; IS 18551, shoot fly resistant check and Swarna, shoot fly susceptible check) was screened for shoot fly resistance and for grain yield and other agronomic traits during the 2008 rainy season. In the screening nursery, the resistant controls IS 18551 and CSH 16 had 39% and 80% SFDH, respectively. All the hybrids tested had SFDH, ranging from 19 to 63%, significantly lesser (by 13 to 73%) than CSH 16 % (SFDH% 80). For grain yield, two hybrids ICSA 445 × ICSV 702 (5.86 t ha^{-1}), and ICSA 434 × M 35-1-19 (6.55 t ha^{-1}) were significantly superior up to 13% compared to CSH 16 (5.55 t ha^{-1}) for grain yield in the breeding block. Among the parents, six B-lines recorded SFDH (16 to 34%) significantly less by 3 to 56% than 296B (SFDH% 42). Two B-lines among them ICSB 452, and ICSB 458 were significantly superior (3.77 t ha^{-1} and 5.64 t ha^{-1}) up to 59% for grain yield compared to 296B (3.29 t ha^{-1}).

b. Grain mold resistance
Grain mold is one of the major biotic constraints in sorghum during rainy season. Efforts have been underway to develop new hybrid seed parents for grain mold resistance (GMR) as the available hybrid parents possess moderate resistance.

1. **Grain Mold Advanced B-line progenies Trial:** A trial consisting of 16 B-line progenies (4 BC_5s, 2 BC_7s and 8 BC_8s on A_1 and 2 BC_9s on A_2) was screened along with three controls (296B-high yielding B-line, IS 14384-grain mold resistant check and Bulk-Y, grain mold susceptible check) for grain mold tolerance in a screening nursery and for grain yield and agronomic traits in a breeding block during the 2008 rainy season. In the screening block, the grain mold scores were recorded at physiological maturity (PM) using a 1 to 9 scale, where =0 to <1% mold infection- highly resistant and 9=76−100% molded grains on a panicle- highly susceptible. Controls 296B and Bulk-Y had PGMR score 9, whereas IS 14384 recorded 2. All test entries recorded PGMR score 6 to 8. This may be due to heavy rainfall (652 mm) in the season (August to October) from flowering to harvest. For grain yield, three lines were significantly superior by 7 to 33% (range 5.13 t ha-^{1} to 6.79 t ha-^{1}) to 296B (4.52 t ha-^{1}) in the breeding block. All the selected B-lines were white grained, similar to 296 B.

2. Grain Mold Hybrids and Parents Trial: A trial consisting of nine hybrids along with their 12 parents (5 B-lines and 7 R-lines) and four controls (296B-high yielding B-line; CSH 16, commercial hybrid; IS 14384, grain mold resistant check and Bulk-Y, grain mold susceptible check) was screened for grain mold tolerance in screening nursery and grain yield and agronomic traits in a breeding nursery during the 2008 rainy season. Controls 296B and Bulk-Y recorded PGMR score 9 and 8, respectively whereas IS 14384 recorded score 1. All the test hybrids recorded PGMR score between 2 to 4, whereas control hybrid CSH 16 recorded PGMR score 6. For grain yield, two hybrids [ICSA 101×PVK 801 (6.64 t ha-^{1}) and ICSA 101 × IS 41675 (7.39 t ha-^{1})] were significantly superior (up to 15%) to CSH 16 (6.41 t ha-^{1}). Of the 12 parental lines, GD 65028 (score 2.2) and ICSV 96105 (score 3.0) were resistant and ICSB 384 (score 4.0) was moderately resistant.

Output target 2010 5.1.3 SO Two F_6 RIL populations developed and QTL for traits associated with grain mold resistance identified

No report submitted

Output target 2010 5.1.2 SO: At least 30 scientists participate in sorghum field day and select more than 300 breeding lines

Achievement of Output Target (%):
To be reported in 2010.

Countries Involved:
Open to all

Partners Involved:
NARS (Public and Private sector)

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Sorghum field days are organized in every even year. In 2008, the sorghum scientists' field day was organized at ICRISAT-Patancheru on 7th and 8th October 2008. A total of 27 scientists from the public sector and 19 scientists from the private sector scientists from India participated. A field day will be organized in 2010.

Output Target 2011: 5.1.1 SO: At least six high-yielding and large-seeded male-sterile lines with resistance to shoot fly and grain mold (3 each) developed
Achievement of Output Target: 80%. A wide array of material ranging from F_3 to BC_{13} stages from which a number of male-sterile lines can be identified in diverse backgrounds for rainy and postrainy season adaptations. Nine BC_4s (from 20 BC_3s) were selected (with A_1 cytoplasm) for high yield and bold grain during the 2007 postrainy season. It takes 2–3 years for developing high yielding large-seeded male-sterile lines with postrainy season adaptation.
Countries Involved: India, The Philippines and Mali
Partners Involved: Indian NARS (Public and Private sector)
Special Project Funding: Sorghum Hybrid Parents Research Consortium and IFAD Biofuels Project

Progress/Results:

Dual purpose B-line development

Postrainy season adaptation. All the progenies for postrainy season adaptation (derived from crosses involving Giddi Maldandi and other postrainy season adapted lines) were planted during the 2008 rainy season and selections were made for large grain and high yielding progenies with rainy season adaptation. All these progenies, including F_1s, are under evaluation in the 2008 postrainy season for selection for agronomic traits and postrainy season adaptation.

From the 105 test crosses (TCs) (with A_1 cytoplasm) involving the material developed from the crosses between high-yielding B-lines, postrainy B-lines, shoot fly resistant B-lines and postrainy varieties, 21 R-lines on A_1 cytoplasm were selected for high yield and bold grain during the 2007 postrainy season. Nine BC_4s (from 20 BC_3s) were selected (with A_1 cytoplasm) for high yield and bold grain during the 2007 postrainy season. From the TCs(with A_1 cytoplasm) of 133 F_5s obtained from the crosses between high yielding B-lines, postrainy B-lines, shoot fly resistant B-lines and postrainy varieties 63 R-lines were selected and none of the progenies showed maintainer reaction. Twenty three TCs obtained from Giddi Maldandi individual selections during the 2007 postrainy season will be evaluated during the 2008 postrainy season. From 1411 F_4s (including 150 Giddi Maldandi derived F_4s) derived from the crosses between high yielding B-lines, postrainy season varieties, lustrous-seed germplasm lines, shoot fly resistant lines, 939 F_5s (including 41 Giddi Maldandi derived F_5s) were selected for large grain and grain yield during the 2008 rainy season. The selected F_5s and the F_4s are being evaluated during the 2008 postrainy season.

A total of 200 F_4s (including 12 Giddi Maldandi derived F_4s) with bold grain and high yield were selected from 398 F_3s (including 15 Giddi Maldandi derived F_3s) derived from the crosses between bold grain germplasm lines and high yielding dwarf B-lines during the 2008 rainy season. The selected F_4s and the F_3s are being evaluated during the 2008 postrainy season.

From 397 F_1s planted, 154 were advanced to F_2 that include 40 populations including 34 Giddi maldandi based crosses (from 83 F_1s) made between F_3s derived from crosses involving M 35-1 and Giddi Maldandi and M 35-1 derived B-lines, Giddi Maldandi derived B-lines and postrainy season adapted varieties; 11 F_2s including 6 Giddi Maldandi based F_2s (from 171 F_1s) derived from crosses involving bold grain germplasm lines (highland Eritrea, Yemen and Muskwari lines) and Giddi Maldandi B-line derivatives, postrainy season varieties and direct Giddi Maldandi; 31 F_2s including 30 Giddi maldandi based F_2s (from 42 F_1s) derived from Giddi Maldandi R and M 35-1 derived B-lines, 72 F_2s (from 101 F_1s) including 49 Giddi maldandi based F_2s made between M 35-1 derived B-lines and Giddi Maldandi derived B-lines, direct Giddi Maldandi B (with A_2 cytoplasm) and white grain 296B derivatives.

Output target 2011 5.1.2 SO Relationship between grain and stover yield heterosis and genetic diversity of parental lines assessed

Achievement of Output Target (%):
50% With the clustering of hybrid parents based on SSR marker data, and development and evaluation of hybrids for one season, we are half way through (achieved 50% of the output target) in achieving the output target.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private sector)

Progress/Results:
Over the years we have developed a large number of trait-based hybrid parents (more than 600 A/B lines and more than 800 R-lines) and substantially contributed to the hybrid technology development and its adoption by farmers with the help of NARS partners (Public and Private) in India and other countries. While morphological characterization (based on DUS test guidelines) of hybrid parents is critical for IP protection of the

lines, the molecular characterization (fingerprinting) of hybrid parents provides ancillary data for taking IP protection (also prevents others from infringement). It also helps in understanding the diversity in the hybrid parents at the molecular level that enables the breeders to develop more heterotic hybrids. Also, it is possible to correlate the morphological and molecular diversity with heterosis for grain and stover yields. In this direction, 140 B-lines and 140 R-lines were sown in glass house and genomic DNA was isolated from the young leaves. Genotyping of these lines was done with 30 SSR markers standardized in GCP.

The molecular characterization of B- and R-lines was further advanced by addition of more number of genotypes and markers. The characterization data for additional 23 sorghum SSRs across B- and R-lines (140 nos. each) to the already existing data for 16 SSRs across 94 B- and R-lines were generated. The initial analysis revealed a better resolution of the groups as observed in the analyses with limited data generated last year. The final analysis to study the groupings and inter-relation of the B-and R-lines is in progress. This set of B- and R-lines (140 nos each) will be further genotyped with Diversity Array Technology (DArT). The DNA samples for this purpose will be sent to DArT PL Australia in January 2009.

For assessing within-line variability, ten each of B- and R-lines were sown during the 2007 rainy season and 40 selfed plants were randomly selected from each line and harvested separately. These were planted individually during the 2007 postrainy season for collecting the agronomic data and the same is being repeated in the 2008 post rainy season.

The intra-line diversity studies to check the level of variation within the lines at molecular level were initiated during this year. A set of 6 B- and R-lines each are used in this study. The DNA from 30 selfed head-to-row progenies for each B-and R-line was extracted.

Evaluation of hybrids developed by crossing parents selected based on molecular diversity:
Based on the clustering of 188 sorghum hybrid parents (94 B and 94 R lines) using the SSR marker data, 364 hybrids (64 early maturity group, 176 medium maturity group and 124 late maturity group) were developed using selected B-lines based on phenology (11 early, 19 medium and 12 late flowering) and selected R-lines (8 early, 14 medium and 14 late flowering). All these hybrids along with parents (80) for grain and stover yields and other agronomic traits along with promising hybrids CSH 16 and CSH 23 as control were evaluated in a triplicate trial in the 2008 rainy season.

The objective is to study the correlation between the grain and stover yield heterosis with molecular diversity. We have got one season data and the correlation of heterosis with morphological diversity is in progress. Some promising hybrids have been identified for grain and stover yields in different maturity backgrounds.

Among the 64 hybrids in early maturity group, compared to the recently released sorghum hybrid, CSH 23, 20 hybrids were significantly superior up to 30% with grain yield ranging from 5.45 t ha^{-1} to 6.90 t ha^{-1} than CSH 23 (4.64 t ha^{-1}); Among these nine hybrids, two hybrids were also significantly superior up to 10% for dry fodder yield (12.33 t ha^{-1} and 12.76 t ha^{-1}) compared to CSH 23 (10.31 t ha^{-1}).

Among the 176 medium maturity group hybrids tested, 125 of them were significantly superior up to 56% for grain yield ranging from 5.00 t ha^{-1} to 7.72 t ha^{-1} than check CSH 23 (4.35 t ha^{-1}). For dry fodder yield, among these 125 hybrids, 46 hybrids were significantly superior up to 74% (range 17.66 t ha^{-1} to 30.49 t ha^{-1}) than CSH 23 (15.16 t ha^{-1}).

Among the 124 late maturity group hybrids, 76 hybrids were significantly superior with grain yield ranging from 4.32 t ha^{-1} to 6.29 t ha^{-1} compared to CSH 23 (3.81 t ha^{-1}). Among these 76 hybrids, 36 hybrids were also significantly superior for dry fodder yield ranging from 11.70 t ha^{-1} and 24.22 t ha^{-1} compared to CSH 23 (10.09 t ha^{-1}).

From this evaluation, hybrids in medium maturity group appear more promising for grain and stover yields. All these hybrids are under evaluation in the 2008 post rainy season for selecting the best hybrids for postrainy season adaptation. These trials will be repeated in 2009 so that the heterosis from pooled data can be correlated with molecular diversity.

Special Project Funding: Sehgal Endowment Fund Project

Output target 2011 5.1.3 SO: Two putative QTLs for traits associated with grain mold resistance identified from two mapping populations

No report submitted

Pearl Millet

Output target 2008 5.1.1 PM QTL mapping of downy mildew (DM) resistance in five F_6 RIL populations completed.

Achievement of Output Target:
>50 Achieved

Countries Involved: No report submitted

Comments/Explanations: No report submitted

No report submitted

Output target 2008: 5.1.2 PM Additional hybrid parents (9 each of male-sterile and restorer lines) and more than 500 trait-specific and DM resistant improved breeding lines developed and disseminated with associated capacity building
Achievement of Output Target:
Fully Achieved

Countries Involved:
India

Comments/Explanations:
The number of male-sterile lines and restorer lines indicated in the output targets were developed and disseminated as per request. The number of trait-specific breeding lines is likely to far exceed the number given in the target, with dissemination to continue till January 2009.

Partners Involved:
None

Progress/Results:
Development and dissemination of a diverse range of A-lines and restorer lines with high grain yield potential and downy mildew (DM) resistance every year makes direct contribution to hybrid development efforts in the public and the private sector. A large number of improved breeding lines selected by scientists in the Scientists Field Days held biennially provide even more wider sources of improved germplasm. Nine male-sterile lines (A-lines) of diverse parentage and morphological characteristics, varying from 45 to 54 days for 50% flowering time, 14 to 34 cm panicle length and 7.3 to 14.6 g of 1000-seed weight were developed and disseminated. Eight of these lines were highly resistant to at least two of the five diverse pathotypes of downy mildew (<10% disease incidence) under high disease pressure in the greenhouse seedling inoculation test (>96% disease incidence in the susceptible check 7042S). One line was highly resistant to only Jalna pathotype, and four A-lines were highly resistant to four of the five pathotypes. Similarly, nine restorer lines (R-lines) of diverse parentage and morphological characteristics varying from 44 to 58 days for time to 50% flower, 145 to 185 cm plant height, 15 to 30 cm panicle length and 4.9 to 9.8 g of 1000-seed weight were developed and disseminated. All of these were highly resistant to at least two of the five diverse pathotypes with six of these highly resistant to four of the five pathotypes and two highly resistant to all five pathotypes. Three lines were restorers of both A_1 and A_4 CMS systems, five lines were restorers of the A_1 and maintainers of the A_4 CMS system, and one line was restorer of the A_4 and maintainer of the A_1 CMS system. More than 400 B-lines at the BC_1 to BC_{10} stages of backcrossing into different cytoplasmic backgrounds (131 A_1, 264 A_4 and 303 A_5 cytoplasm) were planted, of which 209 B-lines and the corresponding BC lines with 59 in A_1 cytoplasm, 121 in A_4 cytoplasm and 143 in A_5 cytoplasm were selected for further evaluation and conversion into A-lines.

A Pearl Millet Scientists Field Day was held on 30 and 31 October in which participants were shown and explained about a wide range and a large number of trait-specific breeding lines and hybrid parents. Fifty scientists (38 from 31 public sector organizations and 12 from 12 consortium seed companies) participated and selected 2473 distinct plots, with 196 distinct plots selected by more than 10 participants and 18 distinct plots selected by more than 20 participants. Since some of the lines are planted in several trait-specific nurseries because they excel for more than one trait, the number of lines selected will be less than the number of plots, but these lines will far exceed the number that was targeted for 2008. Following the Field Day event, a one-day brainstorming meeting was held on 31 October with a representative group of scientists from the public and private sector for an in-depth discussion of downy mildew resistance breeding strategy. The discussion highlighted the need for strengthening downy mildew disease nurseries at the partners test locations and greater participation of the public and private sector partners in the evaluation of ICRISAT-bred breeding lines for downy mildew resistance. It was agreed that blast has recently emerged as a very serious problem for which ICRISAT and its partners should pay greater attention for resistance breeding. Rust was also pointed out as another emerging problem of greater importance than in the past. As a result of these interactions, ICRISAT has now enhanced its efforts in screening and breeding for blast and rust resistance, which eventually will strengthen its public and private sector partners research program in these areas.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2008 5.1.3 PM: Knowledge on relative efficiency of three diverse CMS systems documented

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
India

Partners Involved:
All India Coordinated Pearl Millet Improvement Project and its sub-center at Gujarat Agricultural University, Jam nagar

Comments/Explanations:
Results published in journal Euphytica.

Progress/Results:
Pearl millet hybrids, grown widely in India and to some extent in the United States, are all based on an A_1 CMS (cytoplasmic male sterility system) source, leaving the pearl millet hybrid seed industry vulnerable to potential disease or insect pest epidemics. A comparison of this CMS system with two additional CMS systems (A_4 and A_5) based on isonuclear A-lines (seed parents) and their isonuclear hybrids showed that A-lines with the A_4 cytoplasm had much fewer pollen shedders and much reduced selfed seed set in visually assessed non-shedding plants as compared to those with the A_1 cytoplasm. A-lines with the A_5 cytoplasm had neither any pollen shedders nor did they set any seed when selfed. This showed that the A_5 CMS system imparts complete and most stable male sterility, followed by the A_4 and A_1 CMS systems in that order. The frequency of maintainers, averaged across a diverse range of 26 populations, was highest for the A_5 CMS system (98%), followed by the A_4 CMS system (59%) and the A_1 CMS system (34%), indicating the greatest prospects of genetic diversification of A-lines with the A_5 cytoplasm, and least with the A_1 cytoplasm. Mean grain yield of hybrids with the A_1 cytoplasm was 5% more than the A_4-system hybrids, while there was no difference between the mean grain yield of the A_1-system hybrids and the A_5-system hybrids. Based on these results, it is suggested that seed parents breeding efficiency will be greatest with the A_5 CMS system, followed by the A_4 CMS system, and least with the currently commercial A_1 CMS system. These results should now provide a stimulus to pearl millet breeders around the world to accelerate the utilization of A_5 and A_4 CMS systems in seed parents breeding and hybrid development.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.1 PM Two improved populations of pearl millet with high forage yield potential developed

Achievement of Output Target (%):
75
Three high-yielding populations from trials conducted in five year × season environments at Patancheru were identified with final evaluation to be completed in 2009.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Starting with the evaluation of nine improved populations in 2005 rainy season, two high-yielding populations (ICMV 05555 and ICMV 05777) have been identified from five year × season trials conducted at Patancheru that have given an average dry fodder yield of 9.5–11.0 t ha^{-1} at 80-day harvest. These yields are comparable to a sorghum-sudan grass hybrid (SSG 59-3) used as a control that had an average dry fodder yield of 11.1 t ha^{-1}. Another high-yielding population (ICMV 05222) with 9.5 t ha^{-1} of dry fodder has also been identified. These three populations will be evaluated in a final yield trial in 2009.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.2 PM Virulence changes in Indian pearl millet downy mildew populations characterized

Achievement of Output Target (%):
80% Sixty-nine isolates collected from susceptible hybrids in three of the four states, 28 representative isolates characterized for pathogenicity and virulence and three most virulent isolates, one from each state, identified for using in the screening. However, no collection was made from Maharashtra because of prevailing drought and low incidence of DM during the past 3−4 years.

Countries Involved:
India

Partners Involved**:**
Indian NARS and Private Seed Companies

Progress/Results:
Isolates of *Sclerospora graminicola*, the pearl millet downy mildew (DM) pathogen, collected from highly susceptible pearl millet hybrids during on-farm surveys in different states of India are characterized for pathogenic variation to monitor virulence change the pathogen populations. Highly virulent isolates thus identified from different states are used for screening breeding lines to develop DM-resistant hybrid parental lines and hybrids.

Under the ICAR-ICRISAT partnership project, roving surveys were conducted in Gujarat, Rajasthan and Uttar Pradesh in collaboration with AICPMIP pathologists of the respective states to collect DM isolates for virulence diversity studies. During the past 4 years (2005–08) a total of 69 isolates (Gujarat- 23; Rajasthan- 22; Uttar Pradesh- 24) were collected from different susceptible pearl millet cultivars, mostly hybrids. These isolates were established on 7042S/ICMP 451 under greenhouse conditions at ICRISAT- Patancheru. A total of 28 isolates (Gujarat- 11; Rajasthan- 9; Uttar Pradesh- 8) were characterized for virulence diversity using seven host differentials (P 7-4, P 310-17, 700651, 7042R, 852B, IP 18292 and IP 18293) and two susceptible lines (ICMP 451 and 7042S) under greenhouse conditions. Pot-grown seedlings of pearl millet lines were spray-inoculated at the coleoptile stage with sporangia of test isolates. The inoculated seedlings were incubated at 20ºC and >90% RH for 20 h, and then transferred to a greenhouse for disease development. Downy mildew incidence was recorded 14 days after inoculation as percent infected plants.

Analysis of variance (ANOVA) revealed significant variation among isolates, host differential lines and their interactions for downy mildew incidence. Based on DM incidence, Sg 445 (Banaskantha), Sg 384 (Barmer) and Sg 492 (Aligarh) were identified as highly virulent pathotypes from Gujarat, Rajasthan and Uttar Pradesh, respectively. These isolates have been selected for use in the screening of breeding lines in greenhouse for developing downy mildew resistant hybrid parental lines and hybrids targeted for Gujarat, Rajasthan and Uttar Pradesh. As of now we have identified 12 pathotypes that are being used to screen breeding lines for resistance to specific targets under greenhouse conditions at Patancheru.

Spatial virulence pattern of *Sclerospora graminicola* populations was assessed through pearl millet downy mildew virulence nursery (PMDMVN) and temporal virulence change was assessed by virulence diversity studies in the populations of the pathogen collected over time.

Spatial variation. The PMDMVN-2007, consisting of 50 test entries including 36 from ICRISAT, 14 from AICPMIP, Mandor and one local susceptible check was established at 12 locations – Durgapura, Jodhpur and Fatehpur Shekhawati (Rajasthan), Hisar (Haryana), Anand and Jamnagar (Gujarat), Aurangabad and Dhule (Maharashtra), Gwalior (Madhya Pradesh), Patancheru (Andhra Pradesh), Mysore (Karnataka) and Coimbatore (Tamil Nadu). At each location the nursery was planted in a "downy mildew sick plot" developed using oospore inoculum from the local susceptible cultivars. Infector rows of a highly susceptible line (7042S) in every fifth/ninth row were planted in the sick plot. DM incidence was recorded at 30-day and 60-day after emergence.

The disease pressure, as indicated by the disease incidence on 7042S (at the soft-dough stage), was adequate (64–100%) at all locations except Aurangabad (20%). The local susceptible lines recorded 66–99% incidence at seven locations (Mandor, Fatehpur Shekhawati, Hisar, Anand, Jamnagar, Dhule and Patancheru) whereas it was relatively low at Gwalior and Coimbatore (32%), Durgapura (33%), and Mysore (34%). Pearl millet lines IP 18292 and IP 18293 continued to remain resistant across most locations with an incidence of ≤10% at any location. Three AICPMIP entries (J 2405, G 73-107 and H 77/833-2-20) were found resistant with ≤7% mean incidence across locations for two consecutive years. Eleven entries from AICPMIP (J 2290, RIB 20K86, J 2340, G 73-107, H 77/833-2, H 77/29-2, H 90/4-5, PPMI 69, RIB 3135-18, PMI 301 and RHRBH 138) and many entries from ICRISAT showed variable reactions at different locations.

Spatial variation in the virulence of pathogen populations was evident from the mean disease incidence levels at different locations. Considering the disease incidence at the soft-dough stage, the pathogen population at Anand appeared to be most virulent with 48 test entries exhibiting >10% DM incidence, followed by the population at Coimbatore (41 entries with >10% incidence), Fatehpur Shekhawati (30 entries with >10% incidence), and the Jamnagar population was the least virulent.

Temporal variation. In a greenhouse experiment at ICRISAT, 23 pearl millet B-lines along with a highly susceptible check 7042S were screened against six pathotypes, two highly virulent Sg 445 (Banaskantha) and Sg 384 (Barmer) as well as old and new isolates of *S. graminicola* from Patancheru (Sg 153-old and Sg 409-new) and Durgapura (Sg 151-old and Sg 212-new) to study temporal virulence change in the pathogen. In general, new pathotypes of *S. graminicola* from Patancheru and Durgapura exhibited high disease incidence on the test lines than the respective old pathotypes. Of the 23 B-lines screened, 4 lines (ICMB 03555, -03777, -06111 and -07888) could differentiate the virulence of old (Sg 153) and new (Sg 409) pathotypes from Patancheru; the lines were resistant (1−10% incidence) to old pathotype (Sg 153), but susceptible (20−23% incidence) to the new pathotype (Sg 409). Similarly, ICMB 02333, -04333, -06111, -06888, -07333, -07666, -07777 and -07999 were found resistant to old Durgapura pathotype (Sg 151), but susceptible to new pathotype (Sg 212). Disease incidence in these lines was significantly higher for the new pathotypes than the old ones confirming temporal virulence change in the pathogen populations.

We also evaluated 123 pearl millet germplasm accessions that were found resistant to DM during 1990−93 against new population of *S. graminicola* both under field and greenhouse conditions during 2006−07. Results of this study revealed that most of these accessions have lost their resistance to the changed population of *S. graminicola* at Patancheru in 2006, and only 21 accessions were resistant. This clearly indicates the temporal virulence change in the pathogen population at Patancheru. The mean DM incidence across few selected test accessions was significantly higher for the new Patancheru pathotype (55−100%) than the old Patancheru pathotype (0−6%).

Therefore, monitoring virulence shift in the pathogen populations and resistance in the host against changing virulence is of utmost importance for the effective management of downy mildew through resistance breeding in pearl millet.

Special Project Funding**:**
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.3 PM More than 30 scientists develop pearl millet research and development skills through an international training course

Achievement of Output Target (%):
0% Field Day will be held in 2010 as per the schedule. The 2009 training course will be postponed to 2010.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Results of the 2008 Scientists Field Day are reported under output Target 2008: 5.1.2 PM, and 2010 Field Day will be held as per the schedule as in the past. The training course planned for 2009 will be postponed to 2010 as the publication of a book based on a training course held in 2006 has been delayed because of the expansion of the scope of the book far beyond the training course lectures and involvement of multiple editors and authors/co-authors. Also, this postponement is to have enough time to explore at least partial funding support for this course.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.4 PM At least five each of blast and rust resistance sources identified

Achievement of Output Target (%)**:**
50% The work was started in April 2008 and by December 2008 we have standardized greenhouse and field screening techniques for blast, and identified some promising resistant lines among B- and R-lines that would be confirmed by 2009. Work on rust resistance is yet to begin.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Blast caused by *Pyricularia grisea* has recently emerged as a major diseases affecting pearl millet production in several states in India. The disease appears as grayish, water-soaked lesions on foliage that enlarge and become necrotic, resulting in extensive chlorosis, necrosis and premature drying of young leaves. The disease becomes most severe during humid weather conditions especially with dense plant stands. On-farm surveys conducted in Rajasthan, Uttar Pradesh and Gujarat have revealed increased incidence of pearl millet blast. . Therefore, we standardized greenhouse and field screening techniques to evaluate pearl millet for blast resistance.

Development of greenhouse screening technique for foliar blast: A greenhouse screening technique was standardized to evaluate pearl millet for resistance to foliar blast. The main steps involved in the technique are: isolation and maintenance of pure culture of the pathogen, mass multiplication of inoculum on autoclaved pearl millet leaf peaces at 28^{o}C for 10 days, artificial inoculation of pot-grown 10−15 day-old seedlings with an aqueous conidial suspension (ca. $1{\times}10^5$ spores ml^{-1}), and exposure of inoculated seedlings to high humidity under misting for 10 days.

These led to the development of the typical blast symptoms. Disease symptoms appeared 5 days after inoculation and the blast severity was recorded 15 days after inoculation using a 1-5 scale (1=<1% leaf area infected with lesions; 2=1−10%; 3=11−25%, 4=26−50% and 5=>50% leaf area infected with typical enlarged blast lesions). The inoculated plants were observed till dough stage to record neck and/or head blast. No neck/head blast was observed in pearl millet plants inoculated at seedling stage. Using this greenhouse screening technique pearl millet breeding lines can be rapidly evaluated for blast resistance in about 40 days.

Development of field screening technique for blast resistance: Field screening technique to evaluate pearl millet for blast resistance was standardized. The technique involved planting of test material in 1 row of 2m/entry with two replications in CRBD. Systematic susceptible checks were planted on every 5th row. Plants were thinned to 20 plants/row 15 days after planting and other agronomic practices were followed as required. Mass multiplication of fungal spores for field inoculation was achieved by growing the fungus on autoclaved pearl millet leaves at 28°C for 15 days. Plants were spray-inoculated at pre- tillering and flowering stage with an aqueous conidial suspension (ca. 1×10^5 spores ml^{-1}) of *P. grisea*. High humidity was provided by perfo-irrigation twice a day on rain-free days, 30 min each to facilitate the disease development. Disease symptoms appeared 5−7 days after inoculation on the susceptible checks. Blast severity was recorded at the dough stage using a 1−5 scale as described above.

Screening designated B- and R-lines of pearl millet for resistance to blast: A total of 234 breeding lines, including 126 designated B-lines, 20 designated R-lines, 65 potential R-lines and 23 B- and R-lines used in developing mapping populations for identifying QTL for DM resistance were evaluated for blast resistance in the disease nursery using the standard screening procedure. The experiment was conducted in a CRBD with 2 replications, 1 rows of 2 m length/entry in each replication. Systematic susceptible checks (ICMB 99111, -99666, and -89111) were planted every 5th row alternately. Plants were spray-inoculated at pre- tillering and flowering stage. High humidity was provided by perfo-irrigation twice a day on rain-free days, 30 min each to facilitate the disease development. Disease severity was recorded at dough stage using a 1−5 scale. DM incidence was also recorded in the test lines at the soft-dough stage.

Blast severity scores in the designated B-lines ranged from 2.0−5.0 compared to 3.0-5.0 score in the susceptible checks. Of the 126 designated B-lines, 9 (ICMB 93222, -97222, -01333, -01777, -02111, -02444, -02777, -03444 and -03999) were resistant (score ≤2), 55 moderately resistant (score 2.1−3.0) and the remaining 62 were susceptible (score >3.0) to blast. The lines found resistant to blast were also resistant to DM (≤10% incidence).

Blast score in designated 20 R-lines varied from 2.0 to 3.5. Six lines (ICMR 06111, -06222, -06444, 06666, -07555 and -356) were resistant to both blast and DM. Thirteen lines were moderately resistant to blast and only one line (ICMR 07111) recorded blast score >3.0. High level of resistance to blast was observed in the potential R-lines. Of the 65 potential R-lines, 30 were resistant, 23 moderately resistant and only 12 were susceptible. Most of these lines (57) were resistant to DM as well. Among 23 B and R-lines, ICMB90111-P6 and NC D2 BC7F4-22-2-1-4-1-B were resistant to both blast and DM. The lines found resistant in the field screen will be further evaluated under greenhouse condition to confirm their resistance against *P. grisea*.

These 234 B- and R-lines are currently being evaluated for rust resistance under natural infection in field conditions.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2009 5.1.5 PM Two PhD scholars completed their dissertation research

Achievement of Output Target (%):
75% One PhD thesis is already submitted and the degree will be awarded early 2009. The other one is as per the schedule.

Countries Involved:
India

Partners Involved:
Tamil Nadu Agricultural University, Coimbatore

Progress/Results:
A PhD thesis that investigated the genetics and carried out QTL analysis of sink size traits in pearl millet was submitted to Tamil Nadu Agricultural University, Coimbatore in 2008. The genetic architecture of three sink size component traits (panicle length, panicle diameter and grain size) was studied using genetic (generation means and triple test cross) and QTL analyses. The plant materials consisted of two crosses for the generation means, and one cross for triple test cross (TTC) analysis for each of the three traits. The F_2 plants and $F_{2:3}$ progenies from one cross between inbred lines primarily differing for grain size were used for QTL analysis. The genetic linkage map for the QTL analysis was constructed using $F_{2:3}$ progenies genotyped with 44 (24 SSCP-SNP, 10 SSR, 6 EST-SSR and 4 STS) markers. The results of genetic analysis showed that a large part of the genetic variation for sink size was under the epistatic control, particularly for grain size. This finding was consistent with the results obtained from the QTL analysis, where five significant main effect QTLs were detected for grain size on chromosome 1, 3, 5, 6 and 7 with significant epistatic interactions.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.1 PM At least five each of pearl millet seed and restorer parents for arid conditions developed.

Achievement of Output Target (%)**:**
25% Candidate lines have been identified for further evaluation, and more of the new lines are available for evaluation.

Countries Involved:
India

Partners Involved:
All India Coordinated Pearl Millet Improvement Project and its sub-centers.

Progress/Results:
In an effort to develop hybrid parents adapted to arid zone, more than 370 progenies derived from ICRISAT-CAZRI B-composite and from B×B crosses were evaluated in ICRISAT-Patancheru drought nursery during the 2008 post rainy season, of which 162 were selected for further evaluation. Early maturity is an important requirement for the arid zone. Twenty-one of these selected progenies flowered in less than 46 days (the earliest-maturing control 843A flowered in 39−40 days) and additional 27 progenies flowered in 46−50 days. In the restorer development program, 206 progenies (including stay-green lines) were evaluated in the drought nursery. Of these 50 were selected, of which 11 flowered in less than 51

days. More than 160 breeding lines had been selected from ICRISAT-constituted nurseries evaluated in arid zone in 2006 and 2007 under ICAR-ICRISAT Partnership project. These were re-evaluated in 2008 in the arid zone under the same partnership project. Results are awaited

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.2 PM Genetics of four diverse CMS systems documented

Achievement of Output Target (%)**:**
15% This output target is about the publication of journal articles from a PhD thesis submitted in 2005. The first article on the genetics of A_1CMS system is under preparation.

Countries Involved:
India

Partners Involved:
CCSHAU, Hisar

Progress/Results:
A journal article on the genetics of the A_1 CMS system progressed to the initial draft stage. This paper reports on segregation of male-fertile and male-sterile plants in 12 F_2 and 12 BC populations generated from 12 crosses made by crossing 3 A_1-system male-sterile lines with 4 diverse restorer lines. The populations had been evaluated during the rainy and postrainy (summer) season at Patancheru. The 45 fertile: 19 sterile segregation ratio in the F_2 and 1 fertile: 1 sterile segregation ratio in the BC generation, in general, was suggestive of a 3- gene control of male sterility and fertility restoration , with one dominant basic gene and two dominant duplicate complimentary genes required for male fertility restoration. The deviations from this segregation patterns observed in some crosses and in some environments (e.g., 54 fertile: 10 sterile in the F_2 and 3 fertile: 1 sterile in the BC) could have resulted from a different genetic control where any two of the three genes had dominant duplicate complementary interactions, or due to the effects of the major genes proposed in the first model being influenced by modifiers and/or the environments.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2010 5.1.4 PM Effect of putative QTLs identified for stover yield and quality on these traits in two genetic backgrounds assessed

No report submitted

Output target 2011 5.1.3 PM Relationship between grain and stover yield heterosis and genetic diversity of parental lines documented

Achievement of Output Target (%):
30% Hybrids developed on the basis of molecular diversity among designated B- and R-lines were evaluated for grain and stover yield components with one more season to go. Molecular diversity analysis of a second set of promising B- and R-lines has nearly been completed. Lines are being identified for a third and final set of such studies.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
The efficiency of breeding high-yielding hybrids can be significantly enhanced with the formation of heterotic gene pools. A series of experiments has been planned to assess the relationship between molecular diversity and yield heterosis as a first step to initiate the heterotic pool formation. We analyzed 126 designated B-lines and 150 designated R-lines (set I) for molecular diversity using 40 polymorphic markers (36 SSR and 4 EST), well distributed across all seven linkage groups. Diversity analysis of molecular data was carried out using DARwin 5.0 software. The genetic distance between B- and R-lines ranged from 0.28 to 0.91 with a mean of 0.75. Based on the genetic distances from molecular data (276 B×R distance matrix and 150 R×R distance matrix), pedigree information, and days to 50% flowering, 23 pairs of parental combinations (20 B×R and 3 R×R pairs) were selected and hybrids were produced. These hybrids along with their parental lines were evaluated in rainy season of 2008 at ICRISAT-Patancheru in a RCBD with three replications, with hybrids and parental lines planted side-by-side as the blocks in each replication. Data for grain yield, stover yield and components traits were recorded. This trial will be repeated in postrainy season of 2009. In Set II, comprising of 88 potential B-lines and 78 potential R- lines, DNA fingerprinting has been completed for diversity analysis. Similar procedure (as in Set I) will be followed to select parental combinations in Set II to generate hybrids for evaluation for grain and stover yield. Potential B-lines and R-lines are being identified to make a third set for similar studies. Results of these three sets put together will provide a broad picture of whether molecular diversity is related to yield heterosis, and if so, then facilitate in the identification of lines to initiate the formation of two heterotic gene pools.
Special Project Funding:
Sehgal Foundation Endowment Fund

Pigeonpea

Output target 2009 5.1.1 PP At least 15 high-yielding pigeonpea hybrids and a short-duration determinate male-sterile line made available to NARS partners

Achievement of Output Target (%):
80% We have made available nine pigeonpea hybrids, and a determinate male-sterile line to various private companies and NARS partners. Additional six hybrids will be shared during 2009.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results
During 2007, seed of nine high-yielding hybrids was shared with various NARS, private and public seed sector partners. Of these, five belonged to the short-duration maturity group (ICPH 2433, ICPH 2438, ICPH 2429, ICPH 2363 and ICPH 2447), and six were in medium-duration maturity group (ICPH 2671, ICPH 2740, ICPH 2673, ICPH 3464, ICPH 2744 and ICPH 2751). These hybrids were shared with nine private and public sector seed companies. In short-duration group, ICPH 2433 (24% grain yield advantage over check variety UPAS 120, and 94% grain yield advantage over check variety ICPL 88039) and ICPH 2438 (22% grain yield advantage over check variety UPAS 120, and 91% grain yield advantage over check variety ICPL 88039) and ICPH 2429 (18% grain yield advantage over check variety UPAS 120, and 84% grain yield advantage over check variety ICPL 88039) and ICPH 2363 (15% grain yield advantage over check variety UPAS 120, and 80% grain yield advantage over check variety ICPL 88039) were found promising in the multi-location trials conducted over 10 locations in central and south India. A short-duration A_4 CMS system determinate male-sterile line (ICPA 2039) was made available to 10 private seed companies (Bioseeds, Pioneer Overseas Corporation, JK Seeds, MAHYCO, Ankur Seeds, Nuziveedu Seeds, Pradham Biotech, Maharashtra State Seeds Corporation Limited, MAU Parbhani, Nimbkar Seeds, Krishidhan Seeds and Nath Biogene) in the year 2007. This line was in $BC_{11}F_1$ generation, and was stable for various agronomic traits.

Special Project Funding:
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output target 2009 5.1.2 PP Elite pigeonpea hybrid parents characterized for important agronomic traits and molecular diversity

Achievement of Output Target (%):
75% Out of 151 elite hybrid parental lines, 114 lines have been characterized for agronomic traits. The molecular characterization will commence in 2009.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results

Characterization of B-lines of A_4 cytoplasm:
During 2007 rainy season, 39 B-lines were characterized at ICRISAT-Patancheru for important agronomic traits such as days to flower, days to maturity, seeds pod^{-1}, 100-seed mass, seed color, reaction to diseases [*Fusarium* wilt and sterility mosaic (SM)], and grain yield. There was a significant variation for most of the listed traits. In the extra-short duration group (comprising of only determinate types) variation for days to flower ranged from 60 to105 days, days to maturity 90 to140 days, plant height 69 to 184 cm, seeds pod^{-1} 3.6 to 4.1, 100-seed mass 7.9 to 12.3 grams, wilt score 12 to 92%, and SM score 0 to 79%, and grain yield 310 to 1388 kg ha^{-1}. In short-maturity group (determinate types) days to flower ranged from 79 to 87 days, days to maturity 120 to 133 days, plant height 127 to 148 cm, seeds pod^{-1} 3.8 to 6.7, 100-seed mass 8.4 to 13.7 grams, wilt 5 to 92%, sterility mosaic (SM) 0–58%, and grain yield 224 to 1107 kg ha^{-1}. In short-maturity group (non-determinate types) days to flower ranged from 67 to 89 days, days to maturity 110 to 128 days, plant height 145 to 192 cm, seeds pod^{-1} 3.7 to 3.8, 100-seed mass 7.6 to 9.9 grams, wilt 31to 78%, sterility mosaic (SM) 33 to 67%, and grain yield 730 to 854 kg ha^{-1}. The medium-duration B-lines were classified into Asha and Maruti maturity groups. In Asha group days to flower ranged from 117 to 140 days, days to maturity 179 to 205 days, plant height 240 to 275 cm, seeds pod^{-1} 4.0 to 5.0, 100-seed mass 6.8 to 16.4, wilt 0 to 84%, sterility mosaic (SM) 0 to 44%, and grain yield 1215 to 2704 kg ha^{-1}. In Maruti group days to flower ranged from 107–118 days, days to maturity 159–176 days, plant height 107–252 cm, seeds pod^{-1} 3.0 to 4.0, 100-seed mass 7.7 to 12.4, wilt 0 to 88%, sterility mosaic (SM) 0 to 74%, and grain yield 506–2753 kg ha^{-1}. Eight B-lines were found resistant to both *Fusarium* wilt and sterility mosaic diseases. The molecular characterization of A- and B-lines will commence in 2009.

Characterization of R-lines of A_4 cytoplasm:
A total of 75 R-lines belonging to A_4 system were characterized at ICRISAT-Patancheru during 2007 rainy season for important agronomic traits such as days to flower, days to maturity, seeds pod^{-1}, 100-seed mass, seed color, reaction to diseases [*Fusarium* wilt and sterility mosaic (SM)], and grain yield. There was a large variation for most of the traits. In the extra-short duration group, variation for days to flower ranged from 66 to 118 days, days to maturity 110 to 155 days, plant height 125 to 207 cm, seeds pod^{-1} 3.6 to 4.0, 100-seed mass 7.5 to 10.3 grams, wilt 32 to 96%, SM 0 to 72%, and grain yield 479 to 865 kg ha^{-1}. In short-duration maturity group days to flower ranged from 78 to 90 days, days to maturity 121 to 134 days, plant height 158 to 198 cm, seeds pod^{-1} 3.7 to 4.0, 100-seed mass 7.0 to 9.4 grams, wilt 30 to 100%, sterility mosaic (SM) 0–76%, and grain yield 890 to 1754 kg ha^{-1}. In medium-maturity group days to flower ranged from 121 to 142 days, days to maturity 183 to 206 days, plant height 220 to 280 cm, seeds pod^{-1} 3.8 to 5.4, 100-seed mass 7.6 to 14.4 grams, wilt 0 to 78%, sterility mosaic (SM) 0 to 63%, and grain yield 922 to 3157 kg ha^{-1}. Across the three maturity groups, a total of 28 R-lines had dual resistance to *Fusarium* wilt and sterility mosaic diseases.

Special Project Funding**:**
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output target 2010 5.1.1 PP Consensus molecular marker and genetic linkage maps developed and shared with partners

Output target 2010 5.1.1 PP Consensus molecular marker and genetic linkage maps developed and shared with partners

Progress/Results:
Development of genetic maps: Developed SSR markers are being screened on parental genotypes of intraspecific and interspecific mapping populations at present. The polymorphic markers will be used to genotype respective mapping populations and subsequently genetic maps will be developed.

Special Project Funding:
Generation Challenge Programme, Pigeonpea Genomics Initiative of ICAR, Department of Biotechnology, Government of India.

Output target 2010 5.1.2 PP At least three short-duration, determinate male-sterile lines and 10 hybrids made available to NARS partners

Achievement of Output Target (%):
50
We have shared four CMS lines belonging to the extra-short and short-duration maturity group. Hybrids will be shared during rainy season 2009 and 2010.
Countries Involved**:**
India

Partners Involved:
Pigeonpea Hybrid Parents Research Consortium

Progress/Results:
During 2007, three extra-short duration, non-determinate, segregating (BC_3F_1 generation) CMS lines (ICPA 2076, ICPA 2079 and ICPA 2080), and a short-duration, stable (in $BC_{11}F_1$ generation) determinate A_4 CMS system line (ICPA 2039)was made available to nine private and public sector seed companies. In addition, two extra-short duration non-determinate CMS lines ICPA 2089 (BC_3F_1 in generation) and ICPA 2156 (BC_3F_3 in generation) were also shared with nine public and private seed companies. All these segregating CMS lines were selected for different agro-ecological zones by different private seed companies. Ten additional hybrids will be shared during 2009 cropping season.

Special Project Funding:
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output target 2010 5.1.3 PP Two Master's students and 50 scientists and technicians from NARS and private sector trained in pigeonpea breeding

Achievement of Output Target (%):
50% Fifty scientists and technicians have been trained during 2007. Two students will complete their Master's thesis in pigeonpea breeding by 2009.

Countries Involved**:**
India

Partners Involved**:**
Indian NARS (Public and Private Sector)

Progress/Results:
ICRISAT has been involved in capacity building of its NARS and private sector partners through series of structured training programs, field days and group meetings. Training program was imparted in hybrid breeding, seed production, agronomy, plant protection, and post harvest management technologies. During the year 2007, two scientists from Research Institute for Insects CAF, Bai Longsi, Kumming, Yunnan, China, and one scientist from Organization of Food Crops research Institute, Yunnan Academy of Agricultural Sciences (YAAS), Yunnan, China were trained in pigeonpea seed production technology. One research technician from Food Legumes Section, Department of Agricultural Research (DAR) Yezin, Myanmar was trained in pigeonpea breeding for three months at ICRISAT-Patancheru. In addition, during 2007 a total of 50 scientists, technicians and extension officials were trained in pigeonpea breeding, seed production and ICM technologies in day-long training programs at ICRISAT-Patancheru. ICRISAT is in the process of selecting Master's students from ANGRAU-Hyderabad, MAU-Parbhani, PDKV-Akola, and other universities from India, Myanmar and Kenya.

Special Project Funding**:**
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output target 2011 5.1.1 PP Seven medium-duration male-sterile lines made available to NARS and private sector for use in hybrid development

Achievement of Output Target (%):
70% We have made available five medium-duration male-sterile lines to NARS and private sector seed companies for hybrid development.
Countries Involved:
India

Partners Involved**:**
Indian NARS (Public and Private Sector)

Progress/Results:
During 2007 five A_4 system medium-duration CMS lines ICPA 2043 (BC_5F_1 in generation), ICPA 2047 (BC_4F_1 in generation), ICPA 2048 (BC_4F_1 in generation), ICPA 2078 (BC_3F_1 in generation) and ICPA 2092 (BC_3F_1 in generation) were shared with nine private and public sector seed companies. These CMS lines were also distributed to the Indian and Myanmarese NARS partners during the same year. These lines were used by private seed companies for generating experimental hybrids for their target locations in India.

Special Project Funding**:**
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output target 2011 5.1.2 PP One PhD scholar and 35 scientists and technicians from NARS and seed sector trained in pigeonpea breeding

Achievement of Output Target (%):
50
Thirty-five scientists and technicians have been trained. One PhD student will carry out thesis research work in pigeonpea breeding by 2011.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results:
During the 2007, training was imparted in hybrid breeding, seed production, agronomy, plant protection, and post harvest management technologies. A total of 39 scientists, technicians and extension officials were trained in pigeonpea breeding, seed production and integrated crop management (ICM) technologies in day-long training programs (held in Feb and Dec 2008) at ICRISAT-Patancheru. In addition, ICRISAT also trained 108 scientists, technicians and extension officials in pigeonpea breeding, seed production and ICM technologies during 2008. We have selected one PhD student from MAU Parbhani in 2008. The student has been assigned research work entitled "Study of Heterosis, Combining ability and Stability of Yield Quality Parameters in CMS-based Pigeonpea Hybrids". The research work has started during 2008 rainy season at ICRISAT- Patancheru.

Special Project Funding:
1. Enhancing Yield and Stability of Pigeonpea through Heterosis Breeding (ISOPOM); 2. Pigeonpea Hybrid Parents Research Consortium

Output 5B: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners biennially (from 2008) with associated knowledge and capacity building in SAT Asia

Sorghum

Output target 2009 5.2.1 SOPM Physiological mechanisms explaining the stay-green trait dissected in sorghum near-isogenic lines with stay-green QTLs

Achievement of Output Target (%):
50% This is based on a number of preliminary evidences that we have gathered in the previous years, some of them following the example of pearl millet, along with crop simulation modeling data that show that differences between staygreen and non-staygreen materials are likely to be related to differences in the leaf area index at anthesis (lower in staygreen by about 25%), which would contribute to water saving.

Countries involved**:**
India, Australia

Partners involved**:**
National Research Centre for Sorghum, Hyderabad, India, Queensland Department of Primary Industries and Fisheries (QDPI&F), and University of Queensland, Australia.

Progress/Results:
We are following the example of pearl millet, and a similar hypothesis because stay-green contributes to a slower senescence of leaves and better grain filling. We are in the process of measuring also the rates of water loss per unit of leaf area in sorghum, to test any possible relation with the presence/absence of stay-green QTL. In addition, we are testing whether stay-green differences could originate from differences in the proportion of water used from the soil profile during the pre-anthesis period, in comparison to the water used during the grain-filling period.

Special project funding**:**
ACIAR

Output Target 2009 5.2.2 SO Dual-purpose stay-green and foliar disease resistant forage/sweet sorghum hybrid parents developed (partly associated with SLP SWEP)

Achievement of Output Target (%):
70% Based on the evaluation of recently developed sweet sorghum varieties, hybrids and hybrid parents for pest and disease resistance, some promising sweet sorghum varieties, hybrids and hybrid parents were identified for shoot fly, downy mildew, anthracnose and grain mold resistance.

Countries Involved:
India; Mali ; The Philippines

Partners Involved:
NARS (Public and Private sector) in India, The Philippines and Mali

Progress/Results:
Evaluation of sweet sorghum varieties for shoot fly resistance and downy mildew and anthracnose resistance: Sweet sorghum hybrids – 53 elite, and 42 advanced; 64 hybrid seed parents (41 B-lines and 23 R-lines), 30 varieties/R-lines and 30 elite B-lines were evaluated for disease reaction (anthracnose and downy mildew) and resistance to shoot fly in the 2008 rainy season.

For shoot fly resistance, 11 elite hybrids showed 11–42% less shoot fly deadhearts (54–84%) than control CSH 22SS (94% deadheats); 4 advanced hybrids showed 11–14% less shoot fly deadhearts (80–83%) than control (CSH 22SS: 93%); 13 hybrid seed parents showed 11–52% less shoot fly deadhearts (44–83%) than control (SSV 84: 93%); ten varieties/R-lines showed 10–42% less shoot fly deadhearts (55–86%) than control (SSV 84: 96%); and six elite B-lines showed 19–51% less shoot fly deadhearts (43–71%) than control (ICSB 38: 88%).

Twenty-nine sweet sorghum varieties/R-lines were evaluated for resistance to sorghum downy mildew (*Peronosclerospora sorghi*) using sandwich as well as spray-inoculation techniques under greenhouse conditions in 2008. A known DM resistant line (QL 3) and a susceptible line (296B) were included as checks. The lines were evaluated in 4 replications, one pot (15cm dia) per replication with 30–35 seedlings per pot. Downy mildew incidence was recorded 14 days after inoculation. The incidence on test varieties varied from 29–100% compared to 18% on QL 3 under sandwich inoculation and 79–100% compared to 3% on QL 3 under spray-inoculation.

For anthracnose resistance, disease severity on a 1–9 scale (1=0 to <1% leaf area covered with hypersensitive lesions with yellow flecks – highly resistant and 9=76–100% leaf area covered with coalescing necrotic lesions with acervuli – highly susceptible) was recorded on whole plant basis at the soft-dough stage. Grain mold severity was also recorded in these entries at physiological maturity using the 1–9 scale.

Of the 53 elite hybrids, four hybrids (ICSA 731 × NTJ 2, ICSA 38 × SPV 422, ICSA 502 × SPV 422 and ICSA 724 × SPV 422) were found resistant (≤3.0 score) and 34 moderately resistant (score >3 to ≤5) to anthracnose compared to a 9 score on the susceptible check H 112. The hybrids found resistant to anthracnose also exhibited moderate resistance to grain mold.

Five of the 42 advanced hybrids (ICSA 702 × SPV 422, ICSA 344 × AKSV 22, ICSA 344 × RSSV 106, ICSA 702 × ICSR165 and ICSA 702 × SSV 53) were resistant to anthracnose (Table 1). ICSA 344 × AKSV 22 was also resistant to grain mold and the other four had moderate level of grain mold resistance. Twenty six of the 42 advanced hybrids were resistant (≤3.0 score) to grain mold and moderately resistant to anthracnose

Ten of the 30 elite B-lines (ICSB 73, -94, -271, -307, -319, -324, -401, -428, -279 and -311) were resistant to anthracnose. ICSB 401 also showed resistance to grain mold.

Of the 70 hybrid parental lines, 21 were found resistant to anthracnose. Two lines ICSA 401 and SSV 53 were resistant to both the diseases. These hybrids and hybrid parental lines are currently being evaluated for leaf blight resistance as well.

Evaluation of sweet sorghum varieties for shoot fly resistance: Among the breeding lines evaluated for shoot fly resistance, 11 elite hybrids showed 11−42% less shoot fly deadhearts (54–84%) than control (CSH 22SS: 94%); 4 advanced hybrids showed 11−14% less shoot fly deadhearts (80–83%) than control (CSH 22SS: 93%); 13 hybrid seed parents showed 11−52% less shoot fly deadhearts (44–83%) than control (SSV 84: 93%); 10 varieties/R-lines showed 10−42% less shoot fly deadhearts (55–86%) than control (SSV 84: 96%); and six elite B-lines showed 19−51% less shoot fly deadhearts (43–71%) than control (ICSB 38: 88%).

Evaluation of sweet sorghum varieties for anthracnose and grain mold resistance: For anthracnose resistance, data on disease severity on a 1−9 scale (1=0 to <1% leaf area covered with hypersensitive lesions with yellow flecks – highly resistant, and 9 = 76−100% leaf area covered with coalescing necrotic lesions with acervuli – highly susceptible) were recorded on whole plant basis at the soft-dough stage. Grain mold severity was also recorded in these entries at physiological maturity using the 1−9 scale (1=0 to <1% mold infection – highly resistant and 9=76−100% molded grains on a panicle − highly susceptible). Of the 53 elite hybrids, only four (ICSA 731 × NTJ 2, ICSA 38 × SPV 422, ICSA 502 × SPV 422 and ICSA 724 × SPV 422) were found to be resistant (≤3.0 score) and 34 moderately resistant (score >3 to ≤5) to anthracnose, compared to a 9 score on the susceptible check H 112. Five of the 42 advanced hybrids (ICSA 702 × SPV 422, ICSA 344 × AKSV 22, ICSA 344 × RSSV 106, ICSA 702 × ICSR165 and ICSA 702 × SSV 53) were resistant to anthracnose. ICSA 344 × AKSV 22 was also found resistant to grain mold and the other four had moderate level of grain mold resistance. Twenty six of the 42 advanced hybrids were resistant (≤3.0 score) to grain mold and moderately resistant to anthracnose.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium and IFAD Biofuels Project

Output target 2010 5.2.1 SOPM Relationship between yield under terminal drought stay-green and root-related traits established in sorghum

Achievement of Output Target (%):
30% This is based on a number of preliminary evidences showing deeper rooting in some staygreen materials under drought conditions. However, the system that would allow testing this hypothesis has only been recently developed (a lysimetric system allowing the assessment of water uptake in a soil profile under receding moisture) and will now be used to test the relationship.

Countries involved:
Australia; India
Partners involved:
National Research Centre for Sorghum, Hyderabad, India, Queensland Department of Primary Industries and Fisheries (QDPI&F), and University of Queensland, Australia.

Progress/Results:
A lysimetric system has been developed at ICRISAT, which involves large and long PVC tubes (2.0 m long and 25 cm diameter) filled with Alfisol at a bulk density of 1.4. These are currently used to assess putative differences in water extraction from sorghum plants, and to test possible relations with stay-green trait.

Special project funding:
ACIAR, DBT

Output target 2010 5.2.3 SOPM Mapping and introgression of stay-green QTLs into elite parental lines, and assessment of their effects on hybrid performance completed

No report submitted

Pearl Millet

Output target 2008 5.2.1 SOPM Physiological traits explaining terminal drought tolerance in pearl millet lines with drought tolerance QTL dissected

Achievement of Output Target:
Fully Achieved

Countries involved:
India; Ghana

Partners involved:
National programs in India and Ghana

Comments/Explanations:
This is based on a number of clear evidences of traits that discriminate well the terminal drought sensitive from the terminal drought tolerant lines. Namely, the transpiration rate (g water loss cm-2 leaf area), the leaf ABA content, and the stomatal conductance response to VPD increases under well-watered conditions clearly discriminate tolerant from sensitive lines. Yet, work continues on this to identify QTL for these particular traits and gain precision in our modern breeding efforts.

Progress/Results:
Terminal drought tolerance of pearl millet lines is related to a higher spikelet fertility and a better seed filling. Both these characteristics are efficiently phenotyped by measuring the panicle harvest index (PNHI), i.e., the ratio of grain weight/panicle weight. One question that has remained unanswered is what could be the physiological mechanisms involved in having a higher PNHI. We hypothesized that terminal drought tolerant lines might have more water availability in the soil profile during the grain filling period. This might be related to use of water sparingly before anthesis, when water was available (under well-watered conditions). Therefore, we characterized the control of water loss in leaves, as this could possibly underlie a major QTL for yield under terminal drought. Two pearl millet parental genotypes differing in terminal drought tolerance, i.e., PRLT-2/89-33 (tolerant and QTL donor parent) and H 77/833-2 (sensitive), and several near-isogenic lines (NILs), introgressed with the QTL in the background of sensitive H 77/833-2 (BC_4F_2) were tested. We found that the transpiration rate (TR [g cm^{-2}] d^{-1}) was lower in the tolerant parent and in the NILs than in H 77/833-2. We also found that the TR response to an increasing vapor pressure deficit (VPD) was linear until about 2.0kPa in all genotypes. Above that threshold, transpiration increased linearly in H 77/833-2 whereas there was a clear slow down in the transpiration response of tolerant parent and NILs. Finally, we found that although there were no differences in stomata number between the parents, the ABA content in the leaves of well-watered PRLT-2/89-33 and NILs was higher than in H 77/833-2. Besides, TR was examined in 106 recombinant inbred lines (RILs) derived from the cross between PRLT-2/89-33 and H 77/833-2, where a good segregation pattern was found, with both parents at each end of the distribution. We propose that a lower TR and TR response to varying VPD found in tolerant genotypes may help in conserving soil water under well-watered conditions, leaving water available for grain filling. This TR tuning could be linked to differences in stomatal conductance regulation, possibly related to ABA differences.

The anti-oxidative machinery in plant cells, involved in the detoxification of free radicals that can abound during stress period has received much attention from physiologists interested in stress response. Therefore, we evaluated the differences in proline, chlorophyll a, b (Chl a, b) and carotenoids (Car) contents and activities of ascorbic peroxidase (APX), superoxid dismutase (SOD) and catalase (CAT) isozymes under well-watered and water stress conditions in pearl millet genotypes varying for the presence of a terminal drought tolerance QTL. Lines used in this study were PRLT-2/89-33 – tolerant and QTL donor, H 77/833-2 – sensitive, and QTL-introgressed near-isogenic lines (NILs) in the background of H 77/833-2. Results confirmed the above results, i.e., a lower TR (g cm^{-2}) and higher ABA concentration in tolerant parental line and NILs than in sensitive H 77/833-2 under well-watered conditions, with NILs exhibiting similar TR and ABA values as tolerant parent. Proline level under well-watered conditions was lower in tolerant parent and NILs than in H 77/833-2 and proline values were negatively correlated to ABA. When the fraction of transpirable soil water dropped below 20%, i.e., plants were severely stressed, all genotypes showed large proline increment, which in NILs and tolerant parent far exceeded the levels in sensitive parent. Furthermore, drought increased APX 5 isozyme activity in all genotypes except H 77/833-2. Under drought, new CAT isozyme was induced in all genotypes. Other traits (Chl and Car content and SOD activity) didn't vary among genotypes under both water regimes. Differences in proline levels and APX spectrum of tolerant genotypes under water depletion could signify an earlier drought sensing system. However, it appears that the anti-oxidative machinery parameters did not show differences between tolerant and sensitive lines until very severe stress levels were reached. Therefore, we conclude that they may have a limited role to play in the drought tolerance differences. Rather, traits related to plant water loss by leaves under well-watered conditions, which would contribute to soil water conservation, may be more important to get yield benefit under terminal drought conditions.

A third hypothesis, related to rooting traits and putative water extraction differences between tolerant and sensitive lines is being tested.

Special project funding:
DFID

Output Target 2010: 5.2.2 SOPM: At least three pearl millet lines with flowering-period heat tolerance at air temperature exceeding 42°C identified (new output target)

Achievement of Output Target (%):
10% Screening under natural field condition failed due to unfavorable weather during flowering. The procedure under controlled environment was standardized (which might need further fine-tuning) and three lines were tentatively identified with heat tolerance.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Based on the previous field observations of flowering-period heat tolerance, 6 parental lines and 3 hybrids of pearl millet were screened at 42°C temperatures at two different reproductive stages under controlled environmental conditions in growth chamber. Climatic conditions were simulated in growth chamber for a normal day with peak temperatures of 42°C and relative humidity of 32−42% which summer grown crop of pearl millet faces in N.W. India. Pot-grown plants of each genotype under study were shifted to growth chamber at boot leaf stage and panicle emergence stage and kept there until half way through grain filling, after which the pots were brought back and retained outside till maturity for recording seed set. Seed set of heat-treated plants was compared with plants kept in open (control) facing maximum temperatures of about 34°C at flowering time. Under control condition, seed set in all the lines varied from 90 to 100%. Within-line variability was observed for seed set in all the lines and in both treatments. Only two lines had any plants with > 20% seed set when heat treated at the boot leaf stage (20−60% with a mean of 39% in 841B, and 3−30% with a mean of 15% in ICMB 92777). When treated at panicle emergence stage, the seed set in plants of ICMB 92777 varied from 20 to 60% with a mean of 40%, and that in 841B it varied from 20 to 70% with a mean of 47%. Clearly, the sensitivity to high temperatures was more at the boot leaf stage than at the panicle emergence stage. There were two additional lines which had high seed set when plants were exposed to high temperatures at the panicle emergence stage: Plants in Nandi 32 R had 70−80% seed set and plants in PP 38 had 30−55% seed set. These results indicate that screening for heat tolerance under this controlled environment facility can be very effective and the relative sensitivity of various growth stages can be dissected. However, such screening and its application to breeding program, including QTL identification, will require this facility to be substantially enlarged.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Output target 2011 5.2.1 SOPM Relationship between yield under terminal drought and root-related traits established in pearl millet

Achievement of Output Target (%):
10% The system that would allow testing this hypothesis has only been recently developed (a lysimetric system allowing the assessment of water uptake in a soil profile under receding moisture). It is the same one used for sorghum to test similar hypothesis.

Countries Involved:
Ghana; UK

Partners Involved:
Institute of Grassland and Environmental Research (IGER), UK

Progress/Results:
To test this hypothesis, we will be using 2.0 m long and 25-cm diameter cylinders filled with Alfisol, at a 1.4 bulk density. Plants will be grown under well-watered conditions until anthesis. The amount of water used before and after anthesis will be assessed. In particular, we will be testing whether pearl millet entries varying for the presence of absence of a major terminal drought tolerance QTL (including near-isogenic lines) differ in their pattern of water use and in their capacity to extract water from a soil profile.

Special Project Funding:
Department for International Development (DFID-UK)-Biotechnology and Biological Sciences Research Council (BBSRC-UK)

Output Target 2011 5.2.2 SOPM At least four parental lines of sorghum and six parental lines and populations of pearl millet with salinity tolerance developed/ identified

Achievement of Output Target (%):
50% Crosses were made using selected salinity-tolerant parents and advanced progenies developed. The established pearl millet and sorghum hybrids and varieties are under evaluation for salinity tolerance

Countries Involved:
India and CAC countries

Partners Involved:
ICBA, Dubai; NARS (Public and Private sector) in India and CAC countries

Progress/Results:
In sorghum, salinity tolerance has been introgressed in high-yielding backgrounds. A total of 436 F_6s and 316 F_5s have been developed for B-line development and 67 F_6s and 239 F_5s have been developed for R-line development. Promising sweet sorghum hybrids (86) and sweet sorghum varieties (24) are being evaluated as late rainy season crop at Gangavathi, Karnataka under natural saline conditions (8 to 10 dsm^{-1}). Data are being collected.

In pearl millet, a pot-grown trial consisting of 38 breeding lines that were tested previously, a set of 45 B-lines, and 18 R-lines was carried out under both saline and non-saline conditions, in an outdoor environment equipped with a rain-out shelter to prevent rains. Data are currently being analyzed.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium; OFID-OPEC-funded Project on Salinity Tolerance

Output 5C: Germplasm and improved breeding lines with high and stable grain Fe and Zn density in sorghum and pearl millet made available to specific partners biennially (from 2008) with associated knowledge and capacity building

Output target 2009 5.3.1 SO At least five sorghum hybrid parental lines with high Fe (>50 ppm) and Zn (>40 ppm) identified and made available to partners.

Achievement of output target (%):
50% Some promising sorghum seed parents with high grain Fe and Zn contents.

Countries Involved:
India and Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

Progress/Results:
The hybrid parents (218 B-lines) developed at ICRISAT-Patancheru were evaluated during the 2007 postrainy season and data were recorded on agronomic traits including the grain yield. The grain Fe and Zn status of 218 sorghum hybrid parents were analyzed. The lines ranged from 22 to 51 ppm for grain Fe contents and 15 to 39 ppm for Zn. Validation of the results is in progress in the 2008 post rainy season.

Special Project Funding:
HarvestPlus Challenge Program

Output Target 2011: 5.3.1 SO: At least 10 germplasm accessions of sorghum from core collection with >60 ppm grain Fe and >40 ppm Zn content identified

Achievement of Output Target:
50% Promising core germplasm lines identified for grain Fe and Zn contents. Validation of results is in progress.
Countries Involved: India and Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

Progress/Results:
Core germplasm set captures most of the variability present in world repository of sorghum germplasm collection (>3600) maintained at ICRISAT. The information on the genetic variability would enable to identify micronutrient-rich lines for use in crossing with agronomically elite lines to generate exploitable variability to develop micronutrient-dense cultivars. Of the total core germplasm accessions (>3600) in sorghum, 2974 accessions were planted during 2005 postrainy season and 1401 accessions were assessed for their grain Fe and Zn contents and 153 accessions were selected based on their high grain Fe and Zn contents. Remaining 1062 accessions (leaving the 511 accessions which are highly photoperiod-sensitive) whose grain Fe and Zn contents could not be estimated earlier were planted during 2006 postrainy season to assess the genetic variability for Fe and Zn.

For validation of the grain Fe and Zn contents in the selected core germplasm collection (>200 accessions) with different maturity (early-less than 65 days to 50% flowering), medium (65 to 75 days) and late (more than 75 days) durations were evaluated in the 2007 postrainy season for agronomic data in three different trials (micronutrient dense germplasm lines (50), freely threshable micronutrient dense germplasm lines (118), and non threshable micronutrient dense germplasm lines (55).

The Fe and Zn contents estimations are completed for 50 micro nutrient dense germplasm lines and 23 breeding progenies. The rest of the grain samples are under processing for Fe and Zn contents estimation.

Among the 50 micronutrient dense germplasm lines 31 had Fe contents above 45 ppm, ranging from 45 to 145 ppm; and among these 31 lines, 15 had Zn contents from 45 to 65 ppm. Among 23 breeding lines, 8 had Fe contents above 45 ppm, ranging from 46 to 59 ppm with Zn contents from 37 to 60 ppm. Validation of the Fe and Zn contents in the promising core germplasm lines is in progress in the 2008 post rainy season.

Special Project Funding: HarvestPlus Challenge Program

Pearl Millet

Output target 2008 5.3.1 SOPM Variability for Fe and Zn in commercial hybrids and core collection of germplasm assessed in pearl millet

Achievement of Output Target:
>75% Achieved
Countries Involved:
India

Partners Involved:
None

Comments/Explanations:
Achieved 80%. Results of hybrids have been reported in e-Journal of SAT Agricultural Research; Grain samples of core collection has been produced and Fe/Zn analysis is to done.

Progress/Results:
Fifty-two hybrids (35 commercial and 17 pipeline hybrids) from 19 private seed companies and a public-sector-bred hybrid had been evaluated for two seasons (2006 rainy season and 2007 post rainy season). Grain samples produced from these trials were analyzed for grain Fe and Zn contents. Large differences among the hybrids were found for both micronutrients. Based on the mean performance across the two seasons, the Fe content among the hybrids varied from 47 to 85 ppm and Zn content varied from 36 to 70 ppm. Eleven hybrids had >70 ppm Fe, of which 11 hybrids had >50 ppm Zn. A private seed company hybrid (MLBH 504) had the highest level of Fe (85 ppm) and it also had the highest level of Zn (70 ppm). Another seed company hybrid (MRB 204) had 80 ppm Fe and 70 ppm Zn content. According to the information received from these seed companies, MLBH 504 is cultivated on 50, 000 ha in Maharashtra and Karnataka states of India, while MRB 204 is cultivated more widely on 3000, 000 ha in Maharashtra, Madhya Pradesh, Uttar Pradesh and Haryana states of India. There were eight additional hybrids under cultivation which had >70 ppm Fe and > 50 ppm Zn. Thus, this study identified commercial hybrids with Fe and Zn levels far higher than those reported in improved cultivars of other major cereals. There were weak, though significant, positive correlations of grain size with Fe and Zn contents, and weak and negative correlation between flowering time and Fe content, indicating that breeding for both Fe and Zn with early-maturity and large seed size should be a relatively easier proposition in pearl millet.

Five hundred-four core collection accessions subjected to Perls Prussian Blue Staining in 2006 rainy season had identified 166 accessions that had medium to dark blue color, and hence presumably high Fe content, which were thereafter evaluated for two seasons (2007 rainy and post rainy seasons). Laboratory analysis of grain samples produced from these two trials is under way. We evaluated 100 S_1 progenies each from two *iniadi* populations (GP and GGP). Based on the staining results, 50 progenies from each that stained dark to medium blue were selected for laboratory analysis of Fe and Zn contents.

Special Project Funding:
HarvestPlus Challenge Program

Output Target 2010 5.3.2 SOPM Comprehensive information on genetics of grain Fe and Zn content in sorghum and pearl millet generated

Achievement of Output Target (%):
25% in pearl millet and 10% in sorghum. Data analysis from a diallel experiment in pearl millet has been completed and a JA is under preparation. One trial of Line × Tester experiment was completed and grain samples were produced. In sorghum we made a beginning by identification of parents and by making crosses in three diallels for studying the inheritance of grain Fe and Zn contents in sorghum. It needs minimum three years to generate different generations and evaluate them to work out the inheritance.

Countries Involved:
India; Mali

Partners Involved:
National Institute of Nutrition; Hyderabad; Tamil Nadu Agricultural University; Coimbatore; NARS (Public and Private sector) in India and Mali

Progress/Results:
In pearl millet, a 10×10 diallel experiment in pearl millet was conducted for two seasons (2006 rainy and 2007 post rainy seasons) and grain samples were analyzed for Fe and Zn contents. Results showed highly significant differences among the parents for general combining ability and among crosses for specific combining ability. However, both Fe and Zn contents were predominantly under additive genetic control, implying that intra-population improvement is likely to be highly effective in the genetic improvement of both micronutrients. In fact, this hypothesis was tested by conducting one cycle of recurrent selection in two open-pollinated varieties (OPVs) and comparing the Fe and Zn contents of the C_o and C_1 bulks (see output targets 2012:5.3.1 SOPM for details). There was highly significant positive correlation between the mid-parental values and hybrid performance both for Fe and Zn, which further showed the greater importance of additive gene effects. There was no hybrid that exceeded the Fe or Zn levels of the parental lines having higher Fe or Zn contents. Fewer hybrids had significant deviations from the mid-parental values, and these mid-parent heterosis were in both directions (slightly more frequent in the negative direction) for both micronutrients. This indicated that to breed hybrids having high Fe and Zn levels, it would be necessary to breed for these micronutrients in both parental lines of hybrids. This research is being further pursued, making largely a part of a PhD thesis. A 12×14 Line × Tester trial was conducted in the 2008 rainy season and grain samples were produced for laboratory analysis of Fe and Zn contents.

In sorghum, in order to study the genetics of grain Fe and Zn contents, crosses were made between adapted breeding lines and unadapted germplasm lines (contrasting for Fe and Zn contents) in three diallels in the 2006 postrainy season. The three diallels (a 6×6 diallel with parents contrasting for grain Fe content, a 4×4 diallel with parents contrasting for grain Zn content and a 5×5 diallel with parents contrasting for both grain Fe and Zn contents) were sown in separate trials during the 2007 postrainy season but germination was poor in some of the crosses. The crosses are being repeated in the 2008 post rainy season.

Special Project Funding:
HarvestPlus Challenge Program

Output target 2011 5.3.2 SOPM At least six improved breeding lines of pearl millet with >90 ppm grain Fe and >60 ppm Zn developed.

Achievement of Output Target (%):
25% materials were identified with some of the early-generation progenies indicating both Fe and Zn above the target levels.
Countries Involved:
India

Partners Involved:
None

Progress/Results:
Fifty S_1 progenies each of the four populations (CGP, GGP, PVGGP 6 and ICTP 8203) (set 1) had earlier been evaluated to assess the magnitude of intra-population variability for grain Fe and Zn contents. Results of this preliminary trial led to the identification of six progenies each of the four populations that had >100 ppm Fe and >70 ppm Zn. Additional 100 progenies each from CGP and GGP (set 2) were also evaluated and grain samples produced in 2007. The 24 progenies from the first set and those yet-to-be identified for high Fe and Zn contents from the second set will be further evaluated for these micronutrients along with yield potential and DM resistance to derive improved inbred lines having the target levels of both micronutrients. Similar selection program for exploitation of genetic variability to develop improved breeding lines with high Fe and Zn contents has been initiated in three *iniad*i germplasm accessions identified with high levels of these both micronutrients**.**

Special Project Funding:
HarvestPlus Challenge Program

Output target 2011 5.3.3 SOPM At least two high-yielding hybrids of pearl millet with >70 ppm Fe and > 50 ppm Zn developed.

Achievement of Output Target (%):
10% Twenty seed parents and 15 restorer parents with the target levels of both micronutrients have been identified, and extensive screening to identify additional lines is well under way.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Of the 96 maintainers (B-lines) of the corresponding male-sterile lines (A-lines) previously evaluated, 20 B-lines with >65 ppm Fe and >50 ppm Zn contents had been identified. Similarly, of the 88 restorer lines previously evaluated, 15 lines with >55 ppm Fe and >40 ppm Zn had been identified. More than 450 hybrids made from crosses between some of these seed and restorer parents as well with other pollen parents had been evaluated for grain yield during 2007 rainy season. Further evaluation of selected hybrids finally identified 38 hybrids which were evaluated for grain yield in 2008 rainy season.

Data are yet to be analyzed.

Special Project Funding:
HarvestPlus Challenge Program

Output target 2012 5.3.1 SOPM Effectiveness of recurrent selection for grain iron and zinc content in pearl millet demonstrated.

Achievement of Output Target (%):
30
One cycle of recurrent selection in AIMP 92901 and GB 8735 was completed and results are summarized. Fe and Zn data on S_1 progenies of CGP and GGP evaluated for two seasons were generated. Also, Fe and Zn data on S_1 progenies of ICTP 8203 evaluated for one season were generated and grain samples from the second season trial were produced.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Based on two-season evaluation in 2005/2006 of more than 60 S_2/S_3 progenies each of two populations (AIMP 92901 released in India, and GB 8735 released in several countries of Western and Central Africa), nine top-ranking progenies for Fe and nine top ranking progenies for Zn progenies had been selected from each population to constitute their C_1 cycled bulks. These were compared with the original population bulks (Co) and the random-mated (CoRM) bulks of both populations generated by random mating all the progenies included in the trial. The grains produced from the trials conducted in 2006 rainy season and 2007 post rainy season had been analyzed at ICRISAT for Fe and Zn contents. These were again re-analyzed at the Waite Analytical Research Laboratory in Australia. Results from this analysis were broadly supportive of those based of ICRISAT laboratory data. Briefly, the C_1 bulks of these populations constituted for high Fe had 16–27% higher Fe over the Co bulks and 11–13% higher Fe over CoRM bulks. Selection for Fe also resulted in positive genetic changes for Zn content in both populations. The C_1 bulks constituted for Zn content led to 14–23% improvement in Zn when compared with Co bulks and 9–13% improvement when compared to CoRM bulks. Selection for Zn also led to positive change in Fe content (7–18% gain when compared to C_0 bulks and 4% gain when compared to CoRM bulks). Interestingly, selection for either of these micronutrients led to 12–23% gain in grain yield when compared to Co bulks and 5–18% gain when compared to CoRM bulks in the two populations. Selection for Fe or Zn led to increase in grain size (9–17% improvement when compared to Co bulk and 6–12% improvement when compared to CoRM bulks), which perhaps made a major contribution to genetic gains in grain yield. Selection for Fe and Zn had no adverse effect on plant height and maturity.

Based on the above results, effectiveness of recurrent selection for Fe and Zn is being tested in three more populations. Field trials of 100 S_1 progenies each of two populations (CGP and GGP) had been conducted for two seasons in 2007 and grain samples produced for the evaluation of Fe and Zn contents. Based on Perls Prussian Blue staining about 50 progenies each of CGP and GGP with medium to deep stains (and hence presumably with high Fe content) were selected and sent for the AAS analysis of Fe and Zn contents. The progenies of ICTP 8203 were evaluated for high Fe and Zn content using NIRS method at CIP, Peru and using AAS method at the Waite Analytical Laboratory (Australia) primarily for the calibration purposes to develop a rapid screening procedure. The correlations between the two estimates were >0.93 for Fe content. A large-scale recurrent selection program is now under way on ICTP 8203, a popular commercial variety in India. Three hundred S_1 progenies selected based on staining results were evaluated during the 2008 post rainy season. Of these, 187 progenies showing >75 ppm Fe were selected for re-evaluation during the 2008 rainy season and grain samples produced for the laboratory analysis of Fe and Zn contents. This variety will be subjected to two cycles of recurrent selection to examine the effectiveness of this method for the genetic improvement of Fe and Zn content and also develop an improved version of this variety with higher Fe and Zn contents.

Special Project Funding:
HarvestPlus Challenge Program

Output 5D: Sweet sorghum improved breeding lines with high and stable sugar and biomass made available to specific partners as hybrid parents with associated knowledge and capacity building

Output target 2009 5.4.1 SO More than 25 farmers trained in sweet sorghum ethanol value chain

Achievement of Output Target (%):
30% A training program conducted for 40 lead farmers on sweet sorghum cultivars, cultivation aspects, use of machines in cultivation, and formation of farmer groups" in 2008 and training materials were developed.

Countries Involved:
India; Mali; Mozambique; Philippines

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
A training program conducted for 40 lead farmers from project villages on "Sweet sorghum cultivation aspects, use of machines in cultivation, and formation of farmer groups" during 15–16 May 2008 at Extension Education Institute, ANGRAU, Hyderabad.

A similar training program will be conducted for lead farmers on sweet sorghum value chain development in 2009.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium; IFAD Biofuels Project and NAIP-ICAR Sweet Sorghum Value Chain Development Project

Output Target 2010 5.4.1 SO First generation improved hybrid parents available to consortium partners for testing with associated capacity development (associated with the SLP)

Achievement of Output Target (%):
30
The first sweet sorghum hybrid CSH 22SS released by Indian national program is based on the ICRISAT-bred female parent ICSA 38. We have identified more than 60 A-/B-lines from ICRISAT-bred seed parents promising of sugar yields. They will be used extensively in development of new sweet sorghum hybrids. The advanced breeding lines will be test crossed and based on the maintainer reaction; the lines will be included in conversion program to develop new male-sterile lines.

Countries Involved:
India; Mali; Philippines

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
Sweet sorghum germplasm lines trial: From a reference set of sorghum germplasm lines evaluated in pots during the 2007 postrainy season and from East and West African germplasm lines evaluated in three-replicated trials in randomized complete block design during the 2007 postrainy season, a total of 190 germplasm lines were selected based on country of origin (16 countries that include Angola, Burkina Faso, Cameroon, Ethiopia, Ghana, Kenya, Malawi, Mali, Niger, Nigeria, Senegal, Sudan, Uganda, Republic of Yemen, Zambia and Zimbabwe) assuming that the lines will contain sources for sweet stalk traits. These 190 lines were evaluated along with the checks, SSV 84 and CSH 22SS in a three-replicated trial during the 2008 rainy season. Brix reading among the germplasm lines ranged from 7.9 to 23 (SSV 84: 21.5 and CSH 22SS: 18; Mean: 17.3; LSD: 3.87), while the height ranged from 1.8 to 4.6m (SSV 84: 3.2m and CSH 22SS: 3.5m) and days to 50% flowering varied from 56 to 104 days (SSV 84: 84 and CSH 22SS: 82). A total of 68 germplasm lines with ^{o}Bx >19 were selected and are being evaluated in a trial during the 2008 postrainy season.

Sweet sorghum preliminary B-lines trial: The F_5 progenies generated from the targeted crosses between high yielding B-lines, sweet sorghum B-lines and sweet sorghum varieties were evaluated in a replicated trial during the 2007 postrainy season. From each plot, three random plants were sampled and all-juice related observations were recorded. Individual panicles were threshed separately. Based on high juice yield, Brix and sugar yield, 73 F_6 progenies were selected. The 73 lines were evaluated along with two checks, SSV 84 and CSH 22SS in a replicated trial during the 2008 rainy season. Forty-eight lines with a sugar yield ranging from 2.5 to 6.0 t ha^{-1} were on par with the hybrid check CSH 22SS (4.31 t ha^{-1}), while seven lines (SP 1020-1, SP 1045-1, SP 1026-2, SP 2042-3, SP 1052-2, SP 2036-2 and SP 1035-3) were numerically superior to it by 1.6 to 39.6%. In these seven lines, Brix varied from 16.5 to 18.9 (CSH 22SS: 18); stem girth varied from 1.7 to 2.0cm (CSH 22SS: 1.7cm); plant height varied from 2.1 to 3.0m (CSH 22SS: 3.2m); days to 50% flowering varied from 72 to 76 days (CSH 22SS: 78 days); and grain yield varied from 0.1 to 3.56 t ha^{-1} (CSH 22SS: 1.36 t ha^{-1}, severe bird damage also contributed to low yield levels).

Sweet sorghum preliminary varietal/R-lines trial: The F_5 progenies generated from the crosses between elite sweet sorghum varieties were evaluated in a replicated trial during the 2007 postrainy season. From each plot, three random plants were sampled and all juice-related observations were recorded. Individual panicles were threshed separately. Based on high juice yield, Brix and sugar yield, 225 F_6 progenies were selected and evaluated in a two-replication RCBD trial along with the checks SSV 84 and CSH 22SS during the 2008 rainy season. Two varieties/R-lines (SP 1033-1 and SP 2035-3) with sugar yield of 13.04 t ha^{-1} and 12.91 t ha^{-1}, respectively were significantly superior to the best performing check SSV 84 (6.11 t ha^{-1}), 209 varieties (sugar yield 1.91 to 9.81 t ha^{-1}) were on par with it, and 91 varieties (6.12 to 13.04 t ha^{-1}) were numerically superior SSV 84. Among these 91 varieties, Brix varied from 15.1 to 19.7 (SSV 84: 21.5), girth varied from 1.7 to 2.5cm (SSV 84: 1.9cm), plant height varied from 2.6 to 4.2m (SSV 84: 3.4m), days to 50% flowering varied from 72 to 81 days (SSV 84: 77 days) and grain yield varied from 0.1 to 6.34 t ha^{-1} (SSV 84: 0.91 t ha^{-1}, severe bird damage also contributed to low yield levels).

Grain sorghum preliminary B-lines trial: Among the existing new B-lines developed for high grain yield, 63 B-lines were evaluated along with the sweet sorghum variety check SSV 84 and sweet sorghum hybrid parent check, ICSB 38 during the 2007 rainy season. Though none of the B-lines were superior to SSV 84 (3.66 t ha^{-1}) for sugar yield, four B-lines with sugar yield ranging from 2.81 to 3.25 t ha^{-1} were on par with it. In these four B-lines, Brix varied from 16.3 to 17.3 (SSV 84: 19.5), girth varied from 1.7 to 2.0 cm (SSV 84: 1.6 cm), plant height was 1.8 m (SSV 84: 2.6 m), days to 50% flowering varied from 72 to 76 days (SSV 84: 79 days) and grain yield ranged from 0.97 to 2.86 t ha^{-1} (SSV 84: 0.47 t ha^{-1}, severe bird damage also contributed to low yield levels). However, for sugar yield, 62 of the 63 B-lines were numerically superior to ICSB 38 (0.68 t ha^{-1}). ICSA 38 is the female parent of CSH 22SS, the first commercial sweet sorghum hybrid released by Indian national program.

Special Project Funding:
Sorghum Hybrid Parents' Research Consortium; IFAD Biofuels Project

Output target 2011 5.4.1 SO More than 25 scientists trained in sweet sorghum hybrid parents development through an international training course

Achievement of Output Target:
20% Ten flyers were developed on various aspects of sweet sorghum cultivation, seed production and ethanol value chain.

Countries Involved:
Open to all sorghum growing countries

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
Capacity enhancement is very critical as sweet sorghum is a new area. Training courses of sorghum hybrid parents and hybrid parents are conducted biennially at ICRISAT. Similar training program will be conducted on sweet sorghum hybrid parents' development to NARS partners. The training material was published in 2008.

Special Project Funding: Sorghum Hybrid Parents' Research Consortium; IFAD Biofuels Project

Output 5A: Hybrid parents and breeding lines of sorghum, pearl millet and pigeonpea with high yield potential and pro-poor traits in diverse and elite backgrounds, for specific target markets, production environments and research application made available biennially (from 2008) to defined partners with associated knowledge and capacity building in the Asian SAT

I. Sorghum

Output target 5A.1: More than 35 parental lines of potential sorghum hybrids with high grain yield, and improved agronomic traits and biotic resistance developed (2007–2009)

Activity 5A.1.1: Develop and characterize a diverse range of improved parental lines

Milestone 5A.1.1.1: Ten male-sterile lines and five restorer lines with high yield and large grain developed (BVSR, 2007)

Achievement of Output Target (%):
100% Based on the evaluation of recently developed grain sorghum hybrid parents (A/B and R-lines), 16 B-lines and 15 R-lines with high grain yield and agronomic desirability were identified.

Countries Involved:
India

Partners Involved:
Indian NARS (in Public sector research institutions and Private sector seed companies)

Progress/Results:
A. Dual purpose B-line development

Rainy season adaptation
The B-lines that were completely converted into male-sterile lines and stabilized were evaluated in replicated yield trials. The results are as under.

Preliminary B-lines (A_1 cytoplasm-based) Trial: Maintainers (B-lines) of 19 newly developed male-sterile lines with A_1 CMS system were evaluated along with two checks (296B and ICSB 52) in preliminary trial during the 2008 rainy season. Eleven B-lines with grain yield ranging from 2.3 to 2.9 t ha^{-1} were significantly superior to the best performing check 296B (1.1 t ha^{-1}). These lines flowered in 70 to 76 days (296B: 72 days) and reached a height of 1.4 to 1.7 m (296B: 1.5 m).

Preliminary B-lines (A_2 Cytoplasm-based) Trial: Maintainers (B-lines) of 21 newly developed male-sterile lines with A_2 CMS system were evaluated along with two checks (296B and ICSB 52) in preliminary A_2-based B-lines trial during the 2008 rainy season. Four B-lines with grain yields ranging from 2.1 to 3.4 t ha^{-1} were significantly superior to the best performing check 296B (1.3 t ha^{-1}). These lines flowered between 70 to 80 days (76 days for 296B) and reached a height of 1.6 to 2.0 m (1.5 m for 296B).

Advanced B-lines Trial: Thirteen selected B-lines and two checks (296B and ICSB 52) were evaluated during the 2008 rainy season. Three B-lines, SP 1004, SP 1007, SP 1013, with grain yield ranging from 2.8 to 3.4 t ha^{-1} were significantly superior to the check 296B (1.4 t ha^{-1}). These B-lines flowered in 71 to 73 days (74 days for 296B) and reached a height of 1.6 to 1.9 m (1.5 m for 296B).

Elite B-lines (A_1 Cytoplasm-based) Trial: Eight high-yielding B-lines and two checks (296B and ICSB 52) were evaluated during the 2008 rainy season. Four B-lines (SP 1001, SP 1002, SP 1003 and SP 1007) with grain yields ranging from 2.8 to 3.2 t ha^{-1} were significantly superior to the best performing check 296B (1.4 t ha^{-1}). These lines flowered in 70 to 72 days (73 days for 296B) and reached a height of 1.9 to 2.0 m (1.3 m for 296B).They were comparable to 296B for overall agronomic appearance.

Elite B-lines (A_2 Cytoplasm-based) Trial: Thirteen high-yielding B-lines selected from the evaluation of Advanced B-lines trial during the 2007 postrainy season and two checks (296B and ICSB 52) were evaluated during the 2008 rainy season. Nine B-lines with grain yield ranging from 2.3 to 3.7 t ha^{-1} were significantly superior to the best performing check 296B (1.2 t ha^{-1}). These lines flowered in 70–73 days (72 days for 296B) and reached a height of 1.5 to 2.1 m (1.5 m for 296B).They were comparable to 296B for overall agronomic appearance.

B. Dual-purpose R-line development

Rainy season adaptation

From the hybrid parent development program, promising F_5 progenies with restorer reaction on A_1 and/or A_2 CMS systems were evaluated in replicated yield trials [Preliminary R-lines Trial (PRT), Advanced R-lines Trial (ART) and Elite R-lines Trial (ERT)]. The results are as follows:

Preliminary R-lines Trial: Fifty four newly developed restorers on A_1 CMS system were evaluated in a PRT along with two high grain-yielding checks RS 29 and SPV 1616 during the 2008 rainy season. Three R-lines (RP 1008, RP 1048 and RP 1051) with 3.4 to 3.7 t ha^{-1} grain yield were on par with the best performing check, RS 29 (3.3 t ha^{-1}). These R-lines flowered in 71 to 78 days and had height of 1.0 to 2.0 m.

Advanced R-lines Trial: Six restorers on A_1 CMS system selected from preliminary R-lines trial evaluated during 2007 postrainy season were evaluated along with two high grain-yielding checks RS 29 and SPV 1616 during the 2008 rainy season. Five R-lines were on par with the check SPV 1616 (3.4 t ha^{-1}) for grain yield. They flowered in 71 to 76 days (75 days for SPV 1616) and grew to a height of 1.8 to 2.0 m (2.9 m for SPV 1616).

Elite R-lines Trial: Ten selected restorers and two checks (296B, SPV 1616) were evaluated during the 2008 rainy season. All the R-lines with grain yield ranging from 1.9 to 2.8 t ha^{-1} were on par with the check SPV 1616 (2.5 t ha^{-1}). The genetic background of these R-lines is different from SPV 1616.

Advanced Varietal Trial: Twelve lines selected earlier along with a variety SPV 462 were evaluated along with the high-yielding checks, SPV 1616 and ICSV 112 during the 2008 rainy season. Eight progenies were on par compared to the best performing check SPV 1616 (3.0 t ha^{-1}) for grain yield. Days to 50% flowering among these eight varieties ranged from 71 to 80 days and the plant height varied from 1.9 to 2.4 m. The selected lines will be advanced and test crossed onto A_1 CMS system during the 2008 postrainy season.

Preliminary Brown-midrib R-lines Trial: Twenty six newly developed restorers of the A_1 CMS system introgressed with brown midrib (bmr) trait utilizing bmr sources IS 21887 (bmr_1), IS 21888 (bmr_3) and IS 21890 (bmr_7) were evaluated along with their bmr sources and high grain-yielding check RS 29 during the 2008 rainy season. Twenty R-lines recorded a bmr score 1 (taken on a 1–3 scale, where 1 = brown, 2 = green and 3 = white). Grain yield in these lines ranged from 1.0 to 2.5 t ha^{-1} (RS 29: 4.5 t ha^{-1}), days to 50% flowering from 71 to 77 days (RS 29: 73 days) and plant height from 1.3 to 2.1 m (RS 29: 2.2 m). Grain yield in the bmr sources ranged from 0.6 to 1.8 t ha^{-1}.

Advanced Brown-midrib R-lines Trial: Ten restorers of the A_1 CMS system introgressed with brown midrib (bmr) trait utilizing bmr sources IS 21887 (bmr_1) and IS 21890 (bmr_7), selected from preliminary brown-midrib R-lines trial evaluated during the 2007 postrainy season were evaluated along with their sources and two high grain-yielding checks ICSR 89058 and RS 29 during the 2008 rainy season. Four R-lines recorded a bmr score 1. Among these, grain yield ranged from 1.4 to 2.6 t ha^{-1} (RS 29: 3.8 t ha^{-1}; ICSR 89058: 2.1 t ha^{-1}; bmr sources: 1.4 to 1.8 t ha^{-1}), days to 50% flowering from 71 to 76 days (RS 29: 70 days; ICSR 89058: 70 days) and plant height from 1.9 to 2.1 m (RS 29: 2.3m; ICSR 89058: 1.9m). The plant biomass of the R-lines is being processed for estimation ***of lignin content. There is a need for introgression of the* bmr *trait into more high-yielding backgrounds for use in cellulosic (second generation) ethanol production, which is being initiated during the 2008 postrainy season.***

Forage/Fodder R-lines Trial: Seven R-lines with both high grain and biomass yields were evaluated along with the checks RS 29 and NTJ 2 during the 2008 rainy season. Compared to the rainy season fodder-purpose check NTJ 2, all the lines were significantly superior for grain yield ranging from 1.7 to 3.4 t ha^{-1}; (0.6 t ha^{-1} for NTJ 2) and four of them were on par with high grain-yielding restorer RS 29 (3.2 t ha^{-1}). Days to flowering among the R-lines ranged from 69 to 77 days (72 days for RS 29 and 78 days for NTJ 2) and plant height ranged from 2.1 to 3.2 m (3.4 m for RS 29 and 2.7 m for NTJ 2).

Brown-midrib Hybrids Trial: Thirty hybrids were evaluated along with their parents (7 B-lines, 8 R-lines) and 3 checks (IS 21888, CSH 25 and CSH 22SS) during the 2008 rainy season. Five hybrids recorded a *bmr* score 1. The grain yield among these five hybrids ranged from 0.6 to 2.4 t ha^{-1} (CSH 25: 1.0 t ha^{-1}; CSH 22SS: 3.2 t ha^{-1}; IS 21888 0.7 t ha^{-1}), plant height ranged from 1.6 to 1.9 m (CSH 25: 2.0 m; CSH 22SS: 3.2 m; IS 21888: 1.2m), days to 50% flowering ranged from 70 to 73 days (74 days for CSH 25; 83 days for CSH 22SS and 73 days for IS 21888). Fertility restoration among these lines varied from 0 to 80%.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Belum VS Reddy and P Srinivasa Rao

Milestone 5A.1.1.2: Five male-sterile lines resistant each to grain mold and shoot fly developed (BVSR/RPT/HCS/RS, 2008)

Achievement of Output Target (%):
40% The parental lines are continuously evaluated for shoot fly resistance, and we have transferred shoot fly resistance into improved lines, but resistance needs to be further transferred into elite lines for use in hybrid production.

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Progress/Results:
Evaluation of male-sterile and maintainer lines for resistance to sorghum shoot fly, *Atherigona soccata:* Nine maintainer lines along with checks 296B and Swarna, and IS 18551 (resistant source) were evaluated for resistance to shoot fly, *A. soccata* during the 2008 rainy season in a randomized complete block design with three replications. Data were recorded on shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence ranged from 30.7 to 70.6%, and the breeding lines 97033, 97035, 97037, 97041, and ABT 1007 suffered 30.7 to 45.8% deadhearts, compared to 58.9% in 296B, and 30.7% in IS 18551.

In the advanced trial, 15 B-lines along with checks 296B, Swarna and IS 18551 were evaluated for resistance to shoot fly, *A. soccata* in a randomized complete block design with three replications. Data were recorded on shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence ranged from 12.0 to 56.9%, and the breeding lines SF F7 2007K 1030-1, SF F7 2007K 1035-1, SF F7 2007K 1030-1, and SF F7 2007K 1110-1 suffered 12.1 to 23.8% deadhearts compared to 44.7% in 296B, and 44.3% in Swarna.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium, IFAD Biofuels Project.

HC Sharma, A Ashok Kumar and Belum VS Reddy

Milestone 5A.1.1.3: Five new high-yielding and large-grain male-sterile lines in diverse backgrounds developed (BVSR/HDU, 2009)

Achievement of Output Target (%):
80% A wide array of material ranging from F_3 to BC_9 stages from which a number of male-sterile lines can be identified in diverse backgrounds for rainy and postrainy season adaptations. Nine BC_4s (from 20 BC_3s) were selected (with A_1 cytoplasm) for high yield and bold grain during the 2007 postrainy season. It takes 2–3 years for developing high yielding large-seeded male-sterile lines with postrainy season adaptation.

Countries Involved:
India; Mali; The Philippines

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
Dual-purpose B-line development

Rainy season adaptation: To diversify the genetic and cytoplasmic base of hybrid parents, diverse parents consisting of high-yielding B-lines and germplasm lines that are sources for various traits were crossed. The resulting progenies were advanced with selection for different traits while maintaining desired maturity and grain yield. Promising F_4 progenies with maintainer reaction are being converted into male-sterile lines (A-lines) with A_1 and A_2 CMS systems.

During the 2008 rainy season, 14 BC_9s (from 8 BC_8s), 2 BC_7s (from 1 BC_6), 23 BC_6s (from 20 BC_5s), 185 BC_4s (from 146 BC_3s) and 78 BC_3s (from 136 BC_2s) on A_1 cytoplasm and 3 BC_8s (from 4 BC_7s) on A_2 cytoplasm were selected for high grain yield and rainy season adaptation. For various other traits (grain luster, grain waxyness, pop sorghum, sweet stalk, brown-midrib) and races (*Guinea*, *Feterita* and *Caudatum*), 2 BC_{13}s (from 2 BC_{12}s), 5 BC_9s (from 10 BC_8s), 5 BC_8s (from 6 BC_7s), 5 BC_7s (from 11 BC_6s) and 10 BC_6s (from 9 BC_5s) on A_1 cytoplasm and 3 BC_{10}s (from 5 BC_9s), 14 BC_9s (from 19 BC_8s), 3 BC_7s (from 4 BC_6s) and 18 BC_6s (from 18 BC_5s) on A_2 cytoplasm were selected. These progenies will be further evaluated/ advanced during the 2008 postrainy season for grain yield and boldness and specific traits as mentioned above.

To diversify the hybrid parents for rainy season adaptation, from the 110 rainy season adapted F_4s derived from a different set of crosses between high yielding B-lines, 58 F_5s were advanced with selection for grain yield and agronomic desirability. From the120 F_1s made between grain mold resistant lines and high-yielding B-lines, 113 F_2s were advanced based on high yield and tolerance to grain mold and from the 25 F_1s made between chalky white-grained A_2 lines and dual R-lines, 17 F_1s were advanced to F_2 generation with selection for high grain yield, boldness and rainy season adaptation.

Postrainy season adaptation: All the progenies for postrainy season adaptation (derived from crosses involving Giddi Maldandi and other postrainy season adapted lines) were planted during the 2008 rainy season and selections were made for large grain and high-yielding progenies. All these progenies including F_1s are under evaluation in the 2008 postrainy season for selection for agronomic traits and postrainy season adaptation.

From the 105 test crosses (TCs) (with A_1 cytoplasm) involving the material developed from the crosses between high-yielding B-lines, postrainy B-lines, shoot fly resistant B-lines and postrainy varieties, 21 R-lines on A_1 cytoplasm were selected for high yield and bold grain during the 2007 postrainy season. Nine BC_4s (from 20 BC_3s) were selected (with A_1 cytoplasm) for high yield and bold grain during the 2007 postrainy season. From the TCs (with A_1 cytoplasm) of 133 F_5s obtained from the crosses between high yielding B-lines, postrainy B-lines, shoot fly resistant B-lines and postrainy varieties 63 R-lines were selected, but none of the progenies showed maintainer reaction. Twenty three TCs obtained from Giddi Maldandi individual selections during the 2007 postrainy season will be evaluated during the 2008 postrainy season. From 1411 F_4s (including 150 Giddi Maldandi derived F_4s) derived from the crosses between high-yielding B-lines, postrainy season varieties, lustrous germplasm lines, shoot fly resistant lines, 939 F_5s (including 41 Giddi Maldandi derived F_5s) were selected for bold grain and grain yield during the 2008 rainy season. The selected F_5s and the F_4s are being evaluated during the 2008 postrainy season.

A total of 200 F_4s (including 12 Giddi Maldandi derived F_4s) with large grain and high yield were selected from 398 F_3s (including 15 Giddi Maldandi derived F_3s) derived from the crosses between large grain germplasm lines and high yielding dwarf B-lines during the 2008 rainy season. The selected F_4s and the F_3s are being evaluated during the 2008 postrainy season.

From 397 F_1s planted, 154 were advanced to F_2 that include 40 populations including 34 Giddi Maldandi based crosses, Giddi Maldandi derived B-lines and postrainy season adapted varieties; 11 F_2s including 6 Giddi maldandi based F_2s derived from crosses involving large grain germplasm lines (highland Eritrea, Yemen and Muskwari lines) and Giddi Maldandi B-line derivatives, postrainy season varieties and direct Giddi Maldandi; 31 F_2s including 30 Giddi Maldandi based F_2s (from 42 F_1s) derived from Giddi Maldandi R and M 35-1 derived B-lines, 72 F_2s (from 101 F_1s) including 49 Giddi Maldandi based F_2s made between M 35-1 derived B-lines and Giddi Maldandi derived B-lines, direct Giddi Maldandi B (with A_2 cytoplasm) and white grain 296B derivatives.

Sweet sorghum: From a total of 252 F_3s made from the crosses involving high-yielding B-lines, sweet sorghum B-lines and sweet sorghum varieties, 307 F_4s were selected and advanced based on stem juiciness, Brix, high biomass and good grain yield for sweet sorghum B-lines development. From a total of 226 F_5s made from the crosses between sweet sorghum B-lines and sweet sorghum varieties, 55 F_6s were selected for high Brix and sugar content. A total of 14 F_2s (from 24 F_1s) made between sweet sorghum improved B-lines and sweet sorghum improved R-lines, 18 F_2s (from 35 F_1s) made between brown midrib source and improved brown midrib B- and R-lines, 8 F_2s (from 19 F_1s) made between brown midrib source and sweet sorghum improved B-lines and sweet sorghum varieties were selected and are being advanced during 2008 postrainy season.

A total of 24 F_3s (from 76 F_2s) were obtained from the crosses between sweet sorghum varieties and sweet sorghum germplasm lines with selection for stalk juiciness, Brix and high biomass.

Dual- purpose R-line development

Rainy season adaptation: The F_1s from the 36 R×R crosses made between dual restorers (restorers on A_1 and A_2) were advanced to F_2 generation.

Postrainy season adaptation: TCs of 20 F_5s obtained from the crosses between postrainy season varieties are being evaluated during the 2008 postrainy season to identify the restorers. From the 315 F_4s (including 126 Giddi Maldandi derived F_4s) derived from the crosses between dual restorers and postrainy season varieties, 23 F_5s (including 17 Giddi Maldandi derived F_5s) were selected for high grain yield during the 2008 rainy season. The selected F_5s and the F_4s are being evaluated during the 2008 postrainy season. From the 259 F_3s derived from the crosses between lustrous germplasm lines, postrainy season varieties and R-lines, dual restorers, 361 F_4s were selected for high grain yield during the 2008 rainy season. The selected F_4s and the F_3s are being evaluated during the 2008 postrainy season.

Sweet sorghum: From a total of 64 F_5s derived from the crosses between elite sweet sorghum varieties, 34 F_6s were selected for high Brix and sugar yield. From a total of 929 F_3s obtained from the crosses made involving sweet sorghum varieties and sweet sorghum germplasm lines, 1234 F_4s were selected for stalk juiciness and high biomass. A total of 333 F_3s (from 74 F_2s) were derived from the crosses between sweet sorghum varieties and sweet sorghum germplasm lines with selection for stalk juiciness, Brix and high biomass. A total of 212 F_2s were harvested from 386 F_1s made between new sweet sorghum varieties, germplasm lines with high stem girth, high Brix and high biomass and germplasm lines from East and West Africa.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium and IFAD Biofuels Project

Belum VS Reddy and P Srinivasa Rao

Milestone 5A.1.1.4: Four new male-sterile lines resistant each to shoot fly and grain mold in diverse backgrounds developed (AAK/BVSR/RPT/HCS, 2010)

Achievement of Output Target (%):
60% For shoot fly resistance, the resistance levels in the advanced lines (BC_7s and BC_9s) was found high with 9 to 25% less shoot deadhearts% compared to the check 296B (59% shoot fly deadhearts-SFDH) and significantly higher grain yield (up to 10%) compared to 296B (4.11 t ha^{-1}). For grain mold, ICSB 384 (panicle grain mold rating-PGMR score 4.0) was found moderately resistant compared to the check 296B (PGMR score 9.0).

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private sector)

Progress/Results:
Dual purpose B-line development

Shoot fly resistance: Selected 14 BC_3s (4 BC_3s on A_1 and 10 BC_3s on A_2) and 12 BC_4s on A_1CMS from postrainy season adapted and shoot fly resistant 20 BC_2s (7 on A_1 and 13 A_2) and 22 BC_3s (21 on A_1 and 2 A_2) for evaluation in the 2008 postrainy season. We also selected 60 F_6s from 55 F_5s and 49 F_7s from 34 F_6s in the 2008 rainy season for developing new B-line progenies for postrainy season adaptation. All these were planted for further conversion in the 2008 postrainy season. 95 BC_3s (56 on A_1 and 39 on A_2) selected from 126 BC_2 progenies (90 on A_1 and 36 on A_2), 7 BC_4s (2 BC_4s on A_1 and 5 BC_4s on A_2) from 11 BC_3s and 5 BC_6s on A_2 from 8 BC_5s from rainy season adapted and shoot fly resistant progenies derived from the crosses between shoot fly resistant maintainer lines and high-yielding breeding lines evaluated in the 2008 rainy season in breeding block. We also selected 11 F_6s from 26 F_5s and 7 F_7s from 7 F_6s with test crosses from 2008 rainy season. All these progenies are planted in the 2008 postrainy season for further conversion to maintainer progenies. Evaluation of 142 F_4s, 29 F_5s, 15 F_8s, and 11 F_6s in RCBD (3 reps) for shoot fly resistance in screening block and in nursery for test crossing in breeding block for rainy and postrainy season adaptations resulted in the identification of 50 F_5s with significantly less shoot fly deadhearts percentage (SFDH%) from 26 to 66 % whereas the control 296B had 75% shoot fly deadhearts;16 F_6s with significantly less SFDH% ranging from 19 to 54%, whereas control 296B had 69% SFDH; one F_7 with significantly less SFDH, where control 296B had 56% shoot fly deadhearts; and 4 F_9s with significantly less SFDH% ranging from 12 to 27 (control 296B recorded 44 SFDH%.) We advanced 262 F_5s derived from the crosses between sweet stalk progenies and high-yielding established B-lines for further selection with shoot fly resistance and test crossed them for rainy and postrainy season adaptations.

Grain mold resistance: Conversion and evaluation of grain mold resistant 66 BC_4 progenies (52 on A_1 and 14 on A_2), 20 BC_3 progenies (10 on A_1 and 10 on A_2) and 82 F_5 progenies and 16 F_6 progenies derived from the crosses between grain mold resistant lines and high-yielding breeding lines resulted in the selection of 58 BC_5 progenies (46 on A_1 and 12 on A_2), 11 BC_4 progenies (4 on A_1 and 7 on A_2) and 56 F_6 progenies and 13 F_7 progenies with test crosses. Additionally, nine test crosses were also made with grain mold resistant landraces.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

A Ashok Kumar, Belum VS Reddy, HC Sharma and RP Thakur

Milestone 5A.1.1.4: Four new male-sterile lines resistant each to shoot fly and grain mold in diverse backgrounds developed (AAK/BVSR/RPT/HCS, 2010)

Achievement of Output Target (%):
50% Hybrids based on improved lines have been evaluated, and the high-yielding hybrids with shoot fly resistance need to be developed.

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Progress/Results:
Evaluation of F_1 hybrids and their parents for resistance to shoot fly, *Atherigona soccata*: Fifteen F_1 hybrids and their parents, along the Swarna as the susceptible check, CSH 16 and 296B as the commercial checks, and IS 18551 as the resistant check, were tested for shoot fly using interlard fishmeal technique. There were three replications in a randomized complete block design. Data were recorded on shoot fly deadhearts 21 days after seedling emergence, when the differences between the resistant and susceptible checks were maximum. Shoot fly deadhearts ranged from 15.6 to 74.5% in the F_1 hybrids and parents, 39.1% in IS 18551, 42.4% 296B, 79.4% in Swarna, and 79.9% in CSH 16. The hybrids ICSA 425 × ICSR 9011 and ICSA 425 × M 35-1-16 had <25% deadhearts compared to 79.4% deadhearts in Swarna.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

HC Sharma, A Ashok Kumar and Belum VS Reddy

Milestone 5A.1.1.5: New male-sterile lines (4) introgressed with three selected shoot fly resistance QTLs in 296B and BTx 623 backgrounds completed (CTH/BVSR/HCS/SS, 2008)

Achievement Output Target (%):
75% QTL associated with shoot fly resistance have been identified, and the shoot fly resistance genes need to be transferred into varieties and hybrid parents using MAS.

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Progress/Results:
Evaluation of QTL-derived backcross progenies for resistance to sorghum shoot fly, *Atherigona soccat*a: Sixty-five QTL-derived BC_4F_3 progenies (296B × IS 18551) were evaluated for resistance to shoot fly, *A. soccata* under artificial infestation in the field, along with the parents BTx 623 and 296B, and the resistant check, IS 18551. Data were recorded on leaf glossiness score, plants with eggs, and deadheart incidence at 28 days after seedling emergence during the 2007/08 postrainy season. Leaf glossiness scores of the derived lines varied from 2.0 to 5.0 compared to 5.0 of BTx 623 and 296B, and 1.0 to 2.0 of the resistant check, IS 18551. There were 3.6 to 67% plants with eggs in the derived progenies compared to 41.3 to 58.3% plants with eggs in BTx 623, 14.8 to 53.1% in 296B, and 3.6 to 18.2% in IS 18551. The deadheart incidence was 39.4 to 62.0% in BTx 623, 14.8 to 61.3% in 296B, and 0.0 to 19.6% in IS 18551. Nine progenies had <20% plants with deadhearts at 28 days after seedling emergence compared to 9.5% deadhearts in IS 18551. In another trial, 14 BC_4F_3 lines from 296B × IS 18551 were evaluated along with BTx 623 and 296B, and IS 18551. Leaf glossiness score of the derived lines varied from 2.7 to 5.0 compared to 5.0 in BTx 623 and 296B, and 1.3 to 1.7 of the resistant check, IS 18551. There were 25.5 to 64.3% plants with eggs, and 17.2 to 46.8% plants with deadhearts in the derived progenies compared to 43.4% plants with deadhearts in BTx 623, 54.3% in 296B, and 13.1% in IS 18551.

In another trial, 44 BC_4F_5 lines derived from BTx 623 × IS 18551 were evaluated for shoot fly resistance along with BTx 623, IS 18551, IS 1054, and IS 2312, and the susceptible check, Swarna. Data were recorded on leaf glossiness score, plants with eggs, and deadheart incidence. Leaf glossiness scores of the derived lines varied from 1.5 to 5.0 compared to 5.0 in BTx 623, and 1.0 to 2.5 in the resistant check, IS 18551. There were 11.6 to 66.4% plants with eggs, and 9.7 to 56.7% plants with deadhearts. Eight lines suffered <20% deadhearts compared to 6.2 to 13.7% deadhearts in IS 18551 and 46.0 to 56.8 deadhearts in Swarna.

Special Project Funding:
Nil

HC Sharma and CT Hash

Output target 5A.2 A diverse range of trait-specific sorghum breeding lines and populations with morphological diversity and resistance to shoot fly, stem borer and grain mold (2011)
Activity 5A.2.1 Generating new breeding lines with resistance to disease and insect pest resistance, and mapping of QTL and assessment of their effects on resistance levels for these traits

Milestone 5A.2.1.1: Forty F_4 lines developed for resistance to each of grain mold and shoot fly (AAK/BVSR/RPT/ HCS/RS, 2008)

Achievement of Output Target (%):
100%
The shoot fly and grain mold progenies were developed as per the target.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private sector)

Progress/Results:
Two hundred forty-three progenies, including 99 F_4s, 81 F_5s, and 15 F_6s along with resistant (IS 14384) and susceptible (Bulk Y and 296B) checks were evaluated for resistance to grain mold (caused by *Fusarium, Curvularia, Alternaria, Phoma* and other spp.). In F_5s grain mold scores ranged from 3.5 to 8.1 (1=Resistant, 9=Susceptible). Moderate levels of resistance (score >3 to ≤5) was observed in 16 lines. Similarly, the 15 F_6s, one line (97511-1) showed moderate level of resistance. In the F_4 progenies, grain mold score ranged from 3.2 to 8.8 compared to 8.1-9.0 in susceptible (296B and Bulk Y) and 1.0 in the resistant check. Moderate resistance was observed in 40 lines and the remaining lines were susceptible. Four (94307, 94308, 94318 and 94326) of the 32 colored grain F_4 lines were found resistant (score≤3) to grain mold. Fourteen lines showed moderate resistance and the remaining were susceptible. Advancing 460 F_3s developed from crosses made between shoot fly resistant RILs derived from the cross 296B × IS 18551 and high-yielding B-lines, shoot fly resistant B-lines, postrainy season varieties, and shoot fly resistant germplasm lines with selection for grain yield potential in the rainy season resulted in the selection of 349 F_4s, and these are planted in the 2008 postrainy season for further advancement.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

A Ashok Kumar, Belum VS Reddy, RP Thakur, HC Sharma and Rajan Sharma

Milestone 5A.2.1.1: Forty F_4 lines developed for resistance to each of grain mold and shoot fly (AAK/BVSR/ RPT/HCS/RS, 2008)

Achievement of Output Target (%):
50%
Improved lines have been evaluated, and the efforts to transfer shoot fly resistance into varieties and hybrid parents is continuing.

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Progress/Results:
Thirty six F_4 lines along with 296B, Swarna, and IS 18551 as the resistant check, were evaluated for resistance to shoot fly, *A. soccata* in a randomized complete block design in three replications. Data were recorded on shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence in this trial varied from 18.3 to 91.4%, and the lines 90342-2, 90343-2, 90345-1, 90346-1, 90349-2, 90350-1, and 90358-1 suffered <40% deadheart incidence compared to 78.3% in 296B, 31.8% in Swarna, and 18.30% in IS 18551. In another set, 262 F_{5s} were evaluated along with resistant and susceptible checks. Deadheart incidence in this trial varied from 30.6 to 91.2%. Four lines suffered <50% deadheart incidence compared to 74.9% in 296B, 85.7% in Swarna, and 30.6% in IS 18551.

Eighteen F_5 lines, along with 296B, Swarna, and IS 18551, were evaluated in a randomized complete block design in three replications. Data were recorded shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence in this trial varied from 19.4 to 75.8%, and the lines SF F_4 2007K 1015-1, SF F_4 2007K 1026-1, SF F_4 2007K 1050-1, and SF F_4 2007K 1100-1 suffered <25% deadheart incidence compared to 69.1% in 296B, 72.2% in Swarna, and 44.6% in IS 18551. In another set, 112 lines were evaluated along with resistant and susceptible checks. Deadheart incidence in this trial varied from 26 to 93%. Fifteen lines suffered <50% deadheart incidence compared to 69.6% in 296B, 73.1% in Swarna, and 32.0% in IS 18551.

Nineteen F_6 lines, along with 296B, Swarna, and IS 18551, were evaluated in a randomized complete block design in three replications. Data were recorded shoot fly deadhearts at 21 days after seedling emergence. Deadheart incidence in this trial varied from 37.5 to 91.7%, and the lines SF F_5 2007K 1021-1, SF F_5 2007K and 1021-2 suffered <50% deadheart incidence compared to 56.1% in 296B, 91.7% in Swarna, and 30.0% in IS 18551.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium, IFAD Biofuels Project

HC Sharma, A Ashok Kumar and Belum VS Reddy

Milestone 5A.2.1.2: Two $F_{2:3}$ populations (300 lines each) developed for mapping grain mold resistance (RS/RPT/CTH, 2008)
Achievement of Output Target (%):
100% Three $F_{2:3}$ mapping populations have been developed and phenotyped for grain mold reaction.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Three $F_{2:3}$ populations were phenotyped for grain mold (caused mainly by the species of *Fusarium, Curvularia, Alternaria* and *Phoma* spp.*)* reaction along with resistant (IS 14384) and susceptible (Bulk Y and 296B) checks. The experiment was conducted in a RCBD with 2 replications, 1 row of 2 m/replication. Sprinkler irrigation was provided twice a day for 30 min each on rain-free days from flowering to physiological maturity (PM) to provide high humidity (>90% RH) essential for grain mold development. The grain mold scores were recorded at physiological maturity (PM) using a progressive 1 to 9 scale, where 1=0 to <1% mold infection- highly resistant and 9=76–100% molded grains on a panicle - highly susceptible.

Three hundred sixty seven $F_{2:3}$ lines from Bulk Y-P1 × ICSB 377-P1 were screened. Grain mold scores in these lines at PM varied from 2.0 to 8.9 compared to 8.1 and 9.0 in 296 B and Bulk Y, respectively, and 1.0 in the resistant check. Of the 367 lines, 81 were resistant (score 1.1-3.0), 156 moderately resistant (score 3.1–5.0) and the remaining 130 were susceptible to grain mold. Grain mold scores in the 404 $F_{2:3}$ lines derived from SP 2417-P3 × IS 41397-3-P6 ranged from 2.4 to 8.9 compared to 7.4 in SP 2417 (susceptible parent) and 3.0 in IS 41397-3 (resistant parent). Only one line recorded <3.0 score, 71 had 3.1-5.0 scores and the remaining lines were susceptible. Grain mold scores of 401 $F_{2:3}$ lines of the third cross ICSB 370-2-9-P2 × IS 8219-P1varied from 2.0 to 6.8 compared to 7.0 in ICSB 370-2-9 (susceptible parent) and 2.0 in IS 8219 (resistant parent). One hundred fifty-nine lines were categorized as resistant, 204 moderately resistant and 120 susceptible. DNA was isolated from each of the $F_{2:3}$ lines of 3 mapping populations for genotyping using SSR markers. The phenotypic and genotypic data of these lines will be used to identify QTL for grain mold resistance.

Special Project Funding:
Sehgal Foundation Endowment Fund

Rajan Sharma, RP Thakur and CT Hash

Milestone 5A.2.1.3: RIL for grain mold resistance from two mapping populations phenotyped and genotyped, and QTL maps developed using 250 markers (RS/RPT/CTH, 2010)

Achievement of Output Target (%):
25
Three mapping populations were advanced to F_4 generation by single seed descent. RILs will be available during 2010 for mapping QTL for grain mold resistance. F_1, $F_{2/3,}$ BC_1F_1s progenies and parents of 2 mapping populations were screened in grain mold nursery and one population screened against *Curvularia lunata* in greenhouse. The phenotypic data will be used to study inheritance of grain mold resistance in sorghum.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
a. Advancing three populations from F_3 to F_4 in field by selfing
Based on the genetic diversity studies, the above 3 pairs of resistant and susceptible parental lines with dissimilarity indices of >0.50 were crossed to develop RIL mapping populations for mapping genomic regions contributing to sorghum grain mold resistance. Three hundred sixty-seven $F_{2:3}$ lines from Bulk Y-P1 × ICSB 377-P1, 404 from SP 2417-P3 × IS 41397-3-P6 and 401 from ICSB 370-2-9-P2 × IS 8219-P1 were advanced to F_4 generation by single seed descent.

b. Inheritance of mold resistance
Field experiment. To study inheritance of resistance to grain mold, $F_{2:3}$ populations from two crosses (SP 2417-P3 × IS 41397-3-P6 and ICSB 370-2-9-P2 × IS 8219-P1) along with F_1s, BC_1 progenies and parents were screened for grain mold reaction in the grain mold nursery. The $F_{2:3}$ lines were planted in 1 row of 2 m length each with 2 replications, 20 plants/replication. F_1s, BC_1F_1s and parents were grown in six replications with 20 plants/replication. Nursery management and mold scoring procedures were same as those described before.

Greenhouse experiment. F_1, F_2, BC_1F_1s progenies and parents of the cross Bulk Y-P1 × ICSB 377-P1 were screened in the greenhouse to study inheritance of resistance against *Curvularia lunata,* a major pathogen in the sorghum grain mold complex. Panicles were inoculated at >80% anthesis stage with conidial suspensions (1×10^6 spores mL^{-1}) of *C. lunata* and exposed to wetness for 48 hr after inoculation. High humidity was again provided from the soft dough stage to physiological maturity by overhead foggers to facilitate disease development. Grain mold was recorded at PM using a 1 to 9 scale. The data from greenhouse and field trials will be analyzed through generation means analysis to study inheritance of grain mold resistance in sorghum.

Special Project Funding:
Sehgal Foundation Endowment Fund

Rajan Sharma, RP Thakur and CT Hash

Milestone 5A.2.1.4: Putative QTL for stem borer resistance and its components based on RIL from two crosses identified (HCS/CTH/SPD, 2009)

Achievement of Output Target (%):
50% Mapping population for stem borer resistance has been phenotyped. Genotyping and data analysis are in progress.

Countries Involved:
India

Partners Involved:
Tamil Nadu Agricultural University

Progress/Results:
Evaluation of mapping population for resistance to spotted stem borer, *Chilo partellus*: To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population based on ICSV 745 × PB 15220 was evaluated for stem borer resistance under artificial infestation in the field. The mapping population (270 lines), along with the resistant (IS 2205) and susceptible checks (ICSV 1), and the parents (PB 15220 and ICSV 745) were planted in a balanced alpha design in three replications. Data were recorded on leaf feeding (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), deadheart formation (%), leaf sheath and plumule pigmentation (1 = highly pigmented, and 5 = Non-pigmented – green colored), stem tunneling (%), days to panicle initiation, recovery resistance (1 = good recovery, 5 = poor), and agronomic score (1 = good, and 5 = poor). There was a significant variation in the traits studied in the mapping population. Leaf damage rating (DR) was 4.63 in the PB 15220 and 6.65 in ICSV 745 compared to 4.72 in the resistant check, IS 2205 and 7.92 in the susceptible check, ICSV 1. The RIL population mean was 6.03. Deadheart formation was 45.01% in PB 15220 and 81.48% in ICSV 745 compared to 19.36% in the resistant check - IS 2205, and 83.30% in the susceptible check ICSV 1. Overall resistance score was 5.44 in the PB 15220 and 7.00 in ICSV 745 compared to 4.83 in the resistant check, IS 2205; and 7.92 in the susceptible check, ICSV 1, the population mean being 6.19.data analysis is in progress to identify QTLs associated with resistance to *C. partellus*.

Special Project Funding:
Sehgal Foundation Project on QTL Mapping for Stem Borer Resistance

HC Sharma, CT Hash and SP Deshpande

Milestone 5A.2.1.5: Comparative mapping of QTL for stem borer resistance in sorghum and maize completed (HCS/SPD/DH/CTH, 2009)

The maize population for comparative mapping was imported, but not phenotyped for comparative analysis because no funding is available for this activity, and hence should be deleted for the tine being.

Milestone 5A.2.1.6: Effectiveness of two best QTL for resistance to shoot fly in two genetic backgrounds demonstrated (CTH/SPD/SS/HCS/BVSR, 2007)

Milestone 5A.2.1.7: Comparisons of lines with single-QTL introgressions and QTL pyramided in two genetic backgrounds for shoot fly resistance completed (HCS/BVSR/CTH/SPD, 2010)

Reported under Milestone 5A.1.1.5.

Output target 5A.3 Transgenics for stem borer resistance in sorghum developed and tested (2009)

Activity 5A.3.1 Developing and testing transgenic sorghums for stem borer resistance

Milestone 5A.3.1.1: Protocols for the genetic transformation of sorghum optimized and two transgenic lines for resistance to stem borer developed and tested in contained field trials (KKS/HCS/BVSR, 2009)

Reported in Project 6

Output target 5A.4: Variation in sorghum grain mold pathogens and mycotoxin contamination risk assessed, insect–host genotype-natural enemy interactions studied, and mechanisms of resistance to insect pests identified (2010)

Activity 5A.4.1: Understanding host-pathogen-environment interaction in grain mold complex.

Milestone 5A.4.1.2: Mycotoxin-producing isolates of Fusarium species associated with grain mold identified and characterized and genetic resistance in relation to other major pathogens determined (RS/RPT/VW, 2009)

Achievement of Output Target (%):
50
Genetic diversity in 66 *Fusarium* isolates was assessed through AFLP and the isolates are currently being sequenced for sequence based identification. Toxigenic strains of different species of *Fusarium* will be selected during 2009 for use in greenhouse screening to identify genetic resistance in sorghum.

Countries Involved:
India

Partners Involved:
Indian NARS

Progress/Results:
Genetic diversity in the 66 isolates of *Fusarium* collected from different sorghum genotypes at 5 locations (Akola, Parbhani, Palem, Patancheru and Surat) in India was assessed through amplified fragment length polymorphism (AFLP). A high level of polymorphism was observed among isolates following selective amplification with 5 AFLP primer combinations (Etg + Mcag, Eaa + Mctt, Eac + Mcag, Etc + Mctt and Etg + Mcag). A total of 473 bands were amplified, of which 470 were polymorphic. The dendrogram generated from the AFLP data revealed genetic diversity among the isolates by clustering them into 5 groups. Of the 66 isolates, 30 were clustered in one major group with ~70% genetic similarity among isolates. Since isolates of the same species of *Fusarium* have been reported to have >60% genetic similarity, the isolates representing this group might be of the same species. The remaining 36 isolates were clustered in 4 major groups and many sub-groups within main clusters indicating the involvement of many species of *Fusarium* in the grain mold complex. These isolates are currently being sequenced for three genes, *β-Tubulin, α-Elongation factor* and *Calmodulin* for sequence based identification of *Fusarium* species.

Special Project Funding:
Sorghum Hybrid parents Research Consortium

Rajan Sharma, RP Thakur and Varsha Wesley

Milestone 5A.4.1.3: Mechanisms of resistance to sorghum grain mold (RS/RPT, 2008)

Achievement of Output Target (%):100
Grain mold resistant and susceptible lines were characterized for total phenols, flavon-4-ols, phenylalanine ammonia lyase (PAL) and peroxidase isozymes. Increased flavon-4-ols and peroxidase activity was observed in resistant lines compared to susceptible ones indicating their role in disease resistance. However, PAL activity and total phenols could not be associated with disease resistance. Among different morphological traits, dark grain color and greater glumes coverage of grains appeared to be more closely associated with grain mold resistance in sorghum.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Characterization of grain mold R/S lines for total phenols, flavon-4-ols, phenylalanine ammonia lyase (PAL) and peroxidase isozymes
Grain mold resistance in sorghum is a complex trait and several morphological/biochemical traits have been shown to be associated with resistance. Total phenols and phenolics have long been considered as important defense related compounds whose levels are naturally high in the resistant plants. To determine the association of phenolics with grain mold resistance in sorghum, 20 genotypes (13 resistant and 7 susceptible) were analyzed for total phenols, flavon-4-ols, phenylalanine ammonia lyase (PAL) and peroxidase isozymes

Flavon-4-ols. Molded as well non-molded grains of the 20 genotypes were used for flavon-4-ol estimation. Mean Flavon-4-ols values of grain mold resistant and susceptible sorghum lines were distinctly different from each other. More Flavon-4-ols were accumulated in the methanol and acidified methanol extracts of both molded as well as non-molded grains of resistant lines in comparison to susceptible lines. Similarly, range of Flavon-4-ols extracted both in methanol as well as acidified methanol was very broad in the resistant lines (0.15–10.95), whereas, it was very narrow (0.10–0.75) for the susceptible lines. More (0.15–10.95) Flavon-4-ols were detected in the colored grains than in the white grains (0.10–2.8). In most of the lines, molded grains recorded more Flavon-4-ols than non-molded grains. Considerable increase in the Flavon-4-ols content in the methanol extract was also observed in the molded grains of a white-grain resistant line SPV 462-3. This indicates that expression level of Flavon-4-ols in the biosynthetic pathway is enhanced in response to the pathogen attack. Therefore, concentration of Flavon-4-ols in the mature sorghum seed can give an indication about the expected reaction of the sorghum cultivars to grain mold

Total phenols and Phenylalanine Ammonia-lyase. No significant variations in the total phenols in resistant and susceptible genotypes were observed. The highest amount of total phenols (21.60 mg/g) was recorded in SGMR 3-3-5-6 (susceptible) and SGMR 24-5-1-2 (resistant), and the lowest amount (15.51mg/g) in the susceptible genotype (IS 36469C 1187-1-2-9-8-2). Highest amount of total phenols both in susceptible and resistant genotypes indicated no association between total phenols and reaction of sorghum genotypes to grain mold. The highest (41.75 µM/min/gm protein) PAL activity was found in the resistant genotype ICSB 377 and the lowest (27.88 µM/min/gm protein) in susceptible genotype SPV 104. In general, there were significant differences in the PAL activity of 20 genotypes tested; however, the enzyme activity was not significantly different in resistant and susceptible groups.

Peroxidase. Native-PAGE profiles of peroxidase isozyme detected 8 isoforms across the resistant and susceptible genotypes. Of the eight isoforms, one isoform was common in all the genotypes and the remaining isoforms had differential expressions. Two distinct isoforms were present in 3 resistant lines-IS 13969, ICSB 377 and IS 8219-1 and one isoform at R_f 0.32 was specific to two lines IS 13969 and ICSB 377 indicating genotype-specific association of peroxidase with grain mold resistance. However, the results need further confirmation using susceptible and resistant lines following artificial inoculations under greenhouse conditions.

Association of physio-morphological traits with grain mold resistance
Fifty morphologically diverse sorghum germplasm accessions were screened in grain mold nursery for disease reaction. The experiment was conducted in a RCBD with 2 replications. Nursery management and mold scoring procedures were those described before.

Data were recorded for agronomic traits such as days to 50% flowering and plant height (cm); and morphological traits such as panicle type, glumes coverage (%) and, glumes and grain color to determine association of these traits with grain mold resistance. The variation in qualitative morphological traits, such as panicle type, glumes color and grain color were assigned numerical ratings following the DUS (Distinctiveness, Uniformity and Stability) ratings developed by National Research Centre for Sorghum (India) to facilitate statistical analysis.

The association studies did not show high correlations between plant traits and grain mold reaction. However, significant ($P<0.01$) negative correlations were observed for grain mold rating with glumes coverage, glumes color, plant height and days to 50% flowering. Among different morphological traits, dark grain color and greater glumes coverage of grains appeared to be more closely associated with grain mold resistance than other traits.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Rajan Sharma and RP Thakur

Activity 5A.4.2 Develop screening techniques and investigate host genotype - natural enemy interactions, resistance mechanisms and genetics of insect pest resistance

Output target 5A.5 Information on association between CMS and agronomic traits, and between molecular diversity and yield heterosis in sorghum (2009)

Activity 5A.5.1 Evaluation of iso-cytoplasmic hybrids for grain yield and agronomic traits

Milestone 5A.5.1.1: Twelve hybrids with four diverse CMS systems compared for agronomic traits and resistance to shoot fly and grain mold (BVSR/RPT/RS/HCS, 2009)

Achievement of Output Target (%):
100% Hybrids in different CMS backgrounds have been evaluated .

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Effect of different cytoplasms on expression of resistance to sorghum shoot fly, *Atherigona soccata*: Seventy-two hybrids based on four cytoplasms, and their parents were evaluated for shoot fly resistance under field conditions using artificial infestation technique, along with CSH 16 and 296B as the susceptible checks. There were three replications in a randomized complete block design. Data were recorded on leaf glossiness and shoot fly deadhearts. The leaf glossiness scores ranged from 4.3 to 5.0 in the test hybrids compared to 1.0 in the resistant check, IS 18551, and 5.0 in the susceptible check, CSH 16. The shoot fly deadhearts ranged from 19.1 to 50.5% in the F_1 hybrids, 4.2% in IS 18551, and 30.4% in CSH 16.

Special Project Funding:
Sorghum Hybrid parents Research Consortium, IFAD project on Biofuels

HC Sharma, A Ashok Kumar and Belum VS Reddy

Output target 5A.6 High-yielding and good combining sorghum hybrid parents developed for postrainy season adaptation (2009)

Activity 5A.6.1 Developing high-yielding and good combining sorghum hybrid parents for postrainy season adaptation

Milestone 5A.6.1.1: Five each of high-yielding and good combining sorghum male-sterile lines and restorer lines for postrainy season developed (BVSR, 2009)

Achievement of Output Target (%):
60% From the evaluation of hybrids and hybrid parents, promising parents (A/B-lines and R-lines) that give heterotic hybrids have been identified.

Countries Involved:
India

Partners Involved**:**
Indian NARS (Public and Private sector)

Progress/Results:
Postrainy Hybrid Trial: About 100 hybrids made between 23 postrainy adapted A-lines (23) and R-lines (16) were evaluated in a three-replicated RCBD during the 2007 postrainy season. Compared to the best performing hybrid check, SPH 840 (6.8 t ha^{-1}), 17 hybrids with grain yield ranging from 6.9 to 8.2 t ha^{-1} were numerically superior, while 58 hybrids were on par. These hybrids flowered in 72 to 82 days, grew to a height of 1.4 to 2.7m and had grain size ranging from 2.8 to 4.5 g 100^{-1} grains. Stay-green score among the hybrids (stay-green score taken on a 1 to 5 scale where 1= most green and 5 = least green) varied from 1 to 2.3, lodging score (lodging score taken on a 1 to 5 scale where 1 = <10% lodging and 5 = 100% lodging) from 1 to 3.3, grain luster from 1 to 2.7 (taken on scale 1 to 5, where 1 = more lustrous equivalent to M 35-1 and 5 = non-lustrous) and restoration from 0 to 90%. Twenty-one of the 58 hybrids had a luster score of 1. The hybrid ICSA 20 × ICSR 93009 was best performing for grain yield (8.2 t ha^{-1}) and had good grain size (4.5 g 100^{-1} grains), luster (1.7) and restoration% (89%) in winter.

Postrainy Advanced Varietal/Restorers Trial: To develop appropriate varieties for postrainy season, crosses were made involving postrainy season adapted landrace varieties (M 35-1, and six M 35-1 bulks) and improved varieties (SPV 1359, NTJ 2 and SPV 1380) during 1999-2000 postrainy season. As a part of participatory plant breeding (PPB) program, the progenies derived from these crosses were selected by a farmer under farmers' (rainfed) condition and by the breeder under research station conditions (with initial two irrigations) from F_2 generation onwards. Also, from M 35-1 bulk (M 35-1 has non tan plant color), tan plant colored selections were made. From these varieties, based on grain yield (≥3.7 t ha^{-1}), grain size (≥ 3.7 g 100^{-1} grains) and grain luster, 31 varieties/ R-lines were selected and evaluated during the 2007 postrainy season along with the checks, M 35-1 and SPV 1411. Eleven varieties (6.2 to 7.7 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.0 t ha^{-1}). These varieties flowered in 74 to 77 days (SPV 1411:76 days), reached a plant height of 1.7 to 3.0m (SPV 1411: 2.7m), had a luster score of 1.0 to 1.7 (SPV 1411: 1.3) and had a grain size of 4.0 to 4.7 g 100^{-1} grains (SPV 1411: 4.6 g 100^{-1} grains). All the varieties were numerically superior to M 35-1 for grain yield (3.6 t ha^{-1}). Eight varieties had lustrous grains like M 35-1 (score 1).

Postrainy Preliminary Varietal Trial: From several crosses involving postrainy varieties, 69 varieties were developed and evaluated during the 2007 postrainy season along with the checks, M 35-1 and SPV 1411. Seven varieties (6.8 to 7.6 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.6 t ha^{-1}). These varieties flowered in 76 to 78 days (SPV 1411:77 days), reached a plant height of 2.2 to 2.9m (SPV 1411: 2.4m), had a luster score of 1.0 to 1.7 (SPV 1411: 1.0) and had a grain size of 3.6 to 4.9 g 100^{-1} grains (SPV 1411: 4.7 g 100^{-1} grains). All the varieties except three were numerically superior to M 35-1 for grain yield (2.9 t ha^{-1}). Four varieties recorded lustrous grains like M 35-1 (score 1).

Special Project Funding**:**
Sorghum Hybrid Parents Research Consortium

Belum VS Reddy

Output target 5A.8: Stay-green QTLs associated with improved fodder quality introgressed into elite sorghum hybrid parents and their potential utility assessed (2010)

Activity 5A. 8.1: Mapping and introgression of stay-green QTL into elite parental lines, and assessment of their effects on hybrid performance

Milestone 5A.8.1.1: Assessment of near-isogenic BC_3F_3 and BC_4F_3 stay-green QTL introgression lines completed in R16 and ISIAP Dorado backgrounds (CTH/SPD/VV/FRB, 2010)
No report submitted

Milestone 5A.8.1.2: Stay-green QTL mapping of E 36-1 confirmed based on phenotypic assessment of two F_6 RIL populations genotyped with DArT, SSR, and CISP-SNP markers (CTH/SS/SPD/VV, 2010)
No report submitted

Milestone 5A.8.1.3: Stay-green QTL introgression sorghum lines based on donor parent E 36-1 available for phenotypic evaluation in two diverse genetic backgrounds (CTH/SPD, 2011)
No report submitted

Milestone 5A.8.1.4: Initial evaluation of animal performance on near-isogenic hybrids differing in allelic composition at two stay-green QTLs completed (CTH/SPD/MB/BVSR, 2010)
No report submitted

Output target 5A.9: Commercialization of sorghum grains and impact of improved germplasm enhanced.

Activity 5A.9.1: Strengthen research and development partnerships, and technology exchange

Milestone 5A.9.1.1: Hybrid parents (>50) and other breeding materials (>100) supplied to NARS and their impact assessed (BVSR/sorghum team—annual)

Achievement of Output Target (%):
100% Sorghum hybrid parents and hybrids were supplied to NARS in different countries.

Countries Involved:
Open to all

Partners Involved:
NARS (Public and Private sector)

Progress/Results:
Consortium Hybrid Trial: To assess the performance of sorghum hybrids produced by different private and public sector organizations, "Seed producers' sorghum hybrid trials" are constituted and coordinated in rainy season by ICRISAT as one of the activities under ICRISAT-Private sector Sorghum Hybrids Parents Research Consortium. The results of SPSHT-2007 rainy season trial were summarized and distributed to all the members of sorghum hybrid parents research consortium who contributed hybrids for the trial. One hundred and twenty eight R-lines were under characterization as per DUS test guidelines of Indian Council of Agricultural Research. During the 2008 rainy season a trial with 18 entries (15 hybrids contributed by 9 seed companies, and two public sector released hybrids included as controls in addition to local control) was conducted at seven consortium members' locations and at ICRISAT, Patancheru. The trial at Ganga Kaveri Seeds and Biostadt MHseeds, Aurangabad was not conducted. The data were received from five centers and the data from the Krishidhan Seeds, Jalna are yet to be received.

Scientists Field Day: A sorghum scientists field day was conducted at ICRISAT- Patancheru on 7 and 8 October 2008. A total of 27 scientists from the public sector and 19 scientists from the private sector from India participated. They visited a range of sorghum materials, from germplasm to progenies, advanced breeding lines, new male-sterile and restorer lines during the field day. More than 200 selections were made by seven public sector scientists and 11 private sector scientists during this period.

Seed supplies: A total of 2479 seed samples of hybrid parents/breeding lines were sent to 20 countries. India received 1296 samples followed and Philippines received 351 samples. Of the 1296 seed samples to India, 374 were sent to public sector scientists, 773 to private sector scientists and the remaining 149 samples to farmers and NGOs/collaborators. Seed in bulk quantities (582 kg) of seven high-yielding/released cultivars, three sweet-stalk hybrids and one A-line were supplied to Indian NARS and farmers. This includes 154 kg seed of six cultivars to 45 farmers and total 355 kg of three cultivars to watershed projects.

Trials and nurseries: Seventeen sets of sweet stalk trials consisting of total 279 entries, each nursery ranging from10 -90, were sent for evaluation in India, Philippines, Vietnam, Kenya and Mali. Seed of sweet sorghum varieties (4), B-lines (4) and hybrids (3) was multiplied and sent to National Research Centre for Sorghum (NRCS), Hyderabad, India, for testing at the All India Coordinated Sorghum Improvement Project (AICSIP) locations in the 2008 rainy season. Ten sweet-stalk varieties and 10 sweet -stalk hybrids were sent to on farm testing ARS, Nandyal, India.

Biofuel research collaboration: The activities under the NAIP-ICAR project on Sweet sorghum value chain development and the IFAD Biofuels project. Under the NAIP project, a decentralized crushing cum syrup unit (DCU) has been established at Ibrahimbad village, Medak district, Andhra Pradesh state, India. Hybrid CSH 22SS was grown in more than 100 acres in farmers fields in Ibrahimbad cluster and the stalks were crushed at the DCU and 23 tons of syrup produced and supplied to Rusni Distilleries for making ethanol. An on-farm breeding trial was conducted to evaluate 8 hybrids and eight varieties along with two checks (CSH 22SS and SSV 84). Four hybrids recorded higher sugar yield (ranging from 1.3 to 1.7 t ha^{-1}) than CSH 22SS (sugar yield 1.4 t ha^{-1}). The Brix % in these hybrids ranged from 14 to 15. The grain yields in these hybrids ranged between 1.4 to 3.0 t ha^{-1} compared to CSH 22 SS (3.9 t ha^{-1}). Two varieties performed better for sugar yield with 1.7 and 1.8 t ha^{-1} than SSV 84 (1.4 t ha^{-1}) with Brix 15 to 16%. The varieties recorded significantly higher grain yields (2.2 to 2.3 t ha^{-1}) compared to SSV 84 (1.0 t ha^{-1}). Overall, the hybrid ICSA 724 × SSV 74 performed better with Brix (15%), sugar yield (1.7 t ha^{-1}) and grain yield (3.0 t ha^{-1}) and the variety SP 4484-2 had higher Brix (15%), sugar yield (1.8 t ha^{-1}) and grain yield (2.2 t ha^{-1}).

In the IFAD Biofuels project, a trial consisting of 12 *bmr* sources, 5 sweet sorghum lines and 5 checks was conducted in a randomized complete block design (RCBD) during the 2008 postrainy season at ICRISAT, Patancheru. Data collection on lignin content, silica content, *in vitro* organic matter digestibility, nitrogen content, and dry matter contents is underway. Selected sweet sorghum hybrids (8) and varieties (8) were evaluated under on-station and on-farm conditions. Results from on-station trial indicated that compared to the best performing check RSSV 9 (7.24 tha^{-1}) for sugar yield, a hybrid ICSA 675 × SSV 74 (7.77 t ha^{-1}) and a variety SP 4487-3 (7.44 t ha^{-1}) were on par, but significantly superior compared to the popular sweet sorghum variety SSV 84 (5.37 t ha^{-1}). Compared to hybrid CSH 22SS (sugar yield 2.43 t ha^{-1}), 13 of the test entries were significantly superior (sugar yield 4.11 to 7.77 t ha^{-1}) for the sugar yield. ICSA 675 × SSV 74 flowered in 80 days, had a plant height of 3.9m, grain yield of 4.23 t ha^{-1} and Brix of 15.1%, while SP 4487-3 flowered in 81 days, had a plant height of 3.8m, grain yield of 1.06 t ha^{-1} and Brix of 15.9%.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium; IFAD Biofuels Project and NAIP-ICAR Sweet sorghum value chain development project

Belum VS Reddy, A Ashok Kumar and P Srinivasa Rao

Milestone 5A.9.1.2: Ten sorghum scientists trained biennially (BVSR/sorghum team—alternate year)

Achievement of Output Target (%):
20% Ten flyers were developed on various aspects of sweet sorghum cultivation, seed production and ethanol value chain.

Countries Involved:
Open to all countries
Partners Involved:
NARS (Public and Private sector)

Progress/Results:
An international training program was organized in 2007 and a new training program is proposed for 2009.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Milestone 5A.9.1.3: Two thousand farmers adopt improved sorghum cultivars and crop production practices in India, China and Thailand (ASA/ChRR/BVSR/PPR/CLLG/FW, 2007)

Achievement of Output Target (%):
100% More than six thousand farmers adopted improved sorghum cultivars and cultivation practices in three countries, India, China and Thailand.

Countries Involved:
India; China; Thailand

Partners Involved:
NARS in India, China and Thailand (Public and Private sector)

Progress/Results:
The target was achieved in 2007. In addition, more than 5000 farmers from two states in India, 800 farmers from one province in China and around 700 farmers from four provinces of Thailand adopted more than 30 improved rainy season sorghum cultivars (15 in India, 10 in China and 6 in Thailand). The capacities of these farm families have been enhanced through season long trainings (6 trainings in India, 2 in China and 3 in Thailand) on adoption of improved production technologies suitable to each region. The sorghum production technologies in the local languages (English, Marathi, Telugu, Kannada, Chinese and Thai) have been published and distributed for the benefit of the farmers. Field level demonstrations on improved production technologies to enhance production were conducted on the farmer's fields. The participation of women farmers was increased through the involvement of women farmer's self help groups (SHGs) in project activities. For the dissemination of the project experiences to wider groups, field days, radio talks, learning visits, publications, press releases and website were used as tools.

Special Project Funding:
CFC Project

Belum VS Reddy, Ashok Alur, Ch Ravinder Reddy, P Parthasarathuy Rao,
CLL Gowda, F Waliyar and Varsha Wesley

Milestone 5A.9.1.4: Market linkages for the sale of sorghum grain (100 t) to poultry feed manufacturers by sorghum farmers in India, China and Thailand established (ASA/ChRR/BVSR/PPR/CLLG/FW, 2008)

Achievement of Output Target (%):
100% Market linkages were established in India, China and Thailand.

Countries Involved
India; China; Thailand

Partners Involved:
NARS in India, China and Thailand (Public and Private sector)

Special Project Funding:
CFC project

Progress/Results:
The project aimed at strengthening of the input and output linkages for the benefit of the project farmers. The farmers associations formed under the project were registered with government under Mutually Aided Cooperative Societies Act for acquiring a legal status and recognition. The farmers associations (six in India, one in China and three in Thailand) were trained and their capacities in running and managing a cooperative society so as to enable them take timely decisions on production and market-related issues. The project also explored the possibility of alternative market opportunities for target crops and two dialogues were organized between farmers associations and the potential buyers to facilitate agreements between the farmers and the industry groups. The management committee members were trained in marketing linkages and price negotiation skills with an objective to ensure that they develop capacities to handle the future market negotiations on their own. The contract farming model was developed and tested in China during 2007 is functioning very well and the farmers from one cluster in China have already sold 900 tons of

sorghum during 2008 to two companies. The farmers in India were able to sell the produce for food purposes as the quality of the produce was extremely high whereas in Thailand the produce was sold to mushroom industry.

Belum VS Reddy, Ashok Alur, Ch Ravinder Reddy, P Parthasarathy Rao, CLL Gowda, F Waliyar and Varsha Wesley

Aflatoxin contamination in sorghum and pearl millet: On-farm trials were organized during the 2008 rainy season in Udityal and Palavai clusters in Mahabubnagar district, Andhra Pradesh. A total of 120 sorghum and pearl millet samples collected from fields as well as storages were analyzed by ELISA for aflatoxin and fumonisin contamination. Results indicated that relatively higher percentage of pearl millet samples contained non-permissible level of aflatoxin than the sorghum samples. Among the sorghum samples from Udityal, storage samples showed higher levels of toxin content (25% of storage and 19% of field samples possessed unacceptable levels of >30 µg kg^{-1} aflatoxin). However, about 38-40% sorghum samples were free from aflatoxin contamination. Higher level of aflatoxin content in stored sorghum could be attributed to either improperly dried grain or poor storage conditions or insect damage in the storage.

Pearl millet analysis indicated more aflatoxin presence in field samples (52%) as against 32% of the storage samples with >30 µg kg^{-1} aflatoxin. Very small proportion (24%) of the millet samples was free from aflatoxin contamination. The fumonisin contamination was well below the permissible 5000 µg kg^{-1} level in both sorghum and pearl millet in both the clusters. Twenty sorghum field samples from Thailand were analyzed for mycotoxin contamination and 85-90% of the samples were free from toxins whereas the remaining samples contained negligible levels of mycotoxins.

The high level of aflatoxin in pearl millet based on repeated ELISA tests over three years warrants for a close look at the crop production practices as well as other factors responsible for high levels of aflatoxin contamination in these villages.

Farid Waliyar and Varsha Wesley

II. Pearl millet

Output target 5A.2: More than 500 trait-specific and DM resistant improved breeding lines of pearl millet developed and disseminated alternate years (2006, 2008, 2010 and 2012) for use in breeding parental lines of grain hybrids

Activity 5A. 2.1: Develop a diverse range of high-yielding and DM resistant trait-specific breeding lines

Milestone 5A.2.1.1: Germplasm with large seed, high biomass yield, white grain color and large panicles identified and introgressed (KNR/RB/HDU/RPT/RS, 2009)

Achievement of Output Target (%):
80% Introgression of large grains and large panicle size is completed, and sources of high biomass yield and stable sources of white grains have been identified.

Countries Involved:
India

Partners Involved:
All India Coordinated Pearl Millet Improvement Project and its sub-centers
Progress/Results:
Evaluation of introgressed lines for large grain size and long panicles continued, as did the inbreeding and purification of white grain sources, and identification of new germplasm for high biomass yield. About 380 F_3–F_7 progenies in the large grain size nursery were planted during the 2008 postrainy season, of which 171 were selected, producing 458 F_4–F_8 progenies. Amongst the progenies selected in 2008 postrainy season, 95 had >16 g of 1000-seed weight, with 25 of these having even >19 g of 1000-seed weight. A majority of these progenies was in mid-late- to late-maturity group (flowering in 51–65 days compared to 50 days for the control line ICMB 04888). In the long panicle group, 521 F_5/F_6 progenies were evaluated during the 2008 rainy season, of which 182 were selected for further evaluation. A majority of these lines flowered in 56–65 days (control line ICMB 04111 flowering in 54 days), indicating their utility in breeding parental lines of late-maturing hybrids. These introgression lines have now reached the stage where they can be utilized in the hybridization program to breed medium-maturing seed parents. Of the 56 white-seeded F_4 progenies, 6 were selected for further use in the hybridization program intended to breed white-seeded seed parents. Fifty-two germplasm accessions with high biomass yield potential selected from the characterization block of the Genetic Resources Unit in 2007 were further evaluated, of which 27 have been selected for further evaluation.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, Ranjana Bhattacharjee, SK Gupta and HD Upadhyaya

Milestone 5A.2.1.2: Genetically diverse trait-specific (e.g., large seed, large panicle size, diverse maturity and height) advanced breeding lines developed and disseminated (KNR/RB/RPT/RS, 2006, 2008, 2010, 2012)

Achievement of Output Target (%):
70% Due to late planting on account of late onset of rains, harvesting and threshing have been delayed.

Countries Involved:
India

Partners Involved:
All India Coordinated Pearl Millet Improvement Project and its sub-centers

Progress/Results:
Development of improved breeding lines in elite agronomic backgrounds with high levels of DM resistance constitutes the largest research activity in pearl millet hybrid parents research. Such lines, mostly at the later stages of inbreeding, are classified and evaluated in trait-specific and eco-

region-specific nurseries for better evaluation and selection for future utilization. Besides grain yield, flowering time and DM resistance are the two common denominators in the selection of breeding lines in all the trait-specific nurseries. These trait-specific nurseries are continuously updated with new materials that are generated almost every year.

Trait-specific seed parent progenies: Results of large-seeded and long-panicle trait-specific breeding lines have been reported under milestone 5A.2.1.1. Besides, more than 2600 breeding lines were evaluated in other trait-specific groups. In the early and extra-early maturity group, 1056 S_{10} and F_5–F_{11} progenies were evaluated of which 230 were selected based on visually assessed yield potential and agronomic traits. Of these, 200 progenies flowered in less than 46 days, with 37 progenies flowering in less than 40 days (39 days for the earliest-maturing commercial seed parent 843B). In the thick panicle group, 104 S_9–S_{11} progenies were evaluated of which 20 were selected. All of these were of late maturity with 15 of these flowering in 56–65 days (control seed parent flowering in 60 days). More than 100 F_6/F_7 progenies of very dwarf height (mostly 60–90 cm) and long panicles (mostly 20–25 cm) were evaluated of which 24 progenies were selected. Six of these flowered in 41–45 days and 15 flowered in 46–50 days. About 300 F_5 progenies with bristled panicles were evaluated of which 91 were selected. A majority of these was of medium-to mid-late maturity with 84 of these flowering in 51–60 days. We also evaluated 52 stay-green progenies of which 24 were selected. Although only two of these flowered in 46-50 days, while 22 flowered in 51–65 days, it was not necessarily a result of association of the stay-green trait with later flowering. In addition, 1030 progenies at various stages of inbreeding (F_5–F_{11}) and with a wide range of flowering (mostly 41–65 days) were also evaluated of which 320 were selected and these are yet to be classified in trait-specific groups.

Trait-specific restorer progenies: More than 3000 progenies under various trait-specific groups were evaluated for field performance and 1294 early-maturing progenies were evaluated for DM resistance. In early and extra-early maturity group, 964 S_3–S_{13}/F_4–F_8 progenies were evaluated of which 513 were selected with 203 of these flowering in less than 46 days and 16 of these flowering in less than 41 days. Of the 1294 early-maturing F_4 progenies evaluated for DM resistance against Durgapura pathotype, 44% of the progenies had <20% DM incidence, and 31% of the progenies had <10% DM incidence. In the large seed size group, 39 S_3–S_{13}/F_4–F_{10} progenies were evaluated of which 27 were selected with 16 of these flowering in 41–50 days and 11 progenies flowering in 51–60 days (48 days for the control lines IPC 1518). In the high-tillering group, 95 S_4–S_{14}/F_5–F_{10} were evaluated of which 61 were selected with 48 of these flowering in 41–50 days. We also evaluated a large number of lines for sources of other traits (stay-green, panicle compactness, lodging resistance and erect growth habit) in elite genetic backgrounds. In the stay-green group, 156 progenies were evaluated and 71 were selected with almost all the lines flowering in less than 56 days, and 34 lines flowering even in less than 46 days. In the compact panicle group, 85 progenies were evaluated and 40 were selected; in lodging resistance group, 168 lines were evaluated and 70 were selected; and in erect growth habit group, 98 were evaluated and 49 were selected, with most of the lines in all three groups flowering in 41–55 days. With respect to the classification of breeding lines with potential adaptation to various eco-regions, three groups have been rationalized: high-tillering and early-maturing types for the arid zone of north-western India; medium-maturing, dual-purpose type for northern and north-western India outside the arid zone; and large-seeded type for the peninsular India. In the arid zone group, 137 S_3–S_{12}/F_4–F_8 progenies were evaluated of which 75 were selected with 39 of these flowering in less than 46 days. In the dual-purpose group, 1030 S_3–S_{14}/F_3–F_{10} progenies (including 85 A_5 restorer progenies) were evaluated of which 332, flowering mostly in 46–60 days, were selected. In the peninsular group, 953 S_2–S_{13}/F_4–F_9 progenies were evaluated and 267 (both medium and short heights) were selected with 175 of these flowering in less than 46 days.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, Ranjana Bhattacharjee, SK Gupta, RP Thakur and Rajan Sharma

Milestone 5A.2.1.3: An elite B-composite and an elite R-composite with resistance to multiple pathotypes of downy mildew populations developed (KNR/RB/RPT/RS, 2009)

Achievement of Output Target (%):
70% Formation of R-composite is nearly completed with the final random mating to be done. For B-composite, constituent DM resistant lines have been identified.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Eleven potential restorers highly resistant to downy mildew (DM) (<10% disease incidence under high disease pressure in the greenhouse) to five diverse pathotypes (Banaskantha, Barmer, Jamnagar, Jodhpur and Jalna) and four potential restorers highly resistant to any four of these five pathotypes were intercrossed (equivalent to first random mating) to constitute a Multiple DM Resistant Restorer Composite (MDMRRC). The seed harvested from these crosses were bulked and planted for second random mating in the isolation from which seeds were harvested for the third and final random mating. While harvesting the bulk seed, OP seed of 80 superior plants were harvested that will be evaluated as half sibs and used for developing restorer lines with resistance to multiple pathotypes. A similar approach was adopted for the formation of a Multiple DM Resistant B-Composite (MDMRBC). Two hundred and sixty-four potential seed parents (including designated seed parents) were evaluated for resistance to Banaskantha pathotype in single pots under high disease pressure in the greenhouse. Based on high DM resistance (<20% disease incidence) 89 lines were selected and re-evaluated in 2 pots each in 2 replication against the Banaskantha pathotype. Based on high levels of DM resistance, (<10% disease incidence), 50 lines were selected and evaluated for resistance to the same four additional pathotypes as used for the formation of MDMRRC. Nineteen lines with high levels of DM resistance to all of these additional four pathotypes have been finally selected for intercrossing to constitute MDMRBC.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, R Bhattacharjee, SK Gupta, R P Thakur and Rajan Sharma

Output target 5A.3: Morphological and molecular diversity of more than 150 elite inbred lines of pearl millet assessed and the relationship between diversity and yield heterosis demonstrated (2009)

Activity 5A 3.1: Evaluate parental lines, advanced breeding lines and their hybrids for grain yield, and morphological and molecular diversity

*Milestone 5A.3.1.1**:** Designated seed parents and restorer lines characterized for DUS traits and molecular diversity (KNR/RB/VV, 2008)*

Achievement of Output Target (%):
80% Characterization and documentation of designated seed parents has been completed. Molecular and morphological data of designated restorer parents have been generated and analyzed. Preparation of the document is under way.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Over the years, a large number of seed parents and restorer parents have been developed in pearl millet. These have been characterized for morphological traits during the years they were developed and designated. Such data get confounded with the environmental effects. Thus, a study had been planned to characterize these for morphological traits in common environments, and also characterize them for molecular diversity. Such data permit the assessment of the extent of genetic diversity and also allow for IPR protection to prevent any infringement on these materials, and thus enable ICRISAT's ability for unrestricted dissemination to global research community in the public sector and to consortium seed companies. While characterizing these lines, within-line variability in a random sample of lines was also investigated.

Morphological diversity
Ninety-nine pairs of A-/B-lines were evaluated for two seasons (postrainy season and rainy season, 2005) for 26 morphological traits using DUS descriptors. A document has now been prepared that has been accepted for publication in e-SAT Journal of Research. These materials were developed utilizing a wide range of germplasm and improved lines. For instance, 9 lines were directly selected from composites and 3 lines from germplasm. Forty B-lines were derived from crosses that involved composites or germplasm lines in their parentage. Plant height in these lines ranged from 61 to 136 cm, days to flowering from 41 to 60 days, panicle length from 12 to 35 cm and panicle diameter from 2.0 to 3.7 cm. Quantitative characters like plant height, and leaf and panicle-related characters had increased expression in the rainy season than in the postrainy season, while the reverse was true for other characters like days to flowering, number of productive tillers plant^{-1} and 1000-grain weight. Based on the mean performance, the differences between A- and B-lines were significant for all the ten quantitative characters though these differences were of small magnitude to have any practical significance. For instance, overall mean for A-lines for days to flowering was 48 days and B- lines flowered in 49 days. A-lines overall had 95 cm plant height in comparison to 96 cm for B-lines. Environment had significant effect on cytoplasm as some A-/B-pairs had significant differences between them in different seasons for some characters, though this behavior was not consistent across the seasons. Amongst 16 qualitative and quasi-qualitative characters under study considerable variation was recorded for most of the traits except for plant growth habit, presence of bristles on the panicles, bristle color, anthocyanin pigmentation on glumes, and nodes and leaf sheath pubescence. Seasonal differences between A- and B- lines in the expression of some qualitative traits like seedling anthocyanin pigmentation and panicle density were observed. For instance, ICMA 94444 had pigmented seedlings and ICMB 94444 had non-pigmented seedlings across both the seasons. Some A-/B- pairs had differential expression for qualitative traits across the two seasons. For instance, ICMA 91777 and ICMB 91777 had predominantly non-pigmented seedlings in the rainy season but pigmented seedlings in the postrainy season. Within–line variability in some of the B-lines was also observed for qualitative traits even across the two replications which may be due to the bulk- pollen technique followed in pearl millet breeding program for development of A-/B-pairs at ICRISAT. It is due to this variability that a word of caution has been made in this document that an alternate phenotype (different from the predominant phenotype) developed from an A-line should not be construed as a new plant type at any given time.

Similar data have been collected for 116 designated R-lines evaluated in two seasons (rainy season, 2007 and postrainy season, 2008) for 26 morphological traits using DUS descriptors and data analyzed. Preparation of the draft document is under way

Molecular diversity
Genotyping of 99 B-lines and 150 R-lines with 40 markers (36 SSR and 4 EST) well distributed across all seven linkage groups was completed. The polymorphic information content (PIC) of these markers for B- lines ranged between 0.31 and 0.89 with a mean of 0.62, and for R- lines it ranged between 0.19 and 0.88 with a mean of 0.68. Preliminary investigations based on hierarchical cluster analysis following weighted neighborhood -joining method clustered all the B- lines into two major groups and all the R-lines into a single cluster.

Within-line variability
Six phenotypically diverse B-lines and R-lines were assessed for within-line variability. Forty selfed progenies each from B-lines and 33 progenies each from R-lines were evaluated in a replicated trial in postrainy season of 2008 and data recorded for days to 50% flowering, plant height, panicle length, panicle diameter and 1000-grain weight. There were significant differences among the 6 B-lines for all the characters. Significant within-line variability was also observed in ICMB 89111 for five traits; in ICMB 93333 for 3 traits; and in 843B, ICMB 02111 and ICMB 97111 for 2 traits. ICMB 01222 had non-significant within-line variability for all the five traits. There was no significant difference among R-lines for all the characters except for panicle diameter. IPC 422, -715, - 795, - 802, - 828 had non-significant differences within the line for all the five traits whereas IPC 909 had non-significant variability for all the traits except for plant height. Data analysis is underway for the same set of 6 B- and 6 R-lines assessed for within-line variability in a replicated trial in rainy season of 2008.Data analysis is also underway for within-line molecular diversity in these 6 B- and 6 R-lines.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium; Sehgal Foundation Endowment Fund

SK Gupta, KN Rai, Ranjana Bhattacharjee and CT Hash

Milestone 5A.3.1.3: Two medium-maturity heterotic gene pools based on molecular marker diversity constituted (KNR/RB/SC/RV, 2012)

Not yet initiated since the molecular diversity as a tool for identifying heterotic crosses is still to be established.

Output target 5A.4 QTLs for downy mildew resistance in pearl millet identified, compared to those previously detected, and their effect on DM resistance assessed (2008)

Activity 5A.4.1 Development of mapping populations and QTL mapping of DM resistance

Milestone 5A.4.1.1: QTL mapping based on F_6 RILs and $F_{2:4}$ progenies from two crosses completed and results compared (CTH/SS/RPT/RS, 2008)
No report submitted

Milestone 5A.4.1.2: Genetically diverse parents of mapping populations identified and crossed to generate F_6 RILs (CTH/KNR/RPT/RS, 2007)
No report submitted

Activity 5A.4.2 Map-directed conventional backcrossing and marker-assisted backcrossing of DM resistance QTLs into parental lines of hybrids

Milestone 5A.4.2.1: Ten major QTL imparting resistance against specific DM pathtypes identified (CTH/RPT/RS, 2007)
No report submitted

Milestone 5A.4.2.2: Near-isogenic lines containing different DM resistance genes (QTL) developed (RPT/RS/CTH, 2010)
No report submitted

Milestone 5A.4.2.3: QTL with known effects against diverse pathotypes pyramided in 843B and other parental lines and their resistance levels determined (CTH/RPT/RS, 2010)

No report submitted

Milestone 5A.4.2.4: Several different single-QTL introgression homozygotes available in genetic backgrounds of two elite seed parents (CTH/RPT/RS, 2007)

No report submitted

Milestone 5A.4.2.5: Several different multiple-QTL introgression homozygotes available in genetic backgrounds of an elite restorer line and three diverse elite seed parents (CTH/TN/SS/RPT/RS, 2009)

No report submitted

Output target 5A.6 At least two improved populations and experimental hybrids of pearl millet with high forage yield potential developed (2009)

Activity 5A 6.1 Develop and evaluate improved open-pollinated varieties and hybrids for their forage yield potential

Milestone 5A.6.1.1: Additional germplasm sources with high biomass yield identified (KNR/RB/HDU/MB, 2009)

Achievement of Output Target (%):
60% More than 240 S_1 progenies from five high biomass accessions/ gene pools were produced and additional 27 accessions were identified.

Countries Involved:
India

Partners Involved:
None.

Progress/Results:
A high-tillering gene pool that had produced high forage yield in the previous trials and had large variability among the plants was selfed and 167 S_1 progenies were produced during the seed increase. Four partially converted country-specific gene pools were selfed and 77 plants with apparently high biomass potential were selected with S_1 seed produced. Also, 52 new germplasm accessions with high biomass potential selected from a characterization block of the Genetic Resources Unit in 2007 were evaluated and 27 accessions with high biomass yield were selected for further evaluation and utilization.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, Ranjana Bhattacharjee, SK Gupta and HD Upadhyaya

Milestone 5A.6.1.2: Improved populations and experimental hybrids with high forage yield potential developed (KNR/RB/HDU/MB, 2009)

Achievement of Output Target (%):
75% Three high-yielding populations from trials conducted in five year × season environments at Patancheru were identified with final evaluation to be completed in 2009.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Starting with the evaluation of nine improved populations in 2005 rainy season, two high-yielding populations (ICMV 05555 and ICMV 05777) have been identified from five year×season trials conducted at Patancheru that have given an average dry fodder yield of 9.5–11.0 t ha^{-1} at 80-day harvest. These yields are comparable to a sorghum-sudan grass hybrid (SSG 59-3) used as a control that had an average dry fodder yield of 11.1 t ha^{-1}. Another high-yielding population (ICMV 05222) with 9.5 t ha^{-1} of dry fodder has also been identified. These three populations will be evaluated in a final yield trial in 2009.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Milestone 5A.6.1.3: Diverse seed parents with high forage yield potential developed and characterized (KNR/RB/MB, 2012)

Achievement of Output Target (%):
25% Candidate lines have been identified for further evaluation and utilization in hybridization program to develop forage seed parents.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
More than 100 progenies from various trait-specific seed parents and restorer parents nurseries (bred initially with an objective to develop seed parents of grain hybrids) that had high biomass potential were evaluated during the 2008 postrainy season, of which 35 lines were selected. These and their single plant progenies in some cases leading to 67 progenies were planted in 2008 rainy season, of which 31 were selected for further evaluation. Conversion of some of these lines to A-lines and their hybridization *inter se* to further enhance the biomass yield potential is yet to start.

Special Project Funding:
Pearl Millet Hybrid Parent Research Consortium

KN Rai, Ranjana Bhattacharjee and SK Gupta

Output target 5A.8 Pearl millet technology exchange, capacity building and impact assessment undertaken and documented (2009)

Activity 5A 8.1 Enhance technology exchange and partnership building, and assess its impact

Milestone 5A.8.1.1: Seed of hybrid parents and breeding lines multiplied and distributed (KNR/RB, annual)

Achievement of Output Target (%):
90% All the hybrid parents and breeding lines have been multiplied and supplied as per the seed request, except for the lines from 2008 field days which have been harvested but are yet to be threshed.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
One hundred and fifty kg breeder seed of ICTP 8203, a restorer line and three pairs of A/B lines were supplied as per the seed request. About 10 kg seed of 35 populations (including OPVs) was supplied to ICBA and three populations were planted for large scale seed production and supply to ICBA as a part of the collaborative research program. Seed of six populations was supplied to Afghanistan. We produced 690 kg breeder seed of 7 pairs of A-/B-lines for supply to NARS collaborators in India whose hybrids are based on these male-sterile lines.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, Ranjana Bhattacharjee and SK Gupta

Milestone 5A.8.1.2: ICRISAT's partnerships with NARS, networks and regional for a strengthened (KNR/CLLG/pearl millet team, annual)

Achievement of Output Target (%):
100% The target set out as per the work plan achieved.

Countries Involved:
India
Partners Involved:
None

Progress/Results:
Fifteen trials consisting of a total of 495 lines/progenies were constituted and supplied to the All India Coordinated Pearl Millet Improvement Project (AICPMIP) Coordinator for evaluation at 2–8 locations under the ICAR-ICRISAT Research Partnership project. NARS Scientists were increasingly involved in publications and project development (BMGF project targeted for north-western India, HarvestPlus project, a DBT project on India Biofortification) and joint research planning (Hybrid development for arid zone of north-western India under ICAR initiative). A Joint research project with OPEC Fund was developed and it was funded to strengthen pearl millet research and development activities targeted for the Middle East region. Technical support was provided to strengthen pearl millet research in Central Asia, as a result of which now the Government of Uzbekistan has funded a national project on pearl millet for that country. A joint project with ICBA and ICARDA was drafted to further strengthen pearl millet research and development in Central Asia. Contacts were made to promote pearl millet in Brazil, and a seed company from that country joined pearl millet consortium. A Pearl Millet Consortium Hybrid Trial of 28 hybrids from 13 seed companies was constituted and sent to 10 locations for evaluation.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

KN Rai, SK Gupta and CLL Gowda

Milestone 5A.8.1.3: International Pearl Millet Training Course (2009) and Field Day (2006, 2008, 2010, 2012) conducted (KNR/CLLG/pearl millet team)

Achievement of the Milestone (%):
80% Pearl Millet Scientists' Field Day was held. The 2009 training course will be postponed to 2010

Countries Involved:
India

Partners Involved:
None

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Progress/Results:
Results of the 2008 Scientists Field Day are reported under output Target 2008: 5.1.2 PM. The training course planned for 2009 will be postponed to 2010 as the publication of a book based on a training course held in 2006 has been delayed because of the expansion of the scope of the book far beyond the training course lectures, and involvement of multiple authors/co-authors. Also, this postponement is to have enough time to explore at least partial funding support for this course.

KN Rai, SK Gupta, RP Thakur and CLL Gowda

Milestone 5A.8.1.4: Technical information and public awareness documents developed and disseminated (KNR/CLLG/pearl millet team, annual)

Achievement of the Milestone (%):
80% The intended publications were drafted.

Countries Involved:
India

Partners Involved:
None
Progress/Results:
Fact file for pearl millet was updated. A booklet on Trait-Specific Germplasm Sources of Pearl Millet initiated by AICPMIP Unit was further developed and brought to a near final stage for publication which is likely to be released at the time of AICPMIP workshop in early 2009. A research article on postrainy season cultivation of pearl millet was drafted.

Special Project Funding:
Pearl Millet Hybrid Parents Research Consortium

Milestone 5A.8.1.5: Commercialization of pearl millet grains strengthened through researcher-farmer-industry alliances (KNR/CLLG/pearl millet team-annual)

Achievement of the Milestone (%):
75% Hybrid and crop management technologies and their commercialization potential was demonstrated.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Mostly advisory role was played to support the CFC project team on pearl millet technology, including cultivar selection and field design. As a result of this, pearl millet variety ICTP 8203 in Andhra Pradesh cluster is now almost all replaced with hybrids that give 30-50%.more grain yield than ICTP 8203, thus bringing better returns to farmers. These results are yet to be analyzed.
Special Project Funding:
CFC Project

KN Rai, Ashok Alur, Ch Ravinder Reddy and CLL Gowda

III. Pigeonpea

Output Target 5A.1 About 15 high-yielding pigeonpea hybrids made available for cultivation in different environments (2006-2009)

Achievement of Output Target (%):
80% We have made available nine pigeonpea hybrids to various private companies and NARS partners. Additional six hybrids will be shared during 2009.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Activity 5A.1.1 Development of widely adapted high-yielding hybrids for different environments

Milestone 5A.1.1.1: At least 100 new hybrid combinations evaluated to identify new fertility restorers/male sterility maintainers (KBS/RKS, 2006-09).

Achievement of Output Target (%):
90% We have evaluated more than 100 hybrids in short and medium-maturity groups, and have found 89 new restorers and five new maintainers.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results:
During 2007 rainy season, 132 new hybrids were evaluated for identification of new restorers and maintainers at Patancheru. Of these, 110 hybrids belonged to the short-maturity group. In this group, five hybrids were found to maintain male sterility (pollen sterility >80%). Single plant selections for pollen sterility and plant type were done and backcrossing with their respective male parents was undertaken for the development of new A-lines. In this maturity group, 67 new restorers were also identified on the basis of their fertility restoration in the hybrids. These R-lines are being maintained under selfing and tested again for their fertility restoration during 2008. In medium-maturity group, three trials were conducted involving 22 hybrids during 2007 rainy season. All the hybrids recorded >90% fertility restoration, and no maintainer was found. These lines will be evaluated again in different cross combinations for confirming their fertility restoration.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena and RK Srivastava

Milestone 5A.1.1.2: At least five high-yielding hybrids each in early and medium maturity duration identified for multi-location testing (KBS/RKS, 2007).

Achievement of Output Target (%):
100% A total of 22 hybrids (eight in short-maturity group and 14 in medium-maturity group) have been identified for multi-location testing for 2008 rainy season.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results:
On the basis of performance in 2005, 2006 and 2007 rainy seasons, a total of eight hybrids ICPH 2433 (2244 kg ha^{-1}, with 63% yield superiority over check cultivar UPAS 120), ICPH 2438 (2177 kg ha^{-1}, 58% yield superiority over check cultivar UPAS 120), ICPH 2363 (2062 kg ha^{-1}, 50% yield superiority over check cultivar UPAS 120), ICPH 2429 (1916 kg ha^{-1}, 39% yield superiority over check cultivar UPAS 120), ICPH 2431 (1837 kg ha^{-1}, 34% yield superiority over check cultivar UPAS 120), ICPH 2447 (1820 kg ha^{-1}, 32% yield superiority over check cultivar UPAS 120), and ICPH 3310 (1538 kg ha^{-1}, 12% yield superiority over check cultivar UPAS 120) were selected for multi-location testing. In medium-duration 14 hybrids were identified for multi-location testing. Hybrids ICPH 2673 (2741 kg ha^{-1}, 36% yield superiority over check cultivar Maruti, and 0% *Fusarium* wilt and 17% sterility mosaic incidence), ICPH 3341 (2836 kg ha^{-1}, 31% yield superiority over Maruti, and 14% incidence of *Fusarium* wilt and 10% to sterility mosaic), and ICPH 3472 (2671 kg ha^{-1}, 23% yield superiority over Maruti, and 0% *Fusarium* wilt and sterility mosaic incidence) were found promising. The other high - yielding wilt and sterility mosaic resistant hybrids identified for multi-location testing were ICPH 3337 (2753 kg ha^{-1}, 27% yield superiority over Maruti), ICPH 3758 (2443 kg ha^{-1}, 37% superiority) ICPH 3759 (2218 kg ha^{-1}, 25% superiority), ICPH 3761 (2742 kg ha^{-1}, 54% superiority), ICPH 3763 (1805 kg ha^{-1}, 2% superiority), ICPH 4012 (2459 kg ha^{-1}, 38% superiority), ICPH 4013 (2072 kg ha^{-1}, 17% superiority), ICPH 4017 (2326 kg ha^{-1}, 31% superiority), ICPH 4019 (2524 kg ha^{-1}, 42% superiority), ICPH 4020 (1936 kg ha^{-1}, 9% superiority), and ICPH 4022 (1881 kg ha^{-1}, 6% yield superiority over Asha 1777 kg ha^{-1}). These hybrids are being tested in 14 locations in central and southern India along with appropriate checks such as Asha, Maruti, and ICPH 2671.

Special Project Funding: Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena and RK Srivastava

Milestone 5A.1.1.3: At least five pigeonpea hybrids identified for on-farm testing (KBS/RKS, 2008)

Achievement of Output Target (%):
100% A total of seven hybrids (two in short-maturity group, and five in medium-maturity group) have been identified for on-farm testing during 2008 rainy season.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results:
In the short-duration maturity group, two hybrids were selected for on-farm testing. In the multi-location trials conducted in 2005 (7 locations), 2006 (4 locations), and 2007 (8 locations), ICPH 2433 (2244 kg ha^{-1}) recorded 63% yield advantage over control UPAS 120. Similarly, ICPH 2438 produced 2177 kg ha^{-1} grain, showing 58% advantage over control UPAS 120).

In the medium-duration hybrid group, five hybrids were selected for on-farm testing. In addition to high grain yield, all the hybrids had high levels of resistance to wilt and sterility mosaic diseases. These hybrids were selected on the basis of two (2006 and 2007) years multi-location testing. The selected hybrids were ICPH 3464 (11 locations, with 57% grain yield superiority over control Asha, and 13% *Fusarium* wilt and 0% sterility mosaic incidence), ICPH 3477 (11 locations, with 30% yield superiority over Asha, and 0% *Fusarium* wilt and 0% sterility mosaic incidence), ICPH 3462 (16 locations, with 28% grain yield superiority over Maruti, and 8% incidence of *Fusarium* wilt and sterility mosaic), ICPH 3491 (11 locations, with 23% grain yield advantage over Asha, and 13% incidence of *Fusarium* wilt and sterility mosaic diseases). ICPH 2671 was evaluated for three (2005-2007) years in 21 locations with 42% grain yield superiority over Maruti, and 8% *Fusarium* wilt and 6% sterility mosaic diseases.

At present we have sufficient seed of hybrid ICPH 2671 for on - farm testing. Attempts will be made to produce seed of the other promising hybrids. The main problem we are facing at present is to get more isolations for quality seed production in large quantities.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena and RK Srivastava

Milestone 5A.1.1.4: Elite pigeonpea hybrids evaluated for their resistance to major insects and diseases (HCS/SP/ KBS, 2009)

Achievement of Output Target (%):
75% Ten promising hybrids have been evaluated for pod borer resistance.

Countries Involved:
India

Partners Involved: Indian Institute of Pulses Research, Kanpur, India

Progress/Results:
Relative susceptibility of pigeonpea hybrids to *Helicoverpa armigera:* Ten hybrids along with two maintainer lines, resistant (ICPL 88039 and ICPL 332) and susceptible (UPAS 120) checks were also evaluated for resistance to pod borer, *H. armigera* under field conditions. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage, and recovery and overall resistance scores visually, pod damage, and grain yield. Pod damage due to *H. armigera* in all the hybrids was very high (damage rating 8 to 9). The ability to recover from damage by the pod borer ranged from 5.0 to 9.0, and the hybrids ICPH 2348 and ICPH 2460 showed a recovery resistance comparable to UPAS 120 (5.0) and ICPL 332 (6.0). The hybrids ICPH 3433, ICPH 2460, ICPH 3310, and ICPB 2039, and the resistant check, ICPL 332 also exhibited high levels of resistance to wilt, while ICPH 2364, ICPH 2363, ICPH 2431, ICPH 2447, and ICPB 2089 showed susceptibility to wilt (>40% wilt). ICPH 3433, ICPH 2447, and ICPH 2460 had 64 to 76% healthy pods in the second flush compared to 78% healthy pods in ICPL 332 (the resistant check).

Special Project Funding:
Tropical legumes II, Hybrid Parents Research Consortium

HC Sharma, S Pande and KB Saxena

Output Target 5A.2 Genetically diverse pigeonpea hybrid parents (about 5-10 A lines and 10-15 R lines) with resistance to major biotic stresses developed (2009).

Activity 5A.2.1 Development of high-yielding pigeonpea hybrid parents with resistance to major biotic stresses.

Achievement of Output Target (%):
75% We have developed A/B and R- lines which are highly resistant to Fusarium wilt and sterility mosaic for use in hybrid breeding program.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)
Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

Milestone 5A.2.1.1: At least six A_4 male-sterile and 15 fertility restorer lines with resistance to wilt and sterility mosaic disease developed (KBS/RKS/SP, 2007)

During 2007 season, 57 maintainer lines in BC_3F_1 – BC_4F_1 generations were screened in wilt and sterility mosaic disease sick nursery at Patancheru. Of these, 39 belonged to the short-duration and 18 to medium-duration group. In short-duration group, four maintainer lines 2085, 2087, 2149 and 2160 were resistant to sterility mosaic (with <10% disease incidence). One line (2159) was found resistant to both *Fusarium* wilt and sterility mosaic diseases with 12% disease incidence. In medium-maturity group only four maintainer lines (2049, 2050, 2051, and 2091) were resistant (<10% disease incidence) to sterility mosaic disease. Five lines (2044, 2046, 2047, 2048, and 2092) had dual resistance to both wilt and sterility mosaic diseases. These lines will be further backcrossed during the next season.

In addition to the above, 75 restorers lines were also screened for wilt and sterility mosaic disease resistance during 2007. Of these, 19 belonged to short-duration group, and 56 to medium-duration group. In short-maturity group, two lines (ICPR 3677 and ICPR 3643) were resistant to sterility mosaic disease. None of the lines in short-maturity group were found resistant to *Fusarium* wilt. In medium-maturity group 37 R-lines (ICPR 3972, ICPR 4015, ICPR 3765, ICPR 4011, ICPR 3963, ICPR 4010, ICPR 3464, ICPR 3758, ICPR 3371, ICPR 3762, ICPR 2744, ICPR 3806, ICPR 3495, ICPR 3472, ICPR 4022, ICPR 3849, ICPR 2671, ICPR 3812, ICPR 3497, ICPR 4013, ICPR 3759, ICPR 3524, ICPR 3507, ICPR 3366, ICPR 2741, ICPR 3785, ICPR 3498, ICPR 4020, ICPR 3812, ICPR 3809, ICPR 4018, ICPR 4025, ICPR 3763, ICPR 3810, ICPR 2794, ICPR 4014, and ICPR 2614) had combined resistance to *Fusarium* wilt and sterility mosaic.

Selfed seeds of all the restorers were produced. These lines will be tested again for fertility restoration in the same and different cross combinations, and for disease resistance and other important agronomic traits.

KB Saxena, RK Srivastava and S Pande

Milestone 5A.2.1.2: At least six promising maintainers of A_4 cytoplasm improved for agronomic traits (seed and pod size and disease resistance) through backcrossing (RKS/KBS, 2009).

Achievement of Output Target (%):
70% A total of 89 maintainers are being improved for *Fusarium* wilt and sterility mosaic diseases, and seed size, color and maturity duration. These lines will be fixed for important agronomic traits in following seasons.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

During 2007 season, 39 maintainer (B-) lines were screened for *Fusarium* wilt and sterility mosaic disease resistance. Data were also recorded on their 100-seed mass, seeds pod^{-1}, days to flower, days to maturity, grain yield and other important agronomic traits. To generate new breeding populations of the maintainers, a total of 50 B × B crosses were made among the selected parents. Theses F_1s were planted during 2008 to produce selfed F_2 seed. The advanced generation (F5/6) selections from this material will be used to select new maintainers.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

RK Srivastava, KB Saxena and S Pande

Output target 5A.3 Pigeonpea hybrid parents (25-30 A-lines and 50-55 R-lines) characterized for important agronomic traits and molecular diversity (2009)

Activity 5A.3.1 Assessing the agronomic and molecular diversity of pigeonpea hybrid parental lines.

Achievement of Output Target (%):
75% More than 100 lines have been characterized for various agronomic traits.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Milestone 5A.3.1.1: A-/B- and R-lines characterized for important agronomic traits (KBS/RKS/HCS/SP, 2008)

During 2007 season, 39 B-lines were characterized at Patancheru for days to flower and days to maturity, seeds pod^{-1}, 100-seed mass, and grain yield in replicated trials. The reaction of these lines to *Fusarium* wilt and sterility mosaic diseases was studied in the disease sick plot. In the short-duration group, the variation for 50% flowering and 75% maturity ranged from 60 to 105 days and 90 to 140 days, respectively. Plant height ranged from 69 to 184 cm, seeds pod^{-1} from 3.6 to 6.7, 100-seed mass from 7.9 to 13.7 g, wilt incidence from 5 to 92%, sterility mosaic incidence from 0 to 79%, and grain yield from 224 to 1388 kg ha^{-1}.

In the medium-duration group, B- lines were classified into "Maruti" group with 95 to 110 days to flower and "Asha" group with 120 to 135 days to flower. These two groups have specific adaptation. The Maruti group is suited for shallow Vertisols, while the Asha group performs well in the deep Vertisols.

In Maruti group trial, the days to flower ranged from 107 to118 days, days to maturity from 159 to 176 days, plant height from 107 to 252 cm, seeds pod^{-1} from 3.0 to 4.0, 100-seed mass from 7.7 to 12.4, wilt from 0 to 88%, sterility mosaic from 0 to 74%, and grain yield from 506 - 2753 kg ha^{-1}. In Asha group trial, the days to flower ranged from 117 to 140, plant height from 240 to 275 cm, seeds pod^{-1} from 4.0 to 5.0, 100-seed mass from 6.8 to 16.4, wilt from 0 to 84%, sterility mosaic from 0 to 44%, and grain yield from 1215 to 2704 kg ha^{-1}. Eight B- lines were found resistant to both *Fusarium* wilt and sterility mosaic diseases. The data recorded on this material will be made available to NARS and consortium partners for use in their hybrid breeding program.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India
KB Saxena, RK Srivastava and S Pande

Milestone 5A.3.1.1: A-/B- and R-lines characterized for important agronomic traits (KBS/RKS/HCS/SP, 2008)

Achievement of Output Target (%):
75% Ten maintainer and 10 restorer lines have been evaluated for pod borer resistance.

Countries Involved:
India

Partners Involved:
Indian Institute of Pulses Research, Kanpur, India

Special Project Funding:
Tropical Legumes II, Hybrid Parents Research Consortium

Progress/Results:
Relative susceptibility of maintainer and restorer lines of pigeonpea to *Helicoverpa armigera:* Nineteen maintainer lines along with resistant (ICPL 187-1 and ICPL 332) and susceptible (ICPL 87 and ICPL 87119) checks were evaluated for resistance to the pod borer, *H. armigera*. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage visually (1 = <10% pods damaged, and pods distributed uniformly all along the inflorescences, and 9 = >80% pods damaged, and pods poorly distributed in the inflorescences), recovery and overall resistance scores (1= good, and 9 poor), pod damage (%), and grain yield. Pod damage due to *H. armigera* was very high (damage rating 8 to 9) on all the test entries in the first flush. However, recovery resistance (number of pods produced, and pods damaged in the second and third flushes) ranged from 4.0 to 9.0, and the lines ICPB 2030, ICPB 2045, ICPB 2048, ICPB 2051, ICPB 2080, and ICPB 2156 exhibited a moderate levels of recovery resistance (recovery resistance rating <5.0 compared to 6.5 in ICPL 87).
HC Sharma, RK Srivastava and KB Saxena

<u>Milestone 5A.3.1.2</u>: Available male sterile (A/B) and fertility restorer (R) lines characterized using molecular markers (RKV/RKS/KBS/DAH, 2009)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
None

Progress/Results:

To characterize 133 A-, B- and R- lines of pigeonpea hybrids a set of 148 SSRs was utilized. As a result, 41 markers showed polymorphism among 133 lines. Across the lines surveyed, these markers detected 2-6 alleles (average 3) and PIC value in the range of 0.01- 0.80 (average 0.41) per marker. Among different groups, the present analysis showed a higher diversity among B-lines, followed by R-lines and the least diversity was present in A-lines.

To understand the genetic relationships among and within A-, B- and R- lines, the genotyping data were scored as a 0-1 matrix for the presence or absence of the alleles to analyze the genetic similarity and prepare a dendrogram. The Figure 1 shows two main clusters and these clusters are further sub grouped into sub-clusters. Cluster I contains the majority of A- and a few B- lines, while cluster II contains the majority of R- and a few B- lines. It is anticipated that with the available genotyping data although we could not able to differentiate clearly among A-, B- and R-lines but it shows that B-lines are more close to the R-lines.

Special Project Funding:
Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Government of India)
RK Varshney, RK Srivastava, KB Saxena, RK Saxena and DA Hoisington

Output Target 5A.4 Seed production technology for pigeonpea hybrids and their parents improved (2009)

Activity 5A.4.1: Developing an efficient seed production technology for pigeonpea hybrids and their parents

Achievement of Output Target (%):
60% Although the seed production technology has been developed, some area-specific problems still need to be addressed.

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

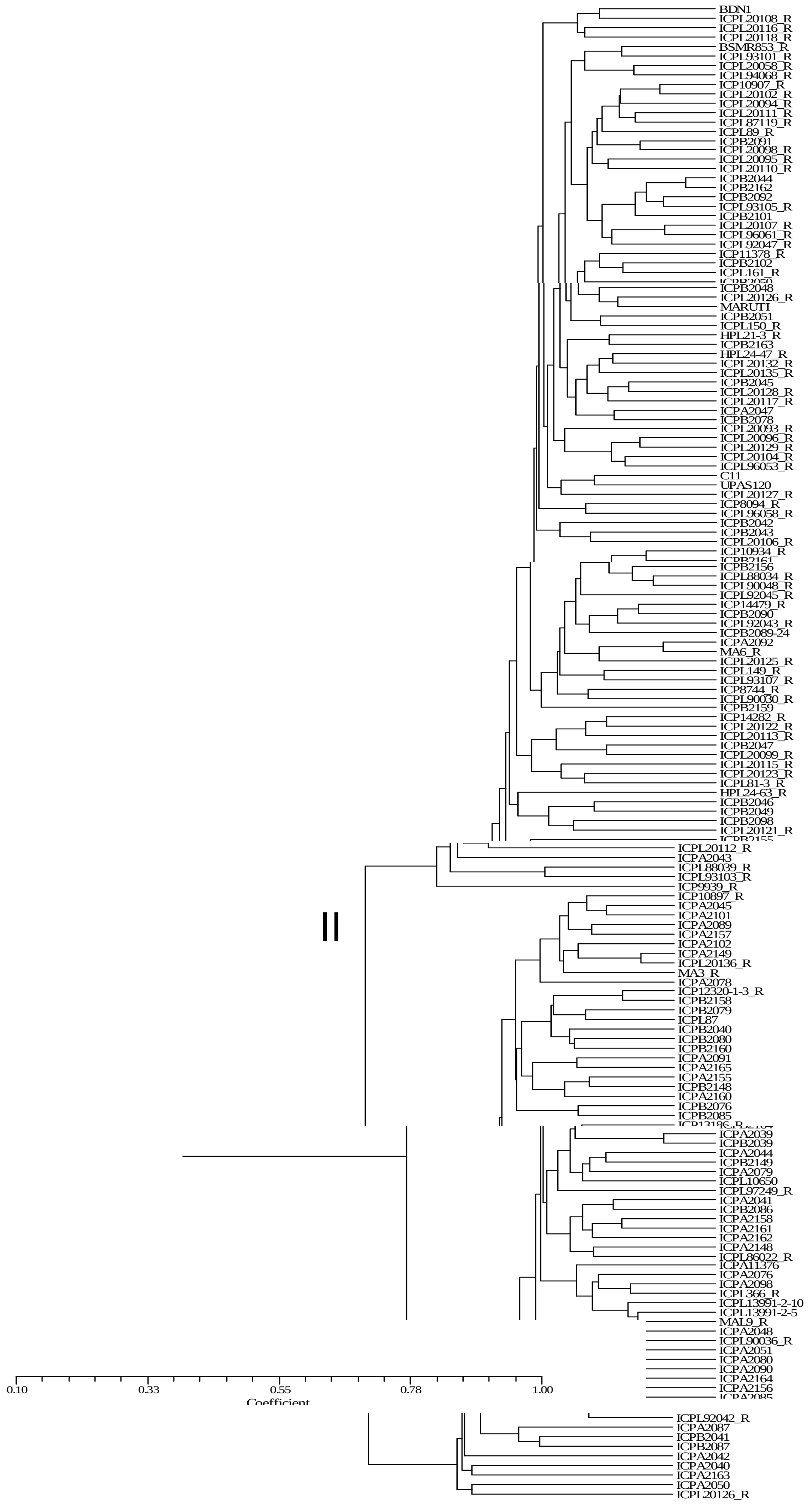


Figure 1. Diversity among the A-, B-, & R-lines of Pigeonpea.

Milestone 5A.4.1.1: Improved seed production technology for pigeonpea hybrids and their parents developed (KBS/RKS, 2009)

Observations on insect-aided natural out-crossing recorded at Patancheru during 2006 and 2007 indicated that even 300 m of isolation distance is not sufficient to maintain high levels of genetic purity. Therefore, an isolation distance of 500 m was tried and it was found to be satisfactory for the maintenance of parental line and hybrid seed production. In order to optimize seed yield of hybrids and their parental lines, studies were conducted to find out optimum row ratio. At Patancheru, a row ratio of 4 A-line : 1B-line and 4 A-line : 1 R-line was found optimum in producing the seed of both A-lines and hybrids. The most advanced CMS line ICPA 2043 produced 1200 kg ha^{-1} at Patancheru. Similarly, in the hybrid seed production block, we harvested 1250 kg ha^{-1}. The Pigeonpea Hybrid Parents Research Consortium (PHPRC) and NARS were advised to adjust the row ratio on the basis of insect activity in their target seed production locations. Staggered sowing of male parent was also suggested for proper nicking of flowering. We also observed very significant environment/location effect on seed yield of parental lines and hybrids. The hybrid (A×R) seed production program of ICPH 2671 taken up at 36 locations in central and south India, showed a large variation in the harvests. The high yielding ($\geq$1000 kg ha^{-1}) locations were Indore (2267 kg ha^{-1}), Nizamabad (1750 kg ha^{-1}), Manoharabad (1258 kg ha^{-1}), Patancheru, Medchal (1250 kg ha^{-1}), Warangal (1063 kg ha^{-1}), Ahmedabad (1063 kg ha^{-1}), and Nandyal (1000 kg ha^{-1}). This will be repeated to confirm the results. These locations were identified as favorable environments for the hybrid seed production. In contrast, the hybrid yield at other locations varied from as low as 60 kg ha^{-1} to 800 kg ha^{-1}. The monitoring of these locations revealed that very poor hybrid yields were primarily due to the absence of pollinating insects. At one location, the pod setting on the male-sterile plants increased rapidly after placing bee hives in the plots. Low yield recorded in other plots were attributed to poor management of fields.

Progress/Results:
ICRISAT scientists are aware of the dangers of banking its pigeonpea hybrid breeding program on just one (A_4) cytoplasm. Therefore, attempts have been underway to diversify the cytoplasm base. For this purpose *Cajanus lineatus*, a wild relative of .pigeonpea, was selected as a donor parent for sterile cytoplasm. Three crosses involving this wild species viz. *C. lineatus* (ICPW 42) × ICPL 99044, *C. lineatus* (ICPW 42) × ICPL 20176, and *C. lineatus* (ICPW 42) × ICPL 87119 were made earlier. The F_1 plants of cross involving *C. lineatus* ICPW 42 and ICPL 99044 were male-sterile, while the F_1 of the other two crosses were male fertile. The BC_3F_1 seeds of the cross *C. lineatus* (ICPW 42) × ICPL 99044 were planted under a net in the 2007 season. Single plant pollinations using ICPL 99044 as a recurrent parent were made on the 48 male-sterile plants. Some BC_3F_1 male-sterile selections were also crossed with 17 adapted lines to identify new maintainers and much needed restorers.

Another wild relative of pigeonpea *C. acutifolius* (ICPW15613), designated as A_5 cytoplasm was used to generate new CMS lines. This wild accession was crossed with diverse cultivated pigeonpea inbred lines. Two lines exhibited complete male sterility. These lines are being crossed with their recurrent parents during 2008.

In 2005, another wild relative of pigeonpea *C. platycarpus* (ICPW 68) that belongs to the tertiary gene pool of pigeonpea was also used to breed a diverse source of CMS. The F_1 and BC_1 generations from the cross *C. platycarpus* × *C. cajan* were obtained by rescuing the aborting embryos using *in vitro* technology. BC_2F_1 plants showed diversity with respect to pollen fertility. One BC_2 selection (E) had open flowers and did not set seeds on self-pollinations, but seed setting was observed when it was backcrossed to the recurrent parent. The resulting BC_3 (E) material was completely male sterile. These plants are being crossed with their recurrent parent to obtain 100% male sterile plants during 2008.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena and N Mallikarjuna

Output target 5A.6 Trait-based breeding populations developed for selecting elite hybrid pigeonpea parental lines (2011)

Activity 5A.6.1 Development of trait specific (diverse maturity, disease resistance, seed and pod size) breeding populations for selecting new maintainers and restorers

Achievement of Output Target (%):
70% We still need to develop hybrid parents resistant / tolerant to pod borers and diversify genetic base of lines with specific traits.

Countries Involved:
India

Partners Involved:
None

Milestone 5A.6.1.1: For each trait, about 10–12 genetically diverse lines will be identified and crossed in a half-diallel mating scheme to generate B and R breeding populations for selection (RKS/SP/HCS, 2011)

In order to broaden the nuclear genetic base of the maintainer and restores lines, genetically diverse B- and R-lines were crossed in two separate partial diallel schemes during 2007 season. The lines for crossing were selected on the basis of diversity in pod length, seeds pod^{-1}, days to flower and maturity, disease resistance, plant height, number of primary branches, and grain yield. A total of 91 B x B crosses and 36 R x R crosses were made.

During 2008, all 36 R×R F_1s were harvested. However, in B×B crosses due to *Maruca* attack only 78 F_1s could be harvested during 2008. The F_1s are being planted during 2008 rainy season at ICRISAT Patancheru. Selections will be made for higher grain yield, more number of pods, seeds pod^{-1}, diverse maturity (early, mid-early and medium duration) and *Fusarium* wilt and sterility mosaic resistance.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

RK Srivastava, S Pande and HC Sharma

Output Target 5A.7 Hybrid pigeonpea technology exchange, capacity building of partners and documentation (2010)

Activity 5A.7.1 Exchange improved technologies and new knowledge with ARIs, NARS, NGOs, private sector, and farmers' groups

Achievement of Output Target (%):
60% We still need to train more people from public/private seed sector and NARS. Also more students need to be trained on various aspects of hybrid technology.

Countries Involved:
India

Partners Involved:
NARS in Asia and Eastern Africa

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

Milestone 5A.7.1.1: ICRISAT partnerships with NARS and Hybrid Parents Research Consortium Partners strengthened (KBS/ RKS/CLLG, annual)

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Progress/Results:
ICRISAT has been strengthening its partnership base with NARS and members of the Pigeonpea Hybrid Parents Research Consortium (PHPRC). There has been a constant interaction and feedback on hybrid pigeonpea technology. Pigeonpea breeders from PHPRC visited and monitored the hybrid pigeonpea experiments and breeding materials. The company representatives who visited ICRISAT were from Ankur Seeds, Avesthagen Grain & Tech., Basant Agro-Tech (India), Biogene Agri Tech, Bioseeds International, Green Life Seed and Bioculture, JK Seeds, Krishidhan, Maharashtra State Seeds Corporation Ltd (MSSCL), Mahyco, Nath Biogene, National Seeds Corporation (NSC), Nimbkar Seeds, Nuziveedu Seeds, Pioneer Overseas Corporation, Pradham Biotech, Pravardhan Seeds, SM Sehgal Foundation, and Zuari Seeds. Scientists had useful discussions about the current and future activities related to hybrid pigeonpea research, seed production, and training. ICRISAT scientists also visited parental line seed multiplication and hybrid seed production plots planted at various research farms of NARS and PHRPC members.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena, CLL Gowda and RK Srivastava

Milestone 5A.7.1.2: Seeds of elite parental lines, and hybrids multiplied and distributed to NARS and seed companies (KBS/RKS, annual)

ICRISAT scientists supplied 30 seed samples of advanced breeding lines and released varieties to various public-sector institutions such as Grazingland Research Laboratory; USDA, USA; Department of Agriculture, Philippines; and Department of Agriculture and Research, Myanmar), 192 seed samples to 11 national public sectors (ANGRAU, Hyderabad; IARI, New Delhi; IIPR, Kanpur; JNKVV, Jabalpur; MAU, Parbhani, MSSCL, Akola; NSC, New Delhi; PAU, Ludhiana; SFCI; TNAU, Coimbtore; MSSRF, Chennai), and 1262 seed samples to 16 national private organizations (Ankur seeds Pvt. Ltd, Nagpur; Avesthagen Tech, Bangalore; Basant Agro-Tech Ltd, Akola; Bio-gene AgriTech, Ahmedabad; Bioseed Research India Pvt, Ltd, Hyderabad; Green life seed and Bioculture, Guntur; JK Agri Genetics Ltd; Hyderabad, Krishidhan Seeds Ltd, Jalna; MAHYCO, Jalna; Nath Biogene (I) Ltd, Aurangabad; Nimbkar Seeds Pvt Ltd, Phaltan; Nuziveedu Seeds Ltd, Secunderabad; Pioneer Overseas Corporation, Hyderabad; Pradham Biotech Pvt Ltd, Hyderabad, Pravardhan Seeds Pvt Ltd, Hyderabad; Zuari Seeds Pvt Ltd, Banglore). These samples included established varieties of pigeonpea, advanced breeding lines, CMS lines, their maintainers and restorers, and some segregating materials.

KB Saxena and RK Srivastava

Milestone 5A.7.1.3: Technical information and public awareness literature developed and disseminated (KBS/HCS/ SP, 2007)

Milestone achieved and reported in 2007 archival report.

Milestone 5A.7.1.4: Capacity of NARS and seed sector scientists/technicians in hybrid breeding strengthened (KBS/RKS, annual).

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Indian NARS (Public and Private Sector)

Porgress/Results:
ICRISAT scientists have been involved in training and capacity building of its research partners. In December 2007 ICRISAT organized training programs for the members of ICRISAT-Private Sector Pigeonpea Hybrid Parents Research Consortium and NARS partners. A total of 23 scientists participated in a day-long training program. Experience of hybrid breeding technology was shared with the participants. Problems associated with hybrid seed production were also discussed. Subsequently, a Follow-up Meeting was organized on 29th February 2008. In this meeting, 11

participants from selected private and public sectors participated and discussed the areas of future research for the success of pigeonpea hybrids for commercial cultivation. In addition, two training programs were also conducted on hybrid seed production technology in the months of March and May 2007. These were attended by 58 scientists and research technicians. During the year, two scientists from Research Institute for Insects, Kumming, China, and one scientist from Organization of Food Crops research Institute, Yunnan Academy of Agricultural Sciences (YAAS), China were trained in hybrid pigeonpea seed production technology. One research technician from Food Legumes Section, Department of Agricultural Research (DAR) Yezin, Myanmar was trained in pigeonpea breeding for three months at ICRISAT Patancheru. One Ph.D. student from Akola, India successfully carried out thesis research work in hybrid pigeonpea breeding at ICRISAT during 2007 rainy season.

Special Project Funding:
Pigeonpea Hybrid Parents Research Consortium, Indian Council of Agriculture Research, National Food Security Mission of India

KB Saxena and RK Srivastava

Milestone 5A.7.1.5: Molecular markers and genetic maps developed and exchanged with the scientific community (RKV/DAH/ RKS/HDU/NM/KBS, 2010)

Achievement of Output Target (%):
60%

Countries Involved:
Asutralia; India; USA

Partners Involved:
NRCPB (IARI), UC-Davis, DArT Pty Ltd.

Progress/Results:
Development of molecular markers: Two approaches were used to develop microsatellite markers in pigeonpea.
1. Development of microsatellites from Bacterial Artificial Chromosome (BAC) end sequences (BES): In collaboration with University of California, Davis (Doug Cook), a total of 87,590 BAC end sequences representing 56.5 Mb genome size, were surveyed for the presence of microsatellite using MIcroSAtellites (MISA) tools. In total 16,308 SSRs were identified in 14,001 BES at the frequency of 1 SSR per 3.52 kb. In this set dinucleotide repeat were most abundant (41%) while tri nucleotide repeats were second most abundant (8% of total SSRs). Primer pairs have been synthesized for 3072 SSRs. These markers have been designated as CcM (*Cajanus cajan* Microsatellite) markers.

2. Gene based markers: In the second approach, the SSR markers were developed from ESTs. A total of 9,888 expressed sequence tags (EST) were generated from 16 cDNA libraries derived from various developmental stages of root tissues of *Fusarium* wilt resistant (ICPL 20102) and susceptible (ICP 2376) genotypes in response to *Fusarium udum* infection; and leaf tissues of SMD (sterility mosaic disease) resistant (ICP 7035) and susceptible (TTB 7) genotypes in response to sterility mosaic disease infection respectively. In order to search for microsatellites a source of marker development, 908 pigeonpea ESTs available in the public domain were also included along with the 9,888 generated ESTs. Data mining of 5085 unigenes defined using the ESTs generated at ICRISAT and available in public domain provided 3583 SSRs in 1365 ESTs at the frequency of 1/ 1.2 kb. Mono-nucleotide SSRs (3498) were present in the highest numbers, followed by di- nucleotide SSRs (40) and tri- nucleotide SSRs (33). Tetrameric, pentameric and hexameric microsatellites were 9, 2 and 1 respectively. Based on the length of SSR motifs, 94 SSRs were chosen for primer synthesis out of 383 designed SSR primers.

RK Varshney, A Dubey, NL Raju, Jayashree B, RK Saxena, DR Cook and DA Hoisington

Development of genetic maps: Developed SSR markers are being screened on parental genotypes of intraspecific and interspecific mapping populations at present. The polymorphic markers will be used to genotype respective mapping populations and subsequently genetic maps will be developed.. In parallel, Diversity Array Technology (DArT) markers are being developed and used for development of genetic maps in collaboration with DArT Pty Ltd (Australia).

RK Varshney, A Dubey, RK Saxena, HD Upadhyaya, RK Srivastava,
KB Saxena, N Mallikarjuna and DA Hoisington

Special Project Funding:
Pigeonpea Genomics Initiative of ICAR, Generation Challenge Programme, Department of Biotechnology (Government of India)

Output 5B: Enhanced molecular genetic and phenotyping platforms for drought and salinity screening and parental lines of hybrid sorghum, pearl millet and pigeonpea with improved tolerance to abiotic stresses, made available to partners biennially (from 2008) with associated knowledge and capacity building in SAT Asia

I. Sorghum

Output target 5B.1 At least five salinity-tolerant sorghum breeding lines/populations and a mapping population developed (2009)

Activity 5B.1.1 Developing/identifying salinity-tolerant improved breeding lines/populations and associated QTL

Milestone 5B.1.1.1: Five salinity-tolerant breeding lines/populations developed/identified (BVSR/VV, 2009)

Achievement of Output Target (%):
50% Crosses were made using selected salinity-tolerant parents and advanced progenies developed. The established sorghum hybrids and varieties are under evaluation for salinity tolerance.

Countries Involved:
India and Central Asia and Caucasus (CAC) countries

Partners Involved:
ICBA, NARS (Public and Private sector) in India and CAC countries

Progress/Results:
For introgressing salinity tolerance from selected salinity-tolerant lines into high-yielding background – a total of 436 F_6s (from 230 F_5s) and 316 F_5s (from 221 F_4s) for B-line development and 67 F_6s (from 43 F_5s) and 239 F_5s (from 112 F_4s) for R-line development were obtained with selection for high grain yield, large grain and agronomic appearance and 272 F_5s (from 146 F_4s) developed from the crosses between germplasm and breeding lines with selection for high grain yield and high biomass at ICRISAT, Patancheru.

Promising sweet sorghum hybrids (86) and sweet sorghum varieties (24) are being evaluated for salinity tolerance as late rainy season crop at Gangavathi, Karnataka, India under natural saline conditions (8 to 10 dsm^{-1}). Data are being compiled.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium; OFID-OPEC-Funded Project on Salinity

Belum VS Reddy, A Ashok Kumar and P Srinivasa Rao

Milestone 5B.1.1.2: New F_6 RIL mapping populations for salinity tolerance available for phenotyping and genotyping (CTH/BVSR/VV, 2009)
No report submitted

II. Pearl millet

Output target 5B.1 At least five salinity-tolerant improved breeding lines/ populations of pearl millet identified and feasibility of breeding salinity tolerant hybrids assessed (VV/KNR/RB) (2009)

Activity 5B 1.1: Develop salinity-tolerant lines and populations in pearl millet and assess their hybrid potential under saline conditions

Milestone 5B.1.1.1: Inbred lines and populations identified as salinity-tolerant in preliminary evaluations re-evaluated for their salinity tolerance and yield potential (KNR/RB/VV, 2008)

Achievement of the Milestone (%):
60% Reduced funding support delayed the achievement of milestone, for which the validated results will be available in 2009.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
A pot-grown trial consisting of 38 breeding lines that were tested previously (and many of these found tolerant to soil salinity), and a new set of 45 B-lines, and 18 R-lines was carried out under both saline and non-saline conditions, in an outdoor environment equipped with a rain-out shelter to evaluated/validate their tolerance levels. Data are currently being analyzed. Also, more than 12 populations earlier identified having good adaptation to saline soils in the Middle East were supplied to ICBA, Dubai for repeat evaluation in that region.

Special Project Funding:
OPEC Fund; Generation Challenge Program

KN Rai, SK Gupta, Vincent Vadez and L Krishnamurthy

Milestone 5B.1.1.2: Relationship between the salinity tolerance of hybrids and their parental lines assessed (KNR/RB/VV, 2010)

It is yet to be initiated after identifying/developing lines confirmed for salinity tolerance under the above milestone.

Output target 5B.2 Putative QTLs for salinity tolerance of grain and stover yield identified in pearl millet (2009)

Activity 5B.2.1 Genotyping and phenotyping of mapping populations for salinity tolerance

Milestone 5B.2.1.1: Putative QTL for salinity tolerance based on 160 RILs from one mapping population identified (CTH/SS/VV, 2009)

In 2007, 160 RIL originating from the cross between tolerant 841B and sensitive 863B were screened under saline and control non-saline conditions. A repeat of such screening has been performed in 2008. In both cases, the trial was carried out in an outdoor environment equipped with a rain-out shelter to prevent rains. Pearl millet was sown in 11” pots filled with 11 kg Alfisol. A salt treatment of 2.34 g NaCl/kg Alfisol was applied, in split doses during the first two weeks after sowing (a third of the dose applied at sowing, a third after one week and the last third of the dose applied 2 weeks after sowing). This treatment was equivalent to the application of a 200 mM NaCl treatment, applied in sufficient quantity to saturate the Alfisol used to field capacity (approximately 20% w/w). We found a good correlation between the seed yield obtained under salt stress across the two years (R^2=0.31). This is commendable given the high stress intensity imposed on the plants in 2007 and 2008 where seed yield was, respectively, 11 and 17% of that under non-saline control. By contrast, total shoot biomass was less reduced by the salt treatment, being 27% and 37% of that under control in 2007 and 2009. Data will now be used for QTL analysis.

Vincent Vadez and CT Hash

Milestone 5B.2.1.2: Putative QTLsfor salinity tolerance based on 35 BC6F3 contiguous segment introgression lines identified (CTH/SS/VV, 2010)

No report submitted

Milestone 5B.2.1.3: New F6 RIL mapping populations for salinity tolerance available in pearl millet for phenotyping and genotyping (CTH/BVSR/KNR/VV, 2009)

No report submitted

Output target 5B.3 Breeding value of putative terminal drought tolerance QTLs in pearl millet documented (2009)

Activity 5B 3.1: Publication of earlier results on drought tolerance QTL and gene pyramiding

Milestone 5B.3.1.1: Publication of results from marker-assisted selection for the linkage group 2 drought tolerance QTL into the genetic background of two parental lines (CTH/FRB, 2008)

No report submitted

Milestone 5B.3.1.2: DM resistance and terminal drought tolerance QTLs pyramided in the genetic background of elite pollinator H 77/833-2 and QTL introgression homozygote product lines available for testing (CTH/PSK/SS/VV/RPT/RS/KNR, 2007)

No report submitted

Output target 5B.4 Pearl millet germplasm with superior P-acquisition identified (2009)

Activity 5B 4.1 Development of an effective protocol and identification of germplasm with enhanced P-acquisition ability

Milestone 5B.4.1.1: An effective P-acquisition protocol applicable for large-scale screening developed (VV/HDU, 2007)

Milestone achieved and reported in 2007 archival report.

Milestone 5B.4.1.2: Pearl millet germplasm with superior P-acquisition from low-P sources identified (VV, 2009)

Grain and stover yields are often low in the SAT particularly under the conditions of widely prevalent low available soil phosphorus (P). Field experiments were carried out with a set of testcross hybrids for their grain and stover yield in both low P and high P environments,. Another objective was to identify parental lines that contrast for food-feed traits under low P conditions to identify quantitative trait loci (QTL) for these traits. Twenty mapping population parental lines were crossed with four male testers to produce 80 test cross hybrids. These hybrids were evaluated for grain and stover yield under moderately low and high phosphorus (P) environment at ICRISAT, India, under rainfed condition in the rainy seasons of 2006 and 2007. For low and high P environments, a field was divided into two blocks with no P fertilizer applied to the low P treatment while P was applied to the block presenting the high P environment. Di-ammonium phosphate at the rate of 100 kg ha^{-1} was applied to provide for P fertilization in the non-limiting P block, and 50 kg of urea was used as nitrogen (N) source for both non-limiting P control and low P treatment; the experimental layout was a replicated alpha-design.

All the 20 mapping population parental lines recorded higher grain yield and stover yield in the P fertilized block compared to the low P environment highlighting the importance of adequate soil P. Low P availability reduced grain yields between 12 to 37% with an average of about 23.4%. Considerable variations in grain yields were also observed under low P and grain yields varied between 170 to 425 g m^{-2} in both environments. Using residual as an index for the tolerance of mapping population parental lines under low P conditions, from the relation between the high and low p yields, the yield potential was extrapolated. Grain yield performance of ICMP 451-P6 and H77/833-2 parental line pair showed a significant contrast under high P-level while WSIL-P8 and Tift 23DB-P1-P5, and ICMB 841B-P3 / 863B-P2 parental line pair differed significantly under low P-level. Significant differences within the pairs of parental lines ICMP 451-P6 and H77/833-2 P, 310-17-B and W 504-1-1 were found under high P and low P-levels for stover yield. It appeared also that the pairs of parental lines ICMP 85410-P7 / LGD 1-B-10, IP 18293-P158 / Tift 238D1-P152, and Tift 23DB-P1-P5 / WSIL-P8, would be suitable for mapping of QTLs for grain yield under low P conditions.

Padmaja Karanam, Vincent Vadez and Michael Blummel

Milestone 5B.4.1.3: QTL for P acquisition from low P sources identified in pearl millet (VV/CTH, 2011)

We are currently analyzing the data of several years of experiment using the parents of pearl millet mapping populations, to identify a suitable parental combination showing good phenotypic contrast for tolerance to low soil P conditions.

Vincent Vadez, Padmaja Karanam and CT Hash

Output target 5B.5 At least five pearl millet breeding lines with tolerance to high air temperatures (>45°C) during reproductive stage developed (2009)

Activity 5B 5.1 Evaluate a diverse range of parental lines, advanced breeding lines and populations for high temperature tolerance during flowering and grain- filling period; and identify major QTL associated with this trait.

Milestone 5B.5.1.2: Relationship between hybrids and their parental lines for tolerance to high temperatures during reproductive stage quantified (KNR/RB/VV, 2010)

It is yet to be initiated after identifying/developing lines confirmed for heat tolerance under the above milestone.

Milestone 5.1.3: QTL for high temperature tolerance from two diverse mapping populations identified (KNR/RB/VV, 2012)

It is yet to be initiated after identifying/developing lines confirmed for heat tolerance under the above milestone.

Output 5C: Germplasm and improved breeding lines with high and stable grain Fe and Zn density in sorghum and pearl millet made available to specific partners biennially (from 2008) with associated knowledge and capacity building

I. Sorghum

Output target 5C.1 Sorghum germplasm lines/breeding lines with stable and high grain Fe (40-50 ppm) and Zn (30-40 ppm) contents identified and their character association, and inheritance studied (2009)

Activity 5C.1.1 Screening of germplasm and breeding lines for grain Fe and Zn and evaluating for grain yield and agronomic traits.

Milestone 5C.1.1.1: Five each of germplasm lines/breeding lines with stable and high grain Fe (40–50 ppm) and Zn (30–40 ppm) contents identified (AAK/BVSR/HDU, 2008)

Achievement of Output Target (%):
50% Twenty B-lines with Fe contents over 45 ppm and 13 B-lines with Zn contents over 32 ppm were identified. From the core germplasm, we identified 17 accessions with grain Fe contents over 90 ppm (range 96–192 ppm) and 11 accessions with grain Zn contents over 58 ppm (range 58–91 ppm) based on one year data and validation of the results is in progress in the postrainy season 2008.

Countries Involved:
India; Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

Progress/Results:
Selected core germplasm collection (>200 accessions) with different maturity [early (less than 65 days to 50% flowering), medium (65 to 75 days) and late (more than 75 days)] durations were evaluated in the 2007 postrainy season for agronomic traits in three different trials: micronutrient dense germplasm lines (50), freely threshable micronutrient dense germplasm lines (118), and non-threshable micronutrient dense germplasm lines (55). In addition to these germplasm lines, 23 breeding lines and 287 late maturity group germplasm (81 to 127 days to 50% flowering) were also evaluated in 2007 postrainy season. Data were recorded for agronomic traits like days to 50% flowering, plant height, grain yield, grain size, plant aspect score and harvested the grain carefully for Fe and Zn analysis without any contamination.

The Fe and Zn contents estimations are completed for 50 micronutrient dense germplasm lines and 23 breeding progenies. The rest of the grain samples are under processing for Fe and Zn contents estimation.

Among the 50 micronutrient dense germplasm lines , 31 had 45–145 ppm Fe, of which 15 had 45–65 ppm Zn. Among 23 breeding lines, 8 had 46–59 ppm Fe and 37 to 60 ppm Zn. The grain Fe and Zn status of 218 sorghum hybrid parents developed at ICRISAT, Patancheru were analyzed. They ranged from 22 to 51 ppm for Fe and 15 to 39 ppm for Zn. Twenty B-lines with 45–51 ppm Fe and 21 to 39 ppm Zn were selected for utilization in breeding programs. We advanced 62 F_6s, 76 F_4s for B-line development and 32 F_6s, 29 F_5s and 57 F_4s for R-line development and test crossed (TC) in the 2008 rainy season, and selected 215 TCs for B-line development and 340 TCs for R-line development. All these are now treated as testcrosses for B-line and R-line development. Evaluated 145 F_2 progenies derived from the crosses between adapted breeding lines and unadapted germplasm lines and selected 438 F_3s for further advancement in the 2008 postrainy season.

Special Project Funding:
HarvestPlus Challenge Program

A Ashok Kumar, Belum VS Reddy and HD Upadhyaya

Milestone 5C.1.1.2: Correlations of grain Fe and Zn contents with grain yield , grain size and agronomic traits estimated (AAK/BVSR, 2008)

Achievement of Output Target (%):
100% Based on the studies using advance breeding lines and core germplasm accessions in the last two years, correlations of grain Fe and Zn contents with grain yield and size and agronomic traits established.

Countries Involved:
India; Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

Progress/Results:
Among the 50 micronutrient dense germplasm lines, grain Fe contents revealed significant negative correlation with grain size indicating that small size gains had higher Fe contents than large grains. Zn content had significant positive correlation with plant height and Fe content; and significant negative correlation with grain yield indicating that lines having more Zn content are tall and also had higher Fe content, but they might record low grain yield. Among 23 breeding lines, the correlation studies revealed significant negative correlation between grain size and grain luster and positive correlation between Fe and Zn indicating that small and lustrous grains had higher Fe content and grains with high Fe content will have more Zn content also.

Special Project Funding:
HarvestPlus Challenge Program

A Ashok Kumar and Belum VS Reddy

Milestone 5C.1.1.3: G×E interactions for grain Fe and Zn contents assessed (AAK/BVSR/HDU, 2008)

Achievement of Output Target (%):
100% Based on the studies for two years, the G×E interactions for grain Fe and Zn contents were assessed in sorghum.

Countries Involved:
India; Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

Progress/Results:
Material for the study comprised of a set of selected 12 sorghum lines (including hybrid seed parents, restorer lines and popular varieties) contrasting (high and low) for grain Fe and Zn contents (high Fe: ICSR 40, IRAT 204; medium Fe: 296B, ICSB 38; low Fe: ICSV 21005, ICSV 745; high Zn: ICSV 93046, ICSR 90017; medium Zn: ICSB 52, ICSB 561; low Zn: ICSR 89004, ICSB 39). These were grown in Vertisols (medium black soil) and Alfisols (red sandy loam soils) with a combination of five different levels of micronutrients in the 2007 postrainy season. To rule out the possible confounding effect of deficiency of other micronutrients such as boron (B) and sulphur (S), Fe and Zn fertilization was combined with recommended levels of boron and sulphur. The five fertilization levels were-first level (T_1): recommended NPK + zero micronutrients; second level (T_2): recommended NPK + recommended Fe @ 10 kg ha^{-1}; (T_3): recommended NPK + recommended Fe @ 10 kg ha^{-1} + recommended S @ 30 kg ha^{-1} + recommended B @ 0.5 kg ha^{-1}; fourth level (T_4): recommended NPK + Zn @ 10 kg ha^{-1} + recommended S @ 30 kg ha^{-1} + recommended B @ 0.5 kg ha^{-1}; and fifth level (T_5): recommended NPK + Zn @ 10 kg ha^{-1}. The experiment was laid out in strip-plot design with three replications. The data were collected on plant growth traits such as days to 50% flowering, plant height, 100-grain weight, grain color, panicle shape, panicle compactness, glume color, glume coverage, grain color, presence/absence of seed sub coat and grain yield. Hand threshed selfed seed samples from each entry grown in each fertilizer level from each replication were analyzed for grain Fe and Zn contents in ICRISAT laboratory.

The analysis of variance indicated significant genetic variability among the genotypes indicating suitability of the material for the study. Soil type did not have significant effect on grain Fe and Zn content as indicated by the non-significant mean squares due to soil type. Non-significant variance due to micronutrient fertilization levels *per se* suggested lack of influence of soil micronutrient fertilization on grain Fe and Zn contents in any particular soil type. Numerically, while no pattern was observed for grain Fe content, grain Zn content seemed to be marginally higher when grown in Alfisols. The first-order and second-order interactions were also non-significant indicating absence of interaction effects on grain micronutrient contents and it leads to the conclusion that genetic potential of the lines need to be enhanced for improvement of grain Fe and Zn contents and that these two micronutrients are highly stable across a range of environments.

Special Project Funding:
HarvestPlus Challenge Program

A Ashok Kumar, Belum VS Reddy and HD Upadhyaya

Activity 5C 1.2 Conduct inheritance studies and develop mapping populations for Fe and Zn

Milestone 5C.1.2.2: F_6 RILs from at least one cross developed (BVSR/CTH, 2009)
Achievement of Output Target (%):
15% Selected 11 parents contrasting for grain Fe, grain Zn and both grain Fe and Zn contents and crossed in a diallel model.

Countries Involved:
India; Mali

Partners Involved:
NARS (Public and Private sector) in India and Mali

A total of 11 parents contrasting for grain Fe and Zn were crossed in a diallel pattern to generate F_1s in the 2007 postrainy season. The parents are being genotyped for estimating the molecular diversity. Based on the genotyping results, crosses involving more diverse parents (contrasting for grain Fe and Zn) will be advanced in the postrainy season 2008.

Special Project Funding:
HarvestPlus Challenge Program

A Ashok Kumar and Belum VS Reddy

II. Pearl millet

Output target 5C.1 Magnitude of variability for grain iron (Fe) and zinc (Zn) in more than 300 inbred lines, 50 improved populations, 400 germplasm accessions, and 40 commercial hybrids of pearl millet quantified, and at least three lines and three populations with high levels of Fe (65-75 ppm) and Zn (45-55 ppm) identified (2009)

Activity 5C1.1 Evaluation of germplasm, breeding lines and improved populations for grain Fe and Zn contents

Milestone 5C.1.1.1: Variability for Fe and Zn in designated hybrid parents, population progenies and improved populations developed in Africa and African regions quantified (KNR/RB//KLS, 2007)

Achievement of the Milestone (%):
100% A part of the information generated under this milestone was published in 2007, another part on populations documented in a publication (accepted as a JA), and data on designated hybrid parents was generated.
Countries Involved:
India

Partners Involved:
None

Progress/Results:
Variability study for Fe and Zn in improved populations from Asia and Africa had already been completed, reported in 2007 Archival Report, and now documented as a Journal Article in Crop Improvement (accepted in 2008). Based on the results of staining method in 2005, designated hybrid parents staining dark to medium blue (41 designated B-lines and 33 designated R-lines) were evaluated during the 2007 rainy season and 2008 postrainy season. Grains produced from these trials were analyzed for Fe and Zn contents. Based on the mean of the two trials, 25 B-lines had >70

ppm Fe, of which 9 had >60 ppm Zn content. In R-line trial, 7 lines had >70 ppm Fe, of which 4 lines had >60 ppm Zn contents. These lines will be evaluated for their stability in a range of environments in India.

Special Project Funding:
HarvestPlus Challenge Program

KN Rai, Ranjana Bhattacharjee, SK Gupta and KL Sahrawat

Milestone 5C.1.1.3: G×E interaction for Fe and Zn assessed and lines stable for >70 ppm Fe and >50 ppm Zn identified (KNR/RB/KLS, 2009)

Achievement of the Milestone (%):
60% Multilocation data from one year of trial on one set were generated and a second year multi-location trial will be done. From the second set, grain samples are yet to be received from all the locations and a second year trial will be done.

Countries Involved:
India

Partners Involved:
All India Coordinated Pearl Millet Improvement Project; Pearl Millet Hybrid Parents Research Consortium

Twenty-nine entries representing a wide range of Fe and Zn content (14 high, 8 medium, 6 low lines and an OPV check, WC-C 75) and selected from two seasons screening of a 120-entries trial, were field evaluated for G×E interaction at Patancheru in five different seasons (rainy and postrainy seasons of 2004 and 2005, and postrainy 2006). Grain Fe and Zn data from these have been generated. This trial had also evaluated at seven other locations in India from which grain samples were received from six locations (Gwalior, Jamnagar, Mandor and Kalai in northern India: and Coimbatore and Aurangabad in Peninsular India in 2006). These have now been analyzed for Fe and Zn contents.
Further, based on two seasons' data of a 69-population trial, 18 populations with diverse grain Fe and Zn density and two checks (WC-C 75 and RCB 2) were field tested during 2006 rainy and 2007 postrainy season at Patancheru for assessing the stability of grain Fe and Zn content. Grain samples had already been analyzed. This trial had been sent to six locations in India and grain samples were received only from one location. In 2008, it was evaluated in two environments (Alfisols and Vertisols) at Patancheru and sent to six locations in India. Grain samples have been produced from Patancheru trials, and also received from four locations and sent for analysis.

Special Project Funding:
HarvestPlus Challenge Program

KN Rai, SK Gupta, Ranjana Bhattacharjee and KL Sahrawat

Other studies:

Effect of dwarfing gene on grain Fe and Zn content: Twelve pairs of tall and d2 dwarf near-isogenic lines were evaluated during 2007 rainy and 2008 postrainy season. Grain samples produced were analyzed for Fe and Zn contents at the Waite Analytical Research Laboratory, Adelaide, Australia. Based on the mean of the two trials, the Fe content varied from 49−97 ppm in dwarf lines and from 42−105 ppm in tall lines, while Zn content varied from 48-90 ppm on dwarf lines and from 41−104 ppm in tall lines. Averaged over all the 12 lines, dwarf lines had 11% higher Fe and 8% higher Zn as compared to tall lines (64 ppm Fe and 62 ppm Zn). However, dwarf lines had 9% less 1000-seed weight as compared to the tall lines (6.8 g of 1000-seed weight). The correlation between the percent change in Fe or Zn and seed size in dwarf lines (or tall lines) was non-significant. Thus, it would appear that higher Fe and Zn contents in the dwarf lines was associated with smaller seed size as compared to the tall lines.

Inbreeding depression for grain Fe and Zn content: A trial of S_0 through S_4 bulks of three populations was conducted during the 2007 rainy season and 2008 postrainy season. Grain samples produced from these trials were analyzed at the Waite Analytical Research Laboratory, Australia for grain Fe and Zn contents. Based on the mean of the two trials, it was observed that Fe content among these populations varied from 45 to 58 ppm, Zn content from 47 to 53 ppm and 1000-seed weight from 11.3 to 13.2 g. As compared to the C_0 bulks, the Fe content in the S_4 bulks of the respective populations increased by 16 to 24% and Zn content increased by 8 to 18%, while seed size reduced by 13 to 22%. Thus, part of the reason for increase in the Fe and Zn contents in the S_4 bulks derived from four generations of inbreeding could be due to reduction in seed size. But, part of the reason could also be due to exposition of recessive alleles responsible for greater Fe and Zn contents.

KN Rai, Ranjana Bhattacharjee, SK Gupta and KL Sahrawat

Output target 5C.2 Information on genetics and recurrent selection efficiency for grain Fe and Zn available (2009)

Activity 5C2.1 Conduct genetical studies and recurrent selection for grain Fe and Zn contents and develop mapping populations

Milestone 5C.2.1.3: QTL for high grain Fe and Zn identified based on F6 RIL mapping populations from two crosses (CTH/SS/KNR, 2010)

No report submitted

MTP Project 6: **Producing More and Better Food at Lower Cost of Stable Open-Pollinated Cereals and Legumes (Sorghum, Pigeonpea, Chickpea and Groundnut) Through Genetic Improvement in the Asian SAT**

Project Coordinator: **PM Gaur**

Research highlights

Groundnut

- Five varieties were released for cultivation in India [ICGV 00440 (a confectionery type) for entire India, ICR 48 (ICGV 07356) for drought-prone areas of Rajasthan and Gujarat, Avatar (ICGV 93468) for spring season cultivation in Uttar Pradesh, Devi (ICGV 91114) for Orissa and Ajeya (ICGV 93261) for Maharashtra, Madhya Pradesh, Bihar, Orissa and West Bengal)].
- Market-preferred and farmer-preferred varieties of groundnut were identified across Tanzania, Malawi, Mali, Niger, Senegal and India. Of these, ICGV 00350, ICGV 00351, ICR 3, JAL 42, TIR 17, ICGS 76 and ICGV 91114 are tolerant to drought.
- A total of 1145 SSR markers available in public domain were screened on TAG 24 and ICGV 86031. As a result, 144 (12.6%) polymorphic markers were identified and these amplified a total of 150 loci. A total of 135 SSR loci could be mapped into 22 linkage groups (LGs). While six LGs had only two SSR loci, the other LGs contained 3 (LG15) to 15 (LG8) loci.
- Two to five QTLs for transpiration (T), transpiration efficiency (TE), specific leaf area (SLA) and SPAD chlorophyll meter reading (SCMR) were identified but the phenotypic variation explained by these QTLs was in the range of 3.5- 14.1%.
- Over 90 T_0 transgenic events have been produced through *Agrobacterium*-mediated genetic transformation of groundnut using binary construct pCAMBIA 2300: oleo-psy for ß-carotene enhancement. Seventy two T_0 events have been advanced to next generation. Extraction and quantification of the total carotenoids and ß-carotene in T_1 transgenic seeds revealed that level of total carotenoids was 10 to 12-fold higher in transgenic events as compared to the untransformed controls. ß-carotene was detected in several transgenic events whereas it did not fall into the detectable limits in the untransformed controls.
- Transgenic approach has been initiated for resistance to the *tobacco streak virus* (TSV) causing the stem necrosis disease in groundnut using the TSV coat protein (*TSVcp*) gene. Several (112) putative transgenic events of the popular groundnut cultivars JL 24, TMV 2, and ICGV 91114 were developed. PCR analysis confirmed integration of *TSVcp* transgene in 92 out of 112 events developed (82.14%). Further, ELISA/western analysis showed significant expression of the coat protein in at least 32 transgenic events.
- Over 20 putative transgenics using a 13S-lipoxygenase (*13S-LOX*) gene were produced for developing aflatoxin resistant groundnut. Molecular characterization of the primary transformants is underway using PCR, RT- PCR analysis.

Pigeonpea

- Nine *Helicoverpa*-resistant lines were evaluated for combined resistance to fusarium wilt (FW) and sterility mosaic (SM) under artificial epiphytotic conditions. Two lines (ICP 7035, ICPL 87119) had combined resistance to both FW and SM.
- Biparental progenies (107) of ICPW 94 x ICP 28 were evaluated for resistance to pod borer, *H. armigera*. Seven lines showed damage and recovery resistance levels comparable to the resistant checks, ICPL 187-1 and/or ICPL 332. Twenty-two lines had 70% healthy pods, as was the case with ICPL 332 and ICPL 187-1.
- Pigeonpea transgenics were developed using dicot codon optimized *Bt cry1Ac* gene constructs under the influence of Ubiquitin (pPZP200) and CaMV35S promoters (PRD 400) using seedling leaf petiole as the explant. A total of 125 independent T_0 transgenic events have been produced and transferred to contained greenhouse for further evaluation.
- Binary gene construct containing *SSA* gene driven by vicillin promoter (pHS723:SSA) in *Agrobacterium tumefaciens* strain C58 was used for the development of pigeonpea transgenics with enhanced levels of seed methionine content. A total of 37 putative transgenic plants were transferred to the containment greenhouse for further analysis. PCR analysis for the T_0 plants was carried out and 26 putative transgenic plants showed integration and expression of the transgene.
- Fifteen vegetable pigeonpea lines from Gujarat were screened for resistance to wilt and sterility mosaic diseases at Patancheru during 2007 rainy season. Of these, four lines were found resistant to sterility mosaic disease, but none of the lines was resistant to *Fusarium* wilt.
- Three hundred accessions of pigeonpea [150 genotypes of the mini core collection, 68 different wild accessions, 69 accessions selected from salinity prone areas worldwide (Bangladesh, Taiwan, Ethiopia, Indonesia, Argentina, Iran, and Brazil), and 13 genotypes from breeding material] and a few pigeonpea hybrids were screened for salinity tolerance based on the biomass under salt stress. Two genotypes belonging to *C. scaraboides* (ICPW 87 and ICPW 94) were most tolerant to salinity with salinity susceptibility index (SSI) value 0.03 and 0.28 and their relative biomass reduction was very small (2.0 and 18.6%).

Chickpea

- Sixty three International Chickpea Screening Nurseries (ICSNs), including 32 ICSN-Desi and 31 ICSN-Kabuli, were distributed to NARS partners across 8 countries for evaluation during 2007/08. The data received from 22 locations of India revealed that ICCV 07112 (2088 kg/ha) in ICSN-Desi and ICCV 06306 (1928 kg/ha) in ICSN-Kabuli were the most promising lines.
- Replicated yield trial on farmer's grown, extra-large (seed size > 50g/100 seed) kabuli chickpea cultivars was conducted during the crop season 2007/08. The entry PG 517 had best combination of earliness (DM 99 days), seed size (100-seed weight 57.0 g), resistance to fusarium wilt (wilt incidence 10.3 %) and yield (2640 kg/ha).
- In another trial on evaluation of large-seeded (seed size >40g/100 seed) kabuli chickpea genotypes, PG 95333 (ICCV 95333) was the best entry with high seed yield (2436 kg/ha), large seed seed size (100-seed weight - 41.1 g), early maturity (DM 89 days) and resistance to fusarium wilt (wilt incidence 9.1%).
- Segregating and advanced generation populations (F_4-F_6) were evaluated for fusarium wilt (FW) resistance (1838 lines) in the wilt sick plot and for ascochyt blight (AB) resistance (1987 lines) under controlled environment conditions. Ten lines were asymptomatic (0% incidence), 7 resistant (0.1-10%) and 53 moderately resistant to FW. For AB, 39 entries were resistant (1-3 rating on 1-9 scale) and 910 moderately resistant (3.1-5.0 rating). Five entries showed combined resistance (asymptomatic to wilt and moderately resistant reaction to AB) to both wilt and AB.
- Forty-four advanced breeding lines were evaluated for resistance to pod borer in two preliminary yield trials (22 entries + 2 checks). Based on pod borer damage and high yield, 28 promising lines were selected for advanced yield trials.
- To obtain transgenic chickpea plants engineered for resistance to *Helicoverpa armigera*, several *Bt* genes have been introgressed in popular chickpea cultivar C 235 through *Agrobacterium tumefaciens*-mediated genetic transformation. Six different gene constructs with

different promoters were used for efficient expression of *cry* genes.Over 200 independent T_1 transgenic events were produced using different *cry* genes and transferred to the contained greenhouse.

- Sixteen simple sequence repeat (SSR) markers with 2-19 alleles were found to be associated with ascochyta blight (AB) resistance and will be used in marker-assisted breeding for AB resistance.
- The BC_1F_1 populations of the crosses (ICCV 93954 × ICC 4958, ICCV 92318 × ICC 8261, ICCV 92311 × ICC8261) made for introgression of drought avoidance root traits from lines ICC 8261 (kabuli) and ICC 4958 (desi) were subjected to foreground selection using a set of 3 SSR markers (TAA170, ICCM 009a, and STMS21). Plants heterozygous for all the 3 markers (56) were used to generate the BC2F1 progenies.

Sorghum

- Efforts were made at ICRISAT, Patancheru to develop improved postrainy season varieties through incorporation of genes from M 35-1. Thirty-one varieties/R-lines were selected and evaluated during 2007 postrainy season along with the checks, M 35-1 and SPV 1411. For grain yield, 11 varieties (6.2 to 7.7 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.0 t ha^{-1}). In preliminary varietal trial, 69 varieties were evaluated during 2007 postrainy season along with the checks. For grain yield, seven varieties (6.8 to 7.6 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.6 t ha^{-1}).
- To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population (270 lines) based on ICSV 745 x PB 15220 was evaluated for stem borer resistance under artificial infestation in the field. Over all resistance score was 5.4 in PB 15220 and 7.0 in ICSV 745 compared to 4.8 in the resistant check, IS 2205; and 7.9 in the susceptible check, ICSV 1, the population mean being 6.2.
- Fourteen maintainer lines and 15 hybrids were evaluated for shoot fly resistance. Deadheart incidence in the maintainers ranged from 0.0 to 19.6%, and eight lines suffered <10% deadheart incidence compared to 7.6% in the resistant check, IS 18551, and 18.5% in cultivar Swarna. Deadheart incidence in the hybrids ranged from 7.1 to 23.6%, and five hybrids suffered <8.6% deadheart incidence compared to 5.3% deadhearts in the resistant check, IS 18551, and 23.6% deadhearts in CSH 16. Five hybrids and nine maintainer/restorer lines showed lower susceptibility to shoot fly than the susceptible check, Swarna.
- Twenty-nine sweet sorghum varieties/R-lines were evaluated for resistance to sorghum downy mildew. The incidence on test varieties varied from 29−100% compared to 18% on QL3 (known DM resistant line) under sandwich inoculation and 79−100% compared to 3% on QL 3 under spray-inoculation. Of the 53 elite hybrids, only 4 were found to be resistant (≤3.0 score) and 34 moderately resistant (score >3 to ≤5) to anthracnose compared to a 9.0 score on the susceptible check H 112. The hybrids that were resistant to anthracnose also exhibited moderate resistance to grain mold. Five of the 42 advanced hybrids were resistant to anthracnose. Twenty six of the 42 advanced hybrids were resistant (≤3.0 score) to grain mold and moderately resistant to anthracnose.
- Among 30 sweet sorghum varieties and R-lines, 5 lines showed resistance to anthracnose and moderate to high levels of resistance to grain mold. Ten of the 30 elite B-lines were resistant to anthracnose. Of the 70 hybrid parent lines, 21 were found resistant to anthracnose. Two lines ICSA 401 and SSV 53 were resistant to both the diseases.

MTP Output 1: Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of breeding methods and capacity building made available to partners internationally

Output target 2008 6.1.1 GN 8-10 elite breeding lines evaluated and selected for resistance to stem necrosis and bud necrosis virus diseases

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
ARS, ANGRAU, Anantapur and Kadiri, Andhra Pradesh, India.

Comments/Explanations:
Due to lack of access to natural hot spot locations in India, the reaction of lines tolerant to PBND and PSND, identified at ICRISAT Center either under low natural disease pressure or in glasshouse screening with artificial inoculation, could not be reconfirmed under field conditions.

Progress/Results
Peanut bud necrosis disease (PBND): PBND is caused by peanut bud necrosis virus (PBNV). The disease pressure at ICRISAT Center is very low to permit any meaningful field screening for resistance to PBND. Twenty advanced breeding lines, earlier identified as tolerant to PBND, were evaluated for agronomic traits in a preliminary trial in the 2007 rainy and 2007/08 postrainy seasons at ICRISAT, Patancheru. In the 2007 rainy season, two lines (3.6-3.3±0.18 t ha^{-1}pod yield) significantly outyielded the best control ICGS 44 (2.9 t ha^{-1}pod yield; 67% shelling outturn; 39 g hundred seed weight). The best line in the trial was ICGV 07084 (3.6 t ha^{-1}pod yield, 73% shelling outturn, 50 g HSW). However, in the 2007/08 postrainy season, none of the test entries could produce significantly higher pod yield than the best control. Although, ICGV 07084 with 4.9 t ha^{-1} pod yield ranked first, the yield difference with the best control was not statistically significant. It was the most promising line as it ranked first in both rainy and postrainy seasons.

Selected lines from this trial will be supplied, on request, to NARS for further evaluation at locations where PBND is prevalent in high intensity.

Peanut stem necrosis disease (PSND): PSND is caused by tobacco streak virus (TSV). It was first reported in groundnut in 2000. It is largely confined to Anantapur and adjoining areas in neighboring districts of Andhra Pradesh and Karnataka, India. In glasshouse screening done in the past, ICGV # 99029, 01276, 92267 and 00068 showed tolerance to TSV. These genotypes also possess tolerance to PBND, rust and late leaf spot. They will make useful parents in multiple diseases resistance breeding program. In wild *Arachis* species, ICG # 8139, 8195, 8200, 8203, 8205 and 11550 belonging to *A. duranensis*, ICG 8144 belonging to *A. villosa* and ICG 13210 belonging to *A. stenosperma* failed to show systemic infection in repeated inoculations. All these genotypes can be used effectively in interspecific breeding programs in Andhra Pradesh and Karnataka.

Special Project Funding:
The OPEC Fund for International Development

SN Nigam, R Aruna, Farid Waliyar and Varsha Wesley

Output Target 2008: 6.1.1 GN 50 lines of advanced generation interspecific derivatives of groundnut evaluated for LLS disease and promising lines identified

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
None

Partners Involved:
None

Progress/Results: The activity could not be carried out this year due to delayed and uncertain rains. The activity will be carried out in 2009

Special Project Funding:
None

Varsha Wesley and Nalini Mallikarjuna

Output Target 2008 6.1.2 CP Markers for Ascochyta Blight and Botrytis Grey mold resistance validated in a new population

Achievement of Output Target (%):
75%

Countries Involved:
None

Partners Involved:
None

Comments/Explanations:
The output target for AB resitance has been fully achieved. Genotypes for valiadation of markers for BGM resistance have been assembled and genotyping and phenotyping will be completed soon.

Progress/Results:
A set of 27 SSR markers reported to be linked with AB resistance QTLs were analyzed on 192 chickpea germplasm/breeding lines showing resistance/susceptible reaction to AB. Sixteen markers with 2-19 alleles were found to be associated with AB resistance. These markers will be used in marker-assisted breeding for AB resistance.
A set of genotypes (germplasm/breeding lines) with variable resistance to botrytis grey mold (BGM) has been assembled. These will be phenotyped for BGM resistance under controlled environments and genotyped with SSR markers earlier identified to be liked with BGM resistance QTLs.

Special Project Funding:
None

RK Varshney, C Siva Kumar, PM Gaur, S Pande, M Sharma and S Tripathi

Output target 2008 6.1.3 CP: Strategies to cross cultivated species with species of secondary and tertiary genepools developed

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Australia; Canada; India

Partners Involved:
CLIMA, Australia; University of Saskatoon, Canada

Comments/Explanations:

Progress/Results:
Techniques are available to cross annual wild *Cicer* from tertiary gene pool (Mallikarjuna et al., 2005; 2007). Since seed set was low in crosses between chickpea and wild species from the tertiary gene pool, *C. reticulatum* and *C. echinospermum*, both belonging to secondary gene pool and which are cross compatible with cultivated chickpea, were used as bridge species and crossed with *Cicer* species from the tertiary gene pool. Crosses between *C. bijugum* and *C. reticulatum* were successful, setting mature seeds, but crosses between *C. bijugum* and *C. echinospermum* were not successful. The hybrid between *C. bijugum* and *C. reticulatum* took longer than *C. bijugum*, but shorter than *C. reticulatum*, to flower. Mature seeds were obtained which resembled *C. bijugum*. Once confirmed through molecular analysis, *C. reticulatum* will be a bridge to transfer useful traits/genes from incompatible *Cicer* species.

Special Project Funding:
USAID

N Mallikarjuna

Output Target 2008 6.1.1 PP: New knowledge on vegetable pigeonpea production synthesized, published and disseminated to partners

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
None

Comments/Explanations:
This information bulletin contains information on various aspects of vegetable pigeonpea cultivation, processing, marketing, seed production and in appendices it has a number of recipes collected from different countries. This document is ready and it will be sent for publication as soon as we receive some more recipes from collaborating partners. It will be sent for professional editing and printing by the first week of April 2009.

Manuscript is near ready, except for the list of international pigeonpea recipes, which is awaited from the cooperators.

Special Project Funding:
Nil

KB Saxena

Output Target 2008 6.1.1 SO Lines with large grain and high grain yield (5) with resistance to shoot fly and adaptation to post-rainy season developed

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, India.

Comments/Explanations:
Efforts were made at ICRISAT, Patancheru to develop improved postrainy season varieties through incorporation of genes from M 35-1. The advanced progenies so obtained were tested in preliminary and advanced varietal trials.

Progress/Results:
Efforts were made at ICRISAT, Patancheru to develop improved postrainy season varieties through incorporation of genes from M 35-1. The advanced progenies so obtained were tested in preliminary and advanced varietal trials, the results of which are given below.

Advanced Varietal/Restorers Trial: To develop appropriate varieties for postrainy season, crosses were made involving postrainy landrace varieties (M 35-1, and six M 35-1 bulks) and improved varieties (SPV 1359, NTJ 2 and SPV 1380) at ICRISAT, Patancheru during 1999-2000 postrainy season. As a part of participatory plant breeding (PPB) program, the progenies derived from these crosses were selected by i) a farmer under farmers' (rainfed) condition and ii) the breeder in research station conditions (with initial two irrigations) from F_2 generation onwards. From these varieties, based on grain yield (≥ 3.7 t ha^{-1}), grain size (≥ 3.7 g 100^{-1} grains) and grain luster (≤ 3.0), 31 varieties/ R-lines were selected and evaluated during 2007 postrainy season along with the checks, M 35-1 and SPV 1411. For grain yield, 11 varieties (6.2 to 7.7 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.0 t ha^{-1}). These varieties flowered in 74 to 77 days (SPV 1411:76 days), reached a plant height of 1.7 to 3.0m (SPV 1411: 2.7m) and had a grain size of 4.0 to 4.7 g 100^{-1} grains (SPV 1411: 4.6 g 100^{-1} grains). All the varieties were numerically superior to M 35-1 for grain yield (3.6 t ha^{-1}).

Preliminary Varietal Trial: From several crosses involving postrainy varieties, 69 varieties were selected and evaluated during 2007 postrainy season along with the checks, M 35-1 and SPV 1411. For grain yield, seven varieties (6.8 to 7.6 t ha^{-1}) were numerically superior to the best performing check SPV 1411 (6.6 t ha^{-1}). These varieties flowered in 76 to 78 days (SPV 1411:77 days), reached a plant height of 2.2 to 2.9 m (SPV 1411: 2.4m) and had a grain size of 3.6 to 4.9 g 100^{-1} grains (SPV 1411: 4.7 g 100^{-1} grains). All the varieties except three were numerically superior to M 35-1 for grain yield (2.9 t ha^{-1}).

Evaluation of advanced and segregating material for resistance to shoot fly, *Atherigona soccata* during the postrainy season: Eighty F_5s along with the resistant, IS 18551 and susceptible, Swarna checks, were evaluated for shoot fly resistance. Deadheart incidence ranged from 1.7 to 47.0%, and 7 lines suffered <10% deadheart incidence compared to 5.6% in the resistant check, IS 18551, and 47.0% in Swarna. Of these, 18 lines exhibited leaf glossiness trait. In the F_7 trial, 153 lines were evaluated for shoot fly resistance along with resistant check IS 18551 and susceptible check Swarna. Deadheart incidence in the test material varied from 0.0 to 51%, and 47 lines suffered <10% deadhearts, and these lines were selected for further testing.

Special Project Funding:
Hybrid Parents Research Consortium; IFAD Biofuels project; Sehgal Foundation Endownment Fund Project on QTL mapping for stem borer resistance.

HC Sharma, A Ashok Kumar and BVS Reddy

Evaluation of mapping population for resistance to spotted stem borer, *Chilo partellus*: To identify molecular markers associated with resistance to spotted stem borer, *C. partellus*, the mapping population based on ICSV 745 x PB 15220 was evaluated for stem borer resistance under artificial infestation in the field. The mapping population (270 lines), along with the resistant (IS 2205) and susceptible checks (ICSV 1), and the parents (PB 15220 and ICSV 745) were planted in a balanced alpha design. Data were recorded on leaf feeding (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), deadheart formation (%), leaf sheath and plumule pigmentation (1 = highly pigmented, and 5 = Non-pigmented – green colored), stem tunneling (%), days to panicle initiation, recovery resistance (1= good recovery, 5 = poor), and agronomic score (1 = good, and 5 = poor). There was a significant variation in the traits studied in the mapping population. Leaf damage rating (DR) was 4.63 in the PB 15220 and 6.65 in ICSV 745 compared to 4.72 in the resistant check, IS 2205 and 7.92 in the susceptible check, ICSV 1. The RIL population mean was 6.03. Deadheart formation was 45.01% in PB 15220 and 81.48% in ICSV 745 compared to 19.36% in the resistant check - IS 2205, and 83.30% in the susceptible check ICSV 1. Over all resistance score was 5.44 in the PB 15220 and 7.00 in ICSV 745 compared to 4.83 in the resistant check, IS 2205; and 7.92 in the susceptible check, ICSV 1, the population mean being 6.19.data analysis is in progress to identify QTLs associated with resistance to *C. partellus*.

HC Sharma, CT Hash and BVS Reddy

MTP Output 2: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of legume mandate crops and associated capacity building made available to partners internationally

Output target 2008 6.2.1 GN New breeding strategies for drought tolerance in groundnut using surrogate traits developed

Achievement of Output Target (%):
>75%

Countries Involved:
Malawi; Niger; Tanzania; Senegal

Partners Involved:
National programs in Malawi, Tanzania, Niger, Senegal

Comments/Explanations:
While we are now confident that TE contributes to a substantial portion of the yield variation under intermittent drought, more work and analysis is needed to understand the inter-relations between TE and other component traits such as HI or T. So, as such, the new breeding strategy based on trait is established but there is still a lot more knowledge to gain on each of these traits.

Progress/Results:

Efforts have been made in the past to develop groundnut genotypes having tolerance to drought, and using conventional techniques. In the past 15 years, a trait-based approach has also been used to improve drought tolerance in groundnut. However, this approach has not proved to be any better (neither worse) than a conventional approach. This approach was based on breeding for transpiration efficiency (TE), a trait that has been reported to be the major trait contributing to intermittent drought tolerance in groundnut. A drawback to this approach has been the widespread use of surrogate traits of TE, such as the specific leaf area (SLA), or the Spad chlorophyll meter reading (SCMR). However, recent data show that these surrogates are not always showing a close correlation to TE.

In a new breeding strategy, we attempt to bring together other traits potentially responsible for a better performance under drought conditions. Indeed, TE is only one of the components of the yield architecture in crops, and work in groundnut is now addressing how rooting traits and differences in the harvest index (due to putative differences in the success of reproduction under drought stress) can contribute to contrast in "drought tolerance", i.e. yield under drought stress. In addition, the recent construction of reference collection in the groundnut germplasm has allowed a wider screening of the diversity for these traits, so that mapping populations using parents with large contrast can be developed. Current phenotyping efforts focus to: (i) assess the range of variations for these traits (rooting, TE, HI) across the reference collection of germplasm; (ii) test the interactions between these traits and assess which of them contribute to better yields under particular stress conditions. A major progress in that effort has been the development of a large throuput phenotyping facility that allows the simultaneous measurement of these different traits, without the need to use surrogate traits. In parallel, genomic tools are being dev eloped to enhance the number of molecular markers that can be used to undertake modern breeding.

Special Project Funding:
BMGF Tropical Legumes I

V Vadez, L Krishnamurthy, P Ratnakumar, SN Nigam and R Aruna

Output target 2008 6.2.2 GN Molecular markers ready for validation in introgression studies for abiotic stresses

Achievement of Output Target (%):
>75%

Countries Involved:
Malawi; Niger; Senegal; Tanzania

Partners Involved:
National programs in Malawi, Tanzania, Niger, Senegal

Comments/Explanations:
We have identified molecular markers for TE. However, the percentage variation
explained by these is low (10%). We could not predict this when starting the work. We have some explanation for this low value of resolution and are attempting to develop more robust markers now. Another explanation is the lack of a sufficient range of variation between the lines that were used to develop the populations. There, new populations need to be developed.

Progress/Results:
Two populations (TAG24 x ICGV86031) and ICGS76 x CSMG84-1 have been developed in the past to map QTL for transpiration efficiency (TE). Three phenotyping experiments have been carried out in the first population in the summer of 2004 and 2005, and in the rainy season of 2008. The range of variation for TE among the RILs in 2004 and 2005 remained fairly low, and the parental lines were not very different (although a good segregation pattern was obtained). This contrasted from the large contrast previously obtained between the parental lines, and which led to choosing these parents to develop a population. From these data, the first cultivated groundnut map has been assembled. A total of 1145 SSR markers available in public domain were screened on TAG 24 and ICGV 86031. As a result, 144 (12.6%) polymorphic markers were identified and these amplified a total of 150 loci. A total of 135 SSR loci could be mapped into 22 linkage groups (LGs). While six LGs had only two SSR loci, the other LGs contained 3 (LG15) to 15 (LG8) loci. The mapping population used for developing the genetic map segregates for drought tolerance traits, and phenotyping data obtained for transpiration (T), transpiration efficiency (TE), specific leaf area (SLA) and SPAD chlorophyll meter reading (SCMR) for two years were analyzed together with genotyping data. Although, 2-5 QTLs for each trait mentioned above were identified, the phenotypic variation explained by these QTLs was in the range of 3.5- 14.1%. In addition, alignment of two linkage groups (LG 3 and LG 6) of the developed genetic map was shown with available genetic maps of AA diploid genome of groundnut and *Lotus* and *Medicago.* Therefore, although none of the QTL identified so far would be useful for a breeding program, the present study reports the construction of the first genetic map for cultivated groundnut and demonstrates its utility for molecular mapping of drought tolerance related traits as well as establishing relationships with diploid AA genome of groundnut and model legume genome species. Therefore, the map should still be useful for the scientific community for a variety of applications.

To better understand the reasons for this lack of large range of contrast among the RIL, we assessed TE in the parental lines TAG24 and ICGV86031 across a range of vapor pressure deficit (VPD) conditions. Interestingly, we found that TE differences between these lines were high when assessment was done under low VPD. This corroborated well the data obtained in the past when these lines were screened under glasshouse conditions (characterized by low VPD conditions). By contrast, the TE differences decreased as VPD increased. This overall decrease in TE upon VPD increase agrees well with the theory (which states that TE is inversely proportional to VPD). However, a striking feature of these data was that the slope of the decrease in TE as a function of VPD increase was different for TAG24 and ICGV86031. In other words, TE decreased relatively more at high VPD in ICGV86031 than in TAG24. This behavior would then explain the limited range of variation found for TE among the RIL, knowing that the assessment was done in outdoor conditions at fairly high VPD (above 3.0 kPa). Therefore, we have again phenotyped this population under more humid conditions, during the rainy season 2008. Data still need to be analyzed.

Special Project Funding:
BMGF Tropical Legumes I

V Vadez, L Krishnamurthy, P Ratnakumar, SN Nigam and R Aruna

Output target 2008 6.2.1 CP Phenotyping of ICCV 2 x JG 62 mapping population for salinity tolerance completed and marker data available for QTL mapping

Achievement of Output Target (%):
Fully Achieved

Countries Involved:
Australia; India

Partners Involved:
University of Western Australia, CLIMA

Special Project Funding:
Project from Council of Grain Grower Organization Ltd (COGGO), Western Australia; ARC-Linkage Grant, Australia

Progress/Results:
Phenotyping of ICCV 2 x JG 62 population for salinity tolerance: In the past years (2005-06, 2006-07, and 2007-08), three sets of phenotyping data have been generated. Data have been analyzed and reported in previous archival reports. The QTL mapping can therefore be done on these yield data under saline and non-saline conditions. However, we have also shown that early maturity and late maturity genotypes of chickpea tended to be less tolerant to salinity than medium duration genotypes, showing that flowering time interacts with salinity response under ICRISAT-Patancheru conditions (i.e. short season length for chickpea). Tolerant JG62 has an early to medium flowering time (around 40-45 days after sowing), compare to extra early sensitive ICCV2 (30-35 DAS). Analysis of the phenotypic data shows that the RIL strongly segregate for time to flowering. Therefore, the QTL analysis will likely have to be done after separating the two groups of RIL according to their flowering time, to ensure that putative QTLs for salinity tolerance are not confounded with QTLs for flowering time.

Vincent Vadez, L Krishnamurthy, RK Varshney and PM Gaur

Genotyping of ICCV 2 x JG 62 population: In order to identify and map QTLs for salinity tolerance in chickpea, genotyping data have been generated for 204 markers on the 126 RILs of mapping population ICCV 2 × JG 62. The segregation data are being used to calculate the map distance. Genotyping and phenotyping data will be analyzed to identify QTLs for salinity tolerance.

RK Varshney, T Mahender, V Vadez, L Krishnamurthy and PM Gaur

Output 3: Knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification breeding, improved germplasm of pearl millet, sorghum, groundnut and pigeon pea crops and associated capacity building made available to partners internationally

Output target 2008 6.3.1 FORT At least 8 groundnut candidate psy1 events with beta- carotene selected for contained field trial

Achievement of Output Target (%):
>75%

Countries Involved:
India

Partners Involved:
National Institute of Nutrition, Hyderabad, India

Comments/Explanations:
Hence, a large sample size is not possible in T1 generation which slowed down the estimations. Moreover, despite several attempts and discussions with experts, it has not been possible, so far, to accurately quantify the level of ß-carotene in groundnut due to the presence of large quantities of oil which interferes with HPLC estimations. We hope to complete this aspect during 2009.

Progress/Results:
Over 90 T_0 transgenic events have been produced through *Agrobacterium*-mediated genetic transformation of groundnut using binary construct pCAMBIA 2300: oleo-psy for ß-carotene enhancement. Seventy two T_0 events have been advanced to next generation. Molecular analysis of the transgenic events using PCR with gene-specific primers revealed the integration and presence of the transgene. The inheritance pattern was studied in the transgenic events which confirmed Mendelian segregation in most of the transgenic events. Transgene expression in the developing pods of groundnut was observed by RT- PCR analysis. The presence of mRNA transcripts for *Zea mays phytoene synthase 1*(zmpsy1) gene was observed in the transgenic plants. Southern analysis was carried out with selected events and copy number ranged from one to three. Extraction and quantification of the total carotenoids and ß-carotene in T_1 transgenic seeds was carried out for screening the events. The level of total carotenoids was 10 to 12-fold higher in transgenic events as compared to the untransformed controls. Events which showed high total carotenoids were subjected to HPLC for profiling of individual carotenoids. It was observed that lutein was predominantly high in most of the events and showed as high as a 20-fold increase as compared to control. ß-carotene was detected in several transgenic events whereas it did not fall into the detectable limits in the untransformed controls.

Besides, 30 marker free transgenic events of oleo:psy carryied by a modified pCambia2300 (without *npt*II marker) and 42 events carrying Pzp200.oleo.psy have been produced. The transformation efficiency is observed to be as high as 70 % using these marker free systems. Nine events were advanced to T_1 generation based on preliminary molecular data on presence, expression and stability of the transgene. So far 7 events have been progressed to T_1 generation. The total carotenoid level in these transgenic events was 6-fold higher than the untransformed control. The individual carotenoid profiling of these events is underway.

An intriguing observation was that the transgenics had much higher lutein content amongst the individual carotenoids. Since, *ß-lycopene cyclase* (*BLYC*) is the key enzyme involved in ß-carotene synthesis pathway (where lutein to γ carotene and γ carotene to ß-carotene conversions take place), we assume that over expression of *BLYC* may result in much higher accumulation of ß-carotene. On the basis of sequence information available we have cloned the *BLYC* gene from tomato in pGEMT-Easy vector and got it sequenced. This will be subsequenty cloned in binary vectors either to be used for pyramiding of the two genes or for transforming the existing ole:psy transgenic plants to meet the target levels of provitamin A.

Special Project Funding:
HarvestPlus Challenge Program

KK Sharma, P Bhatnagar-Mathur, SN Nigam and R Aruna

Output Target 2008 6.3.5 CB Training course on chickpea production organized

Achievement of Output Target:
Fully Achieved

Countries Involved:
India; Ethiopia; Kenya ; Myanmar; Tanzania

Partners Involved:
Department of Agricultural Research (DAR), Yezin, Myanmar
Myanma Agricultural Services (MAS), Myanmar; Ethiopian Institute of Agricultural Research (EIAR), Addis Ababa, Ethiopia; Kenya Agricultural Research Institute (KARI), Nairobi, Kenya; Lake Zone Agricultural Research and Development Institute (LZARDI), Ukiriguru, Tanzania

Special Project Funding:
Tropical Legumes II Project, funded by Bill and Melinda Gates Foundation; ACIAR Legumes Project in Myanmar

Progress/Results:
Nine researchers (5 male + 4 female) from Ethiopia, Tanzania, Kenya and Myanmar were provided 20 days to 3 months training on "Chickpea Breeding and Seed Production" at ICRISAT Patancheru during December 2007 to March 2008 (Table 6.1). The topics covered included conventional and biotechnological approaches of chickpea improvement, improved technologies for chickpea cultivation and seed production. These scientists also received training on screening for resistance and management of root and foliar diseases of chickpea.

Table 6.1: Trainees of chickpea breeding and seed production course

Name of trainee	Gender	Country	Designation and affiliation	Duration of training
Mussa J. Hedo	Male	Ethiopia	Asst. Researcher (Breeding), Debre Zeit Agricultural Research Center, Debre Zeit.	1 month (7th Jan-6th Feb 08)
Ketema D. Abdi	Male	Ethiopia	Asst. Researcher (Breeding), Debre Zeit Agricultural Research Center, Debre Zeit.	1 month (7th Jan-6th Feb 08)
Robert O. Kileo	Male	Tanzania	Principal Research Officer (Agri), Lake Zone Agricultural Research Institute, Ukiriguru, Mwanza.	1 month (7th Jan-8th Feb 08)
Everina P. Lukonge	Female	Tanzania	Principal Research Officer (Agri), Agricultural Research and Training Institute, Ukiriguru, Mwanza.	1 month (7th Jan-8th Feb 08)
Paul K. Kimurto	Male	Kenya	Dept. of Crops and Soil Sciences, Egerton University, Nairobi.	20 days (18th Jan-6th Feb 08)
Peter Kaloki	Male	Kenya	Technician, ICRISAT-Nairobi	21 days (15th Dec 07 to 4th Jan 2008)
Moe Moe Zaw	Female	Myanmar	Senior Research Asst., Agriculture Research Farm, Myingyan, Mandalay	3 months (6th Dec 07 to 5 Mar 2008)
San San Yu	Female	Myanmar	Senior Research Asst., DAR-Yezin	3 months (6th Dec 07 to 5 Mar 2008)
	Female	Myanmar	Senior Research Asst., DAR-Yezin	3 months (6th Dec 07 to 5 Mar 2008)

CLL Gowda, PM Gaur, Shailesh Tripathi, HC Sharma, Suresh Pande and Mamta Sharma

Output 6.1: Improved germplasm and varieties of sorghum, pigeonpea, chickpea and groundnut with pro-poor traits and associated advanced knowledge of selection tools and breeding methods made available to partners internationally

GROUNDNUT

Output target 6.1.1 GN Each year 50-60 diverse trait-specific (resistance to rust, late leaf spot (LLS), and other emerging diseases and pests, short- and medium-duration, dual-purpose (food and fodder), oil types and confectionery types), high yielding breeding populations and advanced breeding lines developed

Activity 6.1.1.1 GN Evaluate and introgress new germplasm sources (cultivated and wild *Arachis* species) of variability for yield components, resistance to rust, LLS, and other emerging diseases, crop duration and food and fodder quality traits

Milestone: 10-15 new high yielding lines with resistance to aforementioned biotic stresses and quality and adaptation traits identified and made available to NARS (SNN/RA/VW) Annual

Achievement of Output Target (%):
100%
Countries Involved:
None

Partners Involved:
None

Progress/Results:
New Crosses: One hundred and two new crosses (29 for foliar diseases resistance, 25 for short-duration, 28 for medium-duration with high oil content and 20 for confectionery traits) were completed in the 2007/08 postrainy and 2008 rainy seasons to generate populations for selection for high yield, disease resistance, required crop-duration and confectionery traits in desirable agronomic backgrounds. New parents used in hybridization included: LCBG # 2, 5, 7 and 8 and ICGV # 06125, 07106, 06175, 04060, 04058, 05092, 06142, 06184 and 05089 for resistance to foliar diseases; ICGV # 06285, 00337, 00309, 02005, 02038, 02022, 06282 and 99195, ICIAR 19 BT, TS 32-1, FLEUR 11 and L 24 for short-duration; GPBD 4 and ICGV # 05036, 06021, 07038, 07063, 98432, 01477, 07075, 06118, 05057, 06018, 07018, 03042, 06420, 00350, 00351 and 01279 for medium-duration and high oil content and NC Ac 17352 and ICGV # 05036, 06021, 07038, 07063, ICGV 07358, 06214, 06211 and 00440 for confectionery traits. The new parents involved germplasm accessions, advanced breeding lines, released cultivars and interspecific derivatives.

Resistance to Foliar Diseases

Breeding populations: As foliar diseases pressure in the postrainy season is low, 229 F_2-F_7 bulks and 95 single plant progenies were sown in the 2007/08 postrainy season mainly for selection for agronomic traits. From these, 163 F_2-F_7 bulk selections were made. Of these, 54 in advanced generations were identified for inclusion in replicated yield trials. Promising selections came from [(ICGS 44 x (ICGV 87128 x ICGV 00246)], (ICGV 91114 x ICGV 98167), (ICGV 02429 x ICGV 98167) and (ICGV 99160 x ICGV 94118) crosses.

Yield trials: Results of agronomic traits and diseases reaction, obtained from elite and advanced trials conducted in the 2007 rainy season (not reported in the 2007 Archival report), are discussed here. Disease reaction was recorded under infector-row system on a 1-9 scale, where 1= no disease and 9= 81-100% foliage damaged. In the 2007/08 postrainy season, these lines were evaluated only for agronomic traits.

***2007 rainy season*:** In an Elite Trial (Spanish), ICGV 06125 produced significantly higher pod yield (4.3 t ha^{-1}pod yield, 65% shelling outturn, 50 g 100-seed weight (HSW), rust score 2.0, LLS score 6.5) than the highest yielding control ICGV 86590 (3.1±0.39 t ha^{-1}pod yield, 62% shelling outturn, 29 g HSW, rust score (at 104 DAS) 2.2, LLS score (at 104 DAS) 8.0).

In an Advanced Trial (Spanish), 20 varieties gave significantly higher pod yield (4.5-3.6 t ha^{-1}) than the highest yielding control GPBD 4 (3.0±0.29 t ha^{-1}pod yield, 67% shelling outturn, 27 g HSW, rust score 3.0, LLS score 6.0) in the trial. The highest yielding genotypes in the trial were ICGV 07106 (4.5 t ha^{-1}pod yield, 67% shelling outturn, 38 g HSW, rust score 2.0, LLS score 5.0) and ICGV 06149 (4.5 t ha^{-1}pod yield, 64% shelling outturn, 36 g HSW, rust score 2.0, LLS score 5.0).

In an Advanced Trial (Virginia), six varieties (4.7-3.9 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGV 86699 (3.3±0.19 t ha^{-}1pod yield with 68% shelling outturn, 52 g HSW, rust score 2.0, LLS score 6.5). ICGV 06175 produced the highest pod yield (4.7 t ha^{-1} pod yield with 69% shelling outturn, 42 g HSW, rust score 2.0, LLS score 6.0) followed by ICGV 07110 (4.4 t ha^{-1}pod yield, 66% shelling outturn, 43 g HSW, rust score 2.0, LLS score 6.0).

***2007/08 postrainy season*:** In an Elite Trial (Spanish), four varieties produced significantly higher pod yield (5.8-5.6±0.33 t ha^{-1}) than the highest yielding control ICGV 86590 (4.9 t ha^{-1} pod yield, 72% shelling outturn, 48 g HSW, oil content (%) 47, protein content (%) 24). ICGV 05092 gave the highest pod yield (5.8 t ha^{-1} pod yield, 74% shelling outturn, 61 g HSW, oil content (%) 44, protein content (%) 26) followed by ICGV 05089 (5.7 t ha^{-1} pod yield, 75% shelling outturn, 64 g HSW, oil content (%) 50, protein content (%) 28).

In an Advanced Trial (Spanish), two varieties (6.4-6.3±0.57 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGV 86590 (5.1 t ha^{-1} pod yield, 73% shelling outturn, 52 g HSW, oil content (%) 48). ICGV 06142 produced the highest pod yield (6.4 t ha^{-1} pod yield, 76% shelling outturn, 42 g HSW, oil content (%) 52). It had also significantly outperformed the best control in the 2007 rainy season trial.

In an Advanced Trial (Virginia), nine varieties (6.1-5.7±0.41 t ha^{-1}pod yield) produced significantly higher pod yield than the highest yielding control ICGV 86699 (4.8 t ha^{-1} pod yield, 72% shelling outturn, 60 g HSW, oil content (%) 48). ICGV 06184 gave the highest pod yield (6.1 t ha^{-1} pod yield, 72% shelling outturn, 53 g HSW, oil content (%) 49) followed by ICGV 06161 (5.9 t ha^{-1} pod yield, 70% shelling outturn, 66 g HSW, oil content (%) 51). The former had also outperformed the best control in the 2007 rainy season trial.

From the varieties included in elite trials, four Spanish and two Virginia varieties, based on their performance in rainy and postrainy seasons, were selected for inclusion in future international trials.

2008 rainy season: Due to shortage of irrigation water and delayed onset of monsoon, no foliar diseases resistant breeding populations and trials were sown in the 2008 rainy season.

Short-duration

Breeding populations: Among 117 F_2-F_7 bulk populations and 310 single plant progenies, grown in the 2007/08 postrainy season, 107 F_2-F_7 bulk and 47 single plant selections were made based on desirable agronomic traits. The most promising selections came from (ICGV 98294 x ICG 3540), (ICGV 01279 x ICGV 92206) and (ICGV 00308 x ICG 3540) crosses. Similarly, in 126 bulk populations and 45 single plant progenies grown in the 2008 rainy season, 123 F_2-F_8 bulk and 110 single plant selections, based on agronomic traits, were made. The most promising selections came from (ICGV 98294 x ICG 3540) and (ICGV 99258 X ICGV 02126) crosses.

Yield trials: Elite short-duration varietal trials are staggered harvested at 75 DAS and 90 DAS in the rainy season. In the postrainy season, they are harvested when genotypes accumulate CTT (cumulative thermal time) equivalent to 75 DAS (1240 $^{\circ}$Cd) and 90 DAS (1470 $^{\circ}$Cd) in the rainy season. Advanced trials are harvested only at 90 DAS. Results of only elite and advanced trials are discussed here.

***2007 rainy season*:** In an ESVG Trial-1 at 75 DAS harvest, five varieties significantly outyielded (3.1-2.6± 0.14 t ha^{-1} pod yield) the highest yielding early-maturing control Dh 86 (2.2 t ha^{-1} pod yield, 59% shelling outturn, 28 g HSW). ICGV 06285 ranked first in pod yield (3.1 t ha^{-1}pod yield, 62% outturn and 31 g HSW) followed by ICGV 06237 (2.9 t ha^{-1}pod yield, 62% shelling outturn and 29 g HSW). At 90 DAS harvest, four varieties outyielded (3.7-3.4± 0.20 t ha^{-1}pod yield) the highest yielding early-maturing control Dh 86 (2.8 t ha^{-1} pod yield, 66% shelling outturn, 32 g HSW). ICGV 06281 (3.7 t ha^{-1}pod yield, 64% shelling outturn and 35 g HSW), ICGV 06285 (3.6 t ha^{-1} pod yield, 68% shelling outturn and 36 g HSW) and ICGV 06282 (3.5 t ha^{-1}pod yield, 62% shelling outturn and 33 g HSW) were the most promising varieties. ICGV# 06281, 06285 and 06282 were among the top four entries at 75 DAS and 90 DAS harvests.

In an ASVG Trial at 90 DAS harvest, three varieties outperformed (3.4-3.2± 0.25 t ha^{-1}pod yield) the highest yielding early-maturing control Dh 86 (2.6 t ha^{-1} pod yield, 67% shelling outturn, 33 g HSW). ICGV 07212 ranked first in the trial (3.5 t ha^{-1}pod yield, 60% shelling outturn and 33 g HSW).

***2007/08 postrainy season*:** In an ESVG Trial-1 at 75 DAS harvest, two varieties (2.8-2.7± 0.09 t ha^{-1}pod yield) outyielded the highest yielding, early-maturing control ICGV 91114 (2.4 t ha^{-1} pod yield, 74% shelling outturn, 45 g HSW). ICGV 06282 ranked first in pod yield (2.8 t ha^{-1}pod yield, 70% shelling outturn and 41 g HSW) followed by ICGV 06279 (2.7 t ha^{-1}pod yield, 64% shelling outturn and 36 g HSW). At 90 DAS harvest, only ICGV 04003 could outyield (3.7 t ha^{-1}pod yield, 64% shelling outturn and 37 g HSW) the highest yielding control.

In an ESVG Trial-2 at 90 DAS harvest, six varieties outperformed (3.9-3.6± 0.11 t ha^{-1}pod yield) the highest yielding early-maturing control ICGV 91114 (3.3 t ha^{-1} pod yield, 67% shelling outturn, 43 g HSW). ICGV 99195 ranked first in pod yield (3.9 t ha^{-1}pod yield, 70% shelling outturn and 40 g HSW) followed by ICGV 96346 (3.8 t ha^{-1}pod yield, 72% shelling outturn and 37 g HSW).

Four Spanish varieties from elite trials were selected for inclusion in future International trials.

***2008 rainy season*:** Forty-one advanced breeding lines (including controls) in two replicated trials were evaluated in the 2008 rainy season. The trial data are being analyzed.

Medium-duration

Breeding populations: Based on agronomic traits, 116 F_2- F_7 bulk and 99 single plant selections were made in 106 F_2- F_7 bulk populations and 150 single plant progenies grown in the 2007/08 postrainy season. The most promising selections came from (ICGV 99212 x ICGV 00196), (TAG 24 x ICG 13919) and (ICGV 00337 x ICGV 99258) crosses. From the selected bulks, 46 were identified for inclusion in replicated yield trials. In the 2008 rainy season, 84 bulk populations and 99 plant progenies were sown for evaluation. From these, 160 F_2-F_7 bulk and 76 single plant selections were made. The most promising selections came from (ICGV 99159 x ICGV 95042) and (ICGV 99159 x ICGV 95047) crosses.

Yield trials: One hundred and ninety-three advanced breeding lines including controls in six replicated trials in the 2007 rainy season and 218 advanced breeding lines including controls in seven replicated trials in the 2007/08 postrainy season were evaluated. However, results only from elite and advanced trials are discussed here.

2007 rainy season**:** Seventeen (5.7-3.8 t ha^{-1}pod yield) of the 18 test varieties in an EMGV Trial (Spanish) significantly outyielded the highest yielding control GPBD 4 (2.8±0.40 t ha^{-1}pod yield, 60% shelling outturn, 35 g HSW). In this trial six varieties gave more than 5 t ha^{-1}pod yield. ICGV 05036 ranked first (5.7 t ha^{-1}pod yield, 66% shelling outturn, 48 g HSW) followed by ICGV 05035 (5.4 t ha^{-1}pod yield, 68% shelling outturn, 51 g HSW).

In an EMGV Trial (Virginia), 13 out of 15 test varieties produced significantly higher pod yield (5.1-3.3 t ha^{-1}) than the highest yielding control M 335 (2.4±0.31 t ha^{-1}pod yield, 67% shelling outturn, 42 g HSW). ICGV 06021 ranked first in pod yield (5.1t ha^{-1}pod yield, 66% shelling outturn, 58 g HSW) followed by ICGV 05057 (4.8 t ha^{-1}pod yield, 70% shelling outturn, 48 g HSW).

In an AMGV Trial (Spanish), 35 (5.3-3.5 t ha^{-1}pod yield) out of 64 test varieties significantly outperformed the highest yielding control ICGS 44 (2.8±0.35 t ha^{-1}pod yield, 69% shelling outturn, 34 g HSW). ICGV 07038 ranked first in pod yield (5.4 t ha^{-1}pod yield, 71% shelling outturn, 41g HSW) followed by ICGV 06041 (5.1 t ha^{-1}pod yield, 72% shelling outturn, 47 g HSW).

In an AMGV Trial (Virginia), eight varieties produced significantly higher pod yield (4.4-3.4 t ha^{-1}) than the highest yielding control ICGV 86325 (2.4±0.29 t ha^{-1}pod yield, 66% shelling outturn, 28 g HSW). ICGV 07043 ranked first in pod yield (4.4 t ha^{-1}pod yield, 70% shelling outturn, 37 g HSW) followed by ICGV 07040 (4.3 t ha^{-1}pod yield, 67% shelling outturn, 43 g HSW).

2007/08 postrainy season**:** In an EMGV Trial (Spanish), 12 varieties (5.8-5.1±0.40 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGS 44 (4.2 t ha^{-1}pod yield, 73% shelling outturn, 55 g HSW, oil content (%) 48, protein content (%) 27). ICGV 06018 ranked first in pod yield (5.8 t ha^{-1}pod yield, 70% shelling outturn, 56 g HSW, oil content (%) 50, protein content (%) 26) followed by ICGV 05035 (5.7 t ha^{-1} pod yield, 70% shelling outturn, 61 g 100 HSW, oil content (%) 51, protein content (%) 25). ICGV 05035 ranked second in pod yield in both rainy and postrainy season trials.

In an EMGV Trial (Virginia), two varieties (5.4-5.3±0.36 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGS 76 (4.4 t ha^{-1}pod yield, 72% shelling outturn, 55 g HSW, oil content (%) 44, protein content (%) 25). ICGV 05057 ranked first in pod yield (5.4 t ha^{-1}pod yield, 72% shelling outturn, 57 g HSW, oil content (%) 50, protein content (%) 25. ICGV # 05057 and 06021 were the top two varieties in both rainy and postrainy season trials.

In an AMGV Trial (Spanish), three varieties gave significantly higher pod yield (5.3-5.0±0.32 t ha^{-1}) than the highest yielding control ICGV 95070 (4.3 t ha^{-1}pod yield, 71% shelling outturn, 54 g HSW, oil content (%) 49). ICGV 07018 ranked first in pod yield (5.3 t ha^{-1}pod yield, 74% shelling outturn, 53 g HSW, oil content (%) 50) followed by ICGV 07023 (5.0 t ha^{-1} pod yield, 74% shelling outturn, 55 g HSW, oil content (%) 54).

In an AMGV Trial (Virginia), two varieties produced significantly higher pod yield (5.5-5.4±0.42 t ha^{-1} pod yield) than the highest yielding control ICGS 76 (4.5 t ha^{-1}pod yield, 75% shelling outturn, 64 g HSW, oil content (%) 44). ICGV 06118 ranked first in pod yield (5.5 t ha^{-1}pod yield, 72% shelling outturn, 85 g HSW, oil content (%) 47) followed by ICGV 06122 (5.4 t ha^{-1}pod yield, 73% shelling outturn, 75 g HSW, oil content (%) 50). ICGV 06118 outperformed the highest yielding control in both rainy and postrainy season trials.

In a High Oil Content Groundnut Varietal Trial, 12 varieties (6.4-5.7 ±0.11 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGV 00351 (5.2 t ha^{-1}pod yield, 73% shelling outturn, 46 g HSW, oil content (%) 54, protein content (%) 24). ICGV 03042 ranked first in pod yield (6.4 t ha^{-1}pod yield, 73% shelling outturn, 48 g HSW, oil content (%) 52, protein content (%) 24) followed by ICGV 03043 (6.2 t ha^{-1}pod yield, 73% shelling outturn, 51 g HSW, oil content (%) 52, protein content (%) 24).

Eight Spanish and five Virginia varieties were selected for inclusion in future International trials.

2008 rainy season**:** Data on 168 advanced breeding lines including controls in six replicated trials and 220 high oil and protein contents advanced breeding lines including controls in two replicated trials, evaluated in the 2008 rainy season, are under processing.

Confectionery Traits

Breeding populations: During the 2007/08 postrainy season, 322 F_2-F_6 bulk populations and 85 single plant progenies were sown for evaluation. From these, 179 F_2-F_6 bulk and 112 single plants were selected for further evaluation. From these, 89 advanced generation bulks were identified for inclusion in replicated yield trials. The most promising selections with high pod yield and large pod size came from (ICGX-010073 x ICGX-010077), (ICGX-010073 x ICGV 02242), (ICGV 00440 x ICGX 960065), (ICGV 00456 x ICGX 960067) and (ICGV 00440 x ICGV 02252) crosses. During the 2008 rainy season, 212 selections were planted for evaluation. From these, 116 F_2-F_7 bulks and 21 single plants were selected. The most promising selections came from (ICGV 02226 x ICGV 02227), (ICGV 00456 x ICGX 960067) and (ICGV 00456 x ICGV 00451) crosses.

Yield trials: Seventy advanced breeding lines including controls in five replicated trials in the 2007 rainy and 2007/08 postrainy seasons were evaluated for confectionery traits. However, results from elite and advanced trials only are discussed here.

2007 rainy season: In an Elite Trial (Spanish), two varieties, ICGV 05176 (3.4±0.38 t ha^{-1}pod yield, 54% shelling outturn, 73 g HSW) and ICGV 05184 (3.3 t ha^{-1}pod yield, 63% shelling outturn, 60 g HSW), produced significantly higher pod yield than the highest yielding control ICGV 97045 (2.5 t ha^{-1}pod yield, 67% shelling outturn, 60 g HSW).

In an Advanced Trial (Spanish), three varieties (3.6-3.3±0.23 t ha^{-1}pod yield) produced significantly higher pod yield than the highest yielding control ICGV 97045 (2.6 t ha^{-1}pod yield, 62% shelling outturn, 57 g HSW). ICGV 06189 produced the highest pod yield (3.6 t ha^{-1}pod yield, 75% shelling outturn, 65 g HSW).

In an Advanced Trial-2 (Virginia), ICGV 07366 (3.5±0.24 t ha^{-1}pod yield, 69% shelling outturn, 49 g HSW) produced significantly higher pod yield than the highest yielding control ICGV 86564 (2.8 t ha^{-1}pod yield, 67% shelling outturn, 59 g HSW).

***2007/08 postrainy season*:** In an Advanced Trial (Spanish), two varieties (5.8-5.7±0.26 t ha^{-1} pod yield) significantly outyielded the highest yielding control ICGV 97045 (5.1 t ha^{-1}pod yield, 74% shelling outturn, 80 g HSW). ICGV 06211 ranked first in pod yield (5.8 t ha^{-1}pod yield, 71% shelling outturn, 83 g HSW) followed by ICGV 06212 (5.7 t ha^{-1} pod yield, 70% shelling outturn, 74 g HSW). ICGV 06211 performed well in both the seasons.

Four Spanish and three Virginia varieties were selected for inclusion in future international trials.

***2008 rainy season*:** In the 2008 rainy season, 135 advanced breeding lines including controls were evaluated in five replicated trials. Data from these trials are being processed.

Enrichment of Breeding Resources of NARS

Thirty-one sets of five trait-specific international trials (XI ISGVT, XI IMGVT (SB), XI IMGVT (VB), XI ICGVT and XI IFDRGVT) and 122 advanced breeding lines were made available to our NARS partners in Afghanistan, Cambodia, India, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Turkey, Vietnam and South Africa.

Special Project Funding:
The OPEC Fund for International Development, Tropical Legumes II, ISOPOM, IFAD Grant 954

SN Nigam, R Aruna and Varsha Wesley

Milestone: 6-8 high yielding dual-purpose groundnut varieties in a range of maturity groups with resistance to chronic biotic constraints available for release and commercialization (SNN/RA) 2009

Achievement of Output Target (%):
90%

Countries Involved:
Cambodia; India; Myanmar; Nepal; Pakistan; Papua New Guinea; Philippines; South Africa; Vietnam (Recipients of international trials)

Partners Involved:
NARS in the above listed countries

Progress/Results:
Six sets of foliar diseases resistant international trial (XI IFDRGVT) and six advanced breeding lines to Cambodia, India, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines and South Africa and three sets of *A. flavus* tolerant international trial (III IAFRGVT) and four advanced breeding lines to India and Vietnam were made available for evaluation under local conditions.

Five varieties were released for cultivation in India. These include ICGV 00440 (a confectionery type) for entire India; ICR 48 (ICGV 07356) for drought-prone areas of Rajasthan and Gujarat; Avatar (ICGV 93468) for spring season cultivation in Uttar Pradesh; Devi (ICGV 91114) for Orissa and Ajeya (ICGV 93261) for Maharashtra, Madhya Pradesh, Bihar, Orissa and West Bengal.

Special Project Funding:
The OPEC Fund for International Development (2007/08), ISOPOM, Tropical Legumes II, IFAD Grant 954

SN Nigam and R Aruna

Milestone: 8-10 selected advanced breeding lines in each partner country evaluated for local adaptation and farmer-preferred traits in SAT Asia (Special Projects) (SNN/RA/VW) 2009

Achievement of Output Target (%):
80%

Countries Involved:
Afghanistan; Cambodia; India; Myanmar; Nepal; Pakistan; Papua New Guinea; Philippines; Turkey; Vietnam; South Africa

Partners Involved:
NARS in the above mentioned countries

Progress/Results:
Forty-one set of 15 international trials were made available to partners in 12 countries for evaluation for local adaptation and farmer- and market-preferred traits. The results of these trials are awaited from partners.

Special Project Funding:
The OPEC Fund for International Development, IFAD Grant 954, Tropical Legumes II, ISOPOM

SN Nigam, R Aruna and Varsha Wesley

Milestone: Farmer-preferred variety(ies) in each partner country identified (Special Projects) (SNN/RA/VW) 2010

Achievement of Output Target (%):
90%

Countries Involved:
India; Nepal, Vietnam

Partners Involved:
India: UAS, Dharwad; UAS, Bangalore; TNAU, Coimbatore; OUA&T, Bhubaneswar; BAU, Ranchi; RDT, Anantapur; ARS, Anantapur/Kadiri; NRCG, Junagadh; CTDS, Chhattisgarh; JTDS, Jharkhand; OTELP, Orissa; Nepal: NARC, Khumaltar; Vietnam: LRDC; VAAS, Hanoi

Progress/Results:
From farmer-participatory varietal selection trials at special project locations in partner countries, farmers identified the following groundnut varieties as their preferred choice.

India
Andhra Pradseh: ICGV 91114, ICGV 00350, ICGV 86015, K 6 and K 1375
Chhattisgarh : ICGS 76
Gujarat: JAL 42, ICR 3 and TIR 17
Jaraude: ICGV 91114 and ICGS 76
Karnataka : Chintamani 1, Chintamani 2, ICGV 04096, ICGV 91114, R 2001-2, R 2001-3, ICGV 00350 and GPBD 4
Orissa: ICGV 91114, Smruti, AK 159, JAL 42 and TIR 17
Tamil Nadu: ICGV 97846, ICGV 00351 and VG 0104

Nepal : ICGV 86300 (Rajarshi) and ICGV 90173
Vietnam: L 14, L 23 and L 24

Special Project Funding:
IFAD Grant 954, Tropical Legumes II, ISOPOM, The OPEC Fund for International Development

SN Nigam, R Aruna and Varsha Wesley

Milestone: Five interspecific derivatives of groundnut evaluated for TSV and peanut bud necrosis virus (PBNV) diseases and promising lines identified (NM/VW) 2010

Achievement of Output Target (%):
20% as the selected material has already been screened for one year

Countries Involved:
India

Partners Involved:
None

Progress/Results**:**
The activity is in progress, once completed, the results will be reported

Special Project Funding:
None

N Mallikarjuna and Varsha Weseley

Milestone: Five stable interspecific derivatives with resistance to LLS and TSV/bud necrosis tested on farmers' fields (NM/VW) 2011

Achievement of Output Target (%):
40%, as LLS resistant lines have been identified. Initial screening to identify BND and stem necrosis has been initiated

Countries Involved:
India

Partners Involved:
None

Progress/Results:
To generate new sources of variation for LLS, TSV and PSNV, new sources of allotetlaploid *A. hypogaea* were created by combining the putative genomes which formed *A. hypogaea*. Such newly synthesized *A. hypogaea*, without selection pressure, would have maximum variation. Both the diploid progenitor hybrid and the synthetic tetraploid *A. hypogaea* were screened for LLS by detached leaf technique to check for the presence of LLS resistance trait.

To evaluate components of resistance to LLS, fully expanded third leaves of each diploid hybrid and its tetraploid *A. hypogaea* were selected and excised at the pulvinous notch. The leaves were immediately dipped in sterile distilled water and planted in sand culture. The sand culture was prepared using plastic trays (39.5 cm x 29 cm x 7 cm) containing a layer of sterile sand (roughly 1.5 cm thick) with four glass rods placed to create five equal sections in the tray sand. Inoculum was prepared by suspending conidia in sterile distilled water with 10 drop L^{-1} of the surfactant Tween

80 (Polyoxyethlene sorbitan mono-oleate) added. The suspension was adjusted to a concentration of 30,000 conidia ml^{-1} and applied to leaves with an atomizer. The following parameters were recorded and used for evaluating disease progress from 6-30 days after inoculation:

a) Incubation period (days from inoculation to appearance of first symptom)
b) Latent period (days from inoculation to the appearance of sporulating lesion)
c) Lesion number (number of lesions on leaf surface)
d) Leaf area damage (%) (comparison of test leaf damage with diagrams of leaves with known percentage of their areas affected as depicted by Hassan & Beute, (1977).
e) Lesion diameter (average diameter of four lesions measured at 30 days after inoculation)
f) Infection frequency (number of lesions per sq cm at 32 days after inoculation- estimate obtained by measuring total number of lesions on each leaf and obtaining an estimate of the total leaf area using a leaf area meter (Model: 3100, LI-COR inc., Nebraska, USA). The ratio of number of lesions to the area of a leaf gave the infection frequency for that leaf).

LLS symptoms were first observed on *Arachis hypogaea* cultivar TMV 2. Amongst the *Arachis* species earliest symptoms were observed on *A. batizocoi*. Symptoms were observed latest on *A. duranensis*, *A. hoehnei* and *A. cardenasii*. On some of the *Arachis* species disease symptoms were never observed (Table 1). Amongst diploid hybrids (2x) earliest symptoms were observed on ICG 8960 x ICG 8209 – 2x, followed by ICG 8123 x ICG 8962 – 2x. The diploid hybrids ICG 8124 x ICG 8216, ICG 8139 x ICG 8190 and ICG 8959 x ICG 4983 did not show any LLS symptoms or sporulation. Compared to *A. hypogaea* checks, all the *Arachis* species, diploid hybrids and synthetic tetraploid *A. hypogaea* (4x) in which some LLS symptoms was observed, recorded longer incubation and latent periods. Very few diploid hybrids and tetraploid synthetic *A. hypogaea* showed susceptibility to the disease (not shown in the table). Most of the test material did not show susceptibility to the disease components (Table 1). In many of *Arachis* species, diploid hybrids and synthetic *A. hypogaea,* disease symptoms were never observed. The experiment shows that many of the test material listed in Table 1 are highly resistant to LL disease.

Table 6.2: Evaluation of components of resistance to *Phaeoisariopsis personata* causing late leaf spot (LLS) in some *Arachis* species, *Arachis* species diploid hybrids and synthetic tetraploids under controlled environmental conditions

S. No.	Identity	LN 28	LD 30	LAD %	IP	LP	IF
1	*A. valida*	0	0	0	*	*	0
2	*A. duranensis*	1	0.4	0.2	18.7	*	0.11
3	*A. batizocoi*-2	2.6	1.2	0.8	16.5	*	0.25
4	*A. hoehnei*	0	0	1	*	*	0
5	*A. kempff mercadoi*	0.4	0.4	1.2	22	*	0.05
6	A. batizocoi-1	- 2x	1.4	9	14.33	18	0.29
7	**A. valida**	0	0	0	*	*	0.00
8	*A. batizocoi*-3	0	0	0	*	*	0.00
9	*A. diogoi*	0.67	2	0.67	23	*	0.05
10	*A. duranensis*	0	0	0	*	*	0.00
12	*A. diogoi*	0	0	0	18.65	25.82	0
13	*A. hoehnei*	0	0	0	18.65	25.82	0
14	*A. cardenasii*	0	0	0	18.65	25.82	0
15	ICG 8139 X ICG 8190 - 2x	4.2	0.8	2	15.5	21	0.14
16	ICG 8959 X ICG 8190 - 2x	10.5	1.8	13.5	14	23	0.65
17	ICG 8124 X ICG 8216- 2x	58.4	1.9	25.8	19	23	0.96
18	ICG 8124 X ICG 8216- 2x	0	0	0	*	*	0
19	ICG 8138 X ICG 13160- 2x	3	1.2	3	17	*	0.38
20	ICG 8123-7 X ICG 8962-138- 2x	1.6	0.4	0.6	22.2	*	0.1
21	ICG 11548-40 X ICG 8123-10- 2x	0.2	0	0	16	*	0.01
22	ICG 8960-132 X ICG 8209-70- 2x	6.4	1.5	5.4	17.3	21	0.42
23	ICG 8960-131 X ICG 13230-57- 2x	0.2	0	0	21	*	0.01
24	ICG 13230-57 X ICG 8960-131- 2x	6	2.7	14.3	15.6	28	0.4
25	ICG 8196-91 X ICG 8216-26- 2x	0.2	0	0	21	*	0.01
26	ICG 4983-147 X ICG 8216-23- 2x	9.4	2.2	14.4	18.4	24.5	0.51
27	ICG 8206 X ICG 8123-4x	5	1.067	2.33	22	18	0.19
28	ICG 8139 X ICG 8190- 2x	0	0	0	*	*	0.00
29	ICG 8959 X ICG 4983- 2x	0	0	0	*	*	0.00

30	ICG 8193 X ICG 4983- 2x	0	0	0	*	*	0.00
31	ICG 8193 X ICG 4983- 2x	0	0	0	*	*	0.00
32	ICG 8193 X ICG 4983- 2x	0	0	0	*	*	0.00
33	ICG 8193 X ICG 8139- 2x	0	0	0	*	*	0.00
34	ICG 8164 X ICG 15160- 2x	0	0	0	*	*	0.00
35	ICG 8164 X ICG 15160- 2x	0	0	0	*	*	0.00
36	ICG 8206 X ICG 8123- 2x	0	0	0	*	*	0.00
37	ICG 8959 X ICG 8190- 2x	6.67	1.633	4.67	14	21	0.37
38	ICG 8124 X ICG 8216-4x	0	0	0	*	*	0.00
39	ICG 14270 X ICG 8190- 2x	0	0	0	*	*	0.00
40	ICG 4983 X ICG 8190- 2x	0	0	0	*	*	0.00
41	ICG 11548-41 X ICG 8209-72- 2x	0	0	0	*	*	0.00
42	ICG 8123-7 X ICG 8962-138- 2x	2	0.833	1.33	16	25	0.09
43	ICG 11548-40 X ICG 8123-10- 2x	0	0	0	*	*	0.00
44	ICG 8123-10 X ICG 11548-40- 2x	0.67	0.333	0.33	25	*	0.15
45	ICG 8960-132 X ICG 8209-70- 2x	2	0.556	1	14	25	0.12
46	ICG 8960-120 X ICG 8123-8- 2x	2	0.917	1.33	21	23	0.23
47	ICG 13256-112 X ICG 8123-6- 2x	0	0	0	*	*	0.00
48	ICG 8960-131 X ICG 13230-57- 2x	0	0	0	*	*	0.00
49	ICG 8216-25 X ICG 4983-153- 2x	1	1.333	0.33	28	*	0.05
50	ICG 8124-19 X ICG 8123-2- 2x	0	0	0	*	*	0.00
51	ICG 11548-40 X ICG 8123-10-4x	0	0	0	10.5	*	0
52	ICG 8960-132 X ICG 8209-70-4x	15.6	3.2	21	14	20.3	0.4
53	ICG 13160 X ICG 8138-4x	1.33	0	2	23	25	0.13
54	ICG 8193 X ICG 4983-4x	0	0	0	*	*	0.00
55	ICG 13256-112 X ICG 8123-10-4x	0	0	0	*	*	0.00
56	ICG 8164 X ICG 15160-4x	0	0	0	*	*	0.00
57	*A. hypogeae* ICGS 44	36.5	3.88	36.5	8	18	1.43
58	*A. hypogeae 2* JL 24	18.58	4.25	18.58	9.5	19	0.92
59	*A. hypogaea 3* TMV-2	67.6	7.4	64	7.4	14	1.62
	CV	182.5	239.6	113.6	6.4	8.7	156.3
	Sed	3.981	0.635	2.54	2.38	0.798	0.173
	F. prob.	<.001	<.001	<.001	<.001	<.003	<.001

LAD = Leaf area damage, LN = Lesion number after inoculation, IP = Incubation period, LP = Latent period, LD = Lesion diameter, IF = Infection frequency

Although groundnut exhibits large morphological variation, molecular studies show that the crop rests on a narrow genetic base. In order to introduce variation and broaden the genetic base and in the pursuit to identify variable tetraploid germplasm, ten Bolivian tetraploid germplasm were studied for their genetic diversity using SSR markers. The results of the study showed that Bolivian germplasm is very diverse when compared to wild species from section *Arachis* as well as the commonly used Asian cultivars (Fig. 6.1).

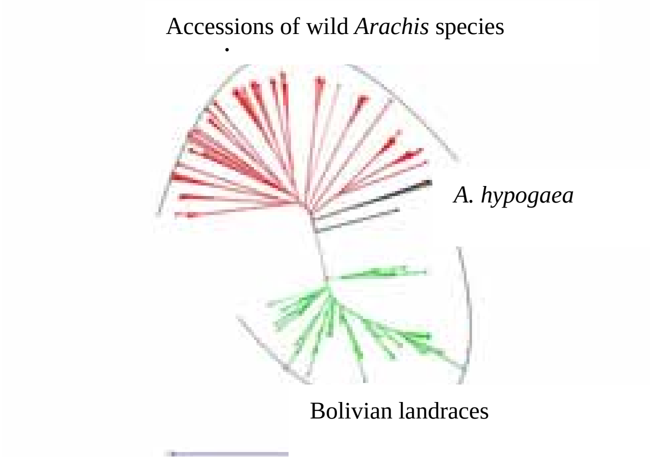


Fig 6.1: Study of genetic diversity in Bolivian landraces, *Arachis* species and *A. hypogaea*.

Wild species from section *Arachis* as well as the ten Bolivian germplasm lines were evaluated for late leaf spot (LLS) resistance. To evaluate components of resistance to LLS, fully expanded third leaves of each diploid *Arachis* species and the Bolivian germplasm were excised at the pulvinous notch. The process of evaluation for components of LLS resistance is as reported above.

Under glasshouse conditions, significant ($P \leq 0.001$) genotypic differences were observed for all components of resistance. Initial disease symptoms appeared first on leaflets of susceptible control *A. hypogaea* variety TMV 2. On the Bolivian landraces, late leaf spot (LLS) symptoms first appeared 13 days after inoculation on PI 331332, PI 339967 and PI 497412. On PI 261096 and PI 468270 disease symptoms were latest to appear. Rest of the PI lines had longer incubation period than the susceptible cultivar. Susceptible cultivar TMV 2 had large leaf area damage compared to all the Bolivian land races. In none of the lines leaf area damage exceeded 20% compared to 62% damage in TMV2. In some of the lines damage was as low as 2% (PI 475971 and PI 475972). Lesion numbers were also low on all the Bolivian land races compared to the susceptible control, so was the average lesion diameter. Latent period of infection was lowest of 11 days on TMV 2 and it was above 22 days in all the Bolivian land races (Fig. 6.2). Compared to Bolivian landraces *Arachis* species (ICG 8193, ICG 8209 and ICG 8962 and ICG 8139) showed higher level of resistance to LLS. *Arachis* species are diploids whereas Bolivian landraces are tetraploids. Traits from tetraploid germplasm can be introgressed faster than from diploid germplasm. It is not known if the alleles for resistance to LLS present in *Archis* species and Bolivian land races are the same. Based on the above observation it can be concluded that Bolivian landraces have resistance to LLS that can be utilized for the improvement of cultivated groundnut.

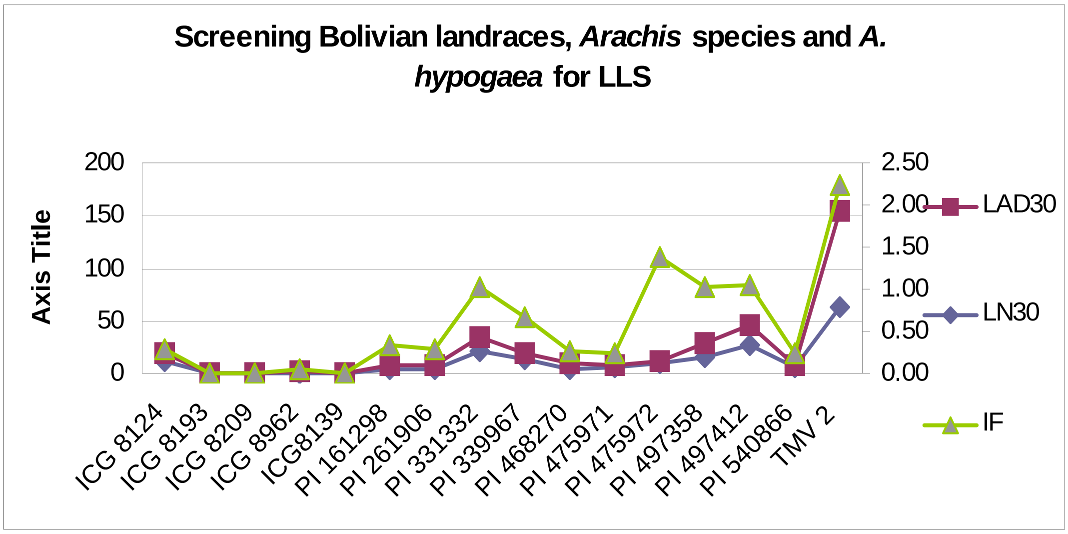


Fig 6.2: Screening of Bolivian landraces Bolivian landraces, *Arachis* species and *A. hypogaea* for LLS

Special Project Funding:
None

Nalini Mallikarjuna, Farid Waliyar and Varsha Wesley

Activity 6.1.1.2 GN Develop a better understanding of inheritance of components of resistance to late leaf spot (LLS) and confectionery traits

Milestone: Inheritance of components of resistance to LLS in three crosses studied and appropriate strategies for breeding devised (SNN/RA/VW) 2008

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Information on gene action of various components of resistance to LLS, incubation period, latent period, leaf area damage, number of lesions in two crosses (ICG 11337 x JL 24 and ICG 13919 x JL 24) was presented in the 2007 Archival Report. A manuscript on inheritance study is under preparation.

Special Project Funding:
The OPEC Fund for International Development

SN Nigam, R Aruna, Farid Waliyar and V Wesley

Milestone: Knowledge of inheritance of confectionery traits in two crosses gained and appropriate breeding strategy devised (SNN/RA) 2010

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Observations on parents, F_1, F_2 and backcrosses of two crosses (Chico x ICGV 01393 and Chico x ICGV 02251) along with their reciprocals, grown in the 2006/07 postrainy season, and repeat observations on these generations along with their F_3 in the 2007/08 postrainy season have been completed. Data analysis is in progress.

Special Project Funding:
The OPEC Fund for International Development

SN Nigam and R Aruna

Milestone: Three mapping populations for LLS and two for confectionery traits developed (RA/SNN) 2011

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Mapping populations of two crosses, (ICG 11337 x JL 24) and (ICG 13919 x JL 24), between resistant (ICG # 11337 and 13919) and susceptible (JL 24) parents are now in F_7 generation. Two populations, (ICGV 01393 x Chico) and (ICGV 02251 x Chico), developed for confectionery traits, are now in F_5 stage.

Special Project Funding:
The OPEC Fund for International Development

R Aruna and SN Nigam

Output target 6.1.2 GN Promising transgenic events of groundnut for resistance to TSV and PBNV available for commercialization and introgression in locally adapted germplasm

Activity 6.1.2.1 GN Develop transgenic events of groundnut for resistance to TSV and evaluate their performance under contained greenhouse and field conditions

Milestone: At least 10 promising TSVcp transgenic events identified and the disease resistance characterized under contained green house conditions (KKS/VW/PB/SNN) 2008

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Donald Danforth Plant Science Research Center, USA.

Progress/Results:
Transgenic approach has been initiated at ICRISAT to engineer resistance to the *tobacco streak virus* (TSV) causing the stem necrosis disease in groundnut by using the TSV coat protein (*TSVcp*) gene through *Agrobacterium tumefaciens*-mediated genetic transformation. Several (112) putative transgenic events of the popular groundnut cultivars JL 24, TMV 2, and ICGV 91114 were developed. PCR analysis confirmed integration of *TSVcp* transgene in 92 out of 112 events developed (82.14%). Further, ELISA/western analysis showed significant expression of the coat protein in at least 32 transgenic events.

In a batch-wise screening (10 events per batch with replication), progenies from 66 transgenic groundnut events were evaluated for resistance to TSV under greenhouse conditions. At the 3-leaf growth stage (8 to 10 day old plants), the test plants along with susceptible controls (JL 24) were dusted with carborundum and inoculated by standard mechanical sap inoculation procedure using 1:30 (w/v) TSV-infected French bean leaf sap extracts. Test plants were subsequently monitored at weekly intervals for virus spread and symptoms. These plants were tested by DAC-ELISA for presence of the virus. All the inoculated plants developed necrotic symptoms on the inoculated leaves 7 days post-inoculation and tested positive to TSV with ELISA.

Twelve transgenic events in the T_1 generation that were generated with the binary plasmid pCAMBIA 2300-*TSVcp* were found to be promising (both at molecular level and at glasshouse virus challenging studies. Progenies from these events did not display any systemic symptoms, confirmed by negative results when tested by DAC ELISA. Considering the fact that TSV was detected in the inoculated leaves of these plants and the lack of virus in the subsequently emerged leaves suggests blockade in the systemic spread of virus which seems to be responsible for the virus resistance. While progenies from 6 events delayed symptom expression by 2 to 3 weeks, compared to the wild type controls. These plants apparently had normal growth pattern. It is likely that these plants may also have some resistance. A comprehensive evaluation of these events will be carried to confirm the above results. At present 20, additional events are under screening process in contained greenhouse conditions.

Besides, the transgenic events that showed promise in virus challenging assays are being advanced to subsequent generations in the containment greenhouse for seed multiplication and to study the inheritance pattern and further evaluations. Marker-free transgenic plants of groundnut with the binary plasmid pZP200-TSVcp that is devoid of any selectable marker gene has been initiated and 6 putative transgenic groundnut events have been transferred to greenhouse and the presence and expression of gene confirmed. Work is ongoing to generate newer events without the marker gene. More recently, the expression studies in bacterial system are underway to look at the protein expression and to carry out purification of the coat protein in order to generate biosafety data pertaining to protein heat stability, and trypisinization as prerequisites for conducting contained field evaluations of these transgenic events.

Special Project Funding:
Department of Biotechnology, Govt. of India.

KK Sharma, P Bhatnagar-Mathur, Varsha Wesley, SN Nigam and R Aruna

Milestone: Two transgenic events with resistance to TSV used for introgression into locally adapted groundnut genotypes (KKS/VW/PB/SNN/RA) 2011

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
Donald Danforth Plant Science Research Center, USA.

Progress/Results
The results reported for the above 2008 milestone represents 30% of the progress towards achieving this milestone.

Special Project Funding:
Department of Biotechnology, Govt. of India.

KK Sharma, P Bhatnagar-Mathur, Varsha Wesley, SN Nigam and R Aruna

Activity 6.1.2.2 GN Develop transgenic events of groundnut for resistance to PBNV and evaluate their performance under contained greenhouse and field conditions

Milestone: At least 10 promising transgenic events identified and resistance to PBNV characterized under greenhouse conditions (KKS/PB/VW/SNN/RA) 2010

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Transgenic approach was undertaken to engineer resistance to PBNV using the nucleocapsid protein (*PBNVnp*) gene in groundnut cultivar JL 24. Forty-eight independent T_0 transgenic events were produced by using binary vectors encoding for *PBNVnp* gene through *Agrobacterium tumefaciens* and micro-projectile mediated genetic transformation. Overall, 24 groundnut T_1 transgenic events (12 biolistic mediated gene transfer and 12 *Agrobacterium* mediated gene transfer) along with control untransformed JL 24 plants were planted in the glasshouse. Plants were dusted with carborandum and challenged with PBNV inoculum at the dilution of 1 : 10 at 13-15 days after sowing (3 - 4 leaf stage). Test plants were

monitored at weekly intervals for viral symptoms and spread and tested with direct antigen coated (DAC) ELISA for the presence or absence of virus. All the inoculated plants developed chlorotic spot symptoms characteristic of PBNV on inoculated leaves approximately 6 days after inoculation. These results confirmed successful inoculation with PBNV. In addition, all plants also tested positive to PBNV when tested with DAC-ELISA, while asymptomatic plants tested negative to PBNV. Symptom appearance was delayed by 2 to 3 weeks in the transgenic plants compared to the controls. Although all the infected transgenic groundnut plants showed severe PBND symptoms, eight plants from the events B 8, B 9, B 11, B 13, B 15, B 19, B 20, and B 22 showed recovery, suggesting some tolerance to PBND. Of the 24 events tested, event numbers 3, 4, 7, and 11 (16.68%) showed lower disease incidence compared to the control JL 24 (90%). The T_2 progenies from these promising transgenic groundnut events were selected for further molecular evaluation and screening.

Apparent lack of resistance to PBNV in transgenic plants could be attributable to the presence of RNA silencing suppressor gene, NSs, in the PBNV genome, which could be rendering *PBNVnp* gene ineffective. Therefore, as an alternate strategy based on RNAi and/or antisense for the development of PBNV resistant groundnut cultivars is under progress. For this, the *PBNVnp* gene in an antisense orientation driven by the double 35S CaMV promoter was cloned in a marker-free plasmid (pZPP200) and mobilised into *Agrobacterium tumefaciens* strain C58 for the transformation of tobacco as a model system and groundnut. In addition, strategies are being developed to use RNAi constructs for conserved domains of PBNV replicase, nucleoprotein, or movement genes, combined with RNAi constructs to counter any NSs gene for inducing RNAi-mediated resistance to PBNV in groundnut and other crops susceptible to this virus.

Special Project Funding:
None

KK Sharma, P Bhatnagar-Mathur, Varsha Wesley, SN Nigam and R Aruna

Chickpea

Output target 6.1.1 CP 50-100 chickpea breeding lines with high yield, improved seed traits and resistance to one or more biotic stresses [Fusarium wilt (FW), Ascochyta blight (AB), Botrytis gray mold (BGM) and *Helicoverpa* pod borer] developed and disseminated to NARS

Activity 6.1.1.1 CP Develop chickpea breeding lines (desi and kabuli) with enhanced resistance to AB, BGM and FW

Milestone: 15-20 new high yielding FW resistant desi and kabuli chickpea breeding lines made available to NARS (PMG/CLLG/ST/SP/MS) Annual

Achievement of Output Target (%):
100%

Countries Involved:
Australia; Bangladesh; Canada; China; India; Morrocco; Myanmar; Nepal; Pakistan; Philippines; South Africa; Spain; Vietnam

Partner Institutions:
NARS in the above countries

Progress/Results
International chickpea screening nurseries (ICSNs) of desi and kabuli chickpeas: Sixty three International Chickpea Screening Nurseries (ICSNs) (32 ICSN-Desi and 31 ICSN-Kabuli) were distributed to NARS partners across 8 countries for evaluation during 2007/08. Each ICSN consisted of 18 entries and 2 checks – one common check (ICCC 37 in ICSN-Desi and KAK 2 in ICSN-Kabuli) and one local check. One set each of ICSN-Desi and ICSN-Kabuli was also evaluated at ICRISAT, Patancheru. The entries were evaluated in Randomized Complete Block Design (RCBD) with 2 replications. In ICSN-Desi (at Patancheru), most of the entries performed better with 12.8 to 77.5 % yield advantage over the best check (ICCC 37) which yielded 1700 kg/ha**.** ICCV 07112 was the best entry with seed yield of 3017 kg/ha followed by ICCV 07110 (2976 kg/ha). In ICSN-Kabuli, two entries (ICCV 07311 and ICCV 07301) were at par with the best check (JGK 1) in terms of yield and resistance to fusarium wilt.

The data received from different locations (22) in India revealed that in ICSN-Desi, ICCV 07112 (2088 kg/ha), ICCV 07103 (2066 kg/ha) and ICCV 07102 (2035 kg/ha) were superior to the common check ICCC 37 which yielded 1895 kg/ha. In case of ICSN-Kabuli, ICCV 06306 with mean seed yield 1928 kg/ha was the best entry followed by ICCV 07308 (1912 kg/ha) and ICCV 07303 (1838 kg/ha). The common check KAK 2 yielded 1728 kg/ha.

PM Gaur, Shailesh Tripathi and CLL Gowda

Development and evaluation of improved breeding lines of desi and kabuli chickpea: Advanced breeding lines of desi (158) and kabuli (57) chickpeas were evaluated in 12 replicated yield trials [10 Preliminary Yield Trials (PYTs) and 2 Advanced Yield Trials (AYTs)] during the crop season 2007-08. JG 11 and JAKI 9218 were used as checks in case of desi, while JGK 1, KAK2, and ICCV 95334 were used as checks in kabuli trials. In PYTs - Desi, three entries (ICCX-030008-F4-P8-BP, ICCX-030042-F4-P14-BP and ICCX-030042-F4-P12-BP) were found to be superior to the best check in terms of yield as well as resistance to fusarium wilt. In AYTs – Desi, none of the entries were superior to the best check JAKI 9218. In PYT – Kabuli, three entries (ICCX-030163-F4-P31-BP, ICCX-030163-F4-P35-BP and ICCX-030207-F4-P4-BP) were found promising as compared to the best check, in terms of yield and resistance to FW with 100-seed weight more than 35g 100-seed^{-1}.

PM Gaur, Shailesh Tripathi and CLL Gowda

Fusarium wilt resistance in desi and kabuli chickpea breeding lines and populations: In collaboration with breeders and NARS partners, 35 F_4 populations (23 Desi + 12 Kabuli), 54 F_6 populations for earliness, 271 trial entries, 41 chickpea lines for sprouts, 265 entries from IIPR Kanpur, 68 entries from Ludhiana and 323 RILs from Dharwad were evaluated for wilt resistance in wilt sick plots following standard evaluation technique at ICRISAT-Patancheru.

F4 populations: Among the Desi populations (23), no line was found resistant to wilt. However, among kabuli populations, one population ICCX-030155-F4 was found moderately resistant (10.1-20% incidence) to wilt. Resistant plants have been advanced.

F6 populations: All the 54 F6 populations for earliness had a susceptible reaction to wilt. Resistant single plants have been advanced.

ICRISAT trial entries: Of the 271 trial entries, three entries ICCX-0300011-F4-P13-BP, ICCX-030053-F4-P1-BP and ICCX-000029-BP-BP-P17-BP were asymptomatic (0% incidence), 44 resistant (0.1-10% incidence) and 55 moderately resistant (10.1 to 20% incidence) to wilt.

Chickpea lines for sprouts: Among the 41 chickpea lines for sprouts, no line was resistant, while 14 lines were susceptible (20.1-50%) and 27 highly susceptible (50.1-100%) to wilt.

Suresh Pande, PM Gaur and Mamta Sharma

ICAR-ICRISAT collaborative research on wilt resistance in chickpea: In collaboration with IIPR Kanpur, 231 trial entries (IVT –desi (19), IVT-late sown (13), AVT -large seeded (14), IVT-large seeded (20), IVT-rainfed (20), IVT-kabuli (12), AVT-extra large kabuli (6), IVT-extra large kabuli (6), Donor lines (11) and National Nursery (110) were evaluated for FW resistance in wilt sick plots at ICRISAT Patancheru.

Hundred per cent wilt incidence in early wilting cultivar ICC 4951 within 30 DAS and in late wilting cultivar K850 in 90 DAS was recorded across the field indicating uniform disease presence in the sick plot. Among the IVT-desi, one line (P 17) was found resistant (<10% incidence) and three moderately resistant (10.1-20%) to wilt. Among the IVT-late sown, no entry was found resistant but two entries (P 60, P63) were moderately resistant (10.1-20.0%). Of the 14 AVT -large seeded entries, two entries (P 113, 114) had resistant (0.1-10% incidence) and four moderately resistant reaction to wilt. Among the IVT-large seeded, only one entry (P 130) was resistant and three moderately resistant to wilt. IVT-rainfed entries were highly susceptible to wilt except two entries P 185 that was resistant and P 179 that was moderately resistant to wilt. All the IVT-kabuli entries were susceptible to wilt except P 210 that was moderately resistant to wilt. Out of six AVT-extra large kabuli entries, none was resistant while two were moderately resistant (P 254, 255) to wilt. Among the IVT-extra large kabuli entries, two were moderately resistant (P 277, 279) to wilt. Among the donor lines, only one line (D 33) was found moderately resistant (10.1-20%) to wilt. Out of 110 National Nursery entries, five entries (NNW 72, NNW 91, NNW 101, NNW 102, NNW 103) showed moderately resistant reaction (10.1-20%) to wilt. Remaining entries were susceptible/highly susceptible to wilt.

Suresh Pande, Mamta Sharma and Indian NARS collaborators

ICRISAT-UAS Dharwad collaborative research on wilt resistance in chickpea: Three hundred and twenty three chickpea RILs received from UAS, Dharwad were evaluated for wilt resistance in wilt sick plot under artificial epiphytotic conditions. Segregation for wilt resistance among these RILs was observed as expected however, three RILs were found resistant (0.1-10% incidence) and four moderately resistant (10.1-20.0% incidence) to wilt.

Suresh Pande, Mamta Sharma and RL Ravikumar

ICRISAT-PAU Ludhiana collaborative research on wilt resistance in chickpea: Sixty eight wilt and ascochyta blight promising chickpea lines received from PAU, Ludhiana were evaluated for wilt resistance in wilt sick plot under artificial epiphytotic conditions. All the 68 lines were susceptible to wilt.

Suresh Pande, Mamta Sharma and Livinder Kaur

Evaluation of advanced wilt promising selections for resistance to FW: A total 74 further advanced wilt promising selections from ICRISAT and 34 advanced wilt and root rot promising selections from Kanpur 2006-07 were evaluated for wilt and root rots resistance in multiple disease sick plot (MDSP) following standardized screening technique.

Of the 74 advanced wilt promising selections, 12 lines (ICCs 2072, 12467, 14386, 14432, 16124, BCP 201, KAK 2, ICCX850636-BH-26H-BH, ICCX-980068-F4-P10-BP, IGD 17, IGRF 12 and IFRG 10) had resistant reaction by showing < 10% wilt and 32 moderately resistant showing 10.1 -20% wilt incidence. Out of 34 promising selections from Kanpur, three lines (IGEB 5, IGRF 16, NNW 3) were resistant (<10% incidence) and three moderately resistant (10.1-20% incidence) to wilt.

Suresh Pande, Mamta Sharma and PM Gaur

Special Project Funding:
None
Milestone: 20-30 sources of resistance to FW, BGM, and AB tested for stability across locations and pathotypes in Asia (SP/PMG/CLLG) Annual

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Indian NARS

Special Project Funding:
None

Progress/Results:
Evaluation of Chickpea Wilt and Root Rot Nursery (CWRRN) for resistance to FW: Chickpea wilt and root rot nursery (CWRRN) consisted of 30 entries (28 wilt resistant +2 wilt susceptible cultivars) and was evaluated at 23 locations (Akola, Badnapur, Bangalore, Berhampore, Coimbatore, Dhaulakuan, Dharwad, Dholi, Faizabad, Gulbarga, Hazribagh (CRUUS, HCKVK), Hisar, ICRISAT-Patancheru, Jabalpur, Junagadh, Kanpur, Ludhiana, New Delhi, Rahuri, Raipur, Sehore and Varanasi) in India during 2007/08 season. Each entry was planted in one row of 4 m long and replicated twice in all the locations. Sowing of the trial (CWRRN) was done between 23 October – 20 November 2007 across locations. Data on wilt was recorded thrice at seedling, flowering and at maturity stages of the crop.

Data from fourteen locations (Badnapur, Bangalore, Berhampore, Dharwad, Dholi, ICRISAT-Patancheru, Jabalpur, Junagadh, Kanpur, Ludhiana, New Delhi, Rahuri, Sehore and Varanasi) was received and compiled. Incidence of wilt in susceptible check was low (<10%) in Dharwad, Varanasi, moderate (between 43-48%) in Bangalore and Kanpur while it was very high (>80%) in other locations. one entry, ICCV 05112 was found resistant (<10% incidence) in seven locations out of 14 locations. Two entries ICCVs 05527, 96818 in six locations, five entries ICC 2072, ICCVs 96851, 04107, 04108, 05528 in five locations, eight entries ICCs 95, 11324, 14364, 14386, 15996, ICCVs 92337, 05110, 05529 in three locations were found resistant to wilt.

Evaluation of International Ascochyta Blight Nursery for resistance to AB: International Ascochyta Blight Nursery (IABN) 2007-08 consisted of 30 entries of which 28 were moderately resistant to AB and two susceptible checks including local check of the respective location. IABN was evaluated under field conditions at six locations (Almora, Dhaulakuan, Gurdaspur, Hisar, ICRISAT-Patancheru and Ludhiana) in India. Each entry was planted in one row of 2-4 m long and replicated twice. The nursery was inoculated with conidial suspension of *A. rabiei* @ 50000 conidia ml^{-1}, two-three times at flowering stage of the crop at weekly intervals in all the locations. Evaluation at ICRISAT-Patancheru was done under controlled environment following standardized whole plant screening technique.

Data was received from five locations except Hisar. Susceptible cultivar ICC 4991 exhibited highly susceptible reaction (around 9 rating on 1-9 scale) in all the five locations in India. Five entries (ICCVs 04537, ECs 517003, 516936, 516971, 517025) in three locations; 12 entries (ICCVs 04537, 98818, ECs 516771, 516792, 516793, 516796, 516850, 516867, 517011, 517039, 516936, 516971) in five locations were found resistant/moderately resistant to AB (< 5.0 rating on 1-9 scale). At ICRISAT-Patancheru, high levels of resistance were not observed but 17 entries were found moderately resistant to AB.

Evaluation of International Botrytis Gray Mold Nursery for resistance to AB: International Botrytis Gray Mold Nursery (IBGMN) consisted of 30 entries of which 29 were BGM promising entries identified under controlled environment at ICRISAT-Patancheru and one susceptible check (ICC 4954). One local susceptible check of respective location was also added. IBGMN was evaluated at four locations in India (Gurdaspur, Ludhiana, ICRISAT-Patancheru, Pantnagar), one location in Nepal (Tarahara), and two locations in Bangladesh (Ishurdi and Jessore). Each entry was planted in 2 to 4 m long rows and replicated twice. All the entries of the nursery were artificially inoculated with conidial suspension of the local isolate of *Botrytis cinerea* at flowering and pod initiation stage of the crop in all the locations. At ICRISAT- Patancheru the nursery was evaluated under controlled environment conditions following standardized whole plant screening technique.

Data was received from all the four locations in India and one location from Nepal. Susceptible checks showed highly susceptible reaction (9 rating on 1-9 scale) in all the locations. Four entries ICCVs 89332, 96817, ECs 516834, 516968 were found resistant (1-3 rating on 1-9 scale) at two locations and 11 entries were found moderately resistant (3.1-5.0 rating) at two locations to BGM.

Suresh Pande, Mamta Sharma and NARS in India Nepal and Bangladesh

Purification and maintenance of virulence of pathotypes of *Fusarium oxysporum* f.sp. *ciceris*: Forty four isolates of *Fusarium oxysporum* f.sp. *ciceris* (FOC) collected from 18 locations in 12 states in India were purified for the maintenance of virulence. Pathogenicity test and Koch's postulates were proved using a common susceptible cultivar JG 62 following standardized evaluation technique under greenhouse conditions at ICRISAT-Patancheru. Pure cultures were selected and single spore isolates were obtained following standardized mycological techniques.

Purification and maintenance of virulence of pathotypes of *Ascochyta rabiei*: A total 23 isolates of *Ascochyta rabiei* collected from 12 locations in five states in India were purified for maintenance of virulence. Pathogenicity and Koch's postulates of all these isolates were proved using a common cultivar Pb 7 following standardized evaluation protocol under controlled environment conditions. Pure cultures were selected and single spored following standard mycological techniques.

Purification and maintenance of virulence of pathotypes of *Botrytis cinerea*: A total 37 isolates of *Botrytis cinerea* collected from 10 locations in five states in India and 10 locations in Nepal were purified for maintenance of virulence. Pathogenicity and Koch's postulates of all these isolates were proved using common cultivar (JG62 or H208) following standardized evaluation protocol under controlled environment conditions. Pure cultures were selected and single spored following standard mycological techniques.

Suresh Pande and Mamta Sharma

Milestone: 10-15 kabuli chickpea breeding lines with extra large seed (>50 g 100-seed^{-1}) and high resistance to FW developed (2009) (PMG/CLLG/ST/SP/MS)

Achievement of Output Target (%):
90%

Countries Involved:
India

Partner Institutions:
Indian Institute of Pulses Research, Kanpur; Mahatma Phule Krishi Vidyapeeth, Rahuri; Indian Agricultural Research Institute, New Delhi; Punjab Agricultural University, Ludhiana

Progress/Results:
Development of FW resistant extra-large seeded kabuli chickpea breeding lines: In a project funded by the Ministry of Agriculture and Cooperation, Government of India under the ISOPOM scheme, our main focus is on development of extra-large seeded (seed size >50g/100 seed) kabuli chickpea genotypes with resistance to fusarium wilt (FW) with early to medium maturity. Foreseeing the loss in yield due to incidence of ascochyta blight, common in the cooler long-season environments of northern India, we initiated developing new breeding material with extra-large seed size and combined resistance to ascochyta blight and fusarium wilt. Hence, five new crosses were made in order to incorporate ascochyta blight resistance from diverse sources (ICC 12961, ICC 12965, ICC 14912, ICC 14915 and ILC 195) in the extra-large seeded, fusarium wilt resistant genotype ICC 17109. F_1s from 15 crosses aimed at developing extra-large seeded, high yielding kabuli genotypes with early to medium maturity and high resistance to fusarium wilt were also grown during 2007/08 crop season. The breeding materials (28 F_2 and 4 F_3 populations), from crosses made earlier, were advanced. Wilt resistant single plants (158) were selected from the 12 F_4 populations grown in the wilt sick field during 2007/08 crop season. A second crop was taken immediately after the harvest of winter crop and wilt resistant single plant progenies (F_5) were grown during Feb-Apr 2008. The F_6 seed obtained will be evaluated for phenology and yield during crop season 2008/09 along with checks.

Total 264 F_6 progenies were evaluated at ICRISAT during crop season 2007/08 in order to select superior progenies which could be supplied to the project partners during 2008. About 130 lines were at par with or better than the best check (KAK 2) in terms of yield of which 61 lines gave ≥10% yield advantage. Three lines, ICCX-030144-F4-P2-BP, ICCX-030157-F_4-P_5-BP and ICCX-030160-F_4-P_4-BP had seed size more than that of ICC 17109 (the best check for seed size with 100-seed weight – 50.8 g) along with high seed yield. Twenty F_6 progenies supplied to the project partners for evaluation during the cropping season 2007/08 were also evaluated at ICRISAT, Patancheru. One set of these 20 F6 progenies was grown in normal field (4 rows plots) for observations on phenology, seed size, and yield (Table 6.3) and another set (one row of each progeny) was grown in wilt sick plots for evaluation of fusarium wilt resistance.

Table 6.3: Performance of 20 F6 progenies supplied to project partners during 2007/08 at ICRISAT.

Entry	50% Flowering	Days to Maturity	Pods/plant	100-seed weight (g)	Yield (kg/ha)	Wilt (%)
ICCX-030141-F4-P3-BP	41	96	29.8	40.7	1438	3.5
ICCX-030141-F4-P20-BP	38	92	50.2	41.1	1418	24.0
ICCX-030144-F4-P1-BP	36	96	31.2	49.2	1192	8.0
ICCX-030147-F4-P1-BP	39	96	48.6	42.8	1300	4.8
ICCX-030156-F4-P3-BP	37	88	25.2	45.5	1320	9.1
ICCX-030156-F4-P4-BP	36	88	40.8	45.2	1472	2.6
ICCX-030157-F4-P1-BP	38	92	39.6	41.1	1607	17.2
ICCX-030160-F4-P2-BP	37	96	35.6	49.5	1940	27.3
ICCX-030160-F4-P5-BP	39	95	43.6	46.3	1692	25.0
ICCX-030160-F4-P7-BP	38	95	49.2	43.0	2089	26.2
ICCX-030163-F4-P3-BP	38	96	39.8	44.5	1938	26.9
ICCX-030163-F4-P7-BP	38	98	43.0	40.9	1551	48.5
ICCX-030163-F4-P13-BP	33	97	62.0	42.7	2242	27.5

All the lines had large seed size (≥40 g/100 seed). The line ICCX-030208-F4-P1-BP was extra-large seeded with 100-seed weight 54.34g (more than that of ICC 17109, the best check for seed size). The maturity duration in the lines was in the range 88 to 99 days. Some of the promising lines in terms of yield include ICCX-030163-F4-P13-BP, ICCX-030204-F4-P11-BP and ICCX-030160-F4-P7-BP.

Evaluation of farmer-grown extra-large seeded (100-seed weight > 50g 100 seed^{-1}) kabuli chickpea cultivars: Replicated yield trial on farmer's grown, extra-large (seed size > 50g/100 seed) kabuli chickpea cultivars, collected from farmers field from different locations across the country, was conducted during the crop season 2007/08. The trial consisted of 10 extra large kabuli cultivars selected based on previous year performance (mainly seed size) and one check (KAK 2). Data was recorded for phenology, seed size, seed quality parameters (hydration capacity, hydration index, swelling capacity, swelling index and protein content), resistance to fusarium wilt and yield. All entries except one (KAK 2) had seed size greater than 50g/100 seed. This year the incidence of fusarium wilt was more severe as compared to the last year. The most promising entries in terms of seed yield and resistance to fusarium wilt were PG 517, Dollar, AP-5 and AP-4. The hydration capacity, which is a measure of quantity of water absorbed by the seed varied from 0.34 to 0.63 g water/seed. However, there was not much variation in hydration index which varied from 0.94 to 1.15. The swelling capacity, which indicates the increase in volume after soaking, ranged from 0.37 ml/seed in KAK 2 to 0.69 ml/seed in AP-5. Both these parameters, i.e., the hydration capacity and swelling capacity, are directly related to cooking time in chickpea. There was not much variation among the entries with regard to protein content, which ranged between 17.2to 18.8%. The entry PG 517 had best combination of earliness (DM- 99 days), 100-seed weight (57.0 g), resistance to fusarium wilt (10.3 %) and yield (2640 kg/ha).

In another trial on evaluation of large-seeded (seed size >40g/100 seed) kabuli chickpea genotypes, PG 95333 was the best entry with high seed yield (2437 kg/ha), good seed size (100-seed weight - 41.1 g), early maturity (DM – 89 days) and resistance to fusarium wilt (9.0%). Six out of nine entries had seed size greater than 40g/100 seed. Hydration capacity varied from 0.32 g water/seed in Virat to 0.63 g water/seed in IPCK 2004-1. The swelling capacity ranged from 0.30 to 0.68 ml/seed. Hydration capacity and swelling capacity were highest in the entry IPCK 2004-1. Hydration index (0.93 – 1.12) and swelling index (1.97 – 2.55) did not show much variation. The entries performing well in the above two trials hold good potential for possible release in the near future after testing in the All India Coordinated Yield Trials.

Special Project Funding:
ISOPOM Project on extra large seeded kabuli chickpea funded by Ministry of Agriculture, Govt. of India.

PM Gaur, Shailesh Tripathi and CLL Gowda

Fusarium wilt resistance in kabuli chickpea breeding lines: Twelve F_4 populations- Kabuli, 20 F_6 progenies and 21 trial entries from ISOPOM were evaluated in the wilt sick plots. Resistance to FW of 12 F_4 kabuli populations is reported under milestone 6.1.1.1.1.

Out of 20 F_6 progenies, five (ICCX-030141-F4-P3-BP, ICCX-030144-F4-P1-BP, ICCX-030147-F4-P1-BP, ICCX-030156-F4-P3-BP, ICCX-030156-F4-P4-BP showed resistant (0.1-10% incidence) and one (ICCX-030157-F4-P1-BP) moderately resistant reaction (10.1-20%) to wilt. Out of 21 ISOPOM trial entries, two entries KAK 2, PG 95333 had a resistant (0.1-10% incidence) reaction and seven entries Dollar, PG 517, AP-5, AP-4, KAK 2, AP-4, and CKJK 21 were found moderately resistant (10.1 to 20%) to wilt.

Suresh Pande, PM Gaur and Mamta Sharma

Milestone: 15-20 desi and kabuli chickpea breeding lines with combined resistances to FW, AB and BGM developed (PMG/SP/CLLG/ST/MS) 2010

Achievement of Output Target (%):
50%

Countries Involved:
Australia; India

Partner Institutions:
Australia: University of Western Australia; CLIMA and Department of Agriculture and Food Western Australia (DAFWA); *India:* Punjab Agricultural University, Ludhiana

Progress/Results:

Development of desi chickpea breeding lines with combined resistance to fusarium wilt (FW), ascochyta blight (AB) and botrytis gray mold (BGM): F_1s of 41 crosses, including 22 intercrosses, made for incorporating ascochyta blight and fusarium wilt resistance into high yielding breeding lines/cultivars, were grown during the crop season 2007/08. Eleven new crosses were also made during the crop season. Of these, 6 were for introgressing resistance to new ascochyta pathotype (from ICC 12964 and ICC 18965) and 5 for earliness (from ICCV 96030, ICCV 2 and JG 11). 34 F_2 and 80 F_3 populations were grown during 2007/08 crop season for advancement of generation. F_3 plants were categorized as early, medium and late based on days to flowering and harvested in three separate bulks (early, medium and late). F_4 (37) and F_5 (19) populations were screened for resistance to AB under controlled conditions during Nov-Dec 2007 and the resistant plants (F_4 - 300 and F_5 - 289) were transplanted in pots in the greenhouse.

F_4 to F_6 single plant progenies (1987) from AB resistant plants were evaluated for phenology and yield along with checks during crop season 2007/08. Of these 1987 progenies, 1838 (lines in which seed was enough) were screened in the wilt sick field. Also 1734 lines were sent to PAU, Ludhiana (India) for screening for AB under field conditions during 2007/08. After harvest of the 2007/08 crop, one set of 1987 progenies was screened for resistance to AB under controlled conditions at ICRISAT-Patancheru in Apr 2008. Twenty-three lines showed resistance to AB (≤ 4 score) at seedling stage at ICRISAT, 844 lines showed resistance to AB (≤ 4 score) under field conditions at PAU and 215 lines showed resistance to AB (≤ 4 score) both at ICRISAT and PAU. 566 lines were as early as or earlier than Sonali (98 days), 438 lines were as tall as or taller than Genesis 836 (59 cm), over 1400 lines had larger seed (> 16g/100 seed) than Sonali (15.3 g), 171 lines gave 5 to 76 % higher yield than Sonali (1508 kg/ha) and 62 lines showed <20% mortality from FW. Nine lines had good combination of AB resistance (≤ 4 score both at ICRISAT-Patancheru and PAU-Ludhiana), maturity (≤ 100 days), plant height (≥ 42cm), seed size (> 16g/100 seed) and grain yield (≥ 1500 kg/ha). However, none of these lines showed resistance to FW.

Total 3809 progenies, obtained from screening of 75 F_4 to F_6 populations for resistance to AB, were planted in the field during crop season 2007/08 for evaluation. Single plants (1639) were selected based on phenology, plant type and seed characteristics. Progenies from these plants were screened for AB resistance under controlled conditions and 200 progenies, selected based on AB resistance, phenology, plant type and seed traits, were sent to collaborators in Western Australia.

Development of desi and kabuli breeding lines with resistance to diseases and tolerance to salinity: Crosses (9) were made during the planting season 2007-08 for incorporating salinity tolerance from ICC 7819, ICCV 10 and CSG 8962 into AB resistant lines (ICCV 04512, ICCV 05530 and ICCV 96836). F_2s of crosses made earlier for enhancing salinity tolerance in desi (ICC 7819 x ICC 8950 and ICCV 10 x ICC 9942) and kabuli (L 550 x ICC 14194 and L 550 x ICC 17109) genotypes were advanced. F_3 generation of crosses made for introgressing salinity tolerance genes from ICC 2580 into well-adapted varieties/advanced breeding lines (JG 11, ICC 4958, JG 130 and CSG 8962) were also advanced.

PM Gaur, S Pande, CLL Gowda, Shailesh Tripathi, and Mamta Sharma

Combined resistance to FW and AB in chickpea under COGGO project: Segregating and advanced generation populations (F4-F6) were evaluated in the wilt sick plot for FW resistance (1838 lines) and for AB resistance (1987 lines) under controlled environment conditions under the COGGO project. Out of 1838 entries, ten entries (ICCX-040147-F3-P14-P1, ICCX-040149-F3-P1-P5, ICCX-040154-F3-P14-P3, ICCX-040155-F3-P31-P1, ICCX-040155-F3-P83-P3, ICCX-040155-F3-P88-P6, ICCX-040162-F3-P16, ICCX-040164-F3-P8, ICCX-040166-F3-P31, ICCX-040166-F3-P34 were asymptomatic (0% incidence), seven resistant (0.1-10%) and 53 moderately resistant to FW. For AB, 39 entries were resistant (1-3 rating on 1-9 scale) and 910 moderately resistant (3.1-5.0 rating). Five entries ICCX-040155-F3-P83-P3, ICCX-040155-F3-P88-P6, ICCX-040166-F3-P34, ICCX-040162-F3-P16 and ICCX-040149-F3-P1-P5 showed combined resistance (asymptomatic to wilt and moderately resistant reaction to AB) to both wilt and AB.

Further in collaboration with CLIMA and COGGO, Australia, a total 1735 F_5-F_7 AB resistant progenies [F_5 (433), F_6 (957) and F_7 (334)] were evaluated for AB resistance using whole plant screening technique under controlled environment at ICRISAT, Patancheru. Among the F_5 populations, two (ICCX-040094-F3-BP-P24-P1 and ICCX-040094-F3-BP-P51-P1) were resistant (1-3 rating on 1-9 scale) and 77 were moderately resistant (3.1-5.0 on 1-9 rating scale). Among the F_6 populations, four were resistant (ICCX-040129 F4-BP-P52-P2, P52-P3, P259-P2 and ICCX-040082-F4-BP-P13-P1) and 384 moderately resistant. Among the F_7 populations, only one (ICCX-040059-F5-BP-P22-P1) was resistant and 145 were moderately resistant.

Another set of F_5-F_6 AB resistant progenies (104 lines) and early and medium maturity F_4 populations (80 early and 8 medium) were also evaluated for AB resistance using whole plant screening technique under controlled environment at ICRISAT, Patancheru. Of these 104 progenies, two (ICCX-040124-F3-P2-BP AND ICCX-040020-F3-P8-BP) were resistant and 44 moderately resistant. Among the early maturity lines, 2057 resistant plants were selected and transplanted. Similarly among medium maturity lines 1003 healthy plants were selected and transplanted.

Additionally 118 breeding lines from Australia were evaluated for AB resistance under controlled environment using standardized whole plant screening technique. High level of resistance was not found in these lines, however, 65 lines were found moderately resistant (3.1 to 5 rating on 1-9 scale), 50 susceptible (5.1 to 7 rating) and 3 highly susceptible to AB**.**

Suresh Pande, PM Gaur and Mamta Sharma

ICAR-ICRISAT collaborative research on AB resistance: In collaboration with IIPR, Kanpur, 137 lines (90 entries from IVT (desi, late sown, large and extra large seeded seeded, rainfed and kabuli), 20 AVT (large and extra large seeded kabuli) and 27 from AB nursery) were evaluated for AB resistance under controlled environment conditions. Among IVTs only one entry P 282 was found moderately resistant to AB by showing < 5 rating on 1-9 rating scale. Among the AVTs, three extra large seeded kabuli lines (P 251, 254, 257) were found moderately resistant to AB by showing < 5 rating on 1-9 rating scale. Among the entries of AB nursery two lines AB 19 and 24 were found moderately resistant to AB. However, most of the IIPR-Kanpur lines were susceptible to AB.

Suresh Pande, Mamta Sharma, and Collaborators

Special Project Funding:
Accelerated Genetic Improvement of Desi Chickpea, funded by Council of Grain Growers Organization Ltd. (COGGO), Western Australia.

Activity 6.1.1.2 Develop chickpea breeding lines with resistance to *Helicoverpa*

Milestone: 5-10 sources of resistance and advanced lines tested for stability of resistance across locations (in India, Myanmar & Ethiopia) (HCS/CLLG/PMG) 2009

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
Indian Institute of Pulses Research, Kanpur

Progress/ Results:
Evaluation of advanced kabuli/desi breeding lines for resistance to *Helicoverpa:* We evaluated the Kabuli international chickpea nursery (20 genotypes) for resistance to the pod borer, *H. armigera* under natural infestation in the field. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative and maturity stges visually on a damage rating (DR) scale of 1 to 9 (1 = <10% leaf area/pods damaged, good pod setting, and pods uniformaly distributed all over the plant, and 9 = >80% leaf area/pods damaged, poor pod setting, and pods present on a few branches only), overall resistance score (1 = highly resistant, and 9 = highly susceptible), pod damage (%), wilt (%), and grain yield. Damage by *H. armigera* larvae at the vegetative stage ranged from 1 to 3 (low damage). Overall resistance scores ranged from 3 to 7, and the genotypes Annigeri, ICCV 04305, ICCV 06302, ICCV 07304, and ICCV 07308 exhibited lower pod borer damage (DR <4.0) than ICCV 07311 (DR 7.0). Pod damage ranged from 3.9 to 41.2%, and the lines Annigeri, ICCV 04305, ICCV 07304, ICCV 07308, ICCV 07310, ICCV 07312, and KAK 2 suffered <15% pod damage compared to 41.2% pod damage in ICCV 07301. Under unprotected conditions, grain yield was 1.43 to 1.53 t ha^{-1} in case of ICCV 07304, ICCV 07308, and ICCV 07311 compared to 0.80 t ha^{-1} in Annigeri.

In another trial, we evaluated the Desi international chickpea nursery (20 genotypes) for resistance to the pod borer, *H. armigera* under natural infestation. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage as described above. Damage by *H. armigera* larvae at the vegetative stage ranged from 1 to 2.5 (low damage). Overall resistance scores ranged from 3.5 (ICCV 07108) to 5.5 (ICCV 07101). Under borer infested conditions, high grain yield (>1.5 t ha^{-1}) was recorded in case of ICCV 07108, ICCV 07112, ICCV 07113, and ICCV 07116 as compared to 0.77 t ha^{-1} in Annigeri. The results suggested that some of the high yielding lines selected for distribution to the NARS/farmers from the conventional breeding program, without being selected for pod borer resistance, exhibited low levels of resistance to *H. armigera*.

Fourty-four advanced breeding lines earlier bred and selected for *H. armigera* resistance were also evaluated for resistance. All the lines exhibited moderate levels of resiatance to pod borer, except the selections 5105, 5100, and 5306. The results suggested that a greater proportion of lines selected for resistance to pod borer in the segregating generations exhibited resistance to this pest than the lines selected for agronomic performance only.

International *Helicoverpa* resistance screening nursery: The international *Helicoverpa* resistance screening nursery (25 lines) were distributed to NARS partners for evaluation. One set was also evaluated at Patancheru. There were three replications in a randomized complete block design. Observations were recorded on *H. armigera* damage on a 1 to 9 scale (1 is ≤ l0% of the leaf area/pods damaged, and 9 is ≥80% leaf area/pods damaged), larval density, and grain yield.

The results were received from nine locations in India. The overall levels of pod borer, *H. armigera* incidence and damage at most of the locations (except at ICRISAT - Patancheru, and GBPUA&T - Pantnagar), were quite low, and therefore, data from other locations was not considered for analysis. At ICRISAT- Patancheru, the genotypes ICC 506, ICCV 10, ICCL 87316, C 235, and ICCV 96572 suffered low leaf damage during the vegetative stage; while ICC 506, Vijay, ICCL 87314, ICCV 96752, and RIL 27 also suffered lower pod damage (<12% pod damage) as compared to ICC 3137 (35% pod damage). The genotypes ICC 14872, ICCV 10, Vishwas, ICCL 87316, and ICCV 95992 yielded >2,000 kg grain/ha as compared to 1,000 kg/ha of ICC 3137. At GBPUA&T – Pantnagar, the levels of pod damage were very high (80 to 100%), but grain yield was 1230 to 3970 kg/ha in case of ICC 506, ICCV 96752, ICCV 95992, PG 186, and L 550 as compared to 130 kg/ha in ICC 3137 (susceptible check).

Special Project Funding:
Tropical Legumes Project II - Gates Foundation; ISOPOM project on Helicoverpa resistance- ICAR

HC Sharma, CLL Gowda, PM Gaur and AICCIP Entomologists

Milestone 5-10 lines with resistance to both FW and Helicoverpa identified (CLLG/HCS/SP) 2011

Achievement of Output Target (%):
80%

Countries Involved:
India; Ethiopia; Myanmar

Partners Involved:
Indian Institute of Pulses Research, Kanpur, India; Central Agricultural Research Institute, Yezin, Myanmar; Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Progress/Results:
During 2008 we made 41 new crosses to incorporate *Helicoverpa* resistance in to adapted high-yielding varieties. We used five *Helicoverpa* resistant germplasm lines (ICC 12475, ICC 12476, ICC 12477, ICC 12478 and ICC 12479) and an improved breeding line with *Helicoverpa* resistance (ICCV 95992) and made crosses with wilt resistant lines and improved high yielding varieties and breeding lines. We also advanced 51single cross and 12 double cross F_1s. We screened 96 F_2s (71 crosses from a 9-parent diallel and 25 other crosses) for wilt and *Helicoverpa* resistance under natural infestation. Pods from healthy plants (that were resistant to fusarium wilt) were harvested as individual bulks (96 F_3 bulks).

From among 299 F_8-F_{10} progenies evaluated during 2007-08 post-rainy season, we selected 44 progenies based on low pod-borer damage and high yield. These progenies will be evaluated in preliminary yield trial during 2008-09 season.

We evaluated 44 advanced breeding lines in two preliminary yield trials (22 entries + 2 checks). Based on pod borer damage (less pod borer damage compared to check) and high yield, we selected 28 promising lines. These will be evaluated in advanced yield trial during 2008-09 post-rainy season.

CLL Gowda, HC Sharma and Suresh Pande

Evaluation of disease-resistant lines for resistance to pod borer, *Helicoverpa armigera:* We evaluated 86 disease-resistant lines (resistant to wilt, Aschochyta blight, and/or gray mold) along with resistant and susceptible checks for resistance to the pod borer, *H. armigera* to identify disease-resistant lines with less susceptibility to pod borer for use in multiple resistance breeding programs. There were two replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative and maturity stages visually, overall resistance scores, pod damage (%),wilt incidence, and grain yield. Damage by *H. armigera* larvae at the vegetative stage ranged from 1.0 to 5.5 (moderate damage). Overall resistance scores ranged from 3.0 to 7.0, and the wilt incidence ranged from 0.0 to 100%. Twenty-five lines showed <20% wilt incidence and moderate levels of resistance to pod borer, *H. armigera* (damage rating <4.0 and overall resistance rating of <5.0), and these lines will be evaluated further to identifiy lines for use in multiple pest resistance breeding program.

HC Sharma and Suresh Pande

Special Project Funding:
Bill and Melinda Gates Foundation, USA; Council of Grain Growers Organizations, Australia.

Milestone: Physico-chemical mechanisms of resistance to Helicoverpa identified and nature of inheritance studied (HCS/CLLG/PMG) 2011

Achievement of Output Target (%):
40%

Countries Involved:
India

Partner Institutions:
None

Progress/Results
Role of morphological and biochemical components for resistance to *Helicoverpa armigera:* We evaluated 37 morphologically diverse germplasm lines along with 12 resistant, susceptible, and commercial checks for resistance to the pod borer, *H. armigera* under natural infestation. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative stage, overall resistance score, pod damage, and grain yield. Damage by *H. armigera* larvae at the vegetative stage ranged from 1 to 7, while the overall resistance scores ranged from 3 to 9. Pod damage varied from 3.0 to 59.5%. The genotypes ICC 4934, ICC 5434, ICC 8923, ICC 14333, JGM 7, ICCV 10, ICCC 86111, ICC 5783, ICC 17159, and ICC 506 exhibited moderate levels of ressitance to *H. armigera*. Morphological and biochemical characterization of these lines is in pregress to identify traits associated with resistance to *H. armigera.*

Special Project Funding:
ISOPOM project on *Helicoverpa* resistance from Government of India

HC Sharma

Output target 6.1.2 CP Molecular markers for AB, BGM, and *Helicoverpa* resistance identified in chickpea

Activity 6.1.2.1 CP Mapping and marker-assisted breeding for diseases and insect resistance in chickpea

Milestone: One intra-specific RIL population for mapping AB resistance QTLs developed (PMG/ST/SP/MS) 2008

Achievement of Output Target:
100%

Countries Involved:
India

Partner Institutions:
None

Progress/Results:
ICCV 04516 (resistant parent with AB score of 3-4 on 1-9 scale, where 1 = immune and 9 = highly susceptible) and Pb 7 (susceptible parent with AB score of 9) were used as parents for developing RIL population for mapping the genes/QTLs for resistance to AB and BGM. A total of 153 RILs were developed and advanced to F_7.

Special Project Funding:
None

PM Gaur, Shailesh Tripathi, Suresh Pande and Mamta Sharma

Milestone: One inter-specific (C. arietinum x C. reticulatum) RIL populations for mapping Helicoverpa resistance QTLs developed (PMG/ST/HCS) 2009

Achievement of Output Target (%):
80%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Inter-specific RIL mapping population is being developed from the cross ICC 3137 (susceptible) x IG 72953 (tolerant). The seeds are vernalized (keeping the seeds at 4°C for one month, prior to planting) in each generation in order to reduce the time taken for flowering as one of the parents (IG 72653) involved in the cross is a wild relative (*Cicer reticulatum*). A total of 237 F_5 RILs are presently being grown.

Special Project Funding:
None

PM Gaur, Shailesh Tripathi and HC Sharma

Milestone: QTLs for Helicoverpa resistance identified from C. arietinum x C. reticulatum RIL population (HCS/RKV/PMG) 2011

Achievement of Output Target (%):
20%

Countries Involved:
India; Ethiopia; Kenya; Tanzania

Partners Involved:
Indian Institute of Pulses Research (IIPR), India; Ethiopian Agricultural Research Organization (EARO), Ethiopia; Kenya Agricultural Research Institute (KARI), Kenya

Progress/Results:
Evaluation of interspecific (*C. arietinum* x *C. reticulatum*) mapping populations for resistance to pod borer, *Helicoverpa armigera*: The mapping population derived from ICC 4958 (*Cicer arietinum*) x PI 489777 (*Cicer reticulatum*) (128 lines along with resistant – ICC 506EB, susceptible - ICC 3137, commercial – ICCC 37, local – Annigeri, and Kabuli – L 550 checks, along with the two parents) was evaluated for resistance to pod borer, *H. armigera* using detached leaf assay in the laboratory, and under natural infestation in the field. Detached leaf assay was conducted in the laboratory at the vegetative (30 days after seedling emergence) and at the flowering stages. For this purpose, the terminal branches (5 to 7 cm long) were brought to lab from the field, inserted in 3% agar-agar as a supporting medium, and infested with 10 neonate larvae in a 250 ml plastic cup. Data were recorded on leaf feeding on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval weight, and larval survival at 5 days after infestation.

During the vegetative phase, leaf damage rating varied from 1 to 5 in the mapping population, 3.0 in PI 489777 and ICC 4958, 1.5 in ICC 506, and 2 in ICCC 37. At the flowering stage, the leaf damage scores ranged from 2.0 to 7.5 in the mapping population, 4.0 in PI 489777, 5.5 in ICC 4958, 4.0 in ICC 506, and 6.0 in ICCC 37. The larval weights varied from 1.7 to 7.8 mg per larva in the mapping population, 2.3 mg in PI 489777, 6.0 mg in ICC 4958, 1.9 mg in ICC 506, and 4.0 mg in ICCC 37 during the vegetative stage. During the flowering stage, the larval weights were 1.7 to 8.2 mg in the mapping population, 6.0 mg on PI 489777, 5.4 mg on ICC 4958, 1.53.8 mg on ICC 506, and 4.7 mg on ICCC 37. The results indicated considerable variation in the test material to damage by *H. armigera*, and growth and survival of the larvae. The CRIL numbers 2-2, 2-13, 2-16, 2-17, 2-25, 2-31, 2-40, 2-60, 2-65, 2-72, 2-81, 2-92, 2-95, and 2-123 showed low leaf feeding and larval weight gain at the vegetative and/or the flowering stages, and these lines may be useful as resistance donors for use by the breeders to develop chickpeas with resistance to *H. armigera*.

Under natural infestation in the field, data were recorded on leaf and pod damage visually on a 1 to 9 scale as described above, egg and larval numbers per 10 plants, and pod damage. Leaf feeding scores at the vegetative stage ranged from 1.5 to 6.5 in the mapping population, 5.5 in PI 489777, 2.0 in ICC 4958, 1.0 in ICC 506, and 2.5 in ICCC 37. There were 0.0 to 8.5 eggs per 10 pants at the vegetative stage and 0.0 to 2.0 eggs at the flowering stage. Very few or no eggs were recorded on the parents and/or resistant and susceptible checks. The mapping population had 0.0 to 8.0 larvae per 10 plants at the vegetative stage, and 4.0 to 40.0 larvae at the flowering stage, suggesting that the pod borer incidence was quite high at the flowering stage and there was considerable variation among the RILs. There were 1.0 and 2.5, and 12.5 and 21.5 larvae per 10 plants at the vegetative and flowering stages in the parents PI 489777 and ICC 4958, respectively. The resistant (ICC 506) and susceptible (ICCC 37) checks had 1.5 and 3.0, and 5.5 and 14.0 larvae per 10 plants at the vegetative and flowering stages, respectively. Some of the late flowering RILs were damaged by rain and that had a considerable effect on pod setting, and hence, on evaluation of the mapping population for pod damage.

HC Sharma, PM Gaur and Rajeev Varshney

Genotyping of the mapping population: Screening of newly developed 1344 CaM (derived from BES) and 311 ICCM markers at ICRISAT with the parental genotypes of this mapping population showed polymorphism with 253 CaM and 52 ICCM markers. In addition, screening of another set of 233 SSR markers (H-series) with these parental genotypes showed polymorphism with 52 markers. All these polymorphic markers were screened on 131 recombinant inbred lines (RILs) of this mapping population. Marker genotyping data generated by other research groups such as University of Frankfurt (Germany) / University of California- Davis (USA) on this population have also been assembled. The genotyping data available so are being analyzed for developing the genetic map for this population.

RK Varshney, SN Nayak, HC Sharma and PM Gaur

Special Project Funding:
Tropical Legume I of Generation Challenge Programme

Output target 6.1.3 CP Interspecific derivatives with resistance to AB, BGM and *Helicoverpa* developed

Activity 6.1.3.1 CP Inter-specific derivatives with resistance to *Helicoverpa* and BGM generated using wild *Cicer* from different gene pools

Milestone: Wild relatives with diverse mechanisms of resistance to Helicoverpa identified (HCS) 2009

Achievement of Output Target (%):
75 %

Countries Involved:
India; USA

Partners Involved:
USDA, Pullman

Progress/Results:
Role of morphological and biochemical components for resistance to *Helicoverpa armigera:* We evaluated 37 morphologically diverse germplasm lines along with 12 resistant, susceptible, and commercial checks for resistance to the pod borer, *H. armigera* under natural infestation. There were three replications in a randomized complete block design. Data were recorded on *H. armigera* damage at the vegetative stage, overall resistance score, pod damage, and grain yield. Damage by *H. armigera* larvae at the vegetative stage ranged from 1 to 7, while the overall resistance scores ranged from 3 to 9. Pod damage varied from 3.0 to 59.5%. The genotypes ICC 4934, ICC 5434, ICC 8923, ICC 14333, JGM 7, ICCV 10, ICCC 86111, ICC 5783, ICC 17159, and ICC 506 exhibited moderate levels of ressitance to *H. armigera*. Morphological and biochemical characterization of these lines is in progress to identify traits associated with resistance to *H. armigera*..

HC Sharma

Evaluation of wild relatives of chickpea for different mechanisms of resistance to *Helicoverpa armigera*. Eighteen accessions of wild relatives of chickpea were evaluated for resistance to *H. armigera* along with resistant (ICC 506) and susceptible (ICCC 37, ICC 3137, and L 550) checks using detached leaf assay. There were three replications in a completely randomized design. Each terminal branch was infested with 10 neonate larvae in a 250 ml plastic cup, and the data were recorded on leaf feeding and larval weights at five days after infestation. Leaf damage rating ranged from 2.0 in ICCC 86111 to 5.0 in PI 510663. The larval weights were lower than 2.0 mg per larva on IG 70006, IG 70012, IG 70018, IG 70022, IG 70032, ICCW 117148, PI 568217, PI 599046, PI 599078, and PI 599097 as compared to 1.35 mg on ICCC 8611, and 4.67 mg on L 550.

HC Sharma

Evaluation of perennial wild chickpeas for resistance to *Helicoverpa armigera*: Sixteen accessions of perennial wild relatives of chickpea along with the local perennial wild chickpea, *Cicer microphyllum*, were evaluated for resistance to *H. armigera* under natural infestation at the Regional Research Station, Himachal Agricultural University, Kukumseri, Himachal Pradesh, India. Data recording and analysis are in progress.

HC Sharma, Dorin Gupta and SL Clement

Special Project Funding:
USAID Linkage Grant; ISOPOM project on Helicoverpa resistance, Govt of India

Milestone: Interspecific derivatives (10) with enhanced resistance to AB, BGM, and Helicoverpa identified and made available to partners (NM/HCS/SP/PMG) 2010

Achievement of Output Target (%):
50% as *H. armigera* and BGM resistant derivatives have been identified, which need to be further verified.

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Evaluation of interspecific derivatives for resistance to *Helicoverpa armigera*: We evaluated six interspecific derivatives from *Cicer arietinum* x *Cicer reticulatum* for resistance to pod borer, *H. armigera* along with resistant and susceptible checks using detached leaf assay. Each terminal branch was infested with 10 neonate larvae in a 250 ml plastic cup, and the data were recorded on leaf feeding and larval weights at five days after infestation. Lower larval weights were recorded on lines 117-10, 320-7, and 321-3 (2.19 to 3.05 mg per larva) as compared to that on the susceptible check, L 550 (4.67 mg per larva). Leaf feedig on these lines was also lower than that on the susceptible control.

One hundred and thirty interspecific derivatives were evaluated for *Helicoverpa armigera* damage under unprotected field conditions. Amongst these 16% lines had less than 10% damage and 39% of the lines had less than 20% damage. Selected plants were picked for laboratory pod bioassay and antibiosis mechanism of resistance was observed in the resistant plants, which showed low larval weight gain, abnormal pupal and adult emergence.

Special Project Funding:
None

N Mallikarjuna and HC Sharma

Output target 6.1.4 CP Promising transgenic events of chickpea with proven resistance to *Helicoverpa* available for introgression in locally adapted germplasm

Activity 6.1.4.1 CP Develop transgenic events of chickpea for resistance to *Helicoverpa armigera* and evaluate their performance under contained greenhouse and field conditions

Milestone: 50 transgenic events of chickpea with Bt genes developed and screened in contained greenhouse (KKS/PB/HCS/MKD/PMG) 2008

Achievement of Output Target (%):
100%
Countries Involved:
India

Partners Involved:
None

Progress/Results:
Efforts are ongoing to develop transgenic plants of chickpea engineered for resistance to *Helicoverpa armigera*. Several *Bt* genes have been used through *Agrobacterium tumefaciens*-mediated genetic transformation of popular chickpea cultivar C 235 using the axillary meristems as the explants. For efficient expression of *cry1Ac* gene in chickpea, six different gene constructs with different promoters were used for production of transgenic Bt-chickpea.

At least, 225 independent T_1 transgnic chickpea events have been produced and transferred to the contained greenhouse using different *cry* genes. Molecular characterization of these plants was carried out to ascertain the integration and expression of the transgenes. All PCR positive events were subjected to ELISA, and the events showing promising results were subjected to insect bioassays. Over 150 (from 25 events) *cry1Ac* transformed chickpea plants, along with non-transformed cultivar C 235, and the resistant line ICC 506 as controls for resistance to pod borer, *H. armigera* were evaluated under laboratory conditions. Three terminal branches from each plant were bioassayed for resistance to *H. armigera* using detached leaf assay. Observations were recorded on leaf damage on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval survival, and larval weights after five days of feeding. In the 1st set, the leaf damage rating varied from 4.0 to 9.0 as compared to 9.0 in C 235 and 5.0 in resistant check ICC 506. Larval weights among the transgenic plants varied between 1.80 to 12.26 mg larva^{-1}, while on the non-transformed C 235 and ICC 506 it was 7.2 and 4.4 mg larva^{-1}, respectively. The percentage of larval survival ranged from 30 to 90% in transgenic events in contrast to 20-100% observed in the untransformed controls. Damage rating ranged from 2.5 to 8.5 in the transgenic events. The weight of larvae feeding on transgenic plants showed significant reduction (0.8 -7.5 mg/larva) in transgenic lines when compared to the controls (1.4 to 15.6 mg/larva). Based on the bioassay results, 10 plants with low leaf damage, larvae survival and weight gain were selected for further testing. In another set, involving 60 *cry1Ac* transformed chickpeas, the leaf damage rating varied between 2.5 to 9.0 as compared to 5.0 and 3.3 in non-transformed C 235 and ICC 506, respectively. Larval weights on *Bt*-transformed plants varied from 0.8 to 7.5 mg larva^{-1} as compared to 3.6 and 2.4 mg larva^{-1} in non-transformed C 235 and resistant check, ICC 506, respectively. The transgenic events showing positive results have been advanced for further evaluations. Additional events are being developed to identify events showing high Bt expression.

Special Project Funding:
Department of Biotechnology (DBT), Govt. of India funded project on transgenic resistance to Helicoverpa, and DBT, ICAR project on transgenic chickpeas

KK Sharma, P Bhatnagar-Mathur, HC Sharma, MK Dhillon and PM Gaur

Milestone: One or two transgenic events of chickpea identified and used for introgression into locally adapted genotypes and the progeny characterized and evaluated (KKS/PB/HCS/MKD/PMG) 2011

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results
The results reported above for 2008 milestone represents 20% of the progress towards achieving this milestone

Special Project Funding:
None

KK Sharma, P Bhatnagar-Mathur, HC Sharma, MK Dhillon and PM Gaur

NON-HYBRID PIGEONPEA

Output target 6.1.1 PP About 5-6 pigeonpea varieties with stable resistance to *Fusarium* wilt, sterility mosaic and *Helicoverpa* made available to NARS

Activity 6.1.1.1 PP About 15 new genetically diverse germplasm sources/breeding lines resistant to wilt and sterility mosaic diseases identified

Milestone: 25-30 pigeonpea lines tested multilocationally for their stability to wilt and sterility mosaic resistance in India (SP) Annual

Achievement of Output Target (%):
40%

Countries Involved:
India

Partners Involved:
ICRISAT-Patancheru, IIPR-Kanpur, UAS-Bangalore, ARS-Badnapur, TNAU- Coimbatore, Tirhut College of Agriculture- Dholi, AICRP (Pulses),-Gulbarga, JNKVV, ARS-Khargone, MPKVV-Rahuri, RAK college of Agriculture-Sehore, TNAU-Vamban

Progress/Results:
Identification of stable sources of resistance to fusarium wilt and sterility mosaic: To identify stable and broad based resistance to fusarium wilt (FW) and sterility mosaic (SM), pigeonpea lines having combined resistance to FW and SM identified at ICRISAT-Patancheru were evaluated for resistance to both these disease at different locations in India through pigeonpea wilt and sterility mosaic disease nursery (PWSMDN). PWSMDN consisted of 30 entries, 28 entries were resistant to both wilt and SM at ICRISAT-Patancheru one wilt susceptible (ICP 2376) and one

SM susceptible (ICP 8863) checks. Additionally, two local susceptible checks, one each for wilt and SM were also included from the participating scientists. The nursery was evaluated at 18 locations in India Akola, Badnapur, Bangalore, Berhampore, Coimbatore, Dholi, Faizabad, Gulbarga, Hazaribag, ICRISAT-Patancheru, Kanpur, Khargone, Vamban (Pudukottai), Raipur, Rahuri, Sehore, S K Nagar, and Varanasi, India. Each entry was planted in one row of 4 m long and replicated twice. In most of the locations the nursery was planted in wilt sick plot and every plant of the nursery inoculated with SM infested pigeonpea leaves using leaf staple technique at two leaf stage wherever possible and if not, SM infested twigs were spread on the plants of the nursery at seedling stage for SM development. Data on FW and SM was recorded twice, at flowering and at maturity stages of the crop.

Out of 18 locations, data on wilt from 9 locations (Badnapur, Bangalore, Dholi, Gulbarga, Kanpur, Khargone, ICRISAT-Patancheru, Rahuri and Sehore) and on SM from seven locations (Badnapur, Bangalore, Coimbatore, Dholi, ICRISAT-Patancheru, Rahuri and Vamban) were received and compiled. Susceptible check, ICP 2376 had high (>80%) wilt incidence in Badnapur, Gulbarga, Kanpur, ICRISAT-Patancheru, Rahuri and Sehore whereas it was moderate (40 %) in Bangalore, Dholi and Khargone. Of the 28 entries, 6 entries (KPBR 80-2-4, ICPL 20096, ICPL 20102, ICPL 20109, ICPL 20113 and ICPL 20115) were found asymptomatic/ resistant (<10% incidence) to FW at eight locations. Twelve entries were found asymtomatic/ resistant to FW at seven locations.

Data on SM was received from seven locations. Of the 28 entries, 3 entries, ICP 20094, ICP 20098 and ICPL 20103 were found asymtomatic/ resistant at four locations (ICRISAT, Badnapur, Rahuri and Vamban). Nine entries were resistant (0.1-10% incidence) at three locations.

ICAR-ICRISAT collaborative research on multilocation evaluation of promising pigeonpea entries: Forty five promising pigeonpea entries for identification of donors from IIPR, Kanpur was evaluated for resistance to FW and SM under artificial epiphytotic conditions during 2007-08 at ICRISAT, Patancheru. Out of 45 entries, eight entries (BDN 2029, BSMR 846, BWR 133, IPA 8F, IPA 204, IPA 234, BSMR 528, NDA 98-1) were resistant to both FW and SM. Sixteen entries were asymptomatic and nine resistant to SM. However, no entry was asymptomatic and ten were resistant to FW.

Suresh Pande, Mamta Sharma, Varsha Wesley and Indian NARS Collaborators

Fusarium wilt and SM reaction in *Helicoverpa* resistant lines: Nine *Helicoverpa*-resistant lines were evaluated for combined resistance to FW and SM under artificial epiphytotic conditions using the standard field screening technique. Among these lines, two lines (ICP 7035, ICPL 87119) had combined resistance to both FW and SM. In addition to this one line was moderately resistant (10.1-20%) to FW. However, two lines were asymptomatic (ICP 7035, ICPL 269) and four resistant to SM (0.1-10 % incidence).

Suresh Pande, Mamta Sharma, Varsha Wesley and HC Sharma

Special Project Funding:
None

Milestone: About 100 germplasm/advanced breeding lines screened for wilt and sterility mosaic disease resistance using different isolates and characterized for agronomic traits (SP/VW/RKS/KBS/HDU) 2009

Achievement of Output Target (%):
70%

Countries Involved:
India

Partners Involved:
IIPR-Kanpur, India

Progress/Results:
Fusarium wilt and SM resistance in advanced breeding lines: Forty seven (17 advanced selections from breeders material and 26 promising selections from IIPR Kanpur) were evaluated for combined resistance to FW and SM under artificial epiphytotic conditions during 2007-08 at ICRISAT, Patancheru.
FW susceptible cultivar showed 100% disease incidence and SM susceptible cultivar showed >90% disease incidence. Of the 17 advanced selections, five lines (ICPLs 20124, 20125, 20130, 94068, 99044) were asymptomatic (0% incidence) and 11 lines were resistant to both FW and SM. However, six lines were asymptomatic and 10 resistant to FW while 11 were asymptomatic and 6 resistant to SM. Among the 26 wilt and SM promising selections from IIPR, Kanpur 18 lines were resistant to both FW and SM.

Confirmation of FW and SM resistance in breeding lines: Sixty- two wilt and 35 SM resistant breeding lines were evaluated for combined resistance to FW and SM under artificial epiphytotic conditions during 2007-08 at ICRISAT, Patancheru. Of the 62 wilt resistant lines, 15 were resistant and 17 moderately resistant to both FW and SM. However among the 35 SM resistant lines, only one line (ICP 7035) was resistant to both FW and SM.

Suresh Pande, Mamta Sharma, Varsha Wesley, KB Saxena and RK Srivastava

ICAR-ICRISAT collaborative research on pigeonpea FW and SM: Under the ICAR-ICRISAT collaboration, 93 entries (79 entries from national nursery of AVT and IVT and 14 entries from national nursery of disease resistant genetic stock to wilt) from IIPR, Kanpur, India were evaluated for FW and SM resistance under artificial epiphytotic conditions following standard field screening technique.

In the AVT and IVT nursery, combined resistance to FW and SM was found in four lines (BDN 2004-1, BDN 2010, BDN 2029, BWR 133). Six entries (BDN 2004-1, IPA 14F, BWR 133, IPA 8F, IPA 15F, IPA 2013) were asymptomatic and nine resistant to SM. No line was asymptomatic to wilt but five lines were resistant. Among the 14 entries in the national nursery for disease-resistant to wilt, one entry KPL 43 had a combined resistance to FW and SM. Seven entries were asymptomatic (0%) to SM and 1 resistant (<10%). One entry (KPL 43) was found resistant and two moderately resistant to FW.

Identification of races/strains of *F. udum*: Ten host plant differential of pigeonpea for identification of races/strains of *F. udum* from IIPR, Kanpur were evaluated for FW and SM resistance under artificial epiphytotic conditions following standard field screening technique. Out of 10 differentials, one (ICP 9174) had combined resistance to both FW and SM. Two lines (ICPs 8863, 9174) were found resistant to FW. One line (Bahar) was asymptomatic and two (ICPs 8862, 9174) resistant to SM.

Suresh Pande, Mamta Sharma, Varsha Wesley and AICRP Collaborators

Collection, purification and maintenance of virulence of isolates of *Fusarium udum:* Twenty six isolates of *Fusarium udum* collected from 18 locations in 5 states in India were purified for the maintenance of virulence. Pathogenicity test was done using a common susceptible cultivar ICP 2376 following root dip technique under greenhouse conditions at ICRISAT-Patancheru. Koch's postulates were proved and isolations were made from freshly wilted seedlings and incubated at 25^0 C in the incubators for seven days. Pure cultures were selected and single spore isolates were obtained following standardized mycological techniques.

Standardization of protocols for pathogenic and molecular characterization of *Fusarium udum* isolates*:* A total 20 isolates collected from 9 locations in 6 states in India till 2007, were evaluated for pathogenic variation of *Fusarium udum* in greenhouse. Root dip technique was standardized and followed for inoculation. Pigeonpea seedlings were raised in sand in polythene bags for seven days. Pure culture of the F. udum was multiplied on potato dextrose broth for 7 days. After seven days seedlings were root inoculated by dipping the roots in the inoculum and transplanted in pre-irrigated pots (12.5cm) @ five seedlings per pot and replicated thrice. Seedlings were observed for 40 days for wilt development. Initial and final wilts in each pot and mortality due to wilt were recorded at weekly intervals. Data analysis is in progress.

All the twenty isolates of *F. udum* were studied for genetic variation using Amplified Fragment Length Polymorphism (AFLP). The protocol for extraction of DNA was standardized. Genomic DNA was extracted from each isolate by the cetyldimethylethyl ammonium bromide (CTAB) method. The AFLP analysis was carried out using the commercial kit (Gibco BRL, USA) following the manufacturer's protocols with slight modifications as described below. Primary template DNA was prepared in a one-step restriction-ligation reaction. Fungal genomic DNA (400ng) was digested with the two restriction endonucleases, *Eco*R1 and *Mse*l and ligated to *Eco*R1 and *Mse*l adapters. The ligation mixture was preamplified in a thermal cycler using a temperature cycle of 94°C for 30 s, 56°C for 60 s, and 72°C for 60 s in a total of 30 cycles. Selective primers provided in the kit were used and the amplification was carried out according to the manufacturer's protocol. The five EcoR1 primer and Mse1 primer were used in different combinations for amplification. Data analysis is in progress.

Suresh Pande and Mamta Sharma

Special Project Funding:
None

Milestone: Molecular characterization of wilt/sterility mosaic resistant and susceptible germplasm/breeding lines for developing mapping populations with diverse genetic background (RKV/SP//KBS/RKS//DAH) 2009

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
None

Progress/Results
In order to develop mapping populations segregating for *Fusarium* wilt and sterility mosaic disease resistant, molecular characterization of the germplasm lines has already been reported in the Archival Report -2007. So this milestone has already been completed.

Based on molecular characterization and phenotyping data, five parental combinations were identified. All (five) populations developed in 2006-2007 were advanced to the F_2. However, in few crosses (ICPL 87119 × ICPL 87091 and ICP 7035 × ICPL 332) any viable F_1 could not be recovered. After repetition of these crosses in the last growing season of 2008 at ICRISAT, F_1s were collected. Polymorphic markers between parents were utilized to confirm the hybridity of F_1s (Fig. RKV1). In all the crosses F_1s were having both the alleles coming from their respective parents.

Special Project Fundings:
Indo-US Agricultural Knowledge Initiative of ICAR, Govt. of India.

RK Varshney, RK Saxena, S Pande, KB Saxena and RK Srivastava

Milestone: At least 5 new varieties with multiple disease and insect resistance made available to partners (KBS/RKS/SP/HCS) 2010

Achievement of Output Target (%):
100%

Countries Involved:
India, Myanmar, Philippines

Partners Involved:
Indian Council of Agricultre Research (ICAR), Govt. of India; Department of Agricultural Research (DAR), Myanmar; Isabela State University (ISU), Philippines

Progress/Results:
New *Fusarrium* wilt and sterility mosaic disease resistant pure-line varieties have been made available to the various NARS partners. A total of 3160 kg of breeder seed of these varieties was made available during 2007 and 2008. These varieties include ICPL 87119 (Asha), ICP 8863 (Maruti), ICPL 85063 (Lakshmi), and ICP 7035 (Kamica). In addition a *Fusarium* wilt resistant and *Helicoverpa* tolerant line ICP 332 WR has been

developed at ICRISAT Patancheru. Limited quantities of breeder seed of this varietiey have been shared with ARS Tandur, ANGRAU Hyderabad, India.

Special Project Fundings:
IFAD Grant 954, ISOPOM, Tropical Legumes II

KB Saxena, RK Srivastava, S Pande and HC Sharma

Activity 6.1.1.2 PP Genetically diverse germplasm/breeding lines with resistance to *Helicoverpa* identified

Milestone: Ten germplasm/advanced breeding lines with resistance to Helicoverpa identified and distributed to NARS (HCS/KBS/RKS//HDU) 2009

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Indian Institute of Pulses Research

Progress/Results:
Evaluation of pigeonpea germplasm for resistance to pod borer, *Helicoverpa armigera*: We evaluated 146 pigeonpea germplasm accessions for resistance to *H. armigera* along with resistant and susceptible checks under field conditions. There were three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 rating scale (1 = <10% pods damaged and the pods uniformly distributed all over the plant, and 9 = >80% pods damaged and pods present only on a few branches), and grain yield. Genotypes ICP 995, ICP 1279, ICP 6128, ICP 8840, ICP 10397, ICP 8863, ICP 332, and ICPL 187-1 exhibited moderate levels of resistance to pod borer, *H. armigera*. These lines also showed good yield potential (>1.5 t ha^{-1}) under unprotected conditions, and these lines can be used for developing pigeonpea vatrieties with less susceptibility to *H. armigera*.

HC Sharma and HD Upadhyaya

Relative susceptibility of white seeded pigeonpea lines for resistance to pod borer, *Helicoverpa armigera*: We evaluated 21 white seeded lines of pigeonpea for resistance to *H. armigera*. There were three replications in a randomized complete block design. Data were recorded on pod borer damage, and recovery resistance on a 1 to 9 rating scale, and grain yield. Genotypes ICP 2711, ICP 6628, and ENT 11 showed moderate levels of pod damage and recovery resistance (scores 4 to 5), and also exhibited good yield potential (1,031 to 1,739 kg ha^{-1}) under unprotected conditions, and these lines can be used for developing white seeded pigeonpea vatrieties with less susceptibility to *H. armigera*.

Relative susceptibility of purple podded pigeonpea lines for resistance to pod borer, *Helicoverpa armigera*: We evaluated 15 purple podded pigeonpea genotypes for resistance to *H. armigera*. There were three replications in a randomized complete block design. Data were recorded on pod borer damage and recovery resistance on a 1 to 9 rating scale, and grain yield. Genotypes ICP 11181, IPC 2933, ICP 7035, and LRG 41 showed moderate levels of pod damage and recovery resistance (scores 4 to 5), and also exhibited good yield potential (1,212 to 2,141 kg ha^{-1}) under unprotected conditions, and these lines can be used for developing vegetable type pigeonpea vatrieties with less susceptibility to *H. armigera*.

Evaluation of morphologically diverse pigeonpea lines for resistance to *Helicoverpa armigera*: Fifteen morphologically diverse lines of pigeonpea were studied for their interaction with *H. armigera* along with the resistant (ICPL 332) and susceptible (ICPL 87 and ICPL 87119) checks in the field. There were three replications in a RCBD. Data were recorded on oviposition, larval density, and pod damage by *H. armigera*, and recovery resistance on 1 to 9 scale as described above. Genotypes ICP 9879, ICP 8102, and ICP 11975 exhibited oviposition nonpreference, and also had low larval density under field conditions; while ICP 12746, ICP 12942, and ICP 9880, though preferred for oviposition, also had lower larval numbers indicating that antibiosis is one of the components of resistance to *H. armigera* in these genotypes. Genotypes ICP 6919, ICP 12476, ICP 12942, and ICP 11975 also suffered lower pod damage (<20%) compared to 43% pod damage in susceptible check ICPL 87119.

HC Sharma

Special Project Fundings:
ISOPOM project on Helicoverpa resistance - ICAR

Milestone: Mechanisms of resistance to Helicoverpa in diverse germplasm characterized (HCS) 2011

Activities 6.1.1.3 PP Advanced generation interspecific derivatives with resistance to *Helicoverpa* and SMD using wild species from different gene pools developed
Milestone: Physico-chemical mechanisms of resistance to Helicoverpa in wild relatives of pigeonpea identified for use in crop improvement (HCS) 2009

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
Indian Institute of Pulses Research, Kanpur, India

Progress/ Results:
Physico-chemical mechanisms of resistance to *Helicoverpa armigera* in pigeonpea: We studied the physico-chemical components associated with expression of resistance to *H. armigera* in wild relatives of pigeonpea to identify accessions with diverse mechanisms of resistance to this pest. Oviposition non-preference was an important component of resistance to *H. armigera* in *Cajanus scarabaeoides*, while heavy egg-laying was recorded on *C. cajanifolius* (ICPW 28) and *Rhynchosia bracteata* (ICPW 214). Accessions belonging to ***R. aurea, C. scarabaeoides, C. sericeus, C.***

acutifolius, and *R. bracteata* showed high levels of resistance to *H. armigera,* while *C. cajanifolius* was as susceptible as the susceptible check, ICPL 87. Glandular trichomes (type A) were associated with susceptibility, while the nonglandular trichomes (trichome type C and D) were associated with resistance to *H. armigera*. Expression of resistance to *H. armigera* was also associated with low amounts of sugars and high amounts of tannins and polyphenols. Accessions of wild relatives of pigeonpea with non-glandular trichomes (type C and D) or low densities of glandular trichomes (type A), high amounts of polyphenols and tannins, and low amounts of sugars may be used in wide hybridization to develop pigeonpea cultivars with resistance to *H. armigera.*

Special Project Funding:
ISOPOM project on Helicoverpa resistance - ICAR

HC Sharma

Milestone: Ten interspecific derivatives from different Cajanus species belonging to different gene pools with resistance to Helicoverpa identified for use in pigeonpea improvement (NM/HCS/HDU) 2011

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
Indian Institute of Pulses Research, Kanpur

Progress/ Results:
Evaluation of interspecific derivatives of pigeonpea for resistance to *Helicoverpa armigera*: Nineteen interspecific derivatives from wild relatives of pigeonpea along with ICP 7035 were evaluated for resistance to pod borer, *H. armigera* under field conditions. There were three replications in a RCBD. Data were recorded on pod damage, recovery resistance, and grain yield. Pod borer damage and recovery ressitance scores ranged from 4.0 to 7.7 and 4.3 to 6.0, respectively. (Pant A-2 x *C. albicans*) 23-2, (Pant A-2 x *C. albicans*) 9-1, (Pant A-2 x *C. albicans*) 23-1, (UPAS 120 x *C. trinervis*)-1-1, and (Pant A-2 x *C. scarabaeoides*) 20-1 showed moderate levels of resistance to *H. armigera*. These lines also exhibited oviposition nonpreference and antibiosis to this pest.

In another trial, we evaluated 107 biparental progenies of ICPW 94 x ICP 28 for resistance to pod borer, *H. armigera*. Data were recored on oviposition, larval density, and pod borer damage. Seven lines showed damage and recovery resistance levels comparable to the resistant checks, ICPL 187-1 and/or ICPL 332. Twenty-two lines had 70% healthy pods, as was the case with ICPL 332 and ICPL 187-1. Signiciant variation was also observed in terms of number of flowers retained on the plant, eggs laid, and larval density.

HC Sharma and HD Upadhyaya

Evaluation of *C. cajan x C. scarabaeoides* crosses: To transfer pod borer resistance from wild species to cultivated pigeonpea, crosses involving cultivated (*C. cajan*) accessions ICP 26, ICP 28, ICP 14770 and *C. scarabaeoides* were attempted during 2004 rainy season. Cross ICP 28 x ICPW 94 was found promising. Biparental crosses were attempted among the selected progenies. A total of 143 F_3 biparental progenies with good agronomic background and tolerant to

pod borer were selected in 2007 and were evaluated in the F_4 generation for tolerance to pod borer and other agronomic traits during 2008. Data recording is in progress.

HD Upadhyaya, HC Sharma and N. Malikarjuna

***Helicoverpa* resistance in *C. acutifolius*:** Lines with high resistant score (2-4, on a scale of 1-9) were selected from 2007 screening experiment and grown in an unprotected field for *Helicoverpa armigera* screening. Twenty lines were selected which had low *H. armigera* damage and low pod fly damage compared to the control cultivars. Five of the lines had higher seed weight (12.0 to 17.0 gms/100 seed weight) in addition to low *H. armigera* damage (Fig. 6.3). These lines have shown low *H. armigera* damage for the last three consecutive screening years. Other interesting characters observed in the lines were seed color (white and brown), stay green trait, where the plants were green when rest of the material had dried.

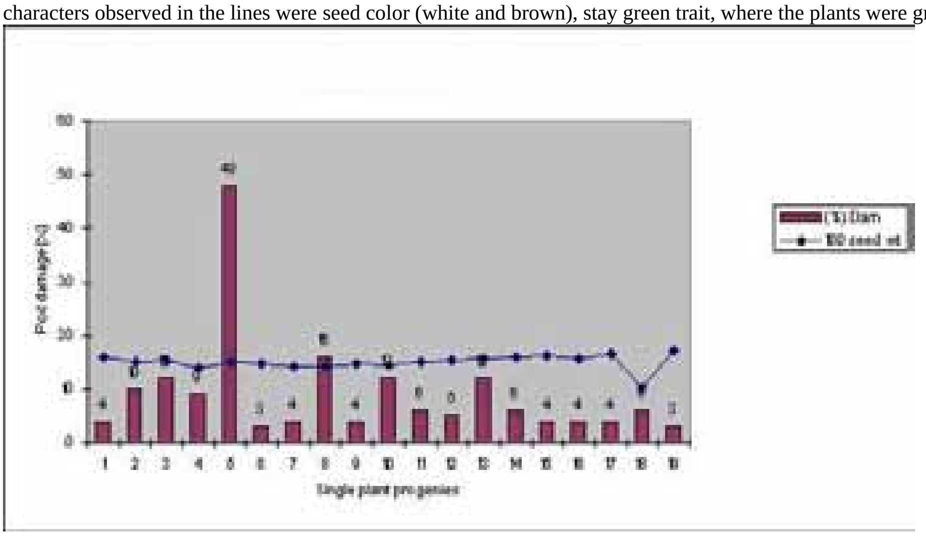


Fig 6.3: *Helicoverpa armigera* pod damage and 100 seed weight in *C. acutifolicus* line 7018-40-26-6

Helicoverpa* resistance in *C. platycarpus: Detailed study on *H. armigera* damage, pod fly (*Melanagromyza obtuse*) damage, Phytophthora blight, stay green trait, plant morphology, seed color, seed weight and yield, was carried out on 30 lines. *H. armigera* damage varied from 2-30% with individual plant damage ranging from 0 to 30%. Many of the lines had less than 15% damage (Fig. 6.4). Two lines had less than 5% *H. armigera* and pod fly damage and 20 lines had less than 15% damage by both the constraints. The line with Phytophthora blight resistance had less than 10% damage due to *H. armigera*.

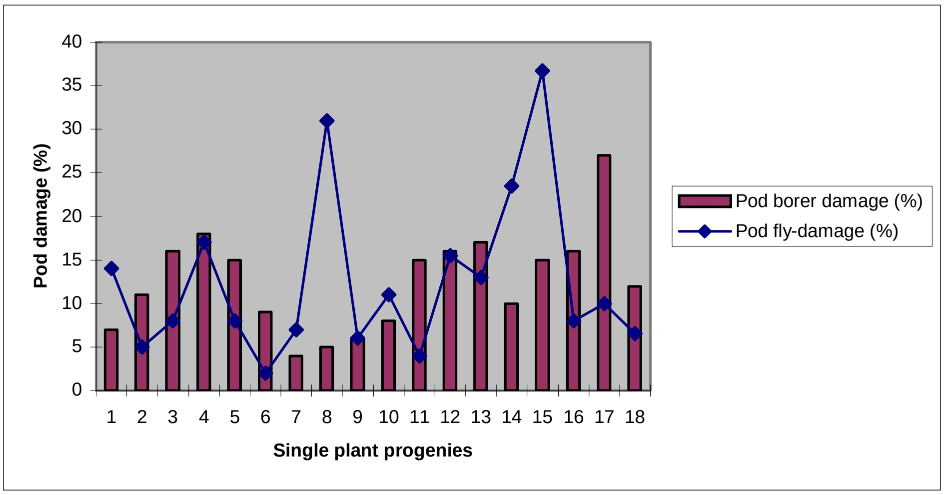


Fig. 6.4: *Helicoverpa armigera* pod damage Pod damage assessment in *C. platycarpus* derived line BC4A4-13-5-1

N Mallikarjuna

Special Project Funding:
Nil

Milestone: New sources of SMD resistance generated through the utilization of wild Cajanus (NM/ VW/SP/ KBS) 2010

Achievement of Output Target (%):
50% of the target has been achieved as introgression of traits from wild *Cajanus* species has been achieved and first year screening for SMD has been completed.

Countries Involved:
India

Partners Involved:
NARS in India

Progress/ Results
Sixty enteries generated utilizing wild *Cajanus acutifolius* and *C. scarabaeoides* were screened for sterility mosaic Patancheru isolate. The material was planted in pots and replicated 6 times. Susceptible checks were repeated after every 10 test material. Two primary leaves of the seedlings were stapled/inoculated with PSMD leaves containing 5-10 mites per leaf. The final observation was recorded after two months of inoculation when the susceptible checks had full blown symptoms of SMD. The susceptible plants showed chlorotic and wrinkled leaves with no reproductive buds. Moderately resistant plants had chlorotic leaves but produced flowers and seeds. Resistant plants had dark green leaves and flowered profusely with normal seed set. Three entries derived from *C. scarabaeoides* did not show any symptoms of SMD and were classified as resistant (Fig. 6.5). One entry derived from *C. acutifolius* was resistant to the disease. Individual resistant as well as moderately resistant plants will also be advanced along with moderately resistant entries for further screening. A few lines were sent to Tandur, Andhra Pradesh for SMD analysis and resistance to SMD was observed in these lines.

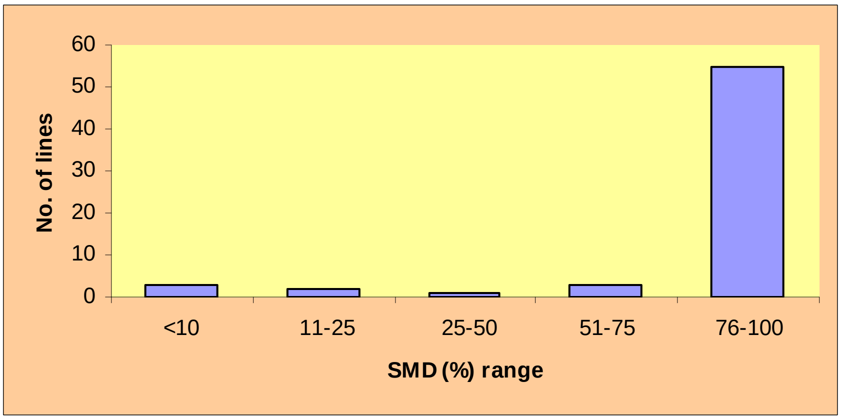


Fig. 6.5: SMD resistance in progenies generated through utilization of wild *Cajanus* species

Special Project Funding:
None

N Mallikarjuna, Varsha Wesley and Sri Lakshmi-Tandur

Output target 6.1.2 PP Promising transgenic events of pigeonpea with proven resistance to *Helicoverpa* available for commercialization and introgression in locally adapted germplasm

Activity 6.1.2.1 PP Develop transgenic events of pigeonpea for resistance to *Helicoverpa armigera* and evaluate their performance under contained greenhouse and field conditions

Milestone: 80 transgenic events of pigeonpea with Bt genes developed and screened in contained greenhouse (KKS/PB/HCS/KBS) 2008

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
In our ongoing efforts to develop transgenic plants of pigeonpea with *Bt* genes, a focused approach has been initiated to engineer resistance to *H. armigera* in pigeonpea by using *cry1Ac* gene through *Agrobacterium tumefaciens*-mediated genetic transformation of a popular pigeonpea cultivar, ICPL 88039. For efficient expression of *cry1Ac* gene in pigeonpea, binary vectors have been constructed with different promoters. Pigeonpea transgenics were developed using dicot codon optimized *Bt cry1Ac* gene constructs under the influence of Ubiquitin (pPZP200) and CaMV35S promoters (PRD 400) using seedling leaf petiole as the explant. A total of 125 independent T_0 transgenic events have been produced and transferred to contained greenhouse for further evaluation. The transgenic plants have been analyzed for the transgenes by PCR, and also characterized for expression of the *Bt* gene using ELISA.

Over 60 *cry1Ac* transformed pigeonpea plants (from 10 events) along with non-transformed ICPL 88039, the resistant check, ICPL 332, and the susceptible check, ICPL 87 for resistance to pod borer, *H. armigera* were evaluated under laboratory conditions. Three trifoliates from each plant were bioassayed for resistance to *H. armigera* using detached leaf assay. Observations were recorded on leaf damage on a 1 to 9 scale (1 = <10% leaf area damaged, and 9 = >80% leaf area damaged), larval survival, and larval weights after five days of feeding. The leaf damage rating in *Bt*-transformed plants varied from 2.3 to 8.0, and 4.8, 6.2, and 3.5 in the non-transformed genotypes ICPL 88039, ICPL 87, and ICPL 332, respectively. Larval weights varied between 0.1 to 2.6 mg $larva^{-1}$, in *Bt*-transformed plants, while on non-transformed ICPL 88039, ICPL 87, and ICPL 332, the larval weights were 1.2, 1.8, and 0.3 mg $larva^{-1}$, respectively. A considerable reduction in larval weights was observed in the transgenic events (0.382) when compared to the non-transformed parent (1.233). The percentage of larval survival was also lower on the leaves of transgenic events than the untransformed controls. Three events (1, 9 and 39) showed a significant reduction in the larval survival when compared to the wild type parent. The flower and pod bioassays are underway with these events.

Special Project Funding:
Department of Biotechnology, Govt. of India

KK Sharma, P Bhatnagar-Mathur, HC Sharma, MK Dhillon and KB Saxena

Milestone: 1-2 promising Bt transgenic events of pigeonpea identified and used for introgression (KKS/PB/HCS/KBS) 2010

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
None

Progress/Results

The results reported above for 2008 milestone represents 30% of the progress towards achieving this milestone.

Special Project Fundings:
Department of Biotechnology, Govt. of India

KK Sharma, P Bhatnagar-Mathur, HC Sharma and KB Saxena

Output Target 6.1.3 PP Twenty medium-long duration vegetable type pigeonpea germplasm/breeding lines made available

Activity 6.1.3.1 PP Evaluation and selection of large podded medium – long duration germplasm and breeding lines for use as vegetable

Milestone: At least 5-10 large seeded high-yielding vegetable type breeding lines and germplasm identified (KBS/RKS/HDU) 2008

Achievement of Output Target (%):
90%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Fifteen vegetable type lines from Gujarat were further screened for resistance to wilt and sterility mosaic diseases at Patancheru during 2007 rainy season. Of these, four lines (ICPL 20289, ICPL 20290, ICPL 20293, and ICPL 20287) were found resistant to sterility mosaic disease, but none of the lines was resistant to *Fusarium* wilt. The resistant lines were selfed to obtain genetically pure seeds. These lines were crossed with wilt resistant lines to breed wilt and sterility mosaic resistant lines. To develop new vegetable type A-lines, these were crossed to ICPA 2043 in 2006. The 14 F_1s obtained were evaluated for fertility restoration, yield, and disease (wilt and sterility mosaic) resistance along with Asha and Maruti as checks during 2007 rainy season. Of these 14 hybrids, two crosses (with ICPL 20283 and ICPL 20287) maintained male sterility. These F_1s had cream seeds, and were back crossed with their respective male parent in 2007. The BC_1F_1 is being grown for further back crossing during 2008.

Special Project Funding:
Nil

KB Saxena, RK Srivastava and HD Upadhyaya

Milestone: Genetically diverse large seeded vegetable type 10-15 breeding populations for further selection developed (KBS/RKS) 2011

Achievement of Output Target (%):
70%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Fifteen advanced vegetable pigeonpea lines (ICPL 20279 to ICPL 20293) were grown in two sets during 2007 rainy season at ICRISAT Patancheru. The first set was gown in the disease nursery, and second set in disease free plot under net for further purification of the lines. ICPL 20289 was used as male parent in two crosses with ICPA 2078 and ICPA 2092, while ICPL 20293 was used in a cross combination with ICPA 2092. The F_1s (ICPH 4211, ICPH 4112 and ICPH 4111) are being evaluated for vegetable quality traits and grain yield in observation nursery during 2008 rainy season.

Special Project Funding:
Nil

RK Srivastava and KB Saxena

SORGHUM

Output target 6.1.1 SO High yielding grain, forage, and sweet sorghum lines with resistance to insect pests and diseases developed

Activity 6.1.1.1 SO Selecting high biomass forage and sweet sorghum lines with resistance to shoot pests and foliar diseases, and grain sorghum with tolerance to grain mold

Milestone: Sweet sorghum lines (5) with high grain yield and shoot fly resistance developed for postrainy season adaptation (BVSR/HCS/AAK) 2010

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad, India

Progress/Results
Evaluation of maintainer lines for resistance to shoot fly, *Atherigona soccata*: During the post rainy season 2007/08, 14 maintainer lines along with the resistant (IS 18551), susceptible (Swarna), and commercial (296B) checks were evaluated for shoot fly resistance in a randomized complete block design with three replications. Because of a long cold spell, and poor soil conditions, the overall shoot fly damage was quite low. Deadheart incidence ranged from 0.0 to 19.6%, and eight lines suffered <10% deadheart incidence compared to 7.6% in the resistant check, IS 18551, and 18.5% in Swarna. The lines 62015, 62051, 63105, 63155-1, 63161-1, and 63161-2 were glossy and also exhibited low susceptibility to shoot fly damage, and these will have greater probability of exhibiting resistance to shoot fly.

Evaluation of hybrids and their parents for resistance to shoot fly, *Atherigona soccata*: Fifteen hybrids and their parents along with the resistant (IS 18551), susceptible (Swarna) and commercial hybrid (CSH 16) checks were evaluated for shoot fly resistance in a randomized complete block design with three replications. Deadheart incidence in the test entries ranged from 7.1 to 23.6%, and five hybrids suffered <8.6% deadheart incidence compared to 5.3% deadhearts in the resistant check, IS 18551, and 23.6% deadhearts in CSH 16. Five hybrids and nine maintainer/restorer lines showed lower susceptibility to shoot fly than the susceptible check, Swarna.

Special Project Fundings:
Sorghum Hybrid Parent Research Consortium; IFAD project on Biofuels.

HC Sharma, A Ashok Kumar and BVS Reddy

Milestone: Ten sweet-sorghum lines with high biomass and resistance to shoot pests and foliar diseases developed (BVSR/HCS/RPT/RS) 2011

Achievement of Output Target:
30%

Countries Involved:
India

Partners Involved:
Partners of Sorghum Hybrid Parent Research Consortium

Progress/Results:
Population improvement for high biomass: The sorghum high tillering (ICSP-HT) population consisting of C_{13} population bulk, SSV 74 F_4 and SSV 84 F_4 crosses bulk is being advanced during 2008 postrainy season based on tillering ability and high biomass.

We evaluated sweet sorghum – elite hybrids (53), and advanced hybrids (42); hybrid seed parents (41 B-lines and 23 R-lines), varieties/R-lines (30) and elite B-lines (30) for disease reaction (anthracnose and downy mildew) and resistance to shoot fly in 2008 rainy season.

Evaluation of sweet sorghum varieties for shoot fly resistance: Among the breeding lines evaluated for shootfly resistance, 11 elite hybrids showed 11−42% less shoot fly dead hearts (54–84%) than control (CSH 22SS: 94%); 4 advanced hybrids showed 11−14% less shoot fly dead hearts (80–83%) than control (CSH 22SS: 93%); 13 hybrid seed parents shown 11− 52% less shoot fly dead hearts (44–83%) than control (SSV 84: 93%); 10 varieties/R-lines shown 10−42% less shoot fly dead hearts (55–86%) than control (SSV 84: 96%); and six elite B-lines shown 19−51% less shoot fly dead hearts (43–71%) than control (ICSB 38: 88%).

Evaluation of sweet sorghum varieties for downy mildew resistance: For downy mildew resistance, 29 sweet sorghum varieties/R-lines were evaluated for resistance to sorghum downy mildew (*Peronosclerospora sorghi*) using sandwich as well as spray-inoculation techniques under greenhouse conditions in 2008. A known DM resistant line, QL3 and a susceptible line (296B) were included as checks. The lines were evaluated in four replications, one pot (15 cm diameter) per replication with 30−35 seedlings per pot. Downy mildew incidence was recorded 14 days after inoculation. The incidence on test varieties varied from 29−100% compared to 18% on QL3 under sandwich inoculation and 79−100% compared to 3% on QL 3 under spray-inoculation.

Evaluation of sweet sorghum varieties for anthracnose and grain mold resistance: For anthracnose resistance, data on disease severity on a 1−9 scale (1=0 to <1% leaf area covered with hypersensitive lesions with yellow flecks – highly resistant and 9 ~76−100% leaf area covered with coalescing necrotic lesions with acervuli – highly susceptible) were recorded on whole plant basis at the soft-dough stage. Grain mold severity was also recorded in these entries at physiological maturity using the 1−9 scale (1=0 to <1% mold infection – highly resistant and 9~76−100% molded grains on a panicle − highly susceptible). Of the 53 elite hybrids, only four (ICSA 731 × NTJ 2, ICSA 38 × SPV 422, ICSA 502 × SPV 422 and ICSA 724 × SPV 422) were found to be resistant (≤3.0 score) and 34 moderately resistant (score >3 to ≤5) to anthracnose (Table 6.4) compared to a 9.0 score on the susceptible check H 112. The hybrids were resistant to anthracnose also exhibited moderate resistance to grain mold. Five of the 42 advanced hybrids (ICSA 702 × SPV 422, ICSA 344 × AKSV 22, ICSA 344 × RSSV 106, ICSA 702 × ICSR165 and ICSA 702 × SSV 53) were resistant to anthracnose (Table 6.4). ICSA 344 × AKSV 22 was also found resistant to grain mold and the other four had moderate level of grain mold resistance. Twenty six of the 42 advanced hybrids were resistant (≤3.0 score) to grain mold and moderately resistant to anthracnose.

Among 30 sweet sorghum varieties and R-lines, five lines (ICSR 165/SPV 422, RSSV 106, IS 23526, 64DTN and S 35) showed resistance to anthracnose and moderate to high levels of resistance to grain mold. Ten of the 30 elite B-lines (ICSB 73, -94, -271, -307, -319, -324, -401, -428, -279 and -311) were resistant to anthracnose (Table 6.4). ICSB 401 also showed resistance to grain mold. Of the 70 hybrid parent lines, 21 were found resistant to anthracnose. Two lines ICSA 401 and SSV 53 were resistant to both the diseases. These hybrids and hybrid parent lines are currently being evaluated for leaf blight resistance as well.

Table 6.4: Summary of sweet sorghum hybrids and hybrid parent lines for anthracnose and grain mold reactions during the 2008 rainy season

Material	Total entries	Number of entries									
		Anthracnose severity class*					Grain mold severity class*				
		≤1	>1−≤3	>3−≤5	>5−≤7	>7−9	≤1	>1−≤3	>3−≤5	>5−≤7	>7−9
Elite hybrids	53	0	4	34	13	2	0	3	41	8	1
Advanced hybrids	42	0	5	33	4	0	0	26	16	0	0
Elite B-lines	30	0	10	17	2	1	0	2	4	11	13
Varieties/R-lines	30	0	5	5	17	3	0	14	12	3	1
Hybrid parents	70	0	21	38	9	2	0	13	9	10	38

*≤1=highly resistant; >1-≤3 resistant; >3-≤5=moderately resistant; >5-≤7=susceptible;
>7-9=highly susceptible

BVS Reddy, HC Sharma, RP Thakur and Rajan Sharma

Evaluation of seed parents of sweet sorghum hybrids for resistance to shoot fly and aphids: Seventy sweet sorghum hybrid parental lines along with resistant (IS 18551) and susceptible (Swarna) checks were evaluated for shoot fly (*A. soccata*) resistance during the rainy season. There were three replications in a randomized complete block design. Data were recorded on percentage plants with shoot fly deadhearts, recovery resistance (1 = good, and 9 = poor), agronomic desirability (1 = good, and 5 = poor), and aphid damage severity (1 = highly resistant, and 9 = hughly susceptible). Deadheart incidence ranged from 44.1 to 100%, and the lines ICSA 475, ICSA 479, ICSA 652, ICSV 700, IS 3556 suffered <60% deadheart formation compared to 53.5% deadhearts in the resistant check, IS 18551, and 92.3% deadhearts in the susceptible check, Swarna. These lines also showed moderate levels of recovery resistance. The lines ICSA 285, ICSA 344, ICSA 479, ICSA 511, ICSA 724, ICSA 731, AKSV 22, Ent 64 DTn, ICSR 93034, ICSV 700, ICSV 93046, and ICSA 469 showed moderate levels of resistance to sugarcane aphid, *Melanaphis sacchari* (damage rating 4.0 to 5.0) compared to comared to damage rating of 6.0 in Swarna.

Evaluation of sweet sorghum elite varietal and restorer lines for resistance to shoot fly and aphids: Sweet sorghum elite varieties and restorer lines (30) were evaluated for shoot fly, *A. soccata* resistance along with resistant (IS 18551) and susceptible (Swarna) checks during the rainy season. There were three replications in a randomized complete block design. Data were recorded on percentage plants with shoot fly deadhearts, recovery resistance, agronomic desirability, and aphid damage severity as described above. Deadheart incidence in this trial ranged from 58.8% in IS 18551 to 97.9% in SP 4484-2. None of the test entries showed resistance levels comparable to the resistant check, except ICSV 700 (55.4%) and Moulee (59.1% deadhearts). Moderate levels of recovery resistance were observed in case of RSSV 106, NSS 254, SP 4504-1, and ICSV 700. The genotypes SP 4511-3, SPV 422, RSSV 106, IS 23526, ICSV 93046, ICSV 700, and NTJ 2 showed moderate levels of resistance/susceptiblity to sugarcane aphid, *M. sacchari*.

Evaluation of sweet sorghum elite maintainer lines for resistance to shoot fly and aphids: Twenty-five sweet sorghum maintainer lines were evaluated for shoot fly, *A. soccata* resistance along with resistant (IS 18551) and susceptible (Swarna) checks during the rainy season. There were three replications in a randomized complete block design. Data were recorded on percentage plants with shoot fly deadhearts, recovery resistance, agronomic desirability, and aphid damage severity as described above. Deadheart incidence in this trial ranged from 38.1% in IS 18551 to 98.2% in ICSB 211. None of the test entries showed resistance levels comparable to the resistant check, but comparatively lower deadheart formation was recorded in ICSB 428 (42.9%) and ICSB 479 (54.4%) as compared to the susceptible check, Swarna (97.7%). Levels of recovery resistance were also low in most of the lines tested. The lines ICSB 307, ICSB 319, ICSB 321, ICSB 468, ICSB 479, ICSB 480, ICSB 487, ICSB 652, ICSB 279, and ICSB 38 showed moderate levels of resistance to the sugarcane aphid, *M. sacchari*.

Evaluation of sweet sorghum hybrids for resistance to shoot fly and aphids: Fifty-three sweet sorghum hybrids were evaluated for shoot fly, *A. soccata* resistance along with resistant (IS 18551) and susceptible (Swarna) checks during the rainy season. There were three replications in a randomized complete block design. Data were recorded on percentage plants with shoot fly deadhearts, recovery resistance, agronomic desirability, and aphid damage severity as described above. Deadheart incidence ranged from 49.91% in IS 18551 to 98.4% in ICSA 38 x ICSV 93046. None of the test entries showed resistance levels comparable to the resistant check, except ICSA 479 x SSV 84 (54.1% deadhearts). Fifteen hybrids showed moderate levels of resistance/susceptibility to the sugarcane aphid, *M. sacchari*.

HC Sharma, A Ashok Kumar and BVS Reddy

Special Project Funding:
Sorghum Hybrid Parent Research Consortium; IFAD project on Biofuels

Activity 6.1.1.2 SO Developing QTL mapping populations for economic yield components of sweet sorghum productivity

Milestone: Four F6 sorghum RIL mapping populations (>350 lines each) available for marker genotyping and multilocational phenotyping for biomass yield, sugar content, and sugar extraction characteristics (CTH/SPD/BVSR) 2009

Achievement of Output Target (%):
75% We have advanced from selection of parental lines, through plant x plant crosses of selected lines, and advanced four candidate RIL populations to F_4 seedlings by modified single seed descent. Two of these four populations have been chosen for final advance to F_6 RILs. Two additional seed generations (out of a total of six) remain to be completed to achieve the output target. In addition, we have initiated crossing and selfing programs to derived RIL mapping populations from another six parental pairs.
Countries Involved:
India

Partners Involved:
Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra

Progress/Results:
RIL mapping populations of >400 progenies each, based on crosses (BTx623 x S 35) and (ICSV 93046 x S 35) were advanced to F_4 seed progenies during the 2007/08 postrainy season. Attempts to advance these a further generation without selection during the 2008 rainy season failed due to uncontrollable insect pest pressure (shoot fly) when sowing was delayed due to the late onset of the rains at Patancheru and lack of adequate irrigation water to permit timely sowing. The F_4 progenies were resown for advance to F_5 (by modified single seed descent) during the 2008/09 postrainy season. Despite losing one generation this year, we are still on track to be able to produce F_6 RILs of these two populations by the end of the 2009 rainy season. Seed multiplication of these RILs for subsequent use in field trials, and DNA isolation for use in linkage map data generation, can then take place during the 2009/10 postrainy season.

In addition, a total of 12 new crosses were made and harvested during the 2008 rainy season. These included 6 crosses: ICSR 77 x SSV 84, ICSB 1 x ICSB 38, ICSB 37 x ICSR 48, ICSB 37 x ICSR 119, ICSB 37 x SSV 84, and ICSB 37 x SP 4487-3; and their reciprocals. Selfed seed of the individual parental plants used in making these crosses were harvested. The F_1 crosses, along with their parental selfs, were sown for generation advancement by selfing during 2008 postrainy season to initiate derivation of the mapping population progeny sets.

We initiated development of segregating populations based on crosses of brown midrib sources with white midrib sweet sorghum B-lines and varieties, and with white midrib grain sorghum B- and R-lines. Sets of homozygous brown midrib and white midrib F_3 progenies from these crosses will be used in bulk segregant analyses for identification of molecular tags for each of the independently segregating recessive genes governing the brown-midrib trait.

Special Project Funding:
IFAD Biofuels Project

CT Hash, SP Deshpande and BVS Reddy

Activity 6.1.1.3 SO Developing high yielding sorghum lines with grain mold resistance for rainy season, and shoot fly resistance for postrainy season

Milestones: Genetically diverse sorghum breeding lines (10) for high yield and large grain size with resistance to grain mold made available to partners (BVSR/AAK/RPT/RS) 2010

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Thirty-four progenies with R- reaction were screened for grain mold tolerance in screening block in 2008 rainy season. The panicle grain mold rating (PGMR) score ranges from 4.0 to 9.0 given on a scale 1 to 9 where 1= no mold and 9= more than 75% mold infected panicle surface. Nine progenies recorded PGMR score ranging from 4.0 to 5.5.Among them three progenies are also early maturing(days to 50% flowering with 64 to 65 days) while the remaining six are ranged from 67 to 74 days.

Special Project Funding:
Sorghum hybrid parents research consortium

A Ashok Kumar, BVS Reddy, and RP Thakur

Output 6.2: Annually knowledge of the improvements of the biotechnological and conventional tools designed to facilitate drought and salinity tolerance breeding and germplasm of mandate crops and associated capacity building made available to partners internationally

GROUNDNUT

Output target 6.2.1 GN Groundnut varieties with tolerance to drought and salinity developed using conventional and biotechnological approaches

Activity 6.2.1.1 GN Identify high yielding groundnut varieties tolerant to drought

Milestone: 6-8 dual purpose groundnut varieties with high biomass and improved haulm digestibility identified and promoted for drought prone areas in Asia (SNN/RA/MB) (collaboration with ILRI) 2009

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
AICRP-Groundnut, NRCG, Junagadh, ILRI, Patancheru

Progress/Results:
A total of 771 genotypes originating from trials of All India Coordinated Research Project (AICRP) on Groundnut and other experiments at NRCG have been analyzed for fodder quality traits (nitrogen, neutral detergent fiber, acid detergent fiber, sugars, metabolizable energy and in vitro organic dry matter digestibility). Data are being analyzed.

Special Project Funding:
The OPEC Fund for International Development

M Blummel, SN Nigam and R Aruna

Milestone: 8 – 10 new advanced lines with resistance to drought tested in South Asian countries (SNN/RA/VV) 2009

Achievement of Output Target (%):
100%

Countries Involved:
Cambodia; India; Pakistan; Philippines; Turkey; South Africa

Partners Involved:
NARS in the above mentioned countries

Progress/Results:
Resistance to Drought**:** Breeding populations and yield trials of drought resistant materials in rainy season are grown under rainfed conditions. In postrainy season, they are grown under soil moisture limiting conditions created by withholding alternate irrigation in the normal irrigation schedule of 12-day interval starting from 65 DAS until harvest. Elite and advanced trials are also grown with full irrigation in the same field to assess the full yield potential of breeding lines included in these trials.

New crosses: During the 2007/08 postrainy and 2008 rainy seasons, 20 new crosses were made to generate populations for selection for resistance to drought along with high pod yield in desirable agronomic backgrounds. TCGS # 888 and 913 and ICGV # 00308, 07223, 07307, 06450, 0740505151, 06423, 06441, 06443, 91116, 04158, 04160, 05159, 86325 and 00308 were the drought tolerant breeding lines used in hybridization program.

Breeding populations: In 258 F_2-F_7 bulk populations and 192 single plant progenies, grown in the 2007/08 postrainy season under soil moisture limiting conditions, 253 F_2-F_7 bulk and 71 single plant selections were made. Out of these, 81 bulk selections from advanced generations were identified for inclusion in replicated yield trials. The most promising selections came from (ICR 09 x ICGX 000052), (ICG 5100 x ICGV 03115) and (ICG 5465 x ICGX 000052) crosses. During the 2008 rainy season, 172 F_2-F_8 bulks and 71 plant progenies were sown for further evaluation. From these, 147 F_2-F_8 bulks and 69 single plants were selected. The most promising selections came from (ICG 5100 x ICGX 000049) and (ICG 8230 x ICGX 000049) crosses.

Yield trials: Sixty-seven advanced breeding lines including controls were evaluated in four replicated trials under rainfed conditions in the 2007 rainy season. In the 2007/08 postrainy season, 127 advanced breeding lines including controls were evaluated in seven replicated trials under soil moisture limiting conditions. Results obtained from elite and advanced trials only are discussed here.

2007 rainy season**:** In an Elite Trial-1, five lines (5.5-4.5±0.40 t ha^{-1}pod yield) significantly outyielded the highest yielding control ICGV 00350 (3.5 t ha^{-1}pod yield, 64% shelling outturn, 28 g HSW, SPAD Chlorophyll Meter Reading (SCMR, 60 DAS) 37, SCMR (90 DAS) 35) under rainfed conditions. The best entry in the trial was ICGV 05163 (5.5 t ha^{-1}pod yield, 66% shelling outturn, 41 g HSW, SCMR (60 DAS) 45, SCMR (90 DAS) 44) followed by ICGV 05158 (5.2 t ha^{-1}pod yield, 78% shelling outturn, 33 g HSW, SCMR (60 DAS) 43, SCMR (90 DAS) 35).

In an Elite Trial-2, all the eight test lines (6.1-5.0±0.36 t ha^{-1}pod yield) gave significantly higher pod yield than the highest yielding control ICGV 00266 (3.4 t ha^{-1}pod yield; 64% shelling outturn; 39 g HSW, SCMR (60 DAS) 38, SCMR (90 DAS) 34). The best entry in the trial was ICGV 06422 (6.1 t ha^{-1}pod yield, 68% shelling outturn, 47g HSW, SCMR (60 DAS) 42, SCMR (90 DAS) 40) followed by ICGV 06424 (5.6 t ha^{-1}pod yield, 68% shelling outturn, 34 g HSW, SCMR (60 DAS) 44, SCMR (90 DAS) 39).

In an ICRISAT-ARS ATP Trial-1, none of the test entries could yield significantly more than the highest yielding control ICGV 00350 (3.6±0.14 t ha^{-1}pod yield, 70% shelling outturn, 35 g HSW, SCMR (60 DAS) 39, SCMR (90 DAS) 33). However, 12 entries (3.2-2.4 t ha^{-1}pod yield) significantly outyielded the short-duration control ICGV 91114 (1.9 t ha^{-1} pod yield, 66% shelling outturn, 33 g HSW, SCMR (60 DAS) 37, SCMR (90 DAS) 29). Among these entries, ICGV 06436 ranked first (3.2 t ha^{-1}pod yield, 67% shelling outturn, 32.0 g HSW, SCMR (60 DAS) 41, SCMR (90 DAS) 28) followed by ICGV 06441 (3.1 t ha^{-1}pod yield, 67% shelling outturn, 32 g HSW, SCMR (60 DAS) 44, SCMR (90 DAS) 29).

2007/08 postrainy season**:** In an Elite Trial-2, only one line, ICGV 06431, (3.3±0.21 t ha^{-1} pod yield, 62% shelling outturn, 44 g HSW, SCMR (65 DAS) 40) significantly outyielded the highest yielding control ICGV 02266 (2.6 t ha^{-1}pod yield, 74% shelling outturn, 56 g HSW, SCMR (65 DAS) 37) under soil moisture limiting conditions.

In an ICRISAT-ATP Trial-1, ICGV 07354 (2.4±0.25 t ha^{-1} pod yield, 80% shelling outturn, 51 g HSW, SCMR (65 DAS) 44, SCMR (105 DAS) 56) produced significantly higher pod yield than the highest yielding control ICGV 00350 (1.8 t ha^{-1}pod yield, 63% shelling outturn, 43 g HSW, SCMR (65 DAS) 32, SCMR (105 DAS) 42).

Four Spanish lines were selected for inclusion in future international trials.

2008 rainy season**:** Two hundred and four advanced breeding lines including controls in six replicated trials were evaluated under rainfed conditions. Four elite and advanced trials were also sown with full irrigation. Data from these trials are being processed.

Enrichment of Breeding Resources of NARS: Seven sets of drought tolerant international trial (VII IDRGVT) and 30 advanced breeding lines were made available to our NARS partners in Cambodia, India, Pakistan, Philippines, Turkey and South Africa.

Special Project Funding:
The OPEC Fund for International Development, Tropical Legumes II, ISOPOM, IFAD Grant 954

SN Nigam, R Aruna and Vincent Vadez

Milestone: Performance of 3-4 dual-purpose varieties validated on-farm in drought prone areas (SNN/RA/MB) 2009

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
ARS, ANGRAU, Anantapur/Kadiri, RARS, ANGRAU, Tirupati and NRCG, Junagadh

Progress/Results:
Farmer-preferred varieties K 1375, TPT 25, ICGV 91114, ICGV 86015, TCGS-APNL 888 and ICGV 00350 are under further evaluation in Anantapur and Chittoor districts in Andhra Pradesh. In addition to high pod yield, these promising varieties also had better haulm yields. Farmers liked K 1375 because of its green leaves even at the time of harvest. In Gujarat, ICGV 87846 gave higher pod yield than GG 20. It was rated highly because of its good fodder quality and 'stay-green' characteristic until harvest.

Special Project Funding:
ISOPOM, The OPEC Fund for International Development

SN Nigam, R Aruna and M Blummel

Milestone: Farmer-preferred drought tolerant varieties identified in partner countries (SNN/RA/VV) 2010

Achievement of Output Target:
90%

Countries Involved:
India; Nepal; Vietnam

Partners Involved:
India: UAS, Dharwad, UAS, Bangalore, TNAU, Coimbatore, OUA&T, Bhubaneswar, BAU, Ranchi, RDT, Anantapur, ARS, Anantapur/Kadiri, NRCG, Junagadh, CTDS, Chhattisgarh, JTDS, Jharkhand, OTELP, Orissa, Nepal: NARC, Khumaltar, Vietnam: LRDC, VAAS, Hanoi

Progress/Results:
Of the farmer-preferred varieties listed in Milestone 5 of Activity 6.1.1.1, ICGV 00350, ICGV 00351, ICR 3, JAL 42, TIR 17, ICGS 76 and ICGV 91114 are tolerant to drought.

SN Nigam, R Aruna and Vincent Vadez

A list of 35 market-preferred and farmer-preferred varieties of groundnut has been identified across Tanzania, Malawi, Mali, Niger and Senegal. These lines will be tested for their response to drought conditions in these countries, along with the reference set of groundnut (268 germplasm entries, representative of the range of variation in the groundnut collection, based on molecular marker).

Vincent Vadez, SN Nigam and R Aruna

Special Project Funding:
IFAD Grant 954, Tropical Legumes II, ISOPOM, The OPEC Fund for International Development

Milestone: Knowledge of inheritance of traits associated with drought tolerance in three crosses gained and appropriate breeding strategy devised (SNN/RA/VV) 2010

Achievement of Output Target (%):
50%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
The trial consisting of parents, F_1, F_2 and backcrosses of four crosses, (ICGS 76 x ICGV 93291, ICGV 99029 x ICGV 91284, JL 24 x ICGV 86031 and ICR 48 x ICGV 99029) along with their reciprocals, sown in the 2007/08 postrainy season, was abandoned due to poor germination. A new trial of these regenerated materials is planned in the 2009 rainy season.

Special Project Funding:
The OPEC Fund for International Development

SN Nigam, R Aruna and Vincent Vadez

Milestone: Range of variation for key physiological traits assessed in breeding materials and varieties from the breeding program (VV/SNN/RA) 2010

Achievement of Output Target (%):
50%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
A set of 9 genotypes, with known contrasting performance under drought conditions, i.e. TMV2 and JL24 as drought susceptible checks, and ICGS76, ICGV86031, ICGV86015, ICG00350, TAG24, Chico, and ICGV91114 as drought tolerant lines, have been selected and they are being tested under a range of drought conditions. In a first trial, carried out in lysimeters (1.2 m long PVC tubes, 20 cm diameters, filled with Alfisol at a bulk density of 1.4), drought was imposed at the time of flowering, i.e. 35 days after sowing (DAS). At that time, the cylinders were saturated with water to ensure that all plants were at 100 % field capacity (FC) at that stage. Cylinders were weighed after drainage of excess water (allowing one days and 2 night after water addition. A layer of 1.5 cm of low density polyethylene beads were applied on a soil surface to prevent soil evaporation. Then cylinders were weighed 1-2 times per week. Water addition of 500 mL to the water stressed lysimeters was performed at 5 weeks after sowing and subsequently every week. Well-watered plants were kept close to field capacity by compensating water loss up to the saturated weight of the cylinder, minus 1000g, to ensure that there was no water leakage. Plant transpiration was determined as the difference in cylinder weights between weighing, plus water added between two consecutive weighing. The bead decreased soil evaporation by approximately 90% and therefore allowed the measurement of plant transpiration.

The purpose of this experiment was to assess genotypic differences in water uptake. Data showed some modest genotypic differences in the capacity of plants to extract water from the soil profile, with genotype ICGS44 extracting approximately 6700 g of water compare to 5500g in JL24. In addition, data showed that genotype TMV2 tended to extract water quickly from the soil profile after being exposed to drought, whereas genotype Chico had a more limited water use after stress imposition, which helped it maintain a rate of water uptake above that of TMV2 from about 3 weeks after stress imposition. A poster of this work has been presented at the Generation Challenge Program Annual Research meeting in Bangkok in 2008.

Special Project Funding:
BMGF Tropical Legumes I Project

Vincent Vadez, SN Nigam and R Aruna

Activity 6.2.1.2 GN Marker-assisted breeding for drought tolerance in groundnut

Milestone: Initial QTL map of component traits of drought tolerance (TE) developed using available populations (VV/RA/SNN/RKV/DH) 2009

Achievement of Output Target (%):
60%

Countries Involved:
India; Malawi; Mali; Niger; Senegal; Tanzania

Partners Involved:
National programs of countries above

Progress/Results
Two populations (TAG24 x ICGV86031) and ICGS76 x CSMG84-1 have been developed in the past to map QTL for transpiration efficiency (TE). Three phenotyping experiments have been carried out in the first population in the summer of 2004 and 2005, and in the rainy season of 2008. The range of variation for TE among the RILs in 2004 and 2005 remained fairly low, and the parental lines were not very different (although a good segregation pattern was obtained). This contrasted from the large contrast previously obtained between the parental lines, and which led to choosing these parents to develop a population.

To better understand the reason for this lack of large range of contrast among the RIL, we assessed TE in the parental lines TAG24 and ICGV86031 across a range of vapor pressure deficit (VPD) conditions. Interestingly, we found that TE differences between these lines were high when assessment was done under low VPD. This corroborated well the data obtained in the past when these lines were screened under glasshouse conditions (characterized by low VPD conditions). By contrast, the TE differences decreased as VPD increased. This overall decrease in TE upon VPD increase agrees well with the theory (which states that TE is inversely proportional to VPD). However, a stricking feature of these data was that the slope of the decrease in TE as a function of VPD increase, was different for TAG24 and ICGV86031. In other words, TE decreased relatively more at high VPD in ICGV86031 than in TAG24. This behavior would then explain the limited range of variation found for TE among the RIL, knowing that the assessment was done in outdoor conditions at fairly high VPD (above 3.0 kPa). Therefore, we have again phenotyped this population under more humid conditions, during the rainy season 2008. Data still need to be analyzed.

The second population has also been phenotyped and the data are being analyzed.

Special Project Funding:
Tropical Legumes I Project; Government of India

Vincent Vadez, SN Nigam and R Aruna

Milestone: Range of variations for root traits assessed in groundnut germplasm, mapping populations initiated and potential for breeding for root traits assessed (VV/SNN/RA/HDU/DH) 2009

Achievement of Output Target (%):
50%

Countries Involved:
India; Malawi; Mali; Niger; Senegal; Tanzania

Partners Involved:
National programs of countries above

Progress/Results
The assessment of water uptake capacity has been reported in Project 2 of the MTP. Experiments are in progress using contrasting varieties for drought tolerance. Comparison of DREB1A transgenics for water uptake capacity under drought conditions is also underway. So far, data tend to suggest that a large range of variation exist in the groundnut germplasm for their capacity to extract water (germplasm varied from approximately 3000 to 6600 g of water extracted under residual moisture). A lower range of variation has been found in elite varieties that contrast for drought (about 1200 g of water between the lines extracting the most and the least). Finally, contrast is found between the transgenics plants in their capacity to extract water, with DREB1A events being capable of extracting more water upon imposition of a water deficit. Work is still in progress to assess the potential of breeding for root traits / water extraction capacity in groundnut, and tend to suggest that such efforts would be worth pursuing. Our preliminary data indicate that the benefit of water extraction differences would be to sustain higher harvest index under drought conditions.

Special Project Funding:
Tropical Legumes I Project; Government of India

Vincent Vadez, SN Nigam and R Aruna

Milestone: QTLs for key root traits of drought tolerance identified (VV/DH/SNN/RA) 2011

Progress/Results
The activity is yet to be started.

Activity 6.2.1.3 GN: Develop groundnut transgenic events for enhanced tolerance to drought

Milestone: At least 8 promising transgenic events of groundnut containing DREB1A gene identified and their drought tolerance characterized under contained field conditions (KKS/VV/PB/RA) 2008
Achievement of Output Target (%):
100%

Countries Involved:
Asia; Africa

Partners Involved:
JIRCAS, Japan

Progress/Results:
A comprehensive evaluation of six selected transgenic events carrying the *DREB1A* gene driven by the stress-responsive *rd29A* gene promoter out of over 50 transgenic events previously developed was carried out. The T_6 generation of these events were screened in dry-down experiments in the greenhouse to study various important component traits including Transpiration (T) and Transpiration Efficiency (TE) that are associated with better performance under intermittent drought conditions. The transgenic events were evaluated in a lysimetric system (long and large PVC cylinders that mimic a soil profile) which showed significantly enhanced root growth triggered in these events under water stress, and the differences in rooting related well with a higher water uptake.

We have now carried out 2 evaluation trials. In a first trial, a terminal stress was imposed by no longer applying water to stress plants from 40 days after sowing. In this trial, we confirmed previous results showing the superiority of the transgenic lines to extract water upon exposure to water deficit. However, there was no yield advantage at maturity. Two events had similar yield than JL24, and slightly higher TE. One transgenic event (RD33) was capable of extracting more water than JL24, and to convert it in a larger biomass than JL24. Overall, the TE of this line was higher than that of JL24 under stress, although the yield of RD33 was lower than that in JL24. In a second trial, we imposed an intermittent stress by imposing the last irrigation at about the time of flowering (35 DAS). The cylinders were then saturated. No water was added for 6-7 weeks (until transpiration fell below 20-30% of control). Then 1 L (equivalent to 30 mm rainfall) was added back to the plants every 3 weeks until harvest. At harvest, we found that RD2, RD12, RD19, RD11, and RD20 had higher pod weight than JL24 under water deficit conditions. By contrast, under well watered conditions, only RD2 and RD20 had a pod weight that was similar to that in JL24, although slightly lower. All the other transgenics had seed weight lower than wild type JL24 under well-watered conditions. Besides, a very high correlation was observed between the water captured and the yield parameters under both DS and WW conditions. These data are yet to be fully confirmed in repeated experiments. Yet, they tend to indicate that a yield benefit from DREB1A was feasible under specific stress conditions. The advantage of the transgenics for TE that was previously found and in part explained by a lower stomatal conductance of the transgenics was in full agreement with the yield data obtained. Lower stomatal conductance might have allowed transgenics to use water more efficiently under water stress. By contrast, such a low stomatal conductance would have meant a yield penalty under optimum water conditions.

The phenotypic differences in component traits of drought tolerance identified in several transgenics provided an opportunity to help unravel some of the unanswered questions about the mechanisms and pathways involved in stress-induced gene expression, which eventually might aid in combining these superior traits into varieties better adapted to water-limited environments.

In addition to screening for drought stress these transgenic events along with wild type controls were screened for salinity stress under contained greenhouse conditions. Salinity stress (125 mM; NaCl) was imposed in three split doses in 10" pots carrying 9 kg of soil. The transgenics were evaluated for different yield parameters such as shoot, pod and seed yield and Harvest Index. Results indicate no significant differences across the genotypes in the yield parameters under salt stress. A detailed experiment has been planned for early 2009 to have some insights on the performance under salt stress. Besides the phenotyping activities, these transgenics were advanced to T7 generation to attain homozygosity of these events.

Special Project Funding:
Nil

KK Sharma, P Bhatnagar-Mathur, V Vadez and R Aruna

Milestone: 1 – 2 transgenic DREB events of groundnut available for introgression into locally adapted germplasm in India (KKS/VV/PB/RA) 2010

Milestone: 15-20 introgressed transgenic lines of groundnut with improved tolerance to water-limiting conditions evaluated (KKS/ PB/VV/SNN/RA) 2011

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
None

Progress/Results
The results reported above for 2008 milestone represents 30% of the progress towards achieving these milestones

Special Project Funding:
Nil

KK Sharma, P Bhatnagar-Mathur, V Vadez and R Aruna

Activity 6.2.1.4 GN: Marker-assisted breeding for salinity tolerance in groundnut

Milestone: Mechanisms responsible for differences in salinity tolerance in groundnut identified and mapping population development initiated. (VV/RA/SNN/DH) 2009

Achievement of Output Target (%):
50%
Countries Involved:
India

Partners Involved:
None

Progress/Results:
Experiments involving peanut genotypes contrasting for salinity tolerance, based on the screening of the mini-core collection of germplasm, have been carried out to investigate the response of transpiration to salt application. Basic consideration prior to undertaking the work was that salinity induces a drop in transpiration which likely decreases the photosynthetic rate and biomass accumulation. In such case, we can logically hypothesize that the "successful" genotypes would be those able to maintain a relatively high rate of transpiration, while being efficient at using that water (high water use efficiency). However, maintaining a high rate of transpiration under salinity may also allow larger amount of salt to get through the xylem stream. This is unless plants have mechanisms to limit the amount of salt loaded in the xylem. So, there were three aspects we wanted to look at in these experiments: (i) the relative reduction in transpiration rate of tolerant and sensitive genotypes (ii) the relation between water use efficiency and biomass accumulation under salt stress; (iii) the apparent xylem Na concentration in plants treated with salt.

Protocol: Plants were grown under non-saline conditions in 8" pots containing a mix of Alfisol and sand (1:1 w/w). At about 30 days after sowing, plants were saturated with water, allowed to drain overnight. The next morning, plants were bagged and weighted (day0). Plants were weighted again on day 1 & 2, so as to evaluate plant transpiration for 2 days. Then, half of the plants were treated with salt. On day 2, plants were saturated with 1500 mL of 62.5 mM and allowed to drain overnight. On day 3, plants were saturated with 1500 mL of 125 mM and allowed to drain overnight. These step-wise increases in salt concentration allowed avoiding a too rapid build up of salt. On the morning of Day4, salt-treated plants were rebagged, and weighted again. During day0 - day4 interval, non-salt-treated plant were re-watered to 80% field capacity (about 200 g less than pot weight on day0 morning). Subsequently, pots were weighted daily for 2 weeks and transpiration computed. All pots were re-watered to 80% field capacity (about 200 g less than saturated weight). At harvest, shoot were harvested and separated in leaves and stems, and these plant parts prepared for Na analysis. The computation of total plant transpiration, divided by total plant Na accumulation compared to control, should give us a measure of the apparent xylem Na concentration.

We found that tranpiration decreased fairly rapidly after imposing the salt treatment. Although we could not assess transpiration on the two days salt treatment was applied, it was very clear that groundnut reached a fairly constant relative rate of transpiration by day 5 compared to control. Another remarkable result is that genotypes of groundnut varied largely in the percentage decrease in transpiration. There was one groundnut genotype maintaining transpiration rate at 90% of control, whereas other had transpiration rate as low as 60% of control. We found very little variation for transpiration efficiency (TE) in groundnut genotypes tested. Only ICG4955 had lower TE under control. By contrast, salinity brought about large changes in the TE among genotypes, with ICG4890 having the highest TE and ICG6022 the lowest (about 40% lower). In fact, the ratio of biomass accumulation, which we used as a proxy for tolerance in that experiment, was well correlated to TE under salinity (R^2 = 0.42). We found in groundnut that large xylem Na concentrations were found, with genotype ICG11144 having almost 4.9 mg Na kg^{-1} water. By contrast, tolerant ICG4998 had only 2.72 4.9 mg Na kg^{-1} water. In fact, the ratio of biomass increase, our proxy for salinity tolerance, was well correlated to xylem Na (R^2 = 0.53).

From the repeated screening of salinity tolerant groundnut genotypes of the groundnut mini-core collection in 2006 and 2006-07, we selected five tolerant genotypes and five susceptible genotypes. With these genotypes, we repeated some measurement of TE, Na accumulation, targeting in particular the reproductive stages, following the hypothesis that, as in chickpea, reproduction might be the weak point for groundnut under salinity stress. Therefore, we tested the effect of salt treatment applied either at sowing, or at flowering time in a number of biochemical indicators (ABA, proline, protein profiling, etc.), on leaf gas exchange measurement (transpiration and leaf conductance), and on transpiration efficiency. The protocol used was essentially the same as the one described above, except that salt treatment was strictly applied to the genotypes when 50% of the plants had at least one flower (in the first experiment carried out in 2005, salt treatment were applied at same number of days). Transpiration was measured in plants before imposing the salt treatment. Upon salt treatment, applied in two split doses to avoid a rapid osmotic potential increase, plants were weighed on alternate days. Samples for biochemical indicators were taken at 3 stages after treatment imposition, spread out during a 3 week period. Plants were harvested at 3 weeks after salt treatment, for TE measurement. A separate set of plants with similar set of treatment, grown in larger pots, was treated in the same way and kept until maturity to measure salinity tolerance based on yield and relative yield reduction in these genotypes in those glasshouse conditions.

The differences between genotypes for pod yield under saline conditions were confirmed in the glasshouse environment for 4 out of 5 tolerant genotypes and for 4 out of 5 sensitive genotypes. Previously found tolerant genotype ICG86155 did not produce pod yield under salt stress, and previously found sensitive ICG156 had a fairly high pod yield under salt stress. One major finding was that tolerant genotypes showed a larger drop in the transpiration rate upon salt treatment compared to the sensitive one. On average, the relative transpiration of the sensitive group was about 60-80% of control, whereas the relative transpiration of the tolerant group was as low as 40% of control.

We also measured the apparent Na concentration in the xylem, by dividing the amount of water transpired during a period of 20 days after salt treatment by the amount of salt accumulating during that time. We found no major differences between the genotypes in xylem Na concentration. Using a parallel set of plants that was also treated by salinity at flowering time, and kept until maturity, we found no relation between the stem, leaf, and shoot Na concentration and the final pod yield, showing that Na accumulation in shoot, and the putative Na toxicity, was not directly responsible for the effect on pod yield under salt stress. This confirmed the lack of relationship between shoot Na concentration and seed yield that we found in the large salinity screening of 2006. We found that tolerant genotypes tended to have higher ABA concentration, even under non-saline control conditions, which agreed well with the data on transpiration response. We found no pattern in the proline increase between tolerant and sensitive genotypes, which indicated that proline did not have any role in the genotype's tolerance. Similar results were found for anti-oxidant enzymes that had similar banding pattern in tolerant and sensitive lines.

Special Project Funding:
Water & Food CP

V Vadez

Milestone: QTLs for salinity tolerance identified (RA/SNN/VV/DH) 2011
Achievement of Output Target (%):
25%
Countries Involved:
India
Partners Involved:
None

Progress/Results:
Mapping populations of crosses between resistant parents (ICG 4746, ICG 6993 and ICG 5051) and susceptible parents (ICGV 87187, ICGS 76 and ICGV 86031) are in the initial stages of development.

Special Project Funding: The OPEC Fund for International Development

R Aruna, SN Nigam and V Vadez

CHICKPEA

Output target 6.2.1 CP Biotechnological strategies developed for improving drought avoidance root traits and salinity tolerance in chickpea

Activity 6.2.1.1 CP Marker-assisted breeding for drought tolerance in chickpea

Milestone: Assessment of water uptake and related kinetics in contrasting genotypes for root traits studied using a lysimetric system (VV/JK/LK) 2009

Achievement of Output Target (%):
30%

Countries Involved:
Ethiopia; India; Tanzania

Partners Involved:
National program of countries above

Progress/Results:
An experiment has been carried out in 2007-08 to assess whether genotypes contrasting for root traits would also contrast for their water extraction capacity. The trial was plant in mid-December and involved ICC4958, ICC 8261, ICC 15264, and ICC 16796 as “profuse rooting” genotypes and Chafa, ICC 2072, ICC 10945, Annigeri as “shallow rooting” genotypes. Plants were grown under residual moisture in 1.2 m long and 20-cm diameter lysimeters filled with Vertisol at a 1.1 bulk density. All genotypes extracted between 5700 g and 6400 g of water from the soil profile, showing limited genotypic variation between the lines.

Special Project Funding:
Tropical Legumes I

V Vadez, L Krishnamurthy, J Kashiwagi

Milestone: QTLs for drought avoidance root traits validated (RKV/PMG/JK/LK) 2010

Achievement of Output Target (%):
70%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
At ICRISAT two intra-specific mapping populations ICC 4958 × ICC 1882 and ICC 283 × ICC 8261 segregating for root traits are used to study the QTLs for drought avoidance in chickpea. The polymorphic survey of the novel SSR markers together with already existing SSR markers on parental genotypes of both mapping populations provided a set of 292 polymorphic markers on ICC 4958 × ICC 1882 and 308 markers in ICC 283 × ICC 8261 (Table 6.5). Genotyping for all the polymorphic markers has been completed on 232 RILs of the mapping population ICC 4958 × ICC 1882 (Fig. RKV2). Development of genetic map is in progress. Phenotyping of ICC 4958 × ICC 1882 population for root traits (2005-07) has already been completed.

Table 6.5: Polymorphism survey of SSR markers in intra specific mapping population segregating for root traits

			ICC 4958 × ICC 1882			ICC 283 × ICC 8261		
Markers	Source	Total	Ampli-fied	Poly-morphic	Poly-morphism %	Ampli-fied	Poly-morphic	Poly-morphism %
H series	Texas A & M University	233	153	32	20.9	153	42	27.5
NIPGR	NIPGR	280	203	56	27.6	203	82	40.4
ICCM	ICRISAT	311	225	23	10.2	225	25	11.1
CaM	ICRISAT and UCD	1344	1214	106	8.7	1214	159	13.1
Winter et al	University of Frankfurt	241	183	75	41	_	_	-
Total		2409	1978	292	14.8	1795	308	17.2

Genotyping of ICC 283 × ICC 8261 population is in progress.

The first set of phenotyping of ICC 283 × ICC 8261 population had been carried out during 2006-07 and that is getting repeated during 2008-09. The population had been planted during the second week of December 2008 and the harvest would be completed by Jan 2009 providing 2 years' data on phenotyping for the key root traits.

The polymorphic makers identified in the cross ICC 283 × ICC 8261 will be genotyped on the progeny lines and will be further used for linkage and trait mapping.

Special Project Funding:
Tropical Legume I of Generation Challenge Programme and National Fund of ICAR, Govt. of India.

RK Varshney, SN Nayak, T Mahender, PM Gaur, V Vadez, L Krishnamurthy and J Kashiwagi

Milestone: MABC derived drought tolerant lines available from 2-3 locally adapted cultivars (PMG/JK/LK/RKV) 2011

Achievement of Output Target:
40%

Countries Involved:
Ethiopia; India; Tanzania

Partners Involved:
NARS of India, Ethiopia and Tanzania

Progress/Results
In order to introgress drought avoidance root traits in drought sensitive locally adapted cultivars, crosses were initiated using lines ICC 8261 (kabuli) and ICC 4958 (desi) as donor parents (ICCV 93954 × ICC 4958, ICCV 92318 × ICC 8261, ICCV 92311 × ICC8261). The BC1F1 populations of the above crosses was subjected to foreground selection using a set of 3 SSR markers (TAA170, ICCM 009a, and STMS21) linked to drought QTLs in the map generated from ICC 4958 × ICC1882. The detailed marker analysis is still in progress. Out of 282 chickpea plants from all the three BC_1F_1 populations, 56 were found to be heterozygous for all the 3 markers. These 56 plants will be used to generate the BC2F1 progenies (Table 6.6)

Table 6.6: Selected plants for MABC1F1 from 3 populations for drought tolerance (root traits) in chickpea

	MABC 1 (JG 11 × ICC 4958)	**MABC 2 (ICC 92318 × ICC 8261)**	**MABC 3 (KAK 2 × ICC 8261)**	**Total**
Population size	94	94	94	282
Marker TAA 170				
Total amplified	84	90	81	255
Heterozygotes	37	50	36	**123***
Marker ICCM 009a				
Total amplified	86	91	94	271
Heterozygotes	47	38	32	117
Marker STMS 21				
Total amplified	88	88	83	259
Heterozygotes	48	40	41	129
Common heterozygotes across all the markers	21	19	16	56

*Total chickpea plants across 3 populations for MABC1F1 = 123 (includes common heterozygotes as well as heterozygotes only in TAA170

Special Project Funding:
Tropical Legume I of Generation Challenge Program

PM Gaur, RK Varshney, C Siva Kumar, S Tripathi, V Vadez and L Krishnamurthy

Activity 6.2.1.2 CP Mapping and marker-assisted breeding for salinity tolerance in chickpea

Milestone: Mechanisms of tolerance to salinity chcracterized (VV/LK/NM)

Achievement of Output Target (%):
100%

Countries Involved:
Australia; India

Partners Involved:
India: PAU, Ludhiana; *Australia:* University of Western Australia and CLIMA, Australia

Pogress/Results:
We assessed a number of pairs of contrasting tolerant/sensitive genotypes of chickpea (to salt stress), and assessed plants that were treated with salt at the time of flowering and plants treated with salt from the time of sowing. In these plants, we followed the reproductive structures from budding to podding and assessed how transpiration responded to salt stress.

The salinity treatment imposed at the time of sowing reduced the plant growth irrespective of the cultivar, which was evident from the decline of dry weight of shoot with increasing stress in salt stage. By contrast, the salinity treatment applied at the time of flowering had a significant effect on the biomass of early flowering genotypes only (ICCV2 and JG62), which was decreased compare to the non-saline control. The biomass was not significantly decreased under salt stress applied at the time of flowering in the later flowering genotypes. These results are to be related to the fact that transpiration was on average more decreased by salt treatment at flowering in early than in late flowering genotypes. These results are unexplained and may suggest that a significant biomass accumulation may take place after flowering, making these genotypes relatively more sensitive to stress where more biomass accumulation has taken place before flowering.

In this work, we confirmed earlier established facts that JG11 and ICC1431 are tolerant to salt stress, whereras ICCV2 and ICC6263 are sensitive. This was seen by a lesser decrease in seed dry weight under salt stress applied at the time of sowing in JG11 and ICC1431. This was the case although ICC1431 suffered desease pressure in that trial. These differences could not be seen from the seed yield across genotypes in the salt treatment applied at flowering in the case of ICC1431 and ICC6263 (both had very similar seed yield under that treatment). By contrast, the difference in seed yield between JG11 and ICCV2 was also very clear, with seed yield being about 30% of that in control in the case of ICCV2, whereas it was about 65% of that of control in the case of JG11. The lack of difference in the seed yield under salt treatment applied at flowering in the case of ICC1431 and ICC6263 was because ICC6263 kept a higher normalized transpiration ratio upon salt treatment than ICC1431. This would indicate that the relatively higher drop in transpiration in ICC1431 had no detrimental consequences on seed yield. By contrast, in the case of JG11 and ICCV2, the drop in transpiration due to salt treatment in ICCV2 was more severe than in JG11, and this may have been causally related to the lower seed yield in ICCV2.

One hypothesis we tested was whether any step during the reproductive stage could have been more sensitive to the application of salt. This motivated the use of a salt treatment applied at the time of flowering to ensure that plants would develop normally until they were treated with salt. Therefore we tested whether the number of flower buds, flowers, pods or seeds might have decreased relatively more in sensitive genotypes such as ICCV2 or ICC6263. Results confirmed earlier results (Vadez et al., 2007) that tolerance of ICC1431 over ICC6263 was related to the maintenance of a relatively large number of seeds compared to control. ICC1431 and JG11 have higher number of flowers under salt stress applied at the time of sowing, compared to ICC6263 and ICCV2 respectively. However, the same was true also from the number of flowers under control conditions and it appears that the decrease in the number of flowers under salt stress compared to control in all genotypes was not very different from each other (about 40-45%). These data tend to suggest that salt affected each of these genotypes in a similar fashion, and those that kept a larger number of flowers under salt stress were also those that had more profuse flowering under control conditions. Therefore, the number of flowers under control conditions might be a good constitutive indicator of salt stress tolerance, and this is one the major output of this work.

Later on, the number of flowers dropped leading to a lower number of pods for sensitive and tolerant genotypes in a similar fashion. That is, the number of pods was about 2/3 of the number of flowers in all genotypes, regardless of the level of tolerance. Similar phenomenon occurred between pod number and seed number. These data indicate that the steps between flowering and podding and between podding and seed development were not particularly more affected in salt sensitive genotypes than in salt tolerant genotypes.

Seed number was decreased in all genotypes due to salt stress at the time of sowing, but on the other hand it increased slightly on the salt stress at the time of flowering and compared with control plant in genotypes ICC 1431, ICC 6263, ICC 9942 and ICC 15802. However, ICCV 2 showed a drastic reduction in seed number compared to other genotypes which underwent the salt stress applied at flowering. The reason for the increase in flowering in some genotypes under salt treatment applied at the time of flowering is unexplained and simply suggest that salt treatment may induce some hormone signal in the shoot that interfere with the hormonal signaling related to flowering initiation and development.

We confirmed the tolerance of ICC1431 and JG11 and also confirmed that ICCV2 and ICC6263 were relatively more sensitive. We have seen that the transpiration response to salt stress varies across genotypes contrasting for salt stress tolerance. However, it was unclear whether these responses had any bearing on the tolerance since the seed weight under the salt treatment applied at flowering was similar to that under control. However, in the case of ICCV2, the inhibition of transpiration upon salt stress was more than in JG11, and this was related to a better relative seed yield under stress conditions. Further work would be needed, using more severe treatment to assess this relation in the other genotypes.

We also confirmed that genotypes achieving higher seed yield under salt conditions were also those able to maintain larger seed number under stress. Apparently, the salt stress induced flowering in most genotypes. The capacity to produce under salt stress was apparently related to the capacity to produce larger number of flowers under control conditions. Although this was not leading to differences in seed yield under control conditions, the maintenance of a fairly similar percentage (about 40%) of flower under stress conditions made that tolerant genotypes ICC1431 and JG11 could obtain better yield under salt conditions.

Special Project Funding:
COGGO, ARC-linkage grant

V Vadez and L Krishnamurthy

Milestone: Contrasting materials (varieties, breeding lines, germplasm) for salinity tolerance assessed under field conditions (VV/LK/PMG) 2010

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
UAS Dharwad, HAU Hisar and PAU Ludhiana.

Progress/Results:
Twenty-five contrasting lines for salinity tolerance were multiplied in 2007-08 and seed was supplied to the partners for evaluation at Gangavathi (Karnataka), Hisar (Haryana), and Ludhiana (Punjab) in saline fields.

Special Project Funding:
COGGO Project; ARC Linkage Grant, Australia

V Vadez, L Krishnamurthy and PM Gaur

Milestone: QTLs for salinity tolerance identified (RKV/VV/LK/PMG) 2011

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Mapping from ICCV 2 x JG 62 population: In order to identify and map QTLs for salinity tolerance in chickpea, genotyping data have been generated for 204 markers on the 126 RILs of mapping population ICCV 2 × JG 62. The segregation data are being used to calculate the map distance. Phenotying of the mapping population ICCV 2 × JG 62 for various salinity tolerance traits such as, days to flower, total shoot weight, total seed weight and harvest index have been done during 2007-08. Genotyping and phenotyping data will be analyzed to identify QTLs for salinity tolerance.

RK Varshney, T Mahender, V Vadez, L Krishnamurthy, PM Gaur and S Tripathi

New RILs population for mapping of salinity tolerance QTLs: Intra-specific RIL populations are being developed for mapping salinity tolerance QTLs. A total of 286 RILs from the ICC 6263 (sensitive) x ICC 1431 (tolerant) cross were advanced to F_6 in the green house during the off-season and the F_7 RILs are being grown in the field during the crop season 2008/09. The RILs (n=291) from the other cross (ICCV 2 x JG 11) are currently in the F_5.

PM Gaur, S Tripathi, V Vadez, L Krishnamurthy and RK Varshney

Special Project Funding:
COGGO Project; ARC Linkage Grant, Australia

Milestone: Introgression of QTLs for salinity tolerance initiated in farmer-preferred varieties (PMG/VV/LK/RKV) 2011

Achievement of Output Target (%):
0%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
The work towards this milestone will start after identification of genes/QTLs for salinity tolerance.

Special Project Funding:
None

PM Gaur, S Tripathi, V Vadez, L Krishnamurthy and RK Varshney

Activity 6.2.1.3 CP: Develop and evaluate chickpea transgenic events for enhanced tolerance to drought stress

Milestone: At least 8 promising transgenic events of chickpea containing DREB1A or P5CSF genes identified and their drought tolerance characterized under contained greenhouse conditions (KKS/VV/PMG) 2008

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Nil

Progress/Results:
Genetic engineering of chickpea for enhanced tolerance to water stress was previously carried out using the osmoregulatory *P5CSF129A* gene and DREB1A transcription factor that acts as a major "switch" triggering a cascade of genes in response to a given stress. Forty-eight chickpea events with 35S:P5CSF129A and 18 events carrying rd29A:DREB1A were developed and advanced to subsequent generations. Southern analysis of the tested events indicated a low copy number (1-2 copies) in the 35S:P5CSF129A transgenics, whereas most of the events carrying rd29A:DREB1A had only a single copy of the transgene. The phenotyping of 10 selected transgenic events each of rd29A:DREB1A and 35S: P5CSF129A in T_5 generation was carried out in dry-down experiments in lysimetric system under greenhouse conditions, where several events exhibited a diversity of stress response patterns, especially with respect to the NTR-FTSW relationship and water use efficiency. The transgenic events differed in response of NTR to FTSW, where their transpiration started declining at lower FTSW values (drier soil) under drought stress. This pattern was essentially the same as observed in the previous dry-down experiments. Five transgenic events (P8, RD10, RD9, RD7 and RD2) along with the nontransformed control were evaluated for their response to terminal drought conditions in greenhouse. The component traits of yield were studied viz., cumulative transpiration, TE, yield (shoot, pod and seed) and HI. However the results indicated no significant differences across transgenic lines as well in comparison to C235 both under well-watered and terminal drought conditions. All the genotypes showed a similar response to terminal drought stress under these conditions. We plan to repeat this experiment in the next season for assessing the component traits and the root responses of these selected events. Seed multiplication and maintenance of desirable transgenic events in T_6 generation has been carried out and the plants are being characterized at molecular level to ascertain homozygosity. Additional marker free transgenic events of chickpea carrying rd29A:DREB1A are also being produced.

Special Project Funding:
Department of Biotechnology, Govt. of India; Swiss Agency for Development & Cooperation (SDC) under Indo-Swiss Collaboration in Biotechnology (ISCB)

KK Sharma, P Bhatnagar-Mathur, Vincent Vadez and PM Gaur

Milestone: Transgenic DREB/P5CSF events transgenic events available for introgression into locally adapted genotypes (KKS/VV/PMG) 2010

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
The results reported above for 2008 milestone represents 30% of the progress towards achieving this milestone

Special Project Funding:
Department of Biotechnology, GoI; Swiss Agency for Development & Cooperation (SDC) under Indo-Swiss Collaboration in Biotechnology (ISCB)

PIGEONPEA

Output target 6.2.1 PP: Improved pigeonpea for salinity tolerance using biotechnology

Activity 6.2.1.1 PP: Identify superior pigeonpea genotypes for salinity tolerance

Milestone: A set of pigeonpea genotypes suitable to breed for breeding salinity tolerance identified (VV/KBS) 2009

Achievement of Output Target (%):
70%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
A large screening of 300 accessions of pigeonpea has been completed. These materials included 150 genotypes of the mini core collection maintained by genetic resource unit at ICRISAT, 68 different wild accessions, 69 accessions selected from salinity prone areas worldwide (Bangladesh, Taiwan, Ethiopia, Indonesia, Argentina, Iran, and Brazil), and 13 genotypes from breeding material (breeding lines and cytoplasmic male sterile lines; derivatives of different wild species), and a few pigeonpea hybrids. The first trial was in alpha lattice design (30X10) in three replications with two treatments (0.88 g NaCl / kg of Alfisol and control), and performed under rainout shelter to avoid rains. The soil was fertilized with DAP and also treated with carbofuran to prevent fungal and thrips infestation. The stressed pots were also treated as above, with saline solutions such that the overall 0.88 g/kg were divided into three split doses. The field capacity of pots was maintained throughout the experiment. The experiment was harvested at 70 days after sowing.

We assessed salinity tolerance based on the percent relative reduction of biomass under saline conditions compared to control, and the salinity susceptibility index by using the formula $SSI= (1-Y_{SS}/Y_{NS})/SII$, where Y_{SS} and Y_{NS} are the mean biomass of a given accession in saline and non saline conditions respectively. SII is the salinity intensity index, was calculated as $SII=1-X_{SS}/X_{NS,}$ where X_{SS} and X_{NS} are the mean of all accessions under salinity stressed and non- stressed environments. The genotypes with less than 50 % relative reduction and with their SSI values ranging between 0-0.75 were considered as tolerant. The genotypes which in biomass had relative reduction more than 50% and less than 70% and SSI values ranged between 0.76-1.05 were assumed as moderately tolerant; and those which had relative reduction ranged between 70-90% and SSI values 1.06-1.37 were considered as moderately susceptible. The genotypes with more than 90% relative reduction in biomass and SII ranged between 1.38-1.52 were assumed as highly susceptible.

In pigeonpea, we found very large range of variation for percent relative reduction in biomass (2-100%) among wild relatives. ICPW 87 and ICPW 94 were most tolerant to salinity with SSI value 0.03 and 0.28 and their relative biomass reduction was very small (2.0 and 18.6%). Both genotypes belong to the *C. scaraboides*. One accession (ICPW 68) of *C. platycarpus* had also low SSI value 0.37 and only 24.3% of relative reduction in biomass. Among the wild accessions, ICPW 87 and ICPW 94 were most tolerant to salinity with SSI value 0.03 and 0.28 and their relative biomass reduction was very small (2.0 and 18.6%). Both genotypes belong to the *C. scaraboides*. In the set originating from areas putatively affected by salinity, ICP 13991, 14974, 13997, and 11412 were tolerant and ICP 13625, 13996, 14175, 11414 and 11420 showed high susceptibility. In the mini-core collection, 13 genotypes were considered as tolerant (ICP 8860, 7803, 7260, 6815,10654,3046, 2746,7426,10559, 7057, 6049, 6859 and ICP 7) whereas four (ICP 15493, 15382, 1071 and 6739) were salinity susceptible based on their SSI and percent relative reduction in biomass. Among the cultivated, there was no better source of salinity tolerance in those from saline areas than in those from the mini-core collection.

For the accessions from different areas putatively affected by salinity, the variation ranged from 42-100% for relative reduction in biomass and 0.64 to 1.52 for SSI values, which also show a very large genotypic variation to identify contrasting entries for salinity tolerance. In this set ICP 13991, 14974, 13997, and 11412 were tolerant and ICP 13625, 13996, 14175, 11414 and 11420 showed high susceptibility. Among the pigeonpea mini-core collection the range of variation for biomass relative reduction was 15-100% and for SSI it ranged between 0.23-1.52. These data show that the mini-core collection contained genotypes having higher salinity tolerance than in the group of genotypes putatively originating from salinity-affected areas. Out of 150 genotypes of mini core 13 were considered as tolerant *viz* ICP 8860, 7803, 7260, 6815,10654,3046, 2746,7426,10559, 7057, 6049, 6859 and ICP 7 and four ICP 15493, 15382, 1071 and 6739 were considered salinity susceptible based on their SSI and percent relative reduction in biomass. Finally, for the set of wild derivatives of pigeonpea the range varied between 42-84% biomass reduction and their SSI values 0.75-1.52. Out of them ICPB 2051, 2030 and 2039 were tolerant and ICPB 2032 was highly susceptible.

Special Project Funding:
Water & Food CP

V Vadez and L Krishnamurthy

Activity 6.2.1.2 PP Develop intra- and inter-specific mapping population of pigeonpea between contrasting materials for salinity tolerance

Milestone: At least two mapping populations developed to map QTLs for salinity tolerance in pigeonpea (VV/RKS/KBS/NM) 2010

Progress/Results:
The activity is yet to be started.

SORGHUM
Output target 6.2.1 SO Improved sorghum for abiotic tolerance

Activity 6.2.1.2 SO Selecting for sorghum lines for abiotic stress tolerance.
Milestone: Five sorghum varieties for salinity tolerance developed (BVSR/AAK/VV) 2009

Achievement of Output Target (%):
30%

Countries Involved:
India and CAC countries

Partners Involved:
UAS, Dharwad, India; ICBA, Dubai; NARS in CAC countries

Progress/Results:
In 2008, a range of breeding lines have been re-tested for salinity tolerance under controlled conditions in outdoor conditions. This follows a screening that was performed during the previous year and where contrasting breeding lines had been identified. Once analyzed, this information will be fed to the sorghum breeding program to guide their breeding efforts. Mapping populations involving parents having phenotypic contrast under salt stress, based on yield differences, are currently under development.

In order to introgress salinity tolerance into high yielding background, a total of 436 F_6s (from 230 F_5s) and 316 F_5s (from 221 F_4s) for B-line development and 67 F_6s (from 43 F_5s) and 239 F_5s (from 112 F_4s) for R-line development were obtained with selection for high grain yield, bold grain and agronomic appearance and 272 F_5s (from 146 F_4s) obtained from the crosses between germplasm and breeding lines with selection for high grain yield and high biomass.

Special Project Funding:
The OPEC Fund for International Development

BVS Reddy, A Ashok Kumar, L Krishnamurthy, and Vincent Vadez

Output 6.3: Annually knowledge of the improvements of the biotechnological and conventional tools designed to facilitate biofortification and biodetoxification, breeding improved germplasm and management strategies (against mycotoxin contamination) of mandate crops and associated capacity building made available to partners internationally

Output target 6.3.1 FORT: High yielding and micronutrient dense hybrids/improved populations/varieties of sorghum and promising transgenic events of groundnut and pigeonpea with high beta-carotene content available for testing in national trials

Activity 6.3.1.1 FORT: Develop groundnut transgenic events for enhanced production of beta-carotene

Milestone: One or two transgenic events of groundnut with high beta-carotene content used for introgression into locally adapted genotypes and the progeny characterized and evaluated (KKS/PB/SNN/RA) 2011

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results
The results reported above for 2008 milestone represents 20% of the progress towards achieving this milestone

Special Project Funding:
Harvest Plus Challenge Programme

KK Sharma, P Bhatnagar-Mathur, SN Nigam and R Aruna

Activity 6.3.1.2 FORT: Develop pigeonpea transgenic events for enhanced production to beta-carotenes.

Milestone: At least 8 promising transgenic events of pigeonpea containing maize psy1 gene identified and their stability characterized under contained greenhouse conditions (KKS/PB/KBS/RKS) 2008

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
National Institute of Nutrition, Hyderabad

Progress/Results:
Agrobacterium-mediated genetic transformation was carried out using the binary vectors containing maize *psy*1 gene driven by oleosin promoter for generating pigeonpea transgenic events with enhanced level of ß-carotene. 140 putative transgenic plants with maize *psy*1 have been transferred to the containment greenhouse and were characterized at molecular level for the integration and expression of the transgenes. Total carotenoids in the primary T_0 putative pigeonpea plants were estimated spectrophotometrically and 11 events selected for further analysis. These events showed 2 to 3-fold increase in ß-carotene levels evidenced using HPLC analysis. Over 60 events were advanced to T_1 generation and PCR and RT PCR analysis was carried out. Biochemical analyses of T_2 generation seeds (Seeds from T_1 generation plants) are underway.

In a separate study, binary gene constructs containing *SSA* gene driven by vicillin promoter (pHS723:SSA) in *Agrobacterium tumefaciens* strain C58 has been used for the development of pigeonpea transgenics with enhanced levels of seed methionine content. 37 putative transgenic plants were transferred to the containment greenhouse for further analysis. PCR analysis for the T_0 plants was carried out and 26 putative transgenic plants showed integration and expression of the transgene. All these 26 events were advanced to T1 generation and molecular analysis was carried out. Biochemical analysis (Estimation of sulphur containing amino acids) is ongoing, to identify the promising events.

Special Project Funding:
Harvest Plus Challenge Programme

KK Sharma, P Bhatnagar-Mathur, KB Saxena and RK Srivastava

Milestone: 5-7 introgressed transgenic lines of pigeonpea with enhanced beta-carotene content evaluated and development of commercialization package initiated (KKS/PB/KBS/RKS) 2011

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
The results reported for 2008 milestone represents 20% of the progress towards achieving this milestone

Special Project Funding:
Harvest Plus Challenge Programme

KK Sharma, P Bhatnagar-Mathur, KB Saxena and RK Srivastava

Activity 6.3.1.3 FORT: Selecting sorghum lines for high grain Fe and Zn contents

Milestone: Three varieties with high grain Fe (>40ppm) and Zn (>30 ppm) contents identified (BVSR/AAK) 2010

Achievement of Output Target (%):
20%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
As a part of developing R-lines/varieties rich in grain Fe and Zn contents, 32 F_6s, 29 F_5s and 145 F_2s developed from crosses involving grain micronutrients (Fe and Zn)-dense germplasm lines and high yielding breeding lines were evaluated in the 2008 rainy season. Test crosses were also made in F_5s and F_6s to convert to A_1 cms lines 438 F_3s were advanced from 145 F_2s based on agronomic performance.

Special Project Funding:
Harvest Plus Challenge Programme

A Ashok Kumar and BVS Reddy

Output target 6.3.2 DTOX Transgenic groundnut with enhanced resistance to *Aspergillus flavus* and aflatoxin production identified and available for introgression into regionally adapted germplasm

Activity 6.3.2.1 DTOX Develop and evaluate groundnut transgenic for enhanced resistance to *Aspergillus flavus*

Milestone: At least 75 transgenic events of groundnut containing the peanut lipoxygenase (PNLOX13S) gene developed and characterized for gene integration and expression (KKS/PB/VW/SNN/RA) 2008

Achievement of Output Target (%):
60%

Countries Involved:
India; USA

Partners Involved:
University of Wisconsin, USA

Progress/Results:
To address the issue of providing resistance to aflatoxin production in groundnut, a 13S-lipoxygenase (*13S-LOX*) gene from groundnut is being. For this, the 13S-LOX gene has been cloned into a binary vector (pPZP200) for marker-free production of transgenic plants. *Agrobacterium tumefaciens*–mediated genetic transformation with the plasmid pZP200:13SLOX was carried using the cotyledon explants from mature seeds of the groundnut variety. Over 20 putative transgenics have been transferred to greenhouse and other 70 are in pipeline. Molecular characterization of the primary transformants is underway using PCR, RT- PCR analysis.

Since the 13S-LOX gene has been cloned under a constitutive *CaM*V promoter, it was observed to have some penalty on rate of growth of the putative transgenic plants under in vitro conditions. The putative transgenics have been observed to grow at a slower rate in tissue cultures when compared to the untransformed controls. To overcome the problem of slow growth, efforts are ongoing to clone Pnlox3 gene under seed specific promoters such as lectin and glycinin. Besides, purification of Pnlox3 protein from crude proteins by Ni-NTA column is being carried out for the production of antibodies. Besides, the protocol for screening and evaluation of transgenic plants for A. flavus infection and aflatoxin contamination are being optimized using lysimetric system, where the cylinders are used to create micro sick plots to facilitate greenhouse screening of the transgenic events produced.

Special Project Funding:
None

KK Sharma, P Bhatnagar-Mathur, Varsha Wesley, SN Nigam and R Aruna

Milestone: Five promising transgenic events of groundnut with PNLOX13S gene identified for introgression (KKS/PB/VW/SNN/RA) 2010

Achievement of Output Target (%):
10%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
The results reported for 2008 milestone represents 10% of the progress towards achieving this milestone

Special Project Funding:
None

KK Sharma, P Bhatnagar-Mathur, Varsha Wesley, SN Nigam and R Aruna

Output target 6.3.3 DTOX: Simple and cost-effect test for the estimation of mycotoxins (Aflatoxins, Fumonisins and Ochratoxin-A) in crops and commodities, and aflatoxin-adducts in human serum developed and validated

Activity 6.3.3.1 DTOX: Develop simple and cost-effective assays for the detection of mycotoxins in crops and commodities

Milestone: Tube/filter paper based semi-quantitative immuno assay developed for the on-site detection of aflatoxins (FW/VW) 2008

Milestone: Multiplex filter paper immunoassay developed for the rapid estimation of aflatoxins and fumonisins (FW/VW) 2009

Achievement of Output Target (%):
0%

Countries Involved:
None

Partners Involved:
None

Progress/Results:
These activities were planned to be carried out in partnership with a private company – Varda Biotech; however, due to change in this company's strategic direction and priorities, we could not carry out these activities. We are in the process of finding a new partner with whom we could carry out these activities.

Special Project Fundings:
None

Varsha Wesley

Output target 6.3.4 DTOX: Aflatoxin resistant/tolerant groundnut genotypes identified

Activity 6.3.4.1 DTOX: Evaluate groundnut varieties for resistance to *Aspergillus flavus* and aflatoxin production by *in vitro* inoculation studies and on-station testing in sick fields

Milestone: 8-10 elite aflatoxin resistant lines identified and made available to NARS (RA/SNN/FW/VW) 2009

Achievement of Output Target (%):
50%

Countries Involved:
Countries in Asia and Africa

Partners Involved:
NARS in Asia and Africa

Progress/Results:
Resistance to Aflatoxin Contamination: As it is not possible to screen for resistance to aflatoxin contamination caused by *Aspergillus flavus* on a single plant/seed basis, selection in early generation breeding materials is done only for agronomic traits. Once the breeding lines are stabilized and enter replicated yield trials, they are also evaluated simultaneously for aflatoxin contamination in an *A. flavus* sick plot.
New crosses: Thirteen new crosses were made in the 2007/08 postrainy and 2008 rainy seasons to develop aflatoxin tolerant breeding lines. ICGV 07152, 07157, 04044, 06347, 07146, ICGV 06347, 04044, 06408, 07146 and 07166 were the new breeding lines which were used as sources of resistance to aflatoxin in hybridization program.

Breeding populations: From 129 F_2-F_7 bulk populations and 267 single plant progenies, grown in the 2007/08 postrainy season, 224 bulk and 34 single plant selections were made for further evaluation for agronomic traits. Out of these, 45 bulks were identified for inclusion in replicated trials. The promising selections for agronomic traits came from (ICGV 95469 x ICGV 01133), (ICGV 93280 x ICGV 01092) and (ICGV 95469 x ICGV 01133) crosses. In the 2008 rainy season, 176 F_2-F_8 bulks and 25 plant progenies were sown for further selection. From these, 135 bulk and 363 single plant selections were made. The promising selections for agronomic traits came from (ICGV 93280 x ICGV 99159) and (ICGV 97281 x ICGV 99159) crosses.

Replicated trials: Evaluation of advanced breeding lines for yield and other agronomic traits is done in replicated trials in rainy and postrainy seasons under normal growing conditions. One set of each trial was also grown in an *A. flavus* sick plot in postrainy season and subjected to end-of-season drought to promote aflatoxin contamination so that genotypic differences for preharvest seed infection and aflatoxin content could be discerned.

***2007 rainy season*:** One hundred and ten advanced breeding lines including controls were evaluated in three replicated trials for agronomic traits. In this season, screening for resistance to aflatoxin contamination was not done.

In an Elite Trial, four lines (4.4-3.9±0.19 t ha^{-1}pod yield) significantly outyielded the highest yielding susceptible control TAG 24 (2.4 t ha^{-1}pod yield, 69% shelling outturn, 45 g HSW) and the resistant control J 11 (2.2 t ha^{-1} pod yield, 67% shelling outturn, 27 g HSW). ICGV 06347 ranked first in pod yield (4.4 t ha^{-1}pod yield, 64% shelling outturn, 52 g HSW) followed by ICGV 06344 (4.2 t ha^{-1}pod yield, 64% shelling outturn, 53 g HSW).

In an Advanced Trial-1, eight lines (4.3-3.1±0.16 t ha^{-1}pod yield) gave significantly higher pod yield than the highest yielding susceptible control TAG 24 (2.5 t ha^{-1}pod yield, 66% shelling outturn, 31 g HSW) and the resistant control J 11 (2.5 t ha^{-1} pod yield, 68% shelling outturn, 27 g HSW). ICGV 07146 ranked first in pod yield (4.3 t ha^{-1}pod yield, 67% shelling outturn, 51 g HSW) followed by ICGV 07147 (4.0 t ha^{-1}pod yield, 66% shelling outturn, 46 g HSW).

In an Advanced Trial-2, nine lines (4.2-3.1±0.17 t ha^{-1} pod yield) gave significantly higher pod yield than the highest yielding susceptible control TAG 24 (2.4 t ha^{-1}pod yield, 62% shelling outturn, 25 g HSW) and the resistant control J 11 (2.0 t ha^{-1} pod yield, 60% shelling outturn, 24 g HSW). ICGV 07165 ranked first in pod yield (4.2 t ha^{-1}pod yield, 69% shelling outturn, 54 g HSW) followed by ICGV 07167 (4.2 t ha^{-1}pod yield, 68% shelling outturn, 52 g HSW).

2007/08 postrainy season: The 2007 rainy season trials were repeated in the 2007/08 postrainy season under normal growing conditions and a set each of them was also grown in an *A. flavus* sick plot under imposed end-of-season drought conditions.

In an Elite Trial, sixteen lines (6.4-5.1±0.17 t ha^{-1}pod yield) significantly outyielded the highest yielding resistant control ICGV 88145 (4.6 t ha^{-1}pod yield, 75% shelling outturn, 51 g HSW). ICGV 06347 ranked first in pod yield (6.4 t ha^{-1}pod yield, 73% shelling outturn, 51 g HSW) followed by ICGV 06344 (6.3 t ha^{-1}pod yield, 72% shelling outturn, 62 g HSW), ICGV 06346 (6.0 t ha^{-1}pod yield, 73% shelling outturn, 61 g HSW) and ICGV 06412 (6.0 t ha^{-1}pod yield, 71% shelling outturn, 52 g HSW). ICGV # 06347 and 06344 were the two most promising lines which significantly outyielded the highest yielding control in both rainy and postrainy seasons. Preharvest *A. flavus* seed infection ranged between 0 and 1.2% and aflatoxin content between 0 and 380.9 µg kg^{-1} in the trial. Aflatoxin content in susceptible controls, JL 24 and TAG 24, was 14.1 and 380.9 µg kg^{-1} and in resistant controls, J 11 and ICGV 88145, it was 0.4 and 86.3 µg kg^{-1}. Among the top yielding test lines, aflatoxin content was 0.4 µg kg^{-1} in ICGV 06347, 361.7 µg kg^{-1}in ICGV 06344, 2.4 µg kg^{-1} in ICGV 06346 and 0 µg kg^{-1} in ICGV 06412.

In an Advanced Trial-1, seven lines (6.9-5.0±0.17 t ha^{-1}pod yield) gave significantly higher pod yield than the highest yielding resistant control J 11 (4.5 t ha^{-1}pod yield, 73% shelling outturn, 35 g HSW). ICGV 07146 ranked first in pod yield (6.9 t ha^{-1} pod yield, 75% shelling outturn, 55 g HSW) followed by ICGV 07148 (6.8 t ha^{-1} pod yield, 71% shelling outturn, 61 g HSW). ICGV 07146 significantly outyielded the highest yielding control in both rainy and postrainy seasons. Preharvest *A. flavus* seed infection ranged between 0 and 3.7% and aflatoxin content between 0 and 663.0 µg kg^{-1} in the trial. Aflatoxin content in susceptible controls, JL 24 and TAG 24, was 663.0 and 1.3 µg kg^{-1} and in resistant controls, J 11 and ICGV 88145, it was 23.4 and 0.4 µg kg^{-1}. Among the top yielding test lines, aflatoxin content was 0.5 µg kg^{-1} in ICGV 07146, 90.1µg kg^{-1}in ICGV 07148, 354.4 µg kg^{-1} in ICGV 07147, 5.7 µg kg^{-1} in ICGV 07145 and 0.8 µg kg^{-1} in ICGV 07144.

In an Advanced Trial-2, seventeen lines (6.1-4.8±0.14 t ha^{-1}pod yield) produced significantly higher pod yield than the highest yielding resistant control J 11 (4.4 t ha^{-1}pod yield, 73% shelling outturn, 35 g HSW). ICGV 07166 ranked first in pod yield (6.1 t ha^{-1}pod yield, 73% shelling outturn, 60 g HSW) followed by ICGV 07174 (6.1 t ha^{-1} pod yield, 74% shelling outturn, 60 g HSW). In this trial, susceptible controls failed to get preharvest seed infection. Both susceptible and resistant controls had low aflatoxin content in the trial. Aflatoxin content in lines giving significantly higher yield ranged between 0.3 and 965.1 µg kg^{-1}. ICGV # 07176, 07169, 07165, 07192, 07190, 07208 and 07172 had < 5.0 µg kg^{-1} aflatoxin content. Field screening techniques requires significant improvements to give consistent results.

Four Spanish type groundnut lines were selected for inclusion in future international trials.

***2008 rainy season*:** Seventy-four advanced breeding lines including controls in two replicated trials were evaluated for agronomic traits. Data from these trials are being processed.

Enrichment of Breeding Resources of NARS: Three sets of *A. flavus* resistant international trial (III IAFRGVT) and four advanced breeding lines were made available to our NARS partners in India and Vietnam.

Special Project Fundings:
The OPEC Fund for International Development (2007/08), ISOPOM

R Aruna, SN Nigam, Farid Waliyar and Varsha Wesley

Milestone: Preliminary, advanced and elite foliar disease resistant breeding lines evaluated for resistance A. flavus and aflatoxin production under artificial inoculation conditions in the field (VW/FW/SNN/RA) 2009
Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
No activity this year for LLS due to lack of sufficient rains for timely sowing in the 2008 rainy season. However, a total of one hundred and thirty six advanced breeding lines (including checks) were evaluated during 2007-08 post rainy season for their resistance to *A. flavus* seed infection and aflatoxin contamination. Based on category of the materials these lines were divided in to five trials and tested in six replications. Five replicated trials namely EAFRGVT (elite *A. flavus* resistant groundnut varietal trial), AAFRGVT 1 (advanced *A. flavus* resistant groundnut varietal trial 1), AAFRGVT 2 (advanced *A. flavus* resistant groundnut varietal trial 2), ECGVT-SB (elite confectionery groundnut varietal trial Spanish bunch), ECGVT-VB (elite confectionery groundnut varietal trial Virginia bunch). The trials were laid out in the field using lattice or RBD. All the test materials were planted in the sick plot, *A. flavus* inoculum multiplied on sorghum or maize seed was applied in the soil near to the groundnut plants. The inoculum was applied 4-5 times at about 10 days interval during the crop growth period and end of season drought was imposed 30 days before harvest to facilitate the seed infection. Pod from each plot was collected separately, shelled manually and kernel sub-samples were taken for *A. flavus* seed infection using blotter plate method and aflatoxin contamination by indirect competitive ELISA method.

A. flavus infection and aflatoxin contamination in individual samples in test lines ranged from 0 to 31% and 0 to 3852 µg kg^{-1} respectively. The resistant control JL11 showed 0 to 6 % and 0 to 23 µg kg^{-1}; susceptible control JL24 showed 0 to 3% infection and 0 – 663 µg kg^{-1}. Mean aflatoxin levels and their distribution in different toxin ranges in all the 136 lines is presented in Figure 6.6. Six EAFRGVT lines (ICGV 06340, 06359, 06360, 06362, 06369, and 06415), three AFRGVT 1 lines (ICGV 07160, 07163, and 07164), seven AAFRGVT 2 lines (ICGV 07173, 07183, 07184, 07191, 07196, 07201, and 07207) three ECGVT-SB line (ICGV 05167, 05170, and 05174) were almost free from *A. flavus* seed infection and aflatoxin contamination. Only one (ICGV 05191) of the twelve ECGVT-VB lines showed lower AF seed infection and aflatoxin contamination. Overall, the infection levels appeared lower this year (please note that the infection levels in the susceptible check is as low as the resistant check);

this could be because of the change in the field due to unavailability of the old sick field (field that has been used for the past twenty years). A new sick plot is being developed and will be used to repeat these screenings next year.

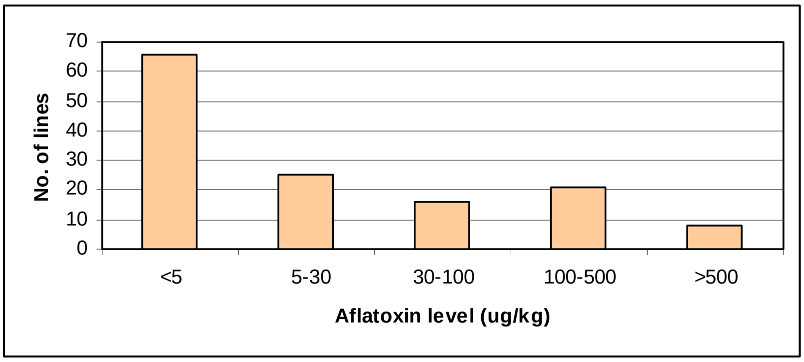


Fig 6.6: Mean aflatoxin levels in 136 groundnut lines

Special Project Fundings:
None

Varsha Wesley, Farid Waliyar, SN Nigam and R Aruna

Milestone: Ten interspecific derivatives of groundnut evaluated for A. flavus and aflatoxin resistance and promising lines identified (VW/FW/NM) 2011

Achievement of Output Target (%):
25% of the target achieved as advanced generation interspecific lines have shown some promise and new sources of *A. hypogaea* (synthetics) are available. It is envisaged that atleast few of them will be aflatoxin resistant

Countries Involved:
India and Africa

Partners Involved:
None

One hundred lines of advance generation interspecific lines derived from *Arachis cardenasii*, *A. diogoi*, *A. stenosperma*, *A. kempff-mercadoi* and *A. batizocoi* were planted in two replications in *Aspergillus flavus* sick plot to screen for *A. flavus* infection. Seeds were harvested and tested for *A. flavus* seed infection by blotter plate method to test for resistance at the seed coat level. Forty-one lines showed zero infection in both the replications. However the susceptible checks showed only 2-3% seed infection. In the next step, based on natural seed infection as well as seed availability, 76 entries were tested for *A. flavus* and aflatoxin resistance at the kernel level. Seeds were artificially inoculated with highly toxigenic AF-11-4 isolate by injuring the seed coat to study seed colonization and aflatoxin production. In all the lines seed colonization ranged from by *A. flavus* 93 to 100% and aflatoxin production ranged from 94 to 13569 µg kg^{-1}. Distribution of contamination levels in all the lines are given in Fig. 6.7. Although most of them succumbed to the seed infection, six lines showed low levels of aflatoxin <300 µg kg^{-1} (4372-1, 4368-7, 4384-2, 4368-2, 4364-6, 4373-12). This is highly significant as kernel resistance to aflatoxin is a very valuable trait in developing aflatoxin-free groundnut lines. These results need to be carefully confirmed with more replications during the next season. If these lines show consistently less aflatoxin, they could be used to map markers associated with kernel resistance.

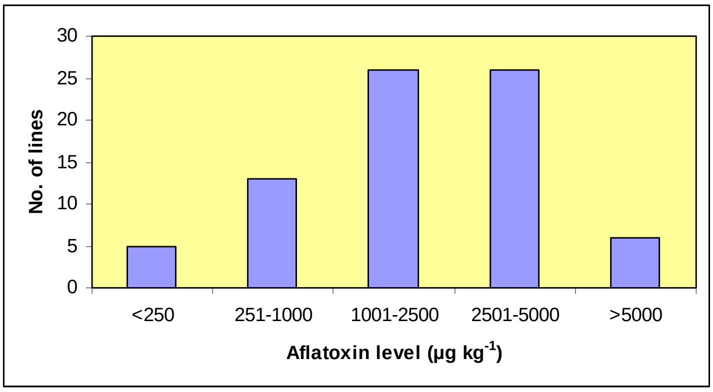


Figure 6.7: Distribution of aflatoxin levels in wild *Arachis* interspecific derivatives

Special Project Funding:
DBT, Govt. of India.

Varsha Wesley, Farid Waliyar and N Mallikarjuna

Activity 6.3.4.2 DTOX Evaluate various soil amendments and biocontrol agents for reducing pre-harvest *A. flavus*/ aflatoxin contamination in groundnut

Milestone: Efficacy of pseudomonas and actinomycets in preventing pre-harvest aflatoxin contamination determined (FW/VW) 2008

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Evaluation of biocontrol agents for reducing pre-harvest A.flavus /aflatoxin contamination in groundnut were carried out to know various biocontrol and plant growth mechanisms of the potential bacteria (CDB 35) and actinomycetes (CDA 19) in vitro. Both CDB 35 and CDA 19 inhibited the growth of other pathogenic fungi (*Fusarium oxysporum, Fusarium udum, Sclerotium rolfsi, Macrophomina phaseolina* and *Rhizoctonia solani)* along with *A.flavus* in plate culture conditions showing their broad range of antagonism. CDB 35 and CDA 19 inhibited spore germination and mycelial development of A.flavus when tested under broth culture conditions. Both of them were tested for various secondary metabolites or active ingredients that play a vital role in fungal cell wall disruption. CDA 19 showed chitinase production. As most of the fungal cell wall is made up of chitin, chitinase production may help for fungal cell wall destruction. Both showed siderophore production that brings the nutrient depletion as well as acts as antibiotic for the fungus that is in close proximity to the plant roots. Both CDB 35 and CDA 19 showed Indole acetic acid (IAA) production, which is a plant growth hormone. All these metabolites are being purified and quantified to study the effect of the active ingredient on fungal growth. This bacteria and actinomycetes have great promise as biocontrol agents. The over all goals are to develop suitable formulations of active compounds produced by CDB 35 and CDA 19 and to transfer them to farmers.

Special Project Fundings:
None

G Harini, Farid Waliyar and Varsha Wesley

Milestone: Integrated management package using various soil amendments and biocontrol agents, for preventing pre-harvest aflatoxin contamination developed (FW/VW) 2009

Achievement of Output Target (%):
0%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
No field trial was conducted this year due to non-availability of *A.* flavus sick field.

Special Project Fundings:
None

Farid Waliyar and Varsha Wesley

Output target 6.3.5. IPM: Effective and eco- friendly IPM technologies designed, evaluated and shared with the NARS/NGOs

Activity 6.3.5.1 IPM: Develop and validate effective IPM technologies for crop production

Milestone: Rural stakeholders trained in biopesticide production and utilization (OPR/SGK) 2009

Achievement of Output Target (%):
50%
Countries Involved:
India

Partners Involved:
NGOs in India, and BRC members

Progress/Results:
Fifty farmers from “Timbaktu Organic Project”, Ananthapur and another 29 farmers from “Accion fraterna”, Ananthapur had hands on training in biopesticide production and evaluation at ICRISAT on 10th Sept 2008 and 5th Nov 2008, respectively.

Special Project Fundings:
Biopesticides Research Consortium (BRC)

OP Rupela and S Gopalakrishnan

Milestone: Mass production techniques developed for biopesticides, and their stable formulations developed (GVRR/OPR/SGK) 2009

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
NGOs in India, and BRC members

Progress/Results:
During this year, mass production of HNPV, BCB-19 and neem products have been further strengthened with farming community for their effective utilization. The previously commissioned biopesticide units in India and Nepal were found to be active sites of production and training units with various NARS. Further studies in pursuing more stable products such as powder formulations of NPV have been initiated for better utilization of the existing technologies. Video CDs concerning the production and utilization of biopesticides have been made available to all concerned partners.

GV Ranga Rao, OP Rupela and S Gopalakrishnan

Milestone: IPM options tested and validated on-station and on-farm, and disseminated to the farmers through NARS and NGOs (GVRR/OPR/ SGK/HCS/VW/SP/RS) 2011

Achievement of Output Target (%):
50%

Countries Involved:
Asia

Partners Involved:
NARS

Progress/Results:
Screening of different botanicals for ability to kill *Helicoverpa* or S*podoptera* larvae: Larvicidal activity of 18 different botanical extracts was studied against the neonates of *Spodopetera litura* viz. foliage powder of Anona, *Parthinium*, *Datura*, neem fruit powder (NFP), rain tree pod powder, foliage powder of Pongamia, Tridax, Neem, Chrysanthemum, Calotropis, Jatropa, Rain tree, Prosopis, *Vitex, Anona* rind and seed powder and tobacco wastes. Commercially available Neem oil (1%) was used as reference. Of the 18 evaluated, Pongamia foliage powder showed maximum mortality (86%) followed by NFP (80%), Tobacco waste (72%), neem foliage powder (70%), Anona rind (68%), foliage powder of Rain tree, Prosopis, Vitax (66%), neem oil (64%), pod powder of rain tree (58%) and Datura (52%). Neem oil, used as a reference, killed only 50% neonates. Some botanicals such as Tridax, Vitex and Anona-Shell had antifeedent activity indicated by reduced growth of larvae by 56 to 60%.

Compatibility studies on botanicals and microorganisms for efficient management of Lepidopteran insects: In order to assess the compatibility of botanical extract and some selected entomopathogenic microorganism such as *Bacillus subtilis* and *Metarhizium anisopliae* and four botanical powders viz., Anona, Datura, Neem Fruit and Parthinium were selected. Neem fruit and Datura were found to be compatible with *Bacillus subtilis* (BCB19). When carrier based formulation of BCB 19 mixed with extraction of Neem fruit powder and Datura powder, separately, there were no signs of suppressing BCB19 for up to 8 days. None of the four botanical powder extractions suppressed *Metarhizium anisopliae* (Ma) up to eight days. Count of *M. anisopliae* on 8^{th} day ranged between 5.90 (log 10 per mL of suspension) in Ma+Anona and 6.41 (log 10 per mL of suspension) in Ma+Neem Fruit. In another study, three botanicals (Anona, Datura, Neem Fruit Powder) and three entomopathogens viz. *Bacillus megaterium* (SB9), *B. pumilus* (SB21) and *Serratia marcesens* (HIB28) were checked for their compatibility. There were no definite signs of suppression by any of the botanicals of the bacteria. But there were some sign of improved growth in case of SB9 + Neem Fruit, SB9 + Anona and HIB28 + Datura.

GV Ranga Rao, OP Rupela and S Gopalakrishnan

Milestone: Insect pest and disease diagnostic tools and pest population dynamics models in relation to climatic changes developed (GVRR/HCS/VW/SP/RS) 2011

Achievement of Output Target (%):
50%

Countries Involved:
Asia

Partners Involved:
NARS

Progress/Results:
Polyhedron gene description of *H. armigera* NPV: A double round PCR protocol was standardized using degenerate primer set to isolate the full length polyhedrin gene of NPV isolated from *H. armigera.* This resulted in a 744 bp product which was cloned and sequenced. Gene sequencing analysis of selected clones resulted in 744 bp nucleotide long ORF with a predicted coding capacity for a polypeptide of 247 amino acids. In BLASTX search the sequence showed homology with baculovirus occlusion body protein domain of known polyhedrin and granulin proteins from the GenBank data base. The sequence was deposited in GenBank with a public accession number of EU047914. The nucleotide sequence of HaNPV-P polyhedrin gene had a high homology with polyhedrins of several NPVs. Among which, it was showing maximum homology of 98.2% with *Mamestra configurata* NPV, 98% with *Mamestra brassicae* NPV, 96.1% with *Leucunia seperata* NPV and 90.6% with *Panolis flammea* NPV. At the same time with minimum homology of 72.4% was noticed with WsNPV. The phylogenetic analysis at nucleotide as well as amino acid levels showed that the virus belongs to Group-II NPVs and the virus was named as *Helicoverpa armigera Nucleopolyhedrovirus* (NPV), Patancheru strain. This is the first report from Indian sub-continent and eighth report worldwide with polyhedron gene description of *H. armigera* NPV.

Pest surveillance data on key groundnut pests: Pest surveillance data generated at ICRISAT on key groundnut pests for the past 10 years has been summarized and subjected to analysis against various abiotic factors such as rainfall, minimum and maximum temperatures and relative humidity (%). The standard week-wise pheromone trap catches and larval population of *Spodoptera* and groundnut leafminer, were correlated with the above abiotic factors. The analysis brought out interesting results with no relationship of maximum temperature and relative humidity on the adult catches and adult populations, irrespective of pooling data, standard week or monthly or yearly. The negative effect of rainfall on *Spodoptera* adult catches and larval populations was very clear through correlation of the standard week level and monthly level. But, cumulative yearly rainfall data has not shown any relationship either adult catch or pest incidence in the field. These results clearly indicated high negative correlation of rain fall and adult catch with standard week-wise data set and the correlation efficiency decreased as one approached monthly data and further. In case of leafminer, all the abiotic factors except minimum temperature and its relation to larval population have not shown any relationship either with adult catch or larval population in the field. However, trap catches have shown strong correlation with larval population, but the relationship between these two parameters was positive irrespective of pooling of data. The data also indicate the need for more refined data such as daily weather and its relation to adult or larval or egg load rather than cumulative effect of weekly information. Hence, it is necessary to produce such a refined data on key species of various crops in order to develop effective pest forecasting systems.

GV Ranga Rao

Effect of climate change on pathogen of chickpea dry root rot: Initiated surveys to study the effect of climate change on the diseases of chickpea and pigeonpea. Dry root rot caused by *Rhizoctonia bataticola* was identified to be an important disease affected by climate change causing up to 30% plant mortality in few chickpea growing regions in India. Dry root rot generally occurs at flowering and podding stage and moisture stress favors disease development. Also the incidence of collar rot caused by *Sclerotium rolfsii* which is a minor disease of chickpea in SAT was found to be significantly high due to unusual rains. Collar rot occurs at the seedling stage particularly if there is high soil moisture after planting.

Suresh Pande and Mamta Sharma

Special Project Funding:
Nil

Activity 6.3.5.2 IPM Develop strategies for deployment of insect resistant transgenic crops for pest management and their bio-safety to nontarget organisms

Milestone: Compatibility of host plant resistance with natural enemies and insecticides studied (HCS/MKD) 2010

Achievement of Output Target (%):
30%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
We studied tritrophic interactions between *Bt* (administered as a spray), chickpea genotypes, and the parasitoid, *Campoletis chlorideae*. Chickpea genotypes resistant to *H. armigera* exercised a significant reduction in leaf feeding, survival, and development of *H. armigera*, but did not influence the development and survival of the parasitoid, *C. chlorideae*. *Bacillus thuringiensis* sprays on different chickpea genotypes prolonged the larval period, and reduced pupation and adult emergence of the parasitoid. The *Bt* intoxicated *H. armigera* larvae also resulted in reduced weight of the cocoons and adults of the parasitoid, *C. chlorideae*. Weights of *H. armigera* larvae at 5 days after feeding on *Bt* sprayed/unsprayed chickpeas were significantly and positively associated with parasitoid cocoon formation ($r = 0.95^{**}$) and adult emergence ($r = 0.91^{**}$), but negatively associated with the larval period ($r = -0.93^{*}$) of *C. chlorideae*. *Bt* toxins were detected in *H. armigera* larvae fed on *Bt* sprayed chickpeas, but not in *C. chlorideae* reared on *H. armigera* larvae fed on *Bt* treated chickpeas, and in the parasitoid adults fed on honey with 0.05% *Bt*. The adverse effects of *Bt* on the parasitoid were largely through early mortality of *H. armigera* larvae or poor quality of the host. This information would be useful for planning appropriate strategies for testing and deployment of *Bt*-transgenic chickpea with resistance to *H. armigera* for sustainable crop production.

Special Project Funding:
ISOPOM project on *Helicoverpa* resistance - ICAR

HC Sharma and MK Dhillon

Milestone: Compatibility of transgenic crops and insecticides for pest management their impact on species diversity assessed (HCS/MKD) 2011

Achievement of Output Target (%):
75%

Countries Involved:
India

Partners Involved:
National Research Center for Sorghum, Hyderabad

Progress/Results:
Compatibility of *Bt*-transgenic cotton and insecticides for pest management, and their impact on nontarget insect pests, natural enemies and other aerial and soil insect fauna: We studied the efficacy of *Bt*-transgenic cotton hybrids for the management of target insect pests and their effects on non-target insects, and seedcotton yield under protected and unprotected conditions in four *Bt*-transgenic and non-transgenic cotton hybrids. The *H. armigera* and *Earias vittella* damage were significantly lower in *Bt* than in non-*Bt* cotton cultivars. There was no significant influence of *Bt* cottons on the populations of non-target insect pests [cotton leafhopper, *Amrasca biguttula biguttula*; white fly, *Bemisia tabaci*; leaf miner, *Liriomyza trifolii*, ash weevils, *Myllocerus* spp.; cotton aphid, *Aphis gossypii*; dusky cotton bug, *Oxycarenus laetus*; red cotton bug, *Dysdercus koenigii*; and green bug, *Nezara viridula*], and the natural enemies [coccinellid, *Cheilomenes sexmaculatus*; chrysopid, *Chrysoperla carnea*; and spiders, *Clubiona* sp. and *Neoscona* sp.]. ELISA testing of aerial insect species collected from *Bt* and non-*Bt* cottons detected high levels of *Bt* toxin (>5.0 ppb) in *Clubiona* sp., short horned grasshopper, green grasshopper, *Blissus* sp., *D. koenigii*, *Mylocerus* sp., *A. bigutulla bigutulla*, *Thrips tabaci*, *Chrysoperla* sp. larvae, and one katydid species; while *H. armigera* larvae, and *C. sexmaculatus* adults and larvae showed moderate (2.5 to 5.0 ppb) amounts of *Bt*-toxins. Five pitfall traps were installed in each *Bt* and non-*Bt* cotton plants planted under insecticide protected and unprotected conditions to monitor the influence of *Bt* cotton and insecticide application on the abundance of soil dwelling insect species. These traps were operated at fortnightly intervals, and the observations are in progress.

Indirect effects of *Bt* toxins on the development and survival of coccinellid beetle, *Cheilomenes sexmaculatus* through *Bt*-transgenic cotton fed *Aphis gossypii*: Effects of *Bt*-transgenic cotton hybrids on coccinellid beetle, *C. sexmaculatus* were studied under laboratory conditions through *Aphis gossypii* fed on *Bt* and non-*Bt* cottons raised under greenhouse conditions. There were 25 replications in a completely randomized design. There was no significant influence of *Bt*-transgenic cottons fed *A. gossypii* on the larval period, larval survival and adult emergence of *C. sexmaculatus*. However, pupal period of *C. sexmaculatus* was significantly shorter on *Bt* cotton than on non-*Bt* cotton fed *A. gossypii*. The larval and adult weights of male and female *C. sexmaculatus* were significantly greater on *Bt* cotton fed *A. gossypii* as compared to those fed on non-*Bt* cotton. No *Bt* toxins were detected in *A. gossypii* reared on *Bt*-transgenic cotton. The results suggest that there were no adverse effects of *Bt* cottons through *A. gossypii* on the development and survival of the predatory beetle, *C. sexmaculatus*.

Special Project Funding:
DST (Govt. of India) project on biosafety of transgenic cotton to nontarget organisms

Milestone: Bio-safety of transgenic crops to non-target organisms assessed (HCS/KKS) 2011

Achievement of Output Target (%):
40%

Countries Involved:
India

Partners Involved:
None

Progress/Results:
Effect of *Bt*-transgenic cottons on management of *Helicoverpa armigera*, and the abundance of non-target insect pests and natural enemies under farmer's field conditions: The *Bt*-transgenic and non-transgenic cottons were surveyed at nine locations in Andhra Pradesh, Maharashtra and Karnataka for parasitization of eggs and larvae of *H. armigera.* Although, there were significant differences in *H. armigera* egg parasitism across states and locations, the differences between *Bt*-transgenic and non-transgenic cottons were nonsignificant. The numbers of *H. armigera* and *Spodoptera litura* larvae were significantly more on non-*Bt* - as compared to that on *Bt*-cottons. The bollworm damage in bolls and squares was significantly more on non-*Bt* as compared to *Bt* cottons. There was a significant variation in abundance of sucking pests [jassids, whiteflies, aphids, and mealy bug], and natural enemies [coccinellids, chrysopids, and spiders] across locations. However no significant differences were observed in abundance of sucking insect pests and natural enemies between *Bt* and non-*Bt* cottons.

Biochemical composition of Bt-transgenic and non-transgenic cottons: Substantial equivalence to the non-transgenic plant/food in terms of nutritional quality and biochemical composition is of prime importance in deciding upon the suitability of commercializing products derived through genetic engineering. Therefore, we studied the changes in nutritional quality (proteins and total sugars) and the secondary metabolites (polyphenols and tannins) in commercial cotton hybrids, Mech 184 and MRC 7201 BGII. The leaves from 30 days old seedlings, 3 to 4 days old squares, and 7 to 8 days old bolls were collected and lyophilized at -45^{o}C for 5 days. The lyophilized samples were powdered in a Willey mill, and the biochemical estimates were carried out using standard A.O.A.C. procedures. There were no significant differences in amounts of total proteins and sugars, while the amounts of polyphenols and tannins were significantly lower in Bt-transgenic hybrids compared to those in the non-transformed ones. Amounts of tannins and polyphenols were greater in bolls and squares than in the leaves, while the reverse was true in case of total sugars. Bt-toxin was detected in leaves of Bt-transgenic cottons, while no Bt toxin was detected in the squares and bolls of Bt-transgenic cottons.

Special Project Funding:
DST project on transgenic crops for IPM and their biosafey to nontarget organisms.

HC Sharma and MK Dhillon

Output targets 6.3.6. CAP Capacity of NARS/NGOs enhanced, and products/information on improved cultivars and crop production technologies disseminated in Asia

Activity 6.3.6.1 CAP Capacity building and dissemination of information on improved cultivars/technologies to NARS/NGOs/farmers in Asia

Milestone: Nearly 20 students, scientists, apprentices, and technicians trained in various aspects of crop improvement, biotechnology, and crop management (All Scientists) 2010

Achievement of Output Target (%):
80%

Countries Involved:
India; Ethiopia; Kenya; Myanmar; Philipinnes; Sri Lanka; Tanzania; Vietnam

Partners Involved:
NARS in above countries

Progress/Results:
Groundnut Improvement: Six Research Fellows from India and Vietnam were trained in groundnut improvement and seed production methodologies.

Table 6.7: List of participants in training course on groundnut breeding and seed production

Name	Country	Category	Date-A	Date-D	Training in
Mr The Truong Thanh	Vietnam	Research Fellow	26-Feb-08	05-Apr-08	Groundnut improvement and other related activities
Ms Nguyen Thi Thuy	Vietnam	Research Fellow	26-Feb-08	05-Apr-08	Groundnut improvement and other related activities
Dr S Siva Kumar	India	Research Fellow	03-Apr-08	02-May-08	Groundnut breeding methodologies and seed systems technology
Dr S Lakshmi Narayanan	India	Research Fellow	04-Apr-08	02-May-08	Groundnut breeding methodologies and seed systems technology
Ms Truong Thi Thuan	Vietnam	Research Fellow	30-Aug-08	29-Oct-08	Groundnut breeding methodologies and seed systems technology
Ms Nguyen Thi Loan	Vietnam	Research Fellow	30-Aug-08	29-Oct-08	Groundnut breeding methodologies and seed systems technology

SN Nigam and R Aruna

Chickpea Improvement: Nine researchers (5 male + 4 female) from Ethiopia, Tanzania, Kenya and Myanmar were provided 20 days to 3 months training on "Chickpea Breeding and Seed Production" at ICRISAT Patancheru during December 2007 to March 2008. The detailed report is presented in the Output Target Reports.

CLL Gowda, PM Gaur, Shailesh Tripathi, HC Sharma, Suresh Pande and Mamta Sharma

Legume Pathology: Four students were trained on characterization (cultural, morphological, pathological and molecular) of *Fusarium oxusporum* f.sp. *ciceris* causing Fusarium wilt of chickpea and *Fusarium udum* causing Fusarium wilt of pigeonpea. Also training was given to to Mr Fernando Sugui from the Philippines on identification of diseases of pigeonpea and their management.

Suresh Pande and Mamta Sharma

Groundnut Pathology: Five PhD students and Four Masters students have been trained this year in aspects of groundnut pathology, including managing aflatoxins and viruses.

Varsha Wesley and Farid Waliyar

Training courses in mycotoxin detection technologies: A 45 day training course on "*Aspergillus flavus* seed infection and aflatoxin estimation by ELISA and aflatoxin management options in groundnut" was given to two trainees from the Field Crops Research Institute, Hanoi, Vietnam. They were trained in various laboratory experiments including *A. flavus* seed infection studies by blotter plate method, varietal screening for *A. flavus* and aflatoxin resistance by artificial inoculation method under laboratory conditions, aflatoxins extraction from various foods/feeds and aflatoxins detection and estimation by indirect competitive ELISA method.

Initially, all the lab exercises were demonstrated to the participants and later they were given free hand to perform themselves so as to get hands on experience to do the analysis. The participants brought about 20 groundnut genotypes for screening under artificial conditions and they observed that 2 lines were promising (<10%) for *A. flavus* seed colonization. They also brought another 100 groundnut samples from their field experiments for aflatoxin analysis and results indicated that 60% of their samples were free from aflatoxin. Except one, the remaining 39 samples showed <4 ppb aflatoxin. They were also trained on standardization of ELISA method in their lab using various AFB1-BSA coating concentrations and antibody dilutions. Instructions to address the trouble shooting issues were also given. With all the exercises and experiments the participants expressed their confidence to set up a new lab and manage with great precision in Vietnam. Their project shows great promise for Vietnam in managing the aflatoxin problem.

Apart from technology transfer through training, we were involved in various capacity building activities. We supplied aflatoxin antibodies, standards, toxin protein conjugates to National Research Center on Sorghum, Hyderabad, India; Maize Research Station, IARI, New Delhi, India; ICRISAT-Nairobi, ICRISAT-Lilongwe, and ICRISAT-Bamako and continue to provide significant amount of support on technical aspects to facilitate smooth functioning of these labs for mycotoxin analysis.

Farmers in Andhra Pradesh have been provided our low aflatoxin groundnut lines and have been supported on a continuous basis along with the local NGOs.

Farid Waliyar, Varsha Wesley and SN Nigam

Training in IPM: Two research scholars and three apprentices were involved in our research covering bio-pesticides and insecticide residues. Three research scholars from Myanmar attended hands on training on chickpea pest management with special emphasis on bio-pesticides. Two researchers representing National Institute of Plant Protection, one from Legume Research Development Centre and one from Agricultural Science Institute, Hanoi, Vietnam had in-depth training in groundnut IPM. During this year, a total of 363 researchers representing various organizations representing Vietnam, Myanmar, Sri Lanka and Indian NARS attended IPM training with special emphasis on legume pest management at ICRISAT.

GV Ranga Rao

Special Project Funding:
The OPEC Fund for International Development, Tropical Legumes II, IFAD Grant 954, ACIAR Legumes Project in Myanmar.

Milestone: Nucleus/Breeder seed production of ICRISAT-bred advanced breeding lines released in partner countries undertaken on request from NARS (All Legume Scientists) Annual

Achievement of Output Target (%):
100%

Countries Involved:
India
Partners Involved:
NARS in India

Progress/Results:
Groundnut
Of 1.7 t Breeder seed of three varieties (ICGV 91114, ICGS 44 and ICGS 76) produced in the 2007 rainy season, 1.5 t was distributed to various seed producing agencies and special project locations in India. Similarly, of 31.6 t Breeder seed of five varieties (ICGV 91114, ICGS 44, ICGS 76, DRG 12 and ICGV 86564) produced in the 2007/08 postrainy season, 29.8 t was distributed to various seed producing agencies and special project locations in India. Small samples were also given to farmers on request.

Due to shortage of irrigation water and delayed onset of monsoon in the 2008 rainy season, no seed production program was undertaken. However, Breeder seed production of ICGV 91114, on experimental basis, was taken up in 2.0 ha in farmers' fields with irrigation in Anantapur district on buy-back basis. In the 2008 rainy season, groundnut crop in Anantapur almost failed due to various reasons (yet to be scientifically ascertained). But groundnut seed farmers were able to harvest 1.1 t ha^{-1} pod yield in ICGV 91114.

Table 6.8: Groundnut breeder seed production and distribution in 2007/08

2007 rainy season

Variety	Area(ha)	Production (kg)	Distribution (kg)
ICGV 91114	0.9	1200	1175
ICGS 44	0.25	300	280
ICGS 76	0.15	200	50
Total	1.3	1700	1505

2007/08 postrainy season

Variety	Area(ha)	Production (kg)	Distribution (kg)
ICGV 91114	9.0	19000	18750
ICGS 44	2.2	5100	5090
ICGS 76	2.8	3700	3295
DRG 12	1.5	2400	2400
ICGV 86564	1.0	1400	300
Total	16.5	31600	29835

Special Project Funding:
ICAR Revolving Fund, ISOPOM, Govt. of India; The OPEC Fund for International Development; Tropical Legumes II; IFAD Grant 954

Chickpea

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
NARS in India

Progress/Results:
Total 32.6 t of Breeder seed of 9 (4 Desi + 5 Kabuli) improved chickpea varieties was produced during the crop season 2007/08. In 2008 about 23 t of Breeder seed was distributed to partner institutions involved in special projects and various seed producing agencies.

Table 6.9: Chickpea breeder seed production and distribution in 2007/08

Variety	Area (ha)	Seed produced (kg)	Distribution (kg)
ICCV 2	4.0	2850	3138
ICCC 37	26.0	24550	15913
KAK 2	1.0	470	823
JG 11	2.2	1500	815
JG 130	1.0	1300	745
JAKI 9218	1.0	1300	1080
Vihar	0.5	260	150
JGK 2	0.5	220	280
ICCV 95334	0.5	150	90
Total	36.7	32600	23034

Special Project Funding:
ICAR Revolving Fund, ISOPOM, Govt. of India; Tropical Legumes II; IFAD Grant 954

Pigeonpea

Achievement of Output Target (%):
100%

Countries Involved:
China; India; Myanmar; Philipinnes; USA

Partners Involved:
NARS of above listed countries

Progress/Results:
During 2007/08 a total of 15.2 tons of breeder seeds of seven [ICPL 87119 (Asha), ICP 8863 (Maruti), ICPL 88039 (VL Arhar 1), ICP 7035 (Kamica), ICPL 87051, ICPL 96053, and ICPL 85063] pure-line varieties were distributed to various 11 NARS partners from India (ANGRAU, Hyderabad; IARI, New Delhi; IIPR, Kanpur; JNKVV, Jabalpur; MAU, Parbhani; MSSCL, Akola; NSC, New Delhi; PAU, Ludhiana; SFCI; TNAU, Coimbtore; and MSSRF, Chennai), Philipinnes [Isabela State University San Mateo, Nueva Vizcaya State University Nueva Vizcaya, Benguet State University Benguet, Mariano Marcos State University Batac City), Myanmar (DAR, Yezin), and China (Research Institute for Insects, Kumming, and Organization of Food Crops Research Institute, Yunnan Academy of Agricultural Sciences). Apart from this small seed samples of released varieties were shared with Grazingland Research Laboratory, USDA, USA. Farmers from Andhra Pradesh, Maharashtra, and Karnataka were distributed a total of 360 kg seeds of Asha, VL Arhar 1 and ICP 7035 during 2007/08.

Special Project Funding:
Tropical Legumes II, IFAD Grant 954

Milestone: Farmers' field days, as and when needed, organized at special project locations (SNN/KBS/PMG/GVVR/RA/RKS/ST/VW/CLLG/MSB) Annual

Groundnut

Achievement of Output Target (%):
80%

Countries Involved:
India; Nepal; Vietnam

Partners Involved:
NARS in India, Nepal and Vietnam

Progress/Results:
More than 12 farmers' field days/training programs/exposure visits in six States in India (Andhra Pradesh, Chhattisgarh, Gujarat, Karnataka, Orissa and Tamil Nadu) and at ICRISAT Center, Patancheru were organized under various special projects. Similarly, in Nepal, farmers' field day and training program were organized during the cropping season at each location (Bajura, Dang, Dailekh, Doti and Surkhet). In addition to one national workshop, eight training courses/farmers' field days were conducted in Vietnam. Details of these events are given in reports of special projects.

Special Project Funding:
ISOPOM, Govt. of India; The OPEC Fund for International Development, Tropical Legumes II, IFAD Grant 954.

SN Nigam and R Aruna

Chickpea

Achievement of Output Target (%):
100%

Countries Involved:
India; Myanmar; Nepal

Partners Involved:
NARS in India, Nepal and Myanmar

Progress/Results:
Farmer participatory varietal selection (FPVS) trials are being conducted in Nepal and India (Jharkhand, Chhattisgarh and Orissa states of India) under IFAD project, Uttar Pradesh and Madhya Pradesh states of India under ISOPOM project, Andhra Pradesh and Karnataka states of India under Tropical Legumes II project and in dry zone of Myanmar under ACIAR project. More than 20 farmers' field days were organized at these locations during the crop season. In addition, over 60 farmers from Jharkhand, Uttar Pradesh and Madhya Pradesh states of India visited ICRISAT to learn more about improved chickpea cultivars and production technologies.

Special Project Funding:
ISOPOM, Govt. of India; Tropical Legumes II, IFAD Grant 954, ACIAR legumes project in Myanmar

PM Gaur, CLL Gowda and Shailesh Tripathi

Pigeonpea

Achievement of Output Target (%):
80%

Countries Involved:
India

Partners Involved:
Indian NARS

Progress/Results:
A toal of eight Famer's Field days/training programs/exporure visits were conducted in India (Maharashtra, Andhra Pradesh, Tamil Nadu, Chhattisgarh, Jharkhand, Karnataka, and Uttrakhand). Farmers were trained in seed production technology, harvesting, processing, and storage. Structured training program was also imparted in integrated pest management technology (IPM), and agronomy.

In December, 2007 ICRISAT organized training programs for various NARS partners. A total of 23 members participated in a day-long training program. In this meeting experiences of hybrid breeding technology were shared with the members. Problems associated with hybrid seed production were also discussed. These were attended by 58 scientists and research technicians. During the year, two scientists from Research Institute for Insects, Kumming, China, and one scientist from Organization of Food Crops research Institute, Yunnan Academy of Agricultural Sciences (YAAS), China were trained in hybrid pigeonpea seed production technology. One research technician from Food Legumes Section, Department of Agricultural Research (DAR) Yezin, Myanmar was trained in pigeonpea breeding for three months at ICRISAT Patancheru.

RK Srivastava and KB Saxena

Integrated aflatoxin management technologies disseminated through farmer participatory trials and village level training courses to farmers: On-farm participatory varietal evaluation was continued during 2007 rainy season with 4 varieties (ICGV 91278, 94379, 94434, 91114), in 42 farmers' fields in six villages in Anantapur area and with 5 varieties (ICGV 91341, 93305, 94379, 94434 and 91114) in 15 farmers' fields in 3 villages in Chittoor district Tirupati region). The crop was harvested in November 2007; yield data, pod samples for *A. flavus* infection and aflatoxin content were analyzed during 2008. Performance of the 4 selected groundnut improved varieties was better in all the 42 farmer fields in six villages in Anantapur district and produced higher pod and haulm yield than the control TMV 2. All the four varieties produced around 8.56-36.9% higher mean pod yields in six villages against the control yield 1016 kg ha^{-1} (Fig. 3). The highest percent pod yield increase was observed with ICGV 91114 (36.9%) followed by ICGV 94434 (32.18%), ICGV 94379 (18.7%) and ICGV 91278 (8.56%). From each plot about one kg pod sample was drawn for lab analysis. Groundnut kernel sub-samples from each plot was used to determine *A. flavus* seed infection using blotter plate method and aflatoxin contamination by indirect competitive ELISA method and seed infection ranged from 0-36% and aflatoxin 0-3375 µg kg^{-1} in individual sub-samples. Analysis of all kernels sub-samples indicated that advanced breeding varieties showed reduction (35.7-64.2%) in *A. flavus* infection and aflatoxin contamination (33.7-74.9%) over the control TMV 2. However, it was observed that there is high variability in *A. flavus* seed infection and aflatoxin levels from field to field and village to village.

Similarly in Chittoor district (Tirupati region) all five varieties showed better performance and produced 15.94-49.45% higher pod yield over the control yield 1468 kg ha^{-1}. The highest percent increase in mean pod yields was obtained with ICGV 94434 (49.45%) followed by ICGV 91341, 94379 (27.45%), ICGV 93305 (17.57%) and ICGV 91114 (15.94%). Moreover, in general the *A. flavus* seed infection and aflatoxin contamination was low in all the varieties including the controls.

Two varieties (ICGV 94379 and ICGV 94434) are performing better for the last five years with low aflatoxin risk in both the Anantapur and Chittoor districts. We are targeting to include these two varieties in ANGRAU Regional Trials for multilocations evaluation in Andhra Pradesh and also for further release the variety based on their performance. During the trials monitoring the farmers expressed their happiness over the performance of the improved varieties and most of them are willing to continue with these varieties on their own. Many farmers in Anantapur are willing to buy the seed if it is available at market price. These varieties have been planted again this year in 35 farmers fields in four villages in Anantapur and 13 farmers filed in four villages in Tirupati region (Chittoor district) and despite continuous rains in the region during the flowering period, the pod formation in our varieties was much higher as compared to the local variety.

Farid Waliyar, Varsha Wesley and SN Nigam

Farmers' training in IPM: Three field days were organized covering chickpea and groundnut IPM and post-harvest activities involving 250 farmers in Junagadh district of Gujarat (150 for groundnut), Nandyal of Kurnool districts (50 for chickpea) and Ongole of Prakasham districts (50 for chickpea).

GV Ranga Rao

Special Project Funding:
ISOPOM, Govt.of India; Tropical Legumes II, IFAD Grant 954

Milestone: Farmer-friendly literature on crop management and seed production technology published and distributed to NARS (All Legume Scientists) Annual

Groundnut

Achievement of Output Target (%):
100%

Countries Involved:
India; Nepal; Vietnam

Partners Involved:
NARS in India, Nepal and Vietnam

Progress/Results:
Eight farmer-friendly literatures on seed production techniques and integrated crop management technologies in four languages (English, Kannad, Tamil and Telugu) were published by ICRISAT and special project partners. Details of these publications are given in special project reports.

Special Project Funding:
ISOPOM, The OPEC Fund for International Development (2007/08), Tropical Legumes II, IFAD Grant 954

SN Nigam and R Aruna

Chickpea

Achievement of Output Target (%):
80%

Countries Involved:
India

Partners Involved:
NARS in india

Progress/Resutls:
A bulletin on chickpea improved production technologies was developed in Hindi by Birsa Agricultural University Ranchi for Jharkhand and by Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur for the farmers of Madhya Pradesh and in Telgu by the Regional Agricultural Research Station of the Acharya NG Ranga Agricultural University for the farmers of Andhra Pradesh. The preparation of similar bulletin in Kannada for the farmers of Karnataka is in progress.
Special Project Funding:
ISOPOM, Govt. of India; Tropical Legumes II, IFAD Grant 954

PM Gaur, Shailesh Tripathi and NARS partners

Pigeonpea

Achievement of Output Target (%):
90%

Countries Involved:
India

Partners Involved:
Indian NARS

Progress/Results:
A total of seven farmer friendly literature on quality seed production, processing, storage and integrated crop management (ICM) technologies were produced in association with PDKV Akola, ANGRAU Hyderabad, and Dept. of Agriculture Uttrakhand. Of these, three bulletins are in Marathi, two each in Telugu and Hindi.

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954

RK Srivastava and KB Saxena

Milestone: NARS scientists field days in sorghum, pigeonpea, groundnut, and chickpea organized (All scientists) Biannual

Sorghum

Achievement of Output Target (%):
100%
Countries Involved:
India

Partners Involved:
NARS in India

Progress/Results:
A field day for sorghum scientists was conducted at ICRISAT- Patancheru on 7 and 8 October 2008. A total of 27 scientists from the public sector and 19 scientists from the private sector from India were participated. They visited a range of sorghum materials, from germplasm to progenies, advanced breeding lines, new male-sterile and restorer lines during the field day. More than 200 selections were made by seven public sector scientists and 11 private sector scientists during this period. A training program was organized to 40 lead farmers from Ibrahimabad village, Medak district, Andhra Pradesh, India on the improved sweet sorghum cultivars and cultivation practices during May 15-16, 2008 at ICRISAT, Patancheru and ANGRAU, Hyderabad.

Special Project Funding:
Sorghum Hybrid Parents Research Consortium

Belum VS Reddy and A Ashok Kumar

Groundnut

Achievement of Output Target (%):
100%

Countries Involved:
Afghanistan; Bangladesh; China; India; Myanmar; Nepal; Philippines; Vietnam

Partners Involved:
NARS in the above stated countries

Progress/Results:
Groundnut: A formal event was not organized in 2008. However, individual scientists from collaborating countries (listed above) visited groundnut breeding fields and made request for breeding materials.

Special Project Funding:
The OPEC Fund for International Development

SN Nigam and R Aruna

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
NARS in India

Progress/Results:
Chickpea: Chickpea Scientists's Meet is organized at ICRISAT Patancheru every alternate year. The earlier Meet was organized in 2007 and the next is planned during January 2009. However, several farmers visited chickpea experiments during crop season and selected breeding materials of their interests.
Pigeonpea:

Achievement of Output Target (%):
100%

Countries Involved:
India

Partners Involved:
Indian NARS

Progress/Results:
A formal field day for pigeonpea varieties was not conducted during 2008. However, during the same period more than 330 farmers, extension officials and village level workers (VLWs) from Maharashtra, Andhra Pradesh, Uttar Pradesh, and Karnataka were made aware about the high yielding varieties of pigeonpea suitable for various cropping systems and environments.

Special Project Funding: ISOPOM, Tropical Legumes II, IFAD Grant 954

RK Srivastava and KB Saxena

Milestone: Farmer-participatory varietal selection trials conducted on legumes to enhance adoption of improved cultivars (All legume scientists) Annual

Groundnut:

Achievement of Output Target (%):
100%
Countries Involved:
India; Nepal; Vietnam

Partners Involved:
India: UAS, Dharwad, UAS, Bangalore, TNAU, Coimbatore, OUA&T, Bhubaneswar, BAU, Ranchi, IGKVV, Raipur, RDT, Anantapur, ARS, Anantapur/Kadiri, NRCG, Junagadh, JTDS, Jharkhand, OTELP, Orissa and CTDS, Chhattisgarh, Nepal: NARC, Khumaltar, Vietnam: LRDC, VAAS, Hanoi

Progress/Results:
More than 1110 farmer-participatory varietal and ICM trials in India, 12 in Nepal and 135 in Vietnam were conducted during the year under various special projects. Details about these trials and their results are given in special project reports.

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954, The OPEC Fund for International Development

SN Nigam and R Aruna

Chickpea:

Achievement of Output Target (%):
100%

Countries Involved:
India; Myanmar

Partners Involved:
India: UAS, Dharwad, ANGRAU, Hyderabad, OUA&T, Bhubaneswar, BAU, Ranchi, IGKVV, Raipur, IIPR, Kanpur, JNKVV, Jabalpur,JTDS, Jharkhand, OTELP, Orissa and CTDS, Chhattisgarh and Myanmar: Department of Agricultural Research, Yezin and Myanma Agricultural Services

Progress/Results:
Over 375 FPVS farmers-participatory varietal selection trials were conducted in India (Andhra Pradesh, Karnataka, Uttar Pradesh, Madhya Pradesh, Chhattisgarh, Jharkhand and Orissa) and Myanmar (Sagaing and Mandalay divisions) during 2007/08 crop season under various special projects. The results of the FPVS trials conducted at different locations in India and Myanmar indicated regional preference for different improved chickpea cultivars with specific traits as indicated in the list below:
INDIA
1. Northern India: DCP 92-3, JG 16 and KWR 108
2. Central India: JAKI 9218, JG 130, JG 322 and JG 63
3. Southern India: JG 11, JAKI 9218, JG 130 and BGD 103 (in Desi) and MNK 1 and ICCV 95334 (in Kabuli)
4. Myanmar: Yezin 6 (ICCV 92944) and Shwenilonegyi

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954

PM Gaur, CLL Gowda and Shailesh Tripathi

Pigeonpea:

Achievement of Output Target (%):
100%

Countries Involved:
China; India; Myanmar; Nepal; Philipinnes

Partners Involved: NARS partners from above listed countries

Progress/Results:
During 2007/08 more than 750 Farmer-Participatory Varietal Selection trails were conducted. Of these 735 trials were conducted in India, two in Nepal, three in Myanmar, and 10 in China. These trials were conducted under various special projects, details of which are available in the respective special project reports.

Special Project Funding:
ISOPOM, Tropical Legumes II, IFAD Grant 954

RK Srivastava and KB Saxena

MTP Project 7: **Reducing Rural Poverty through Agricultural Diversification and merging Opportunities for High-Value Commodities and Products**

Project Coordinator: **SP Wani**

Output 2: New approaches and technological options to create a strategy to diversify SAT systems using available water resources efficiently to grow high- value commodities that increase incomes for disadvantaged households identified and promoted with associated capacity building by consortium partners to Government agencies, donors, NGOs and CBOs.

Output target 2008 7.2.1 Inventory of alternate watershed practices for four Asian countries documented and made available globally

Achievement of Output Target (%):
Fully Achieved

Countries Involved: India, Niger, Mali

Partners Involved: Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad,
Indian Instittue of Soil Science (IISS), Bhopal, India
NGOs in India
IER – Mali

Comments/Explanations:
The case studies and the comprehensive assessment of watershed programs are completed. Similarly, the best bet management manual publication is in print and the paper on Vietnam, Thailand and India is published in the Journal. All the reports are available in the hard copies as well as PDF versions on our website.

Progress/Results:
Activity 7.2.1.1 Community watershed as a growth engine for development of dryland areas

Watershed management is a key national strategy for sustainable management of natural resources and improving agricultural productivity in rainfed areas of India. By 2006, the government of India has invested a total sum of US$ 6 billions on watershed development projects since the inception of the program. The Comprehensive Assessment (CA) of watershed programs was commissioned jointly by the Ministries of Rural Development and Agriculture, Government of India to assess and document the impact of various watershed development programs, identify the drivers of success and draw recommendations for policy, institutional and technical change for efficient management of watershed programs in India. The study was undertaken by the ICRISAT led consortium of 14 institutions include national agricultural research organizations, state agricultural universities and non governmental organizations.

The study critically analyzed macro and micro-level studies emerged from the watershed programs along with detailed analysis of secondary data covering Benefit-Cost ratio, productivity and cropping intensity, irrigation and groundwater availability, development of social, technical, human and physical capital, gender and equity issues, quantitative and qualitative impact indicators and exit strategies, which were then synthesized and documented over all impact of watershed programs in India. The detailed case studies covering different watershed development programs and implementing agencies, bright spots as well as not so successful watersheds representing different agroecoregions in India, were taken up to instill suitable institutional mechanisms and polices for the successful implementation of watershed programs

The study also evaluated the impact of watershed programs using Meta analysis approach covering 636 micro-level studies across India. These micro-level studies were critically reviewed and documented for upscaling the conclusions to stipulate the macro-level picture of the watershed programs. The results of Meta analysis revealed that watersheds generated an average benefit-cost ratio (B: C) of 2 and 0.6 per cent of watersheds failed to commensurate with the investment (<1of B: C). Thirty two per cent of watersheds showed a mean B:C of >2 and 27 per cent of watersheds yielded an internal rate if return of >30 per cent showed immense potential to improve watershed programs in the country.

The study critically reviewed the existing best bet technical options for improving farm productivity and documented productivity enhancement measures for offering quick and substantial returns for various eco regions of the country. The comprehensive assessment has also identified a weakness in the current monitoring and evaluation system in watershed programs. The study provided the scope of using high science tools for identifying, planning, monitoring and evaluation of watersheds by documenting the pilot study carried out by Indian Space Research Organization on the monitoring and evaluation of 60 watersheds implemented during 8th and 9th five year plans. Capacity building was identified one of the critical weakest link in implementing watershed programs as well as for scaling up and scaling out the watershed programs

The comprehensive assessment critically reviewed the guidelines released by various agencies for planning and implementing watershed programs and synthesized the how far the guidelines evolved from time to time kept pace with the changing scenarios and learning from the past programs. The study also has documented the gaps and opportunities as polices for improving the efficiency of watershed programs

The comprehensive assessment of watershed programs has brought the following publications *viz., Community Watershed as a Growth Engine for Development of Dryland Areas* including executive summary for policy makers; *Impact of Watershed Program and Conditions for Success – A Meta-Analysis Approach*; *Guidelines for Planning and Implementation of Watershed Development Program in India: A Review*; *Impact of Watershed Development in the Low Rainfall Region of Maharashtra: A Case Study of Shekta Watershed* and *A Comparative Analysis of Institutional Arrangements in Watershed Development Projects in India*

SP Wani, TK Sreedevi, S Marimuthu, RC Sachan, Piara Singh,
KL Sahrawat, P Pathak, Ch Srinivasarao and AVR Kesava Rao

Output target 2009 7.2.2 Balanced nutrient management options for vegetable cultivation evaluated

Achievement of output target : (80%)

Partners: BAIF, Bhopal
BAIF, Rajasthan
CRIDA, Hyderabad
IISS, Bhopal
Government of India
NGOs

Activity 7.2.2.1. Impact of Balanced Nutrition on Yield and Economics of Vegetables in Participatory Watersheds in Karnataka

The farmer-participatory integrated watershed management program at ICRISAT provided the opportunity to implement nutrient management along with soil and water conservation practices in farmers' fields in the Indian semi-arid tropics. The experiences from several watersheds in different states, revealed that extent of micronutrient deficiencies particularly zinc and boron along with sulphur were widespread and large scale yield benefits were recorded with the application of these nutrients along with N and P in case of field crops. In the present study, the experiences of watersheds in Karnataka are presented by reporting on the extent of Zn, B and S deficiencies in farmers' fields, response of vegetable crops to the applications of S and micronutrients and the economics of balanced nutrition.

Benchmark watersheds in the districts of Dharwad, Haveri, Kolar, Tumkur and Chitradurga (Karnataka), were the test sites for studying the extent of nutrient deficiencies (Table 3). Most of these watersheds are about 500 ha in area (micro-watersheds) and number of farmers cultivating the arable land varied across the watersheds. These watersheds are located in the semi-arid agroecological sub regions of southern India, are characterized by hot summer and mild winter. The experimental sites receive low to high erratic annual rainfall. Different nutrient management trials included response of vegetables to micronutrients and sulphur. For various trials, control based on farmers' nutrient inputs mainly N and P (termed as FP) and application of nutrient amendments viz. 50 kg zinc sulfate (10 kg Zn ha^{-1}), 5 kg borax (0.5 kg B ha^{-1}) and 200 kg gypsum (30 kg S ha^{-1}) were included along with 150 kg urea and 75 kg DAP ha^{-1}. These nutrients were broadcast uniformly on the plots before the final land preparation.

Extent of nutrient deficiencies in Karnataka watersheds
Most of the watersheds studied are about 500 ha (micro watershed) in area and number of farmers cultivating the arable land varied across the watersheds. To have an efficient, cost-effective and representative soil sampling strategy, a stratified random sampling was developed for each watershed. Processed soil samples were used for analysis and sufficiency and deficiency of particular nutrient was done based on the following standard critical limits (Rego et al. 2007). A total of 1260 farmers' fields were sampled from different watersheds in five districts of Karnataka. Extractable (available) Zn, B and S status of soil is presented in Table 1. In Dharwad district, out of 135 farmers fields (black soils), 34 fields were Zn deficient, 54 B deficient and 83 S deficient. In Haveri district, out of 217 farmers' fields, the extent of Zn, B and S deficiency was 79, 63 and 81 per cent, respectively.

Table 1. Extractable (available) Zn, B and S status of soil in farmers' fields in different watersheds of Karnataka

State/ Location	No of farmers' fields	Zn ($\mu g\ g^{-1}$) Min	Zn ($\mu g\ g^{-1}$) Max	B ($\mu g\ g^{-1}$) Min	B ($\mu g\ g^{-1}$) Max	S ($\mu g\ g^{-1}$) Min	S ($\mu g\ g^{-1}$) Max
Dharwad (% deficient fields)	135	0.28	4.72	0.12	2.44	1.80	118.2
			(34)		(54)		(83)
Haveri (% deficient fields)	217	0.20	2.32	0.08	1.58	1.80	60.70
			(79)		(63)		(81)
Kolar (% deficient fields)	408	0.06	5.50	0.04	1.44	0.50	155.8
			(64)		(90)		(87)
Tumkur (% deficient fields)	269	0.14	2.34	0.06	0.98	1.10	59.6
			(88)		(96)		(93)
Chitradurga (% deficient fields)	231	0.08	3.40	0.04	4.08	1.20	601.4
			(93)		(75)		(82)

* Percent deficient

In Kolar district (408 farmers' fields), the extent of Zn, B and S deficiency was 64, 90 and 87 per cent respectively. Similarly, in the Tumkur district (269 farmers' fields), 88, 96 and 93 per cent fields were deficient in Zn, B and S respectively. In case of Chitradurga (231 farmers fields), the deficiencies were 93, 75 and 82 per cent for Zn, B and S, respectively. The extensive deficiency of Zn, B and S was due to poor organic carbon status of soils and their depletion under continuous cropping without application of these plant nutrients. The soils of the sites are mostly Vertisols and Alfisols and the soil texture varied from sandy loam to clay. In general, the soils were low in fertility, especially organic carbon (<0.5%) and available nitrogen (<280 kg ha^{-1}) and low to medium in available P. The input of plant nutrient through external sources and organic matter additions are very low and is the cause of low fertility and low organic carbon status.

Balanced nutrition in vegetables in Sujala watersheds, Karnataka, India
The results revealed that application of 150 kg urea, 70 kg DAP, 200 kg gypsum, 5 kg borax and 25 kg $ZnSO_4$ ha^{-1} increased fruits yields in ridge and bitter gourds, chillies, brinjal and tomatoes compared to farmers' practice (Table 2). However, it was found that the magnitude of yield increase was more in tomato compared to farmers' practice. The trials showed significant response of vegetables to micronutrient application similar field crops. B:C ratio was higher in case of tomato (11.4) followed by green chilli (4.26), brinjal (4.19), bitter gourd (2.71) and ridge gourd (1.87). Among crops, tomato responded well to micronutrient application resulting an additional net returns of Rs. 34,800/- ha^{-1} followed by green chillies (Rs. 13000/- per hectare) and brinjal (Rs. 12770/- per hectare).

Table 2. Response of vegetables to balanced nutrition in Sujala watersheds, Dharwad and Haveri districts of Karnataka, India.

Crop	Fresh fruit yield (t ha^{-1})		Farm gate price (Rs t^{-1})	No of farmers	Additional cost (INR ha^{-1})	Additional net returns (INR ha^{-1})	BC ratio
	FP*	IP**					
Ridgegourd	5.4	6.3 (16%)	6000	4	3050	5700	1.87: 1
Bittergourd	3.0	3.9 (30%)	9250	4	3050	8250	2.71:1
Green chillies	6.0	8.5 (41%)	5500	4	3050	13000	4.26:1
Brinjal	6.0	8.0 (33%)	6810	4	3050	12770	4.19:1
Tomato	11.2	17.1 (52%)	6380	4	3050	34800	11.4:1

FP*: farmers' practice: IP**: NP+ SBZn : 150 kg urea, 70 kg DAP, gypsum 200 kg, borax 5 kg and 25kg $ZnSO_4$ ha^{-1} and % yield increase is indicated in the parenthesis

Response of vegetables to balanced nutrition in Chitradurga, Kolar, Tumkur and Chikballapur districts of Karnataka.

In earlier reports, we reported on the responses of various food crops to the balanced nutrition. In this report we report on the responses of vegetable crops. In Belaganahalli watershed, Kolar district and in Pulsanivaddu and T. Peddahalli watersheds of Chikballapur, tomato yield increases were ranged from 16.0 to 20.4 t ha^{-1} 27.0 to 30.1 t ha^{-1} with balanced nutrition including micronutrients. Potato yields increased from 6.7 t ha^{-1} (farmers practice) to 9.5 t ha^{-1} with balanced nutrition. Similarly, capsicum yields increased from 20t ha^{-1} to 26t ha^{-1} (Fig. 1). In Tumkur district, brinjal yields were improved substantially bringing additional income of Rs. 57,000/- per ha.

Impact of balanced nutrition on onion yields and economics in three watersheds of Chitradurga district is presented in Table 3. In Maradihalli watersheds the mean yields increased form 24.8t ha^{-1} to 34.5 t ha^{-1} (41%). Net returns improved from Rs. 41250 to 80000 with balanced nutrition showing advantage of Rs. 38750 ha^{-1} due to balanced nutrition. In Toparamalige watershed, the mean onion yields improved from 26.7 to 34.7 t ha^{-1} (31%). The advantage in net returns due to balanced nutrition was Rs. 30250 ha^{-1}. In Belagatta watershed also similar yield benefits were recorded.

Table 3. Impact of balanced nutrition on onion yields and economics in different watersheds in Chitradurga district of Karnataka.

Watershed	No. of farmers		Total yields (t ha^{-1}) FP	BN	% increase	Net returns (Rs ha^{-1}) FP	BN	% increase	Advantage with BN (Rs ha^{-1})
Maradihalli	10	Range	21-30	30-37.5	41	22500-67500	57500-95000	116	20000-50000
		Mean	24.8	34.5		41250	80000		38750
		(p<0.05)	14.3			11,400			
Toparamalige	10	Range	22.5-31.5	27.0-38.8	31	30000-75000	42500-101250	70	12500-63750
		Mean	26.7	34.7		50875	81125		30250
		(p<0.05)	5.19			8,800			
Belagatta	4	Range	22.5-31.5	27.0-38.8	45	30000-75000	42500-101250	108	12500-68750
		Mean	27.3	35.6		54172	85609		36125

FP = Farmers practice; BN = Balanced nutrition (S, Zn, B along with NP)

Similarly, impact of foliar spray of zinc and boron were observed on onion yields (Table 4). The mean yield increase was from 25.7 t ha^{-1} to 29.4 t ha^{-1} (15%). In terms of net returns, the increase was from Rs. 46167 to 60750 (increase 38%). The advantage with foliar spray of Zn and B was Rs. 14583 ha^{-1}.

Table 4. Impact of foliar spray of micro and secondary nutrients on yields and economics in onion in Chitradurga district of Karnataka (No. of farmers fields = 15).

Treatment	Yield (t ha^{-1})	% increase	Net returns (Rs.)	% increase	Advantage with foliar nutrition
Farmers practice (no Zn + B)	21.0 – 31.5	-	22500-75000	--	--
	25.7		46167		
Foliar spray (Zn + B)	25.0 – 33.8	15	38750-82500	38	7500-25000
	29.4		60750		14583

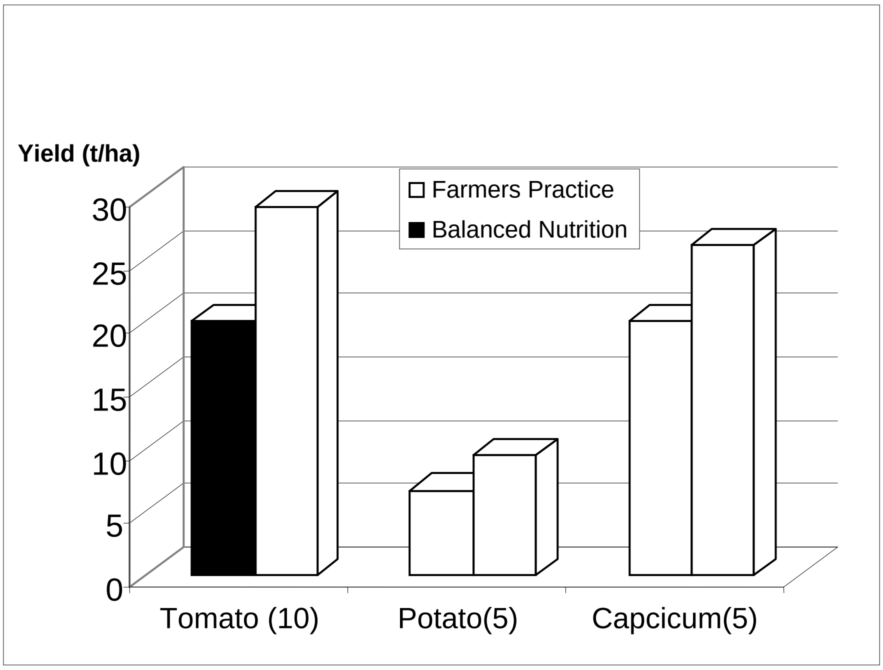


Figure 1. Impact of balanced nutrition on yields of vegetables in Kolar and Chikballapur districts of Karnataka (Figures in Parenthesis indicates no of farmers fields

Ch Srinivasarao, SP Wani, KL Sahrawat, BK Rajasekhara Rao and K Krishnappa

Output Target 2011 7.2.1 Monitoring and management of pesticide residues and impact of IPM established
Achievement of output target: (50%)

Partners: ANGRAU, Rajendra Nagar, Andhra Pradesh, India
NGO Partners
JalSRI, Jalgaon, India

Activity 7.2.1.1 Monitoring of pesticide residues in high value crops established.

The objective of the study is to monitor insecticide residues in different cropping systems at the Kothapally village and to study to the impact of IPM in reducing insecticide residues.

As a part of the objective, from the PRA questionnaire, it was evident that some of the chemicals are being used regularly and determination of the residues of the chemicals used has been taken up in this monitoring study. The insecticidal chemicals selected for the study are monocrotophos, chlorphyriphos, Endosulphan (I & II) and cypermethrin.

As a part of the monitoring of the insecide residues, samples of brinjal and tomato crops and soil and water (open wells, borewells) are being collected on a monthly basis starting from April. Samples of rice, maize and cotton crops are also included.

During 2008, plant soil and water samples were collected at a monthly interval from Kothapally Watershed for monitoring them insecticide residues. The PRA covering plant protection strategies and pesticide usage in Kothapally (IPM) and Yenkepally (non-IPM) villages has been completed with 25 randomly selected farmers. So far 108 samples have been extracted for detection of the commonly used conventional pesticides such as endosulfan, monochrotopos, cypermethrin and chlorpyriphos. The samples include tomato and brinjal crops, rice, maize and cotton products, soil and water samples from both IPM and non-IPM villages. The analyses of the various samples are in progress.

GV Ranga Rao

Output 4: Opportunities for the market exploitation of biodiesel tree products by the poor promoted with associated capacity building
Achievement of output target (60%)
Partners: State Government of Andhra Pradesh, India
Government of India
READ
WCUSS
Kirlosker Oil Ltd., Pune, India

Output Target 2010 7.4.1 Proof of concept that biodiesel trees are an economically and socially viable product for very poor and landless communities when granted usufruct rights on low quality non-titled land

Activity 7.4.1.1 Assessment of existing Pongamia (*Pongamia pinnata*) Plantations using GIS and GPS in Nalgonda District, Andhra Pradesh, India

Pongamia pinnata is leguminous, oil borne tree originated from India, which is identified as good candidate for biodiesel. It is widely distributed across the ecoregions in India and however, the spatial distribution of *Pongamia* is highly heterogeneous and classified under trees out of forest cover. It is important to assess the extent of natural occurrence of *Pongamia* plantations to understand the existing potential for biodiesel production. The standard methodology for assessing the trees under scarce distribution is not available. Narayanpur mandal in Nalgonda district was selected as study area for testing the methodology of assessing natural spread of plantations using GIS techniques and GPS. The study area was divided into 200 ha blocks (grids), where 20 per cent of blocks were randomly selected for recording *Pongamia* trees count and spatial distribution using GPS (Fig.2). The GPS points of trees were super imposed over the integrated map of drainage, soil type, and land use to understand niches or associative characteristics for the existence of *Pongamia* trees *(*Fig.3). Based on the integrated map, extrapolation was done to unsampled areas. It is estimated that dense pattern of trees found in the blocks which fall in forest area along the drains, with an average of 600 trees in a 200 ha block *(*Fig. 4*)*. It is also found that Pongamia trees are mostly found on Alfisols and Inceptisols, scrub lands, permanent pastures barren rocky/ stony waste/sheet rock area and cultural waste in Narayanpur mandal. The study has estimated about 16,000 Nos. of Pongamia trees in the entire Narayanpur mandal.

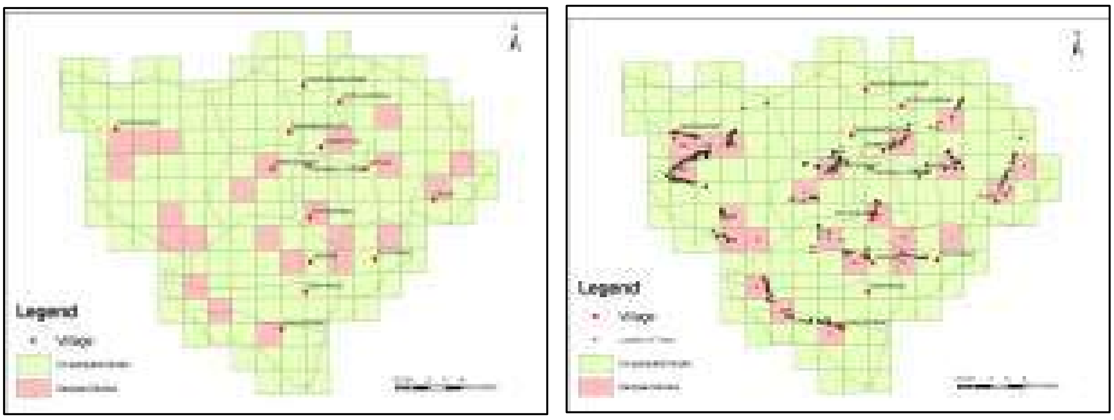


Figure 2. Map showing sampling blocks in Narayanapur Mandal (left) and enumeration points of plantation through of GPS

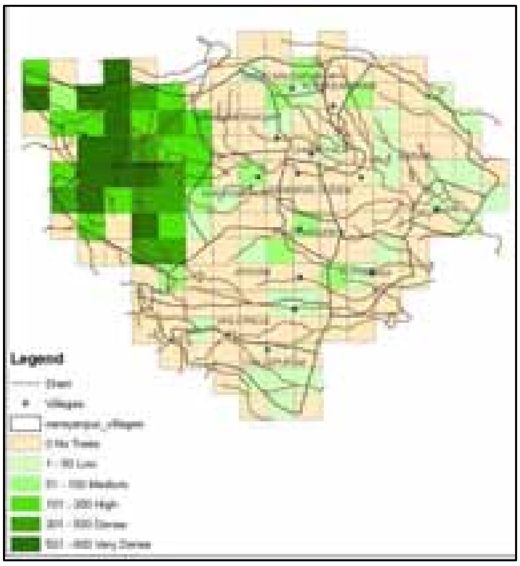
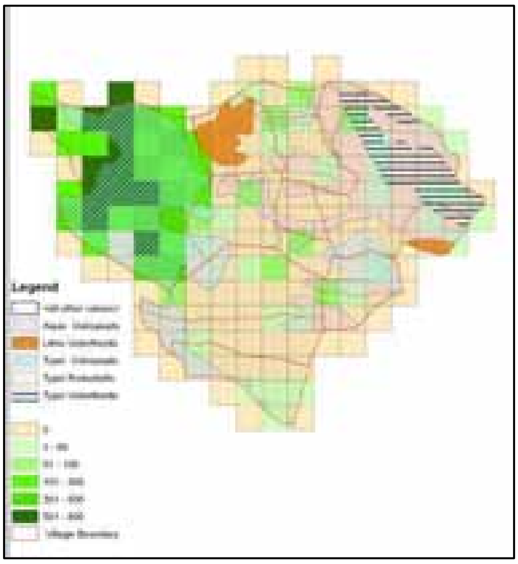


Figure 3. Distribution of Pongamia trees in association with soil type (left) and wastelands (right) in Narayanpur mandal



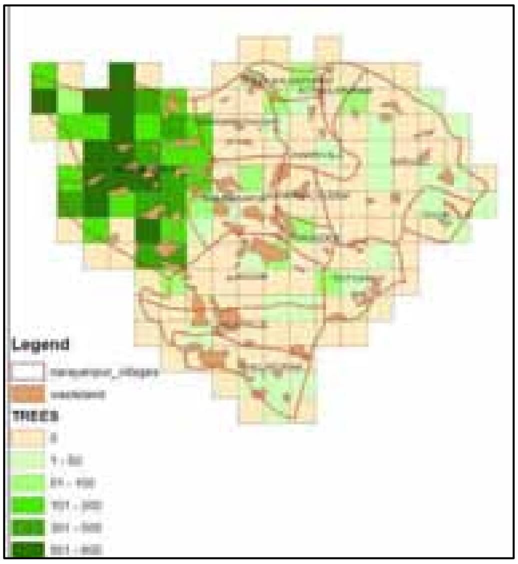


Figure 4. Distribution of Pongamia trees in association with drains in Narayanpur mandal

S Sivasena Reddy, SP Wani, S Marimuthu, Irshad Ahmed and Ch Srinivasarao

Output Target 2011 7.4.1 Recommendations for suitable agronomic practices for the block plantation of trees with potential for use as sources of biodiesel

Activity 7.4.1.1 Effect of pruning on the growth characteristics of *Jatropha curcas*

Jatropha curcas is a drought tolerant shrub belonging to euphorbiaceae, promoted as source of biodiesel. The seeds of Jatropha contain 25-40% inedible oil suitable for use in biodiesel. It is a common sight in tropical countries growing *Jatropha* as live fencing because *Jatropha* is not browsed by the animals. Generally, upper catchments of watershed are becoming degraded lands because of decline in vegetation cover leading to soil erosion. In this context, ICRISAT evaluates *Jatropha* for rehabilitating the degraded lands in upper catchments and promotes *Jatropha* as micro enterprise for poor communities as there is demand as raw material in biodiesel industry. However, systematic and scientific studies on genetics and agronomic management are not available in this species. Jatropha is monoecious plant where unisexual flowers borne in cyme inflorescence produced from new branchlets. It requires systematic pruning for invigorating new branchlets during cropping season. The study was initiated to establish the effect of summer pruning on the growth characteristics of *Jatropha* plants. The study was carried out in block plantations, where half of the plants were pruned at 45 and 75 cm during 1st and 2nd years of planting done during early summer (February-March) and half of them were maintained as such without disturbance. During 3rd year, top one third of both secondary and tertiary branches were nipped off in plants under pruning treatment. The effect of pruning was observed on plant height, stem girth at 10 cm, number of branches and crown area and volume index during 3rd year and the results revealed that pruning significantly influenced growth characteristics of Jatropha plant (Fig. *5*). The pruning of Jatropha plants significantly ($P \leq 0.05$) increased plant height (224 cm), stem girth (36 cm) and volume index (29.4) compared to non pruned plants. However, there is no significant increase in number of branchlets and crown area due to pruning of plants

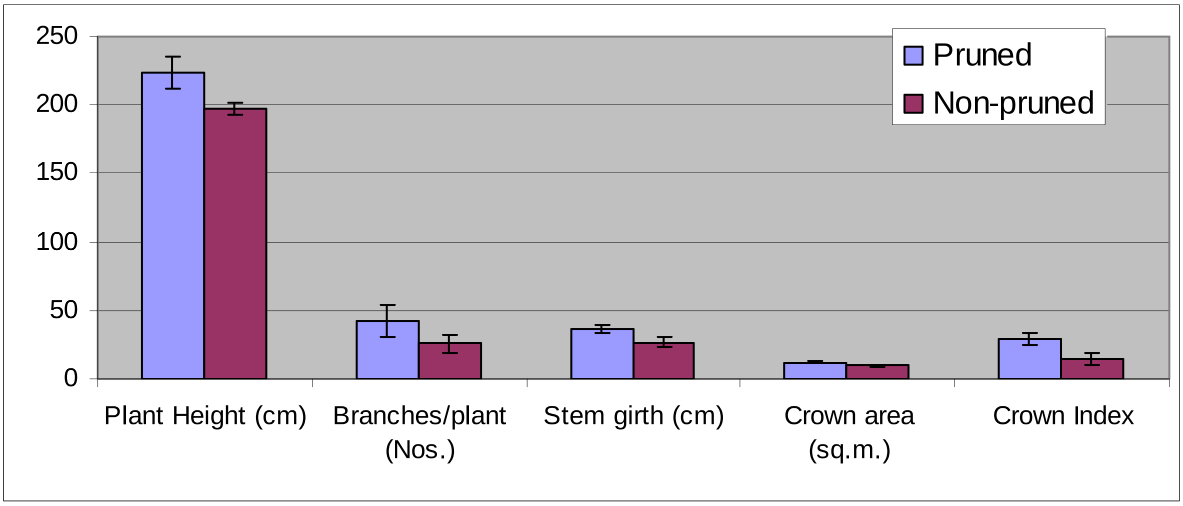


Figure 5. G rowth characteristics of Jatropha plants due to summer pruning during the 3rd of establishment

S Marimuthu, SP Wani, L Mohan Reddy and Ch Srinivasa Rao

Activity 7.4.1.2 Evaluation of deoiled cake of Jatropha as a source of nitrogen in rainfed maize and soybean

Deoiled cake is the byproduct obtained while expelling Jatropha seeds, where two third of seeds remained as deoiled cake after the extraction of oil. Deoiled cake of Jatropha is rich in N (4-6%) having excellent potential to use as organic fertilizer. Field experiments were carried out in black watershed, ICRISAT campus, Patancheru, to study the feasibility of replacing inorganic N in the basal dressing through deoiled cake of Jatropha as a source of nitrogen in rainfed maize cv. Kaveri 235 M and soybean cv. JS 335. The experiment was laid on randomized block design with five replications. Treatment details in maize include; T1: Absolute control; T2: 50% of the basal dressing of 60kg N through deoiled cakes; T3: 100% of the basal dressing 60 kg N through deoiled cakes and T4: 100% N in basal dressing through inorganic fertilizer, whereas in soybean, T1: Absolute control; T2: 50% of the basal dressing 30 kg N through deoiled cakes; T3: 100% of the basal dressing N through deoiled cakes and T4: Entire quantity of basal dressing, 30 kg N through inorganic fertilizer. However, topdressing of N was done through inorganic fertilizers in all treatments.

The results revealed that application 30 kg N through deoiled cake as basal dressing along with 90 kg N through in organic fertilizers in maize resulted in significant ($P \leq 0.05$) increase in maize grain yield followed by the application of entire N requirement through inorganic fertilizers. Similarly significant effect was observed in total dry matter production and cob length due to application of 30 kg N through deoiled cake in maize. The application of entire N requirement (60 kg) for basal dressing through deoiled cake resulted in significant reduction in the grain yield and other parameters (Table 5). It was also revealed that the application of deoiled cake in soybean did not cause significant effect on grain yield and dry matter production. The quantity of N used (30 kg N ha^{-1}) in the experiment may not alter the supplying capacity of the soil significantly (Table 6). The initial soil analysis of experimental site revealed that there is deficiency of boron in the soil and other essential nutrients are at satisfactory levels.

Table 5. Effect of deoiled cake application on growth parameters and grain yield of maize under rainfed condition.

Treatments	Plant height (cm)	DMP (kg ha^{-1})	Cob L* (cm)	Cob D* (cm)	Grain yield (kg ha^{-1})	HI
Absolute control	220	11424	13.44	7.77	6640	0.58
50 % of the basal dressing N (30 kg N/ ha) through deoiled cakes	217	15491	17.38	8.04	9560	0.61
100% of the basal dressing N (60 kg N/ ha) through deoiled cakes	228	14193	16.94	8.02	8490	0.60
Recommended N through inorganic fertilizer (120:60:40 NPK kg ha^{-1})	226	15498	16.82	8.12	9200	0.59
SEd	6.24	369	6.85	0.12	366	0.02
LSD	NS	1240	1.85	NS	796	NS

* Cob L : cob length, cob D: cob diameter

Table 6. Effect of application of deoiled cake on plant height and grain yield in soybean under rainfed condition.

Treatments	Plant height (cm)	DMP (kg ha^{-1})	Grain yield (kg ha^{-1})
Absolute control	42.5	4770	1444
50 % of the basal dressing N (15 kg N/ ha) through deoiled cakes	42	4700	1469
100% of the basal dressing N (30 kg N/ ha) through deoiled cakes	43	4530	1467
Recommended N through inorganic fertilizer (30:60:0 NPK kg ha^{-1})	43	4330	1378
SEd	2.4	256	134
LSD	NS	NS	NS

S Marimuthu, SP Wani and L Mohan Reddy

Activity 7.4.1.3 ET requirements of *Jatropha* plantation in the Semi-Arid South India

Soil moisture is monitored in the Jatropha plantation (seedlings planted in November 2004) at ICRISAT from November 2005 using the neutron probe (Troxler model 4302) at 12 representative locations in the plot. Weather was monitored at the ICRISAT agrometeorological observatory, Patancheru. Daily reference crop evapotranspiration (ET0) was computed following the FAO Penman-Monteith method (1998). Evapotranspiration requirements of Jatropha under ideal soil moisture conditions were estimated based on ET0 and crop coefficients estimated for different phenophases. Evapotranspiration (ETadj) values under actual field conditions of the Jatropha plantation were estimated from soil moisture measurements using the standard water balance equation.

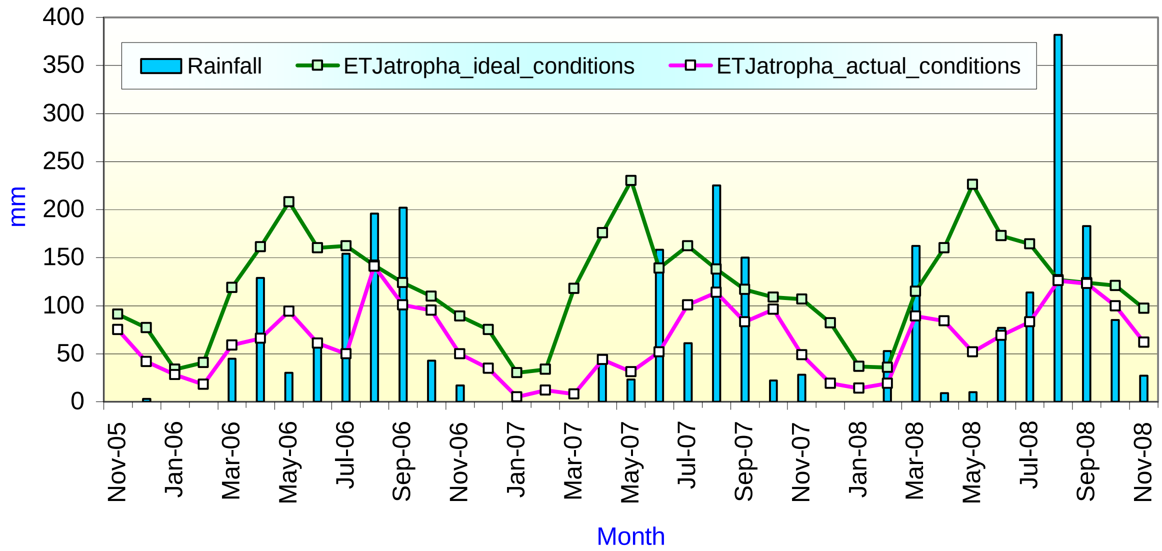


Figure 6. Variation of rainfall and ET in the Jatropha plantation

Monthly crop evapotranspiration values indicate (Fig. 6) that during April to June, ET requirements are high due to atmospheric demands as well as the vegetative stage of plantation. However, this is the period in which the actual availability with respect to demand is low. During July to October, soil moisture status is sufficient to satisfy much of the ET requirements; this period coincides with flowering and fruit set stage. Jatropha has used about 75 to 90% of the rainfall received in the past three years; lower percentage utilization occurred when the rainfall distribution was erratic, though the rainfall amount was high. In the year 2008, rainfall till November was 1103 mm, however, total rainfall during June and July was only 190 mm compared to the normal of 305 mm. August rainfall was 382 mm compared to the normal of 220 mm. There were 8 days in the year 2008 with a rainfall of more than 50 mm and long periods of dry spells occurred in June and July. The total ET use by Jatropha in the year 2008 till November was 820 mm, the highest in the last three years. If the rainfall distribution was good, Jatropha could have used even more water. Study indicates that contrary to the belief that Jatropha needs less water, under favorable soil moisture conditions, Jatropha could use large amounts of water for luxurious growth and high yield.

AVR Kesava Rao and SP Wani

MTP Project 9: **Poverty alleviation and sustainable management of land, water, livestock and forest resources through sustainable agro-ecological intensification in low- and high potential environments of the semi-arid tropics of Africa and Asia**

Project Coordinator: **Peter Cooper**

Highlights for 2008

- APSIM model successful calibrated to capture soil and water nutrient interactions for a range of crops in Limpopo Province Southern Africa
- Basin tillage concept promoted to more than 25,000 households across Zimbabwe and included the Pan-African planning workshops of CARE, World Vision and Concern.
- Zimbabwe focused manuals on Microdosing and Conservation Agriculture produced for final field testing in 2008/2009 season prior to being modified for regional publication
- A stratified random soil sampling methodology for watershed of about 500 ha in area successfully evaluated.
- An MS Excel based simple "Rainfall Analyser" was developed to automate the calculations required for characterizing the temporal variability in rainfall.
- A series of ex-ante analyses undertaken to assess the impacts of various crop management interventions to mitigate the negative aspects of medium to longer term impacts of climate change.
- A computer program was developed in Microsoft QuickBASIC to estimate the start, end and length of rainfed growing period using MarkSim simulated weather data.
- Under the project "*Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate*", a frame work for ex ante analysis of risk and profitability of various indigenous and improved soil and crop management technologies was developed
- A network of model watersheds established across 9 states in India
- Participatory evaluation of the Sahelian Eco-Farm concept undertaken in Ghana
- On-farm trials were conducted on Vertisols of Haveri district to examine the impact of balanced nutrition on yields of groundnut, maize and soybean.
- Baseline diagnostic surveys of the existing crop-livestock systems in Mozambique, Namibia and Zimbabwe were completed and pressure points identified a future entry points for interventions
- Innovation platforms were developed to establish a framework from where technologies can be evaluated within the marketing context.

Achievements in 2008

Output 9.1. New tools and methods for management of multiple use landscapes with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

No output targets declared for 2008

Output Target 2009 9.1.1 Stochastic data assimilation techniques introduced in field to landscape research/modeling

Achievement of Output Target (80%):
The stratified soil sampling method for 500-1000 ha has been standadised. We are validating this in other villages through sacling-up.

Countries Involved:
Different states in India

Partners Involved:
Central Research Inst for Dryland agriculture. (CRIDA) , Hyderabad, India
Government of Andra Pradesh
Government of Karnataka

Progress/Results:
Stretching soil sampling to watershed: Evaluation of soil test parameters in a semi-arid tropical watershed
Soil sampling is an integral component of fertility evaluation and nutrient recommendation for efficient use of nutrients in crop production. Little attention has been devoted to evaluate methodology for sampling watersheds under dryland agriculture.

We adopted and evaluated stratified random sampling methodology for sampling the Appayapally watershed in Mahabubnagar district of Andhra Pradesh state in the semi-arid tropical region of India. The watershed has an area of about 500 ha, with gentle sloping lands (< 1% slope); and 217 farmers own land in the watershed. The soils are Alfisols. A total of 114 soil samples were collected from the top 15 cm layer to represent the entire watershed. Each sample was a composite of 7-8 cores, randomly collected from the area represented by a crop and group of farmers.

The soil samples were air-dried, ground and analyzed for pH, EC, organic C, total N and extractable P, K, Ca, Mg, Na, S, Zn, Mn, Fe, Cu and B. Statistical analysis of the results on soil fertility parameters showed that the mean- or median-based results of soil tests performed in the study did not differ significantly when the sample set size varied from 5 to 114 (100% of the population).

The results of soil analyses showed that the farmers' fields in the Appayapally watershed are uniform in the chemical fertility parameters studied and even a small sample set size can represent the whole population. However, such a sampling strategy may be applicable only to watersheds that are very gently sloping and where fertilizer use is very low, resulting in an overall low fertility in the whole watershed.

The results of our study indicate that stratified random sampling methodology can be adopted for sampling a watershed about 500 ha in area. The results are site specific and such a sampling strategy may be applicable to watersheds uniformly low in organic carbon and available nutrient reserves with very gently sloping lands; and the use of fertilizers by farmers in the watershed is minimal.

Output Target 2010 9.1.2 Cost effective and statistically acceptable GIS based interpretation method for mapping soil deficiencies at micro-watershed and district levels

Achievement of Output Target (80%):
We further stretched stratified soil sampling from a village to district level by covering stratified villages. Furtehr GIS-based maps linking on web is being worked out in partnership.

Countries Involved:
Different states in India

Partners Involved:
Central Research Inst for Dryland agriculture. (CRIDA) , Hyderabad, India
Government of Andra Pradesh
Government of Karnataka

Progress/Results:
To support improved and balanced nutrient management decisions under the World Bank aided Sujala Watershed Project, spatial variability of sulfur and micronutrients boron and zinc in Tumkur district of Karnataka in South India was studied using Geographical Information System (GIS). Tumkur with 10,657 sq. km geographical area is one of the seven target districts and has 19 sub-watersheds. Major soils in the district are Alfisols and Inceptisols. Entisols and Vertisols are also present in patches. Important crops grown in the district are rice, finger millet, horse gram, sorghum, castor, maize, groundnut, sunflower, vegetables, coconut and arecanut. Tumkur district receives an average annual rainfall of 690 mm and the length of the rainfed crop-growing season is about 120-150 days with a large year-to-year variability depending on the amount and distribution of the rainfall.

Soil sampling strategy was based on taking samples to represent the entire village in the watershed. The soil-sampling units were decided on the basis of crop, area covered by the crop and number of farmers owning the land. Stratified random sampling methodology was used for collecting soil samples from each watershed. About 2754 soil samples were collected for boron, sulfur and zinc from 139 villages in the 19 sub watersheds of Tumkur district. Each sample was a composite of 7-8 cores, randomly collected from the area represented by a crop and group of farmers. Soil samples were air-dried and ground to pass a 2 mm sieve before analysis for chemical fertility characteristics. Soil samples were analyzed in the ICRISAT Central Analytical Services Laboratory.

Village level geographical coordinates were obtained using a GPS. Information on soil type, altitude and major crops was collected and included in the database. MS Excel 2000 was used for the basic data entry, formatting and quality checking; MS Access2000 and SPSS were used for database development, statistical analyses and processing. The databases were then imported in to the ArcGIS 9.0 software. The IDW method for interpolation was standardized in this study. The basic parameter the power function (p) with a value of 4 was used. For validating the results of interpolation, data of only 109 out of the 139 original locations were included for creating the interpolated maps. Predicted nutrient status values for the other 30 points, which were not included in the analysis, were picked out and these predicted values were compared with the observed values for these 30 locations.

Boron availability is critically low in almost all the sub-watersheds except C K Halla, D T Halla, Chikkahonnavalli tank and Nagavalli tank sub-watersheds where it is low. In Borankanive-B, Jayamangala Halli, Gummagatta, Jalodu tank, C K Halla, D T Halla, B K Halla sub-watersheds, sulfur availability is critically low and rest of the sub-watersheds are low in sulfur availability. Zinc is one micronutrient, which is available at normal levels in most parts of the district sub-watersheds. Pavagada and parts of Sira and Madhugiri have low levels of zinc available in the soils.
Nutrient availability maps based on 139 locations for Tumkur district were generated for boron, sulfur and zinc and shown in Figure 9.1.2.1. All maps of predicted surfaces are classified in to three classes viz., normal, low and critically low. Boundary limits of nutrient availability for the critically low, low and normal classes were obtained from standard results. If the availability is low, the growth of the crop is affected to some extent and if it is critically low, there will be drastic reduction in the crop performance with respect to growth, development and yield quantity and quality. The classification of availability was made simple with just three classes such that even a layperson can interpret the maps easily. Maps could be used to know if a change in the present situation is required or not.

Boron availability map shows a critically low value over all the taluks except in the northern parts of Sira taluk and southwestern parts of Tiptur taluk, where it is low. Some parts of Tumkur taluk and Turuvekere taluk also have low boron availability confirming that the samples are more aggregated from one side of the taluk. Sulfur availability map shows critically low value in the western and northern taluks of Tiptur, Chikkanayakanahalli, Sira, Pavagada and parts of Madhugiri, Koratagere and Tumkur taluks. Remaining parts of Tumkur district have low sulfur availability in the soils. Boron availability is critically low in almost 88% of the Tumkur district. Availability is low in about 11% of the area. Sulfur availability is critically low in about 50% of the area in the district and low in about 49% of the area. Availability of both boron and sulfur is seen as normal in less than 1% of the area. Zinc availability is normal in almost all the taluks of Tumkur except Pavagada and parts of Sira and Madhugiri, where it is low. Almost 75% of the area in the district, zinc is available and in about 24% of the area the availability is low.

In general, maps of boron and sulfur have shown low to critically low levels of availability for the whole district. Urgent actions are needed for enrichment of these nutrients. Availability of zinc is better in almost all the district except in the extreme northern parts. Therefore, management strategies are required as well to enhance zinc availability in Pavagada, parts of Madhugiri and Sira and parts of Kunigal in south. A linear regression analysis between the predicted and measured values for each nutrient character was made. Zinc and sulfur had lowest prediction errors compared to boron, which has shown higher deviation of predicted values from measured; however for very few points. All predictions were significant at 5% level.

Through the standardized GIS-based interpolation method, agricultural extension personnel and farmers in watersheds can be provided with reliable and cost efficient soil analysis results of total Tumkur district for developing balanced nutrient management strategies. However, due to limitations in the IDW method, the generated maps are to be used only at district level and not for predicting the nutrient availability at single field level.

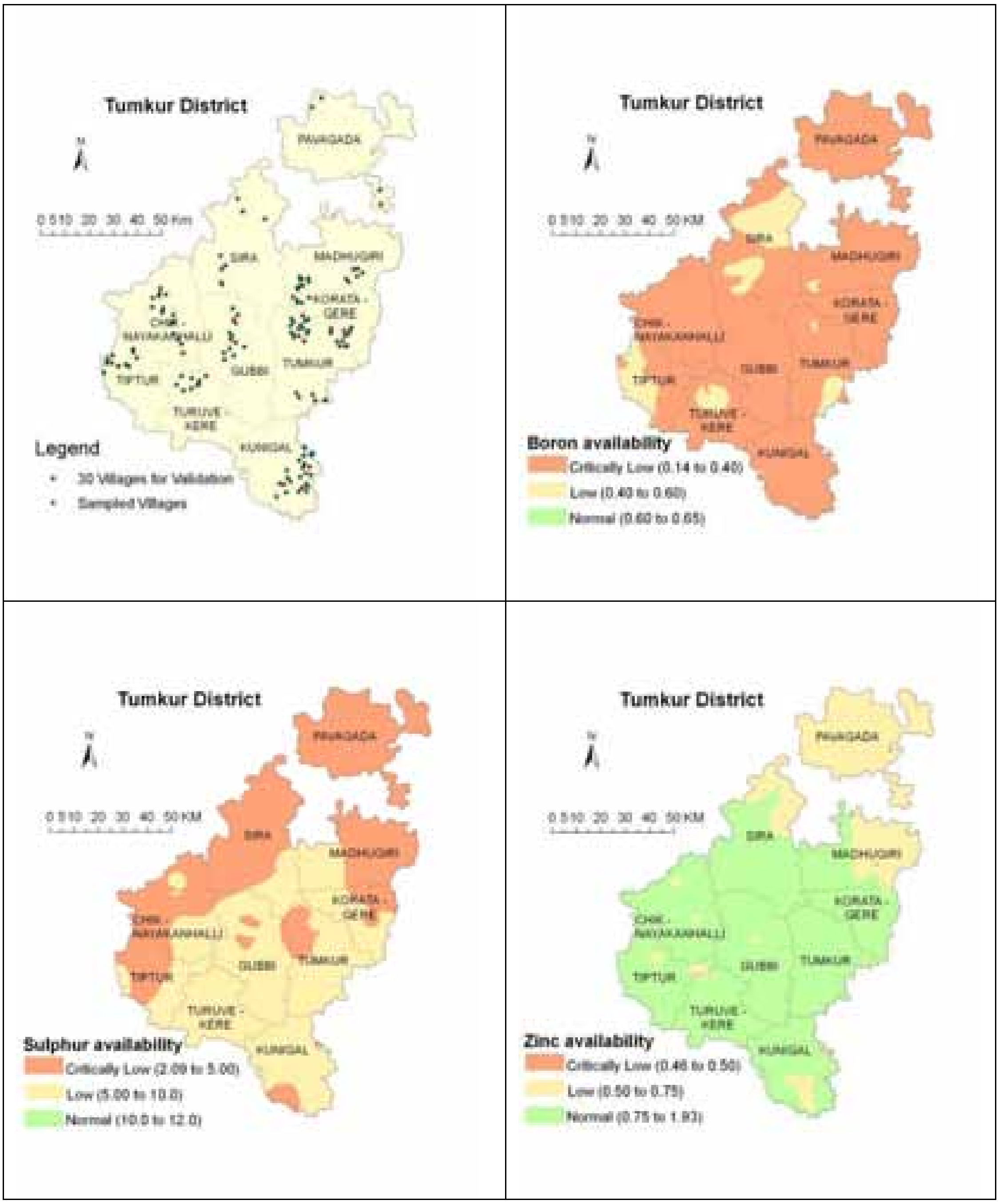


Figure 9.1.2.1. Location of sampled villages and soil micronutrient availability in Tumkur district

Special Project Funding:
World Bank
Output 9.2 New tools and methods for management of climatic variability, with a focus on sustainable productivity enhancement, developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output Target 2008 9.2.1 Ex ante impact assessment of climatic change impacts on SAT agriculture

Achievement of Output Target (%):
>75% Achieved.

Countries Involved:
ICRISAT staff from India; Kenya; Malawi; Niger; Zimbabwe

Partners Involved:
ICRISAT staff in first instance

Box 9.2.1.1 Disaggregated effects of predicted changes in temperature and rainfall on sorghum yields in the SAT

In preliminary cropping simulation exercises to assess the impacts of climate change on sorghum yields in the SAT of Africa and Asia the following three scenarios were examined: current cropping constrained only by climate; current climate modified for temperature change for the region; current climate modified for both temperature and rainfall change for the region. (The impacts of CO_2 rises cannot be adequately accounted for with the currently available cereal modules.)

Future changes in temperature and rainfall in the SAT

(Based on regional predictions for A1B scenario for the end of the 21st century)

Region	Season	Temperature response (°C)	Precipitation response (%)
East Africa	OND	3.1	11
	MAM	3.2	6
Southern Africa	Oct–Mar	3.1	-10
West Africa	Jul–Oct	3.2	2
South Asia	Jun–Feb	3.3	11

Disaggregated effects of climate change on % change in sorghum yields

Region	Potential grain yield (kg ha^{-1})	Rainfall effect on yield	Temp. effect on yield	CC effect on yield
East Africa short rains	3244	+10%	+11%	+21%
East Africa long rains	2232	+6%	+42%	+48%
Southern Africa	2753	–6%	–16%	–22%
West Africa	1896	+6%	–20%	–14%
South Asia	2800	+1%	–38%	–37%

Comments/Explanations:

This output target has been >75% achieved, with major outputs to be reported in 2009. The delay occurred due to both an extensive and continuing dialogue between staff involved in the post May meeting period at Patancheru.

Progress/Results:
During May 2008, ICRISAT staff from Asia and Africa met in Patancheru to initiate a study that used range of computer-based programmes and models to undertake a series of *ex ante* analyses designed to asses, in the medium to longer term (2008-2050 – Box 9.2.1.1), the potential of improved crop, soil and water management innovations coupled with bett er adapted germplasm to mitigate the negative aspects of predicted climate change. This has been an extensive piece of work involving many ICRISAT staff and a great deal of information has been generated and many lessons learned with regard to the suitability of different approaches. A draft synthesis of this work entitled "*Farming with current and future climate risk: Advancing a hypothesis of hope for rain-fed agriculture in the Semi-Arid Tropics"* was circulated for comment in December 2008. This draft summarized key findings and pointed the way forward for ICRISAT in this important field of endeavour. The finalized version of this report is scheduled to be available in February 2009. More detailed work is being undertaken in each region and will be reported in detail in various in 2009.

As part of this evolving expertise within ICRISAT a number of simple computer based tools were developed during the year:

1. In MS Excel simple "Rainfall Analyser" was developed to automate the calculations required for characterizing the temporal variability in rainfall. The main aim of this tool is to generate information that can help in understanding the distribution and patterns of rainfall at any given location. The analyzer allows the user to automatically analyse 50 years of daily rainfall records and compute monthly,

dekadal and weekly rainfall totals, understand the variability through simple statistical and trend analysis. It will also allow the user to get useful information on how major climatic phenomenon like ENSO influences the local rainfall patterns.

2. A computer program was developed in Microsoft QuickBASIC to estimate the start, end and length of rainfed growing period using MarkSim simulated weather data. The program uses Thornthwaite's method to compute the Potential Evapotranspiration (PET) on weekly basis. Year was divided into 52 weeks, each week having seven days starting from 01 January. As there are 365 days in a normal year, there will be 8 days in the last week i.e., 52 week. In leap years with 366 days, the 9th week also will have 8 days. Under rainfed conditions, it was assumed that the growing period begins when rainfall exceeds half the PET for three consecutive weeks or more. Rainfed growing period for most crops continues beyond the rainy season and thus it was assumed that the growing period ends when rainfall falls below one-quarter of PET for four consecutive weeks. Strict following of the method produced unreasonable outputs in some years and for a few locations, hence small changes were made in the program such that the delineation of LGP is both rational and practical, introduced some fuzzy logic to get the best even from the toughest locations.The computer program (software) reads the MarkSim data and does the following:
    a) Converts daily data into weekly format
    b) Computes weekly PET based on latitude and air temperature
    c) Identifies begin and end of season (and length from these)
    d) Repeats the analysis for 15 climate change scenarios
    e) Outputs the results into two files
        - Location details and weekly MaxT, MinT, Rainfall, PET
        - Location details and Begin, End and Length

The software can take any number of years of daily data and for any number of stations and works for any location in both northern and southern hemispheres. The software understands both unimodel and bimodel distribution of rainfall; growing period(s) need not be in one calendar year (between 1 and 52 weeks) and can start in November of one year and end in March of next year. It is not necessary to provide initial values for begin and end of season; the software finds those from the data on its own.

This software was used to compute LGP for 2836 locations (each location for all 16 climate change scenarios). Outputs for each location and scenario include the first begin, end and length, the second begin, end and length, total LGP, annual rainfall and PET. Outputs were quality checked which appear to be reasonable. It was found that for the "Present" scenario, there are 681 locations have growing period in all 52 weeks and 84 locations with no growing period at all. Some of the locations with 52-week LGP are at high altitudes and very good rainfall distribution.

Standalone executable file is small with a size of 55 Kb. Computational time was 7 minutes and 15 seconds on Intel P4 1.8 GHz PC with 256 MB RAM.

Special Project Funding:
ICRISAT core funding

Output Target 2009 9.2.2 Greater application of climate predictions and cropping practices by NARS, extension agencies and farmers to manage climate risks in Africa and Asia

Achievement of Output Target (%):

Africa

About 50% of the planned work from the two funded Projects has been completed in Eastern Africa. The delay was mainly due to delay in stakeholder consultations, slow progress by national institutions in compiling the necessary data for the selected technologies to validate APSIM and conduct economic analysis. Some of this work is a part of the thesis research of two M Sc students whom the project is supporting. The project planned to engage students who have completed their course work but due to non availability of these students the project engaged fresh students who spent much of their first year in completing the course work. *These project are scheduled for 24 months and will be completed towards the end of 2009 or early 2010*

Countries Involved:
Ethiopia; Kenya; Rwanda; Sudan; Tanzania; Uganda

Partners Involved:
Jomo Kenyatta University of Agriculture and Technology, (JKUAT), ,NARO (Uganda),,CIAT, Uganda,Rwanda Met. Service,,Kenya Met. Dept., Kenyan Agricultural Research Institute, Sokoine University of Agriculture, Tanzania, TMA, EIAR, NMA SRC, SMA, ARC Sudan, FAO-Sudan, Reading University, UK, ILRI, ICRAF

Progress/Results:

1. During 2008, the ICRISAT-led ASARECA Project entitled *"Managing Uncertainty: Innovation systems for coping with climate variability and change"* funded and initiated the following Proof of Concept projects designed to illustrate the added value that climate risk analyses provides to agricultural research.

I. "Current and future maize management and variety deployment in ECA as influenced by climate variability and change: A case study from Kenya"
II. "Climate-induced stream flow and erosion risk in the Nyando Basin, Kenya"
III. "Determining climate induced production risk for beans in Uganda and Rwanda: New
IV. collaborative approaches for NARS and NMS in Eastern and Central Africa"
V. "Risk management and adaptations-coping options of (agro-) pastoralist systems in East and Central Africa".
VI. "Comparing Farmer-Perceived and Actual Climate Induced Production Risk for Sorghum in Sudan."

2. Under the project "*Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate*", a frame work for ex ante analysis of risk and profitability of various indigenous and improved soil and crop management technologies was developed (Figure 9.2.2.1). An inventory of technologies relevant to semi-arid regions Ethiopia, Kenya and Tanzania was developed. These technologies are grouped under five categories viz., crops and varieties, crop management, soil and water management, livestock management and post harvest technologies. Through a series of stakeholder consultations, technological interventions related to selection of varieties, optimal planting times, optimal plant population, fertilizer management, and soil and water conservation were identified as high priority. Specific technologies under each of these broad groups as relevant to the participating country were identified and documentation of the same and collection of necessary information to calibrate

and validate APSIM is in progress. In case of Kenya, scenario development and analysis for productivity was completed and economic analysis is in progress. The productivity analysis highlighted the need to look at the interactions of these interventions which made it necessary to refine the methods that are required to conduct economic analysis.

Based on the critical analysis carried out on the impacts of climate variability and opportunities to mitigate this impact through historical and seasonal climate information carried out in earlier years, work was carried out to identify the stake holder requirements of climate information and the format in which they would like to receive this information. During the stakeholder consultations held at Kitui, Mutomo amd Mwingi districts of Eastern province in Kenya, the farmers expressed their desire to have the forecast interpreted for its agricultural significance and provide specific guidance on existing opportunities to select crops, varieties and management practices. Accordingly, a weather based agro-advisory was developed in consultation with KMD, KARI UoN, and Agricultural Extension Officers of Ministry of Agriculture in the three target districts (Figure 9.2.2.2). The information included in this advisory is prediction and performance of previous season, forecast for the forthcoming season and agricultural implications of the forecast. The same was distributed to all the farmers in the target groups and on-farm participatory trials to assess the benefits from the forecast based farming were initiated. This is the first season for these trials and results will be available by February 2009.

Special Project Funding:

1. ASARECA funded (African Development Bank) projects entitled *"Managing Uncertainty: Innovation systems for coping with climate variability and change"*
2. "Managing Risk, Reducing Vulnerability and Enhancing Agricultural Productivity under a Changing Climate" supported by IDRC/DFID-CCAA program

Output 9.3. Affordable and sustainable integrated crop management options (nutrients and water management) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output Targets 2008 9.3.1 At least 2 technical options (nutrients and water management) provided for intensifying and diversifying production systems in low and high potential environments

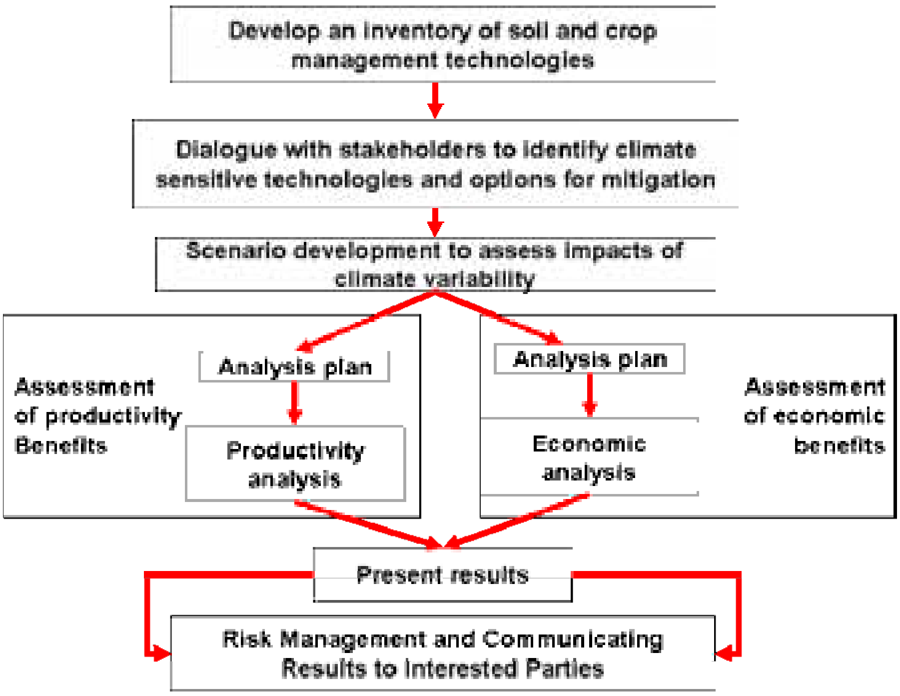


Figure 9.2.2.1: Framework for ex-ante assessment of impacts of climate variability on productivity and profitability of indigenous and improved technologies.

Figure 9.2.2.2: The weather based advisory for Kitui

Partners Involved:
For the Basin Tillage and micro-dosing interventions in southern Africa: AGRITEX, African University, Universities of Bindura and Zimbabwe. Universities of Pretoria and Free State in South Africa, FAO Emergency Offices in southern Africa, NGOs:ACF, CARE, CAFOD, CRS, Concern, Save the Children UK, OXFAM GB, World Vision, Private Sector: Agri-seed Services, Sable Chemicals, Zimbabwe Fertilizer Company

For the water and nutrient use efficiency and improved crop productivity work in West Africa: Savanna Agricultural Research Institute (SARI) Ghana, Institut de l' Environnement et de Recherches Agricoles (INERA) Burkina Faso, Institut d' Economie Rurale (IER) Mali, Institut National de Recherche Agronomique du Niger (INRAN), TSBF-CIAT Kenya, ZEF, Bonn, United Nations University-Institute for Natural Resources in Africa (UNU-INRA) Ghana, European Cooperative for Development (EUCORD) Mali, Projet Intrants FAO Niger, SAFGRAD Burkina Faso

For the watersheds work in India
State Governments - DWMA , TVS-ASRI (PIA), National Research Center on Agroforestry, JalaSRI Program-MJ College, NGOs – PEDO, BAIF, BIRD, Development Alternative, READS, SHRISTI**,** KVK,OUAT Bhubneswar

Comments/Explanations:
The work in Africa is about 75% completed as there are still some additional data on measuring water productivity to be collected and additional economic evaluation is needed. This initial phases of establishing model watersheds as learning centers across 9 states of India is 100% completed.

Progress/Results:
Basin Tillage/Precision Conservation Agriculture
ICRISAT, FAO and Non-Governmental Organizations (NGOs) in southern Africa have been testing modifications of conservation farming techniques that create what can be called precision conservation agriculture (PCA). These strategies for farmers in low potential zones, where most of the most resource-poor and vulnerable farm households exist, encompass three major principles: (i) minimum tillage – for instance, using planting basins which concentrate limited water and nutrient resources to the plant with limited labor input, (ii) the precision application of small doses of nitrogen-based fertilizer to achieve higher nutrient efficiency (from organic and/or inorganic sources), and (iii) combining improved fertility with improved seed for higher productivity. These basic principles are taught to farmers who choose crop mixes adapted to their local conditions and household resource constraints. PCA spreads labor for land preparation over the dry seasons and encourages more timely planting, resulting in a reduction of peak labor loads at planting, higher productivity and incomes. Over four years these simple technologies have consistently increased average yields by 50 to 200% in more than 30,000 farm households (with the yield increase varying by rainfall regime,

soil types and fertility, and market access). Although the area under PCA is not large enough yet to create a marketable surplus, food security has increased substantially. As expected, these farmers are adopting these techniques slowly. The area to which they have applied PCA has more than doubled from 0.1ha to 0.3 ha and this small area is accounting for 35% of household cereal requirements on average. PCA also enables diversification in cropping patterns and more reliable legume production. Returns to labor have been about two times higher than conventional practices on average (Table 9.3.1.1) and making planting basins every year leads to build up of soil fertility and organic matter over time resulting in a more sustainable system. The results have been so encouraging in Zimbabwe that ICRISAT country staff are now working with the NGOs CARE and Concern to develop similar programs throughout sub-Saharan Africa (Figure 9.3.1.1).

Table 9.3.1.1. Sensitivity analysis for PCA versus Conventional Practices under high-, normal-, and low-rainfall situations in Zimbabwe (microdosing with 28 kg N ha^{-1}) (adapted from Mazvimavi and Twomlow, 2008).

		PCA		Conventional farmer practice	
		First year	Second + year	No fertilizer	With fertilizer
High rainfall					
Maize grain	kg ha^{-1}	2000	2650	678	1120
Gross margin	US$ ha^{-1}	654	867	197	357
Cost per kg	US$ kg^{-1}	0.07	0.07	0.15	0.12
Returns to labour	US$ day^{-1}	6.3	7.0	3.3	4.9
Normal rainfall					
Maize grain	kg ha^{-1}	1750	2200	560	728
Gross margin	US$ ha^{-1}	529	697	153	19
Cost per kg	US$ kg^{-1}	0.10	0.08	0.17	0.18
Returns to labour	US$ day^{-1}	5.5	6.3	3.0	3.3
Low rainfall					
Maize grain	kg ha^{-1}	1520	1780	368	400
Gross margin	US$ ha^{-1}	473	535	71	48
Cost per kg	US$ kg^{-1}	0.09	0.10	0.25	0.32
Returns to labour	US$ day^{-1}	5.2	5.3	1.9	1.5

Quantifying water productivity in rain-fed cropping systems in Limpopo Province, RSA

APSIM output was able to provide estimates to fill measurement gaps in water balance components of the field experimentation, thereby allowing more detailed and appropriate calculations for comparing the Water Productivity of the different crops. Such measurement gaps are a common feature of field evaluation studies commissioned by the CPWF. The results of this study show that crop-soil simulation modelling can, and should play an important role in these analyses, firstly by adding value to any field experimentation and ultimately, as a cost effective means of extrapolating the experimental results to alternative management, environment and seasonal conditions for a range of crops (Table 9.3.1.2).

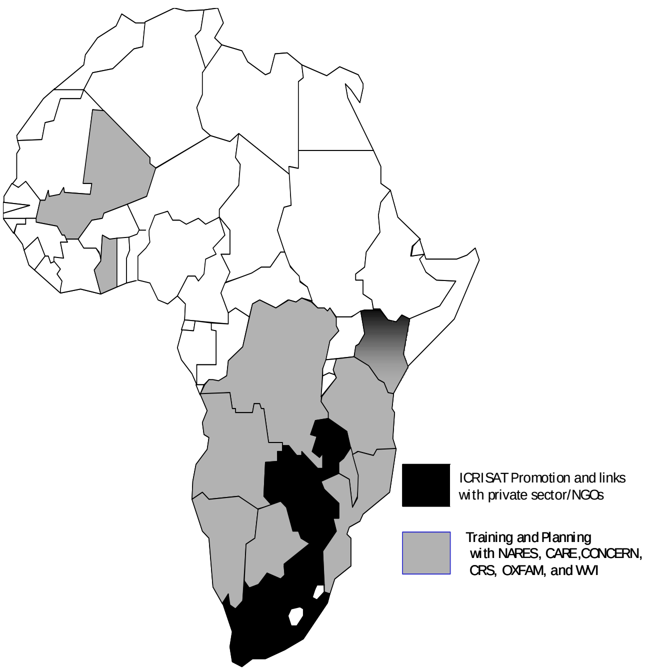


Figure 9.3.1.1Spread of Micro-dosing and Conservation Agriculture from ICRISAT-Zimbabwe since 2004

Table 9.3.1.2 Water productivity of maize, groundnut and cowpea grown at Tafelkop, South Africa, during 2007/2008 cropping season

Crop	WP1	WP2	WP3	Rand WP/mm/ha
Maize	6.0	5.6	4.2	7.6
Groundnut	6.0	5.4	4.1	12.4
Cowpea	3.8	3.0	1.8	7.2

WP1 = grain/ mm/ha in_crop rainfall
WP2 = kg grain/ (mm of rainfall +delta SW storage sowing to harvest – using model outputs)/ha
WP3 = kg grain/ mm of seasonal water balance (Oct 1st 2007 to May 28th 2008)/ha
Rand WP is based on WP3 calculations

Enhancing rainwater and nutrient use efficiency and crop yields in West Africa

In the Volta Basin crop productivity is low due to erratic and unpredictable rainfall, and poor soil fertility. To improve crop productivity promising technologies of integrated soil, water and nutrient management, namely the Sahelian Eco-Farm (SEF), and tied ridging were evaluated in Ghana in partnership with farmers. The SEF combined the use of Acacia trees (*Acacia coli*), micro-catchments or half moons, and high value trees (*Ziziphus mauritania*) planted inside the half moons, and sorghum and cowpea planted in rotation or continuous system. The half moons served as soil and water conservation structures to channel and retain water around the *Ziziphus* trees. Acacia prunings were incorporated in the cropped areas. Sorghum grain yield was increased by rotation with cowpea compared with continuous sorghum system, both inside and outside the SEF. Yields were not significantly influenced by introducing trees into the cropping system. Cowpea did not appear to benefit from rotation until the 4th year. *Acacia coli* had rapid growth and survived the dry seasons. W*ater harvesting using tied ridging increased yield (by up to 20 %) and water productivity of maize and sorghum, and there was a consistent trend for this effect to be enhanced when fertilizer was applied, and the enhancement was significant in one out of three trials.* The combination of water harvesting technique with mineral and organic fertilisers improved water productivity compared to the farmers' traditional practice (control). Furthermore the strategic placement of small quantities of fertilizer (micro-dose) close to the crop at planting increased Nitrogen Use Efficiency (NUE) up to 50% more than that of the recommended rate with broadcasting of fertilizer. Among the different combinations tested, soil amendment with tied-ridging for micro-catchment water harvesting holds the greatest promise for improving crop yields

In Burkina Faso, Niger and Mali water harvesting techniques such as the zai pits and half moon combined with the application of microdose resulted in 2 to 4 times more yields of sorghum, millet and cowpea compared to the farmers traditional practice. In addition to the increased yields, the zai system and the half moon enabled the rehabilitation of degraded lands.

Establishment of model watersheds for sustaining agricultural productivity and improved livelihoods in the different agro-ecoregions of India

The Ministry of Agriculture, Government of India has sponsored a project on the establishment of model watersheds for sustaining agricultural productivity and improved livelihoods in the nine different agro-ecoregions of India. In this project the first major activity, which was taken up, was the selection of appropriate sites for the model watersheds in the nine states of India. This activity was given considerable importance, as the success of the watershed project and its impact will be greatly influenced by the selection of appropriate sites. Following major criteria were considered in the selection of sites for the model watersheds.

- Representativeness in terms of
    - Soils
    - Landscape (slope and terrain)
    - Rainfall
    - Crops
    - Socio-economic conditions

- Cooperative farmers who are willing to take active part in the watershed program.
- Good accessibility even during rainy season.
- Good potential for increasing agricultural productivity, income and conservation of natural resources.
- Strong need for watershed program
- Major area under rainfed.
- Any other special factors such as hazards due to wildlife, floods, etc.

Considering the above key criteria, the few appropriate sites for model watersheds were identified in different states. Multi disciplinary and multi institutional team visited several sites in each target district. At each site, farmers meetings were conducted. Detailed discussions were held with government officials, local institutions and commonly mentors. Based on these discussions and the observation collected, final selection of sites for the model watersheds was made.. At some model watersheds entry point activities have been already taken up and will be reported in subsequent archival reports. The participatory process of the formation of Watershed Association, Watershed Committee and other groups has been initiated. Further details can be obtained from the Watersheds team in Patancheru.

Participatory evaluation of field based land and water management systems and hydrological monitoring in Sujala watersheds, Karnataka

In 2007-08, field based land and water management trials and hydrological monitoring of runoff and soil loss were initiated in Sujala watersheds along with capacity building activities for the effective implementation of farmers participatory trials.

A range of land and water management treatments were imposed in farmers' fields using a participatory approach, with average plot size of 0.4 ha. All practices land and water management practices were compared againsts the farmers own practice. The practices were cross slope cultivation across slope with conservation furrow system for watersheds dominated by Alfisols, and broadbed furrow systems in watersheds dominated by Vertisols. The yields increases observed for the cross slope cultivation conservation furrows ranged between 13-29% for maize, soybean, groundnut and finger millet. For the broadbed and furrow system maize yield responses of between 21-50 % were observed. This work is on going and more detailed reports will be made in subsequent archival reports when several seasons worth of data are available to report.

Special Project Funding

- DFID Protracted Relief Phase I. Recovery and growth of smallholder agriculture in the rural communities of dryland Zimbabwe
- FAO Emergency Office LoAs to assess uptake of Conservation Agriculture
- Technical Support Project to Action Contre la Faim (ACF) – Zimbabwe
- CGIAR Challenge Program on Water and Food Project 17 ''Integrated Water Resource Management for Improved Rural Livelihoods: Managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin''
- The CGIAR Challenge Program on Water and Food (CPWF) Project 5 "Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihoods in the Volta Basin" : Burkina Faso and Ghana
- CORAF/AFDB funded project on water harvesting and nutrient management : Burkina Faso, Mali, Niger and Senegal
- The Ministry of Agriculture, Government of India

2008 9.3.2 At least six water management technologies/ practices for strategic crops, adaptable by smallholder farmers in ESA, are identified and their returns to investment quantified

Achievement of Output Target (%):
>75% Achieved

This is because we achieved,

(i) Paired studies to identify AWM interventions having proven Returns to Investment in Eastern and Southern Africa (technical & Socio-economic) in the six countries (Ethiopia, Kenya, Madagascar, Malawi, Rwanda and Tanzania) have been implemented, and data collected
(ii) Write-shop for cross-review and preparation of country reports was held in Mwanza, Tanzania, from 3rd -7th March 2008.
(iii) Six draft country reports of the findings of Technical/Socio Economic studies were prepared and submitted to IMAWESA PMU
(iv) What is remaining (25%) ids the preeparation of the draft Regional Synthesis report of the findings of Technical/Socio Economic studies.

Countries Involved:
[list countries actually involved in reaching the output target]
List of countries involved
Ethiopia, Kenya, Malawi, Madagascar, Rwanda and Tanzania

Partners Involved:
Amhara Regional Agricultural Research Institute (ARARI) - Ethiopia
University of Bahir Dar - Ethiopia
Kenya Agricultural Research Institute (KARI) – Kenya
Department of Agricultural Research Services, Ministry of Agriculture and Food Security - Malawi
Association Nationale D'actions Environnmentales (ANAE) - – Madagascar
Institut des Sciences Agronomiques du Rwanda (ISAR) - Rwanda
Lake Zone Agricultural Research and Development Institute – Tanzania

Comments/Explanations:
What is remaining (25%) is the preparation of the draft Regional Synthesis report of the findings of Technical/Socio Economic studies.

Progress/Results:
Six draft reports of the studies to *"Identify Agricultural Water Management Interventions with Proven Returns to Investment in Eastern and Southern Africa"* have been received by IMAWESA PMU and are currently undergoing peer reviews.

- The 6 reports are entitled: "Agricultural Water Management Interventions with Proven Returns to Investment under Smallholder Systems:
    1. Findings from a Case study of Ethiopia
    2. Findings from a Case study of Kenya
    3. Findings from a Case study of Madagascar
    4. Findings from a Case study of Malawi
    5. Findings from a Case study of Rwanda
    6. Findings from a Case study of Tanzania

- The proceedings of the "Regional Writeshop for Joint analysis and synthesis of the findings for the Studies to Identify Agricultural Water Management Interventions with Proven Returns to Investment in Eastern and Southern Africa" which was held in Mwanza, Tanzania, 3rd -7th March 2008.

Special Project Funding:
Improved Management of Agricultural Research in Eastern and Southern Africa (IMAWESA) using funds from IFADIFAD

Output Target 2010 9.3.1 Enabling policies for promotion and use of both macro and micronutrients in the semi-arid rainfed areas of Africa and Asia

Achievement of Output Target (60%):
About 25% of the work required to achieve this output target was undertaken through two major activities initiated in 2008 and will be further developed in 2009 in India. These are

- Increasing crop productivity through soil-test based sustainable nutrient management in eight target rain-fed districts
- Impact of balanced nutrition on crop yields in participatory watersheds of Karnataka
- Working on micronutrient policy brief for policymakers and by 2010 we will be able to complete the output.

Countries Involved:
Different States of India

Partners Involved:
Several NGO's's, State Governments of Andra Pradesh, Karnataka, Rajasthan and Madhya Pradesh

Progress/Results:

Activity 9.3.1.1 Increasing crop productivity through soil-test based sustainable nutrient management in eight target rain-fed districts

Wide-spread deficiency of macro, secondary and micro nutrients are reported for rainfed areas throughout the drier areas of India, and Andhra Pradesh; which must be overcome through integrated nutrient management to achieve balanced nutrition of crops to enhance productivity in a sustainable manner.

Initial results from soil samples taken from farmers' fields from eight clusters in eight districts of Andhra Pradesh showed that besides the deficiency of N (in terms of organic C) and P, the deficiencies of S, Zn and B were prevalent in all fields. However, the extent of deficiencies varied depending up on soil type, cropping system being followed and management practices. Sulfur, Zn and B deficiencies were found in up to 90% of the farmers' fields sampled, indicating the severity of the deficiencies of these nutrients. Work is now in progress to introduce practices and technologies that will help alleviate these deficiencies in a sustainable manner – some lessons will be drawn from the experiences gained in Karnataka State.

Activity 9.3.1.2 Impact of balanced nutrition on crop yields in participatory watersheds of Karnataka
Soils of the Haveri district in Karnataka are deficient in N, P, S, B and Zn and farmers rarely apply the micro- and secondary nutrients. On-farm trials were conducted on Vertisols of Haveri district to examine the impact of balanced nutrition on yields of groundnut, maize and soybean. The increase in grain yields over farmer's input was 35, 36 and 54% respectively, in the case of groundnut, maize and soybean (Table 9.3.1.2).

Table 9.3.1.2. Effects of balanced nutrient management on yields (kg ha^{-1}) of groundnut, maize and soybean crops.

Crop	No. of farmers	Control		Improved Nutrient Management		% increase over control		
		Stalk	Grain	Stalk	Grain	Stover	Grain	Pod
Groundnut	10	5951	2168	6493	3109	76	35	30
Maize	21	3309	4762	4375	6493	36	36	
Soybean	4	1121	1056	1534	1627	37	54	

Special Project Funding:
Sir Dorabji tata Trust, (SDTT), Mumbai,
Sir Ratan Tata Trust, (SRTT), Mumbai
Government of India, Ministry of Water Resources
World Bank, Sujala Watershed Project

Output 9.4. Affordable and sustainable integrated crop management options (IPM and IDM) developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Output target 9.4.1: At least two IDM approaches for groundnuts, pigeon pea and chickpeas promoted in at least three regions of Asia

Achievement of Output Target (%):
50%

Countries Involved:
India

Partners Involved:
Banaras Hindu University (BHU) Varanasi, RWC-ICRISAT

Progress/Results:
Pigeonpea in legume-wheat cropping system up scaled in Eastern Indo Gangetic Plains of India: ICRISAT bred extra short duration pigeonpea (ESDP) cultivar; ICPL 88039 was up scaled in collaboration with rice and wheat consortium (RWC) and its partner organizations through on-farm participatory trials in eastern Uttar Pradesh and north Bihar in IGP. Trials were conducted in 100 farmer's fields where wheat was sown after ICRISAT pigeonpea variety ICPL 88039 grown during kharif. Wheat was timely planted and was in tillering stage and at par or better than the wheat planted after rice in the adjoining fields. In an interactive discussion with farmers participating farmers and neighboring farmers were highly impressed with the performance of ICPL 88039 and wheat planted after it. ICPL 88039 emerged as the most accepted pigeonpea and as a potential candidate and alternative to local or any other short duration pigeonpea cultivars (such as UPAS 120) in the IGP. There is a heavy demand of seed of this variety for its further expansion in the area. Two farmers were identified by the collaborators to initiate seed multiplication of ICPL 88039 and maintaining the purity of it. Several farmers have started its multiplication under the guidance of partner scientists and NGOS from the RWC-NARS in eastern India especially in North Bihar following improved IPM/ICM technology.

Special Project Funding**:**
Nil

Output 9.5. Affordable and crop-livestock management options developed and promoted with associated capacity building in collaboration with NARES partners in Africa and Asia

Africa

Output Target 2010 9.5.1 Assessment of drivers for change in water use at the landscape scale including Water Governance profiles in study sites (Ethiopia and Zimbabwe) and an assessment of their effectiveness for integrated water management in crop livestock systems

Achievement of Output Target (%):
About 25% of the work required for this output completed. Although progress was slow in Zimbabwe because of political instability, the main household baseline surveys and PRAs were successfully concluded, data are being analyzed. Initial analysis on land use change and degradation was conducted for both Ethiopian and Zimbabwean sites. One PhD and six Masters degree projects have been developed and are implemented.

Countries Involved:
Ethiopia; Zimbabwe

Partners Involved:
ILRI Ethiopia
IWMI Ethiopia
NARS Zimbabwe

Progress/Results:
Initial work in the project was characterized by the development of six masters degree proposals and one PhD proposal. These projects explore the characteristics and dynamics of crop-livestock systems in Zimbabwe and will define the fundamentals of livestock water productivity. From this a set of potential entry points to improve livestock water productivity will be developed. As livestock water productivity is primarily influenced by the water use efficiency of the feed livestock consume, much emphasis are placed on improving feed systems, in particular the improved management of natural rangeland and greater integration of crops into the livestock production system. Improved crop production in itself contributes significantly to improved livestock water productivity. This includes the testing and implementation of improved dual purpose varieties, especially sweet sorghum, while also testing other species including legumes. Main focus areas of the master degrees includes: characterizing land degradation and land use change, understanding the driving forces of land degradation and quantifying the impact on human livelihoods directly and indirectly through livestock, developing conceptual models of improved water productivity in mixed crop livestock systems, defining entry points in improving livestock production and feed utilization through improved health and feed systems, adopting technologies within the realm of availability of labor using a gendered approach and evaluating dual purpose sweet sorghum varieties. The PhD work evaluate the water use efficiency of entire crop livestock systems using a modeling aproach (mainly APSIM). Various permutations of crops and varieties, soil nutrient management regimes and livestock management systems will be modeled to determine the overall water use efficiency and its interaction between economic returns, absolute production, whole system efficiency as well ecological sustainability. Most of the initial work to achieve this have been done, while data collection and analysis is ongoing.

Special Project Funding:
YIW07
YEU06

Output 7.3 Environmental impacts of livestock intensification reduced during droughts and the dry season by developing and promoting alternative feed and fodder strategies in crop-livestock systems with associated capacity building
Output Target for 2010

2010Output Target 7.3.1 Need for dry season feed and fodder quantified and prioritized based on potential impact within agro- ecological zones, through participatory selection of alternative feeding strategies

Achievement of Output Targets (%):
About 25% of the planned work that will contribute to the achievement of this output target by 2010 is completed.
Innovation Platforms, forums where all role-players participate and articulate needs and define production and marketing priorities were developed, and are being testing. Needs and priorities established here are used to define and test interventions. Major challenges in the system has been identified and appropriate interventions are being packaged for implementation.
1 PhD student enrolled
6 Masters students enrolled (same as in 9.6 but with strong links)

Countries Involved:
Mozambique; Namibia; Zimbabwe

Partners Involved:
ILRI, Kenya, Mozambique, India
NARS: Namibia, Mozambique and Zimbabwe
Universities: National university of science and Technology, NUST, Zimbabwe, University of Pretoria, South Africa

NGOs: Namibia: Namibian National Farmers Association
Zimbabwe: SNV, ORAP, Practical Action

Progress/Results:
Diagnostics: Typology of crop-livestock systems in southern Africa
Baseline surveys were completed in all three countries, that included the survey instrument's development and testing, as well as the household and PRA surveys completed). All data were computerized, analyzed and draft reports are available. Final reports will be available once all partners have commented. From this the most important pressure points were identified with regards to livestock production and marketing. Results are briefly summarized in Tables 1 and 2. This illustrated the holistic approach to the work, the role of the other main partner (ILRI) and indicates ICRISAT's

increased role in providing improved feed systems and facilitating institutional development in a rapidly changing landscape – where demand for livestock products are increasing and where climate change will further increase the role of livestock in these semi-arid areas.

Markets are used as entry points for the adoption of improve production strategies and innovation platforms were developed to establish a framework from where technologies can be evaluated within the marketing context. Thus, participating in the innovation platform provides clear information regarding the positive impact of adopting a specific technology at the market place. Market information regarding grades and standards and the price differences between different grades is a strong signal to spur farmers on to adopt improved health and feeding technologies.

The innovation platform - The basic principle of this approach is that increased communication between the various stakeholders will identify opportunities for improvement, both in identifying pressure points in the production to market system/process and also to allow for novel and more effective approaches to information exchange. Once all relevant parties have been identified and have "bought into the system" the main tasks for this innovation platform would be to engage in the following five main activities:

1.) Improve Markets by
The innovation platform will through their deliberations and analysis identify ways and means to improve on existing markets or even develop new markets. These improvements may be at various levels:

Livestock production systems
Socio economic household characteristics

	Mozambique	Namibia	Zimbabwe
HH headship (%) Literacy of hhh (%)	• > 85 male • 44, Gaza •71, Tete	• 70 male 28, Omatjete, 79, Hoachanas	• 70 male •> 80
HH with cattle & goats (%)	> 90 / > 80	80 / 95, Omatjete 29 / 97, Hoachanas	55 / 90**
Mean herd size, (cattle & goat hds)	14 / 13	80 / 106, Omatjete 12 / 67, Hoachanas	9 / 9, Tsholotsho 6 / 17, Gwanda
Livestock ownership by gender	More male, in Tete also jointly	More male	Cattle more male, goats joint
Most important livestock function (%)	Cattle: cash, draft, ins. Goats: cash, meat, ins.	Cattle: milk, cash, meat Goats: meat, cash, milk	Cattle: draft p., milk, cash Goats: meat, cash, milk
Livestock as first income source (%)	41, Gaza 29, Tete	> 70	66, Tsholotsho 81, Gwanda
HH with remittances or pensions (%)	19 remittances, Gaza 5 remittances, Tete	>56 pension, Omatjete >40 pension Hoachanas	> 40 remittances

a. *Improving Institutions* – improvements may be to develop more transparent markets, managed by more credible people or by improving the institutions around the marketplace that will improve the acceptability of the specific organization managing the market/market place.
b. *Improving Infrastructure* – the innovation platform will identify and facilitate improvements in the infrastructure of the market place. This may include facilities that improve the individual farmer's ability to display his animals such as sales pens, infrastructure that improve the conditions of the animals subject to be sold, shade and water, or facilities that allow for easier loading of animals such as ramps. Infrastructure/procedures that facilitate open / transparent sales such as scales and grading systems may well be identified as important improvements to be implemented.
c. *Access to markets* - this important aspect has two main components which will be dealt with by the innovation platform. Physical access such as roads and access to transport to the market place will be analyzed, while *institutional* access (such as those preventing farmers who are not members of the local farmer or market related institutions or in certain cases farmers may not have access to markets because of veterinary prohibitions.
d. *Information* – improving market related information is quite often an important limiting factor inhibiting producer's participation and confidence in certain markets. Opening up such information and providing access to such information may well increase participation in markets.

2.) ID technologies for:
a. improved productivity – these are technological interventions that are traditionally promoted to increase productivity. Promoted alone will often have very little impact as adoption is normally low. However, done within the framework identified through an iterative process between all stakeholders may hold more 'value'.
b. aligning the *requirements* of the production and demand – more importantly, some technologies/strategies may well bring producers closer to the demands of the market – this may be related to the type of product, its quality, quantity and the temporal requirement of the market/consumer. We hypothesize that technologies identified at this level – i.e. to align the farmers production environment to that of the market demands will well be first to be adopted – as this is dictated by the market, and therefore a direct incentive scheme is in place to account for the return on such investments.

Special Project Funding:
YEU04
YEU06
YIW07

Output Target 2011 9.5.1 Dual purpose crop varieties for food and fodder production evaluated and promoted with farmers participation in the watersheds of India

Ragi (finger millet, *Elusina coracana*) and groundnut (*Arachis hypogea*) are the important food and fodder crops of Karnataka in India. Improved varieties of these crops were evaluated in participation with farmers in Kolar and Tumkur districts of Karnataka.

Achievement of Output Target (%):
Over the 3-year period about 75% of the output target has been achieved. This year these varieties are being further scaled up by the farmers in the region with improved management practices.

Countries Involved:
Most of this work was confined to the state of Karnataka in India

Partners Involved:
ICRISAT as the key facilitator along with Sujala Watershed Development Department, Department of Agriculture, Government of Karnataka; University of Agricultural Sciences at Banglore and Dharwad; National Remote Sensing Agency, Hyderabad; Central Institute of Dryland Agriculture, Hyderabad; and many lead and field NGOs.

Progress/Results:
The improved and local (traditional) varieties of ragi and groundnut were evaluated by farmers under both farmers' and improved management practices in Kolar and Tumkur districts of Karnataka. Over the three seasons (2005-07), ragi cultivars evaluated were GPU 28, MR 1, HR 911 and L 5 and those of groundnut were ICGV 91114, TMV 2, JL 24, Kadiri 1375, Kadiri 6, and GPBD 4. Any variety not liked by the farmers during the first season was dropped and not included for further evaluation. Improved practice comprised of application of 70 kg DAP, 100 kg urea fertilizers, 5 kg borax, 50 kg zinc sulfate and 200 kg gypsum ha^{-1}, except for groundnut the application of urea was reduced to 40 kg ha^{-1}.

In both the districts the variety L 5 consistently gave higher grain yield than other cultivars evaluated. On average the grain yields of GPU 28, MR 1 and L 5 were higher by 22%, 38% and 50%, respectively, over the local cultivar. On average the fodder yields of GPU 28, MR 1 and L 5 were higher by 20%, 41% and 31%, respectively, over the local cultivar. Improved management substantially increased the grain and fodder yields of ragi, which were 54% and 47% higher than the farmers' management This indicated that contribution of improved management to ragi grain and fodder yields were higher than the contribution of improved varieties. Farmers also believed that L 5 is a superior cultivar having potential for higher grain yield and good quality fodder; however, MR 1 was preferred with high input management. The farmers indicated that both varieties could be scaled out for enhancing yields in different watersheds.

In 2005, pod and stalk yields of ICGV 91114 were 94% and 90% higher, respectively, than those of local cultivar. The next best cultivar was JL 24 followed by TMV 2. On average improved management increased the pod and stalk yields by 55% and 48%, respectively, over the farmer's practice. In the low rainfall year of 2006, both ICGV 91114 and Kadiri 1375 yielded higher than the other varieties in the two districts. Between ICGV 91114 and Kadiri 1375, the farmers of Kolar preferred Kadiri 1375 as the variety was mostly devoid of foliar diseases and pod filling was good. Farmers in Tumkur preferred Kadiri 6 over the other two varieties, as this was a high yielder with bold seeds and good filling. However, foliar diseases affected Kadiri 6 as much as the variety ICGV 91114. During 2007, on average, the performance of ICGV 91114 was better in terms of pod and fodder yield than the other cultivars. It produced 46% and 34% higher pod and fodder yields, respectively, than the local cultivar. Kadiri 1375 and GPBD 4 were at par for pod yield. Improved management increased the pod and stalk yield by 67% and 48%, respectively, over the farmers' management.

The above results indicate that ICGV 91114 was consistently a better performer in terms of pod and stalk yield as compared to other varieties evaluated. However, the farmers' preferences for variety varied with their requirement for pod or fodder yield. Except in 2005, the contribution of improved management to the increase in yields was higher than that of the improved varieties indicating the need for integrated crop management approach to achieve higher yields.

Special Project Funding:
This work was supported by the Sujala-ICRISAT watershed project funded by the Government of Karnataka.

MTP Project 10: Virtual Academy for the Semi Arid Tropics in SAT Asia and WCA

Project Coordinator: V Balaji

Summary:
During the year 2008, activities on this project focused on achieving outputs 10.1.1 and 10.1.2 in the logframe. The outputs were generated as projected. A content organization for digital content in agriculture has been developed and tested with partners. A prototype for online and offline content delivery has been tried out with a wide range of partners and its potential for creating a global repository of learning materials has been assessed. We have been able to establish a platform that is allied to the principles of Open Educational Resources practices (pioneered by the UNESCO). Our work on knowledge sharing processes has revealed an interesting possibility of the use of cutting edge practices in knowledge engineering for wider use in support of agricultural education and extension. .

10.1.1 Design of a Blend of Tools in Knowledge Sharing

During 2007, three different approaches were tried out with AGROVOC of FAO as the equivalent of a controlled vocabulary. The Topic Maps were tried out for the ICRISAT mandate crops as the core information-aggregating technology. During this year, we have refined the techniques and have developed a more adavanced approach to content aggregation, based also on the strategies identified in 2007.

Crop Knowledge Modeling: Evolving new approaches to digital content organization

During the year 2007, we conducted trials on the use of semantic web techniques in developing an organization for digital content in SAT agriculture. A technique deployed in these trials is the use of Topic Maps. These tools enable the representation of concept relationships in a map-like form. A user can navigate the map to locate an element of interest, and retrieve all digital content linked or mapped to that element. Topic Maps thus provide a functional as well as elegant way to organize digital information objects that are located across the web.

We built pilot Topic Maps in 2007, and in the last year, developed them for all the ICRISAT mandate crops. They were further refined with the standardization of term relationships; the AGROVOC in English was extensively used in defining the terms. To the Topic Maps was added the "scope" component, enabling a subject matter specialist and an extension worker to gain different "views" of the Topic Maps. Thus, the content linked to the maps can be accessed for different purposes. Use of language switch enables the Topic Maps to be read in a different language that the AGROVOC uses.

During 2008, the five crop Topic Maps with scope and language switch components (English and French) were published in a peer-reviewed journal[1]. They can be accessed at http://test2.icrisat.org. A variety of web sites from across the globe have been linked to these maps.

Crop Topic Maps are final products in a process that is based on the fundamentally new approach of knowledge modeling. This approach has been developed for organizing digital content using subject matter expertise, and makes it easy for experts to contribute highly targeted and specific content to an online content repository. At the same time, it enables the development of a wider range of information services to be customized to suit a user. Knowledge Models enable much greater aggregation of digital content, and far greater ease of search, across languages as well. A good part of emerging technologies for the Deep Web are related to or derived from Knowledge Modeling, and we have adopted this approach in our work last year.

We have developed Crop Knowledge Models for all the mandate crops of ICRISAT. The models allow for high levels of granulation of concepts that have relevance in research or extension or education. These models can be and have been collaboratively developed. They can be viewed on a map-like interface (as in Topic Maps) or can be accessed online as in an indexing or "tagging" service. The crop knowledge models as "concept maps" are available at http://test2.icrisat.org. For each crop, a number of web resources available at the VASAT and other sites have been linked. During 2008, the models for ICRISAT Mandate Crops have been developed using the AGROVOC in English and French among the international languages and in Hindi. The orientation is towards extension in the present stage although it could as easily have been developed for research or education.

With the support of the FAO, we took up the task of refining aspects of the AGROVOC in order to make it fully compatible with our content organization as an ontology (the basis for deriving relationships between different concepts in specific crops). The FAO maintains the master copy of the AGROVOC for use by the agricultural education, research or extension communities across the globe. With that copy as the resource, we have completed the following:

- Revised 21612 out of 28685 relationships between "narrow" and "broad" terms; this set of revisions have been approved by the FAO in the English version.
- We have also assigned broader terms to AGROVOC entries where the BT's did not exist.
- Revised and refined 14,201 out of 17,386 USE relationships
- Developed a software tool to incorporate the Russian and Hungarian versions into the master copy.
- Developed and implemented software tools to monitor changes in the master copy quantitatively.

These steps are considered by the FAO as making a contribution to the development of an online service in information management in support of agricultural education, extension and research globally. Our work with the FAO on AGROVOC can be accessed at http://agrovoc.icrisat.ac.in.

10.1.2 Strengthening Knowledge Flows to Facilitate Ease of Access to IPG's by Partners

During the year, we focused on designing various methods for easy re-use of digital content generated by ICRISAT and partners for a variety of purposes in education and extension. We continued the trials on satellite-connected two-way video conferencing as well. Our combined efforts led to the large scale testing of a prototype online repository of agricultural learning materials that can be accessed online or offline. They also generated inputs for a non-NARES partner, the IIT system, to develop a scaled-up platform to use mobile telephony and simple text messaging to connect a remote user to an online repository; it further contributed to the design of an approach for browsing online information with voice over telephone rather than with mouse-clicks on a PC. The key factor here is the wide-ranging involvement of NARES and ARI partners.

Over the last three years, we have been working with the design and production of reusable learning objects (RLO's), and developed a partnership with the University of Florida to advance our work. During the year 2008, we transformed the CGIAR-wide project for a Global Open Food and

Agriculture University (GOFAU) into a program for the production and distribution of RLO's, online as well as offline, with a curriculum framework at the core. The shift in focus of GOFAU, approved in 2007, led to renaming it as the Agricultural Open Source Curriculum Development (AGROCURI) project in January 2008. We designed the prototype portal based on the following core specification:

- Wiki-like, editable web interfaces with rating features (any user should be able to rate content)
- Work flows that enable to group of experts to initiate creation, review and approval of content for publication
- Granulated curriculum elements should be in the architecture of the portal to enable content creation directly as RLO's.

The prototype was designed and made available for intensive testing by an international audience in April 2008. The testing process was part of a project design workshop and had participants from 7 CGIAR centers, 8 NARES partners from SSA and south Asia, three ARI's besides the FAO. The testing process lasted for two days with 22 experts involved, and gave significant insights into the applicability of RLO techniques in the context of developing countries, especially those in SSA. Based on the inputs, the prototype was refined in its design, and served as a key component of the AGROCURI project. It has a framework that can accommodate up to five MS-level courses. Currently, the curriculum design is complete for two MS-level courses in agro-ecology and agri-economics. Each course typically has Modules, sub divided into Units which are made up of Sub-Units. Each course will have between 1500-1800 Sub-Units.

ICRISAT leads the work on curriculum development in agro-ecology, joined by a group of experts from 4 CG centers, 2 ARI's and 2 NARES partners. There is consensus on the course structure and on the approach of gathering contributions starting at the level of sub-units. Current discussions are on finalizing the RLO definitions: ICRISAT has followed the view of micro-granularity for promoting reuse of a learning object, while the ARI's prefer the sub-unit being defined as an RLO. The discussions are continuing. Based on ICRISAT approach, the Unit on organic farming has been prepared and is in review, and it has 160 RLO's. The prototype repository with VASAT-derived RLO's had approximately 15000 RLO's following ICRISAT definition.

During 2008, we worked with the IIT systems' aAQUA (www.aaqua.org) to formulate a program for the use of mobile telephony to access online content relevant to extension. The prototype was developed a the IIT in Mumbai, India, and has been deployed in three States of India through two NARES partner universities in late 2008. In one State (Maharashtra), the level of messaging in a month has reached an average of 900. Another prototype for voice-browsing of online content is in an advanced stage of design. Together, these methods provide much larger opportunities for sharing of expert-derived knowledge with stakeholders including farmers.

Auxiliary Activities Contributing to the Logframe Outputs:

Three streams of activities have contributed to the core activities on this project. The first stream is the large scale digitization and open archiving process in ICRISAT that makes it possible to create re-usable digital objects on a large scale. The second group of activities involves experiments in technology-mediated rural communication.

Large Scale Digitization and Setting up of Open Institutional Archives:

During the year 2007, ICRISAT commenced activities in association with the globally managed Million Books Project (http://www.ulib.org/) to digitise its publications since inception. As of the end of the year, about 40000 pages have been scanned and digitized and about 60 per cent of these scanned pages have been converted into the searchable PDF that can be indexed by major online search engines. During 2008, a total of 56000 pages in print had been scanned and converted into searchable PDF's, providing public access to just over 400 ICRISAT research publications. The software application to search this collection was designed in-house. These can be accessed at http://books.icrisat.org.; they can be downloaded without restriction on printing or storage.

We continued our efforts on building a digital collection of institutional research publications which included pre-print of journal articles, conference papers, book chapters, books, research publications etc. Around 4300 records having citation details of these categories of publications have been included in the database. During 2008 the database was tested by the OAI-PMH (the Open Archives Initiative Protocol for Metadata Harvesting) for structure conformity for harvestors to capture data. The database passed the test on all parameters. During the early part of the year 2008, this database was registered with the OAIster - an OA database harvestor from the University of Michigan, USA. Soon after the registration the OAIster has started harvesting our full-text digital documents from the database and made them available free to the Internet users. Since this harvestor selects only those records with full text links, out of the 4300 records, around 1100 full text records were harvested.

A simple search on ICRISAT crops in OAIster showed the following results (late 2008):

Crops	Digital Fulltext Documents
Chickpeas	210
Groundnuts	227
Pearl millet	145
Pigeonpeas	175
Sorghum	245

The Open Access database can be accessed at http://openaccess.icrisat.org

Experiments in Rendering Extension Support using ICT-Mediated Methods

We continued with a series of experiments on the effectiveness of video conferencing as an extension support arrangement, using satellite-video connected rural resource centers in three different states of India. with the satellite links provided by the Indian Space Research Organization. We have in this year tried to create a web-accessible database of farmer queries and expert responses using the aAQUA online application (www.aaqua.org). Activities under 10.1 have been linked to this collection of Q&A in order to provide for intelligent "mining" at any stage later. These design experiments are in an advanced stage. We assess that there is a need to train agricultural subject matter experts in providing responses for use on "mobile media" as most of the responses are accessed using mobile devices after the video-conferences. The consistency and regularity of ICRISAT efforts in video conferencing led to the recognition of being one of the top five centers in a network of 400 such centers. Based on the experiences, a publication involving the practices and procedures of Human-Computer Interfaces is under way. Over the last two years, our trials lead us to think that the VC when supplemented by easily accessible terminal devices such as mobile phones can indeed make a contribution towards blostering filed-level extension support. Managerial intensity required to sustain such operations is rather high and most NARES organizations need to build special capacity to take greater advantage of such tools and platforms in agricultural knowledge dissemination.

We continued and expanded our earlier studies on drought vulnerability assessment at a micro-level to cover 21 villages spread over 8200 ha. The methods used were same as in last year. We used satellite-derived imagery on a micro-scale and surface water balance studies to generate a series of color-cded maps of the vulnerable villages. As in the last year, these were presented in grades of three colors indicating scenario variations from extreme stress to business-as-usual. The assessment of the year 2007 experience carried out in early 2008 revealed that the CBO members found the maps useful in generating simple advisory in relation to water use. The scenarios generated for the main rainfall season of 2008 were extensively circulated by the CBO members and led to their approaching the local government to declare their area as drought-hit (14 out of 19 villages were assessed as facing serious water shortage and this was communicated to the CBO in July 2008). There is an ongoing effort to link this effort with a much larger effort using a platform such as the Google Earth.

Impact Pathways:
The Knowledge Models for SAT Crops have been built using software tools of the Semantic Web, and are themselves IPG's. They can be rendered into any language in which the FAO's AGROVOC has been rendered. There are 17 of them as of late 2008. They enable mapping of resources on the web irrespective of the content language, thus enabling ease of locating resources through online search across languages. This technology has long term implications in technology-mediated knowledge sharing in agriculture.

The models are an integral part of the "agropodeia" (http://agropodeia.net) which is a content platform designed by a non-NARES partner, the Indian Institute of Technology (IIT). The IIT, ICRISAT, and the FAO have jointly developed a number of specifications for concept relationships that are ready for standardization. This represents a significant impact, because of the way national and international organizations are creating national and international information public goods.

The knowledge models were "validated" through special-purpose workshops involving ICRISAT, FAO and NARES experts from India. The validation process takes available maps through iterations until the assembled groups of expert consensually agree to the named concepts and their relationships. The exercises commenced in late 2008, and the models available now represent the consensus as of that time. We anticipate that another round of validation will be necessary with wider range of partners in late 2009. This has led to new opportunities for capacity strengthening among NARES partners in the use of more effective methods in extension communication.

The models are now in use in "tagging" the data in a online Q&A forum (www.aaqua.org) and in the design of online decision support system for fertilizer input (www.ekrishi.og), both developed by the IIT system. They both can be deployed for local adaptation anywhere.

Partnerships in design, testing and deployment are at the core of this set of activities. They span the whole range of ARI's, CG centers, NARES partners including the CBO's. A key aspect of work in 2008 is the catalyzing of participation of non-NARES institutions in activities that have strong emphasis on knowledge sharing in agriculture. The comprehensive redesign of GOFAU into a primarily new generation knowledge support system in higher education is a significant development that has received partner endorsement.

Publications

Journal Articles published in Thomson Index

SNo.	ISSN No.	Journal Name	Journal Article
1.	1684-5315	African Journal of Biotechnology	DE VILLIERS S, Emongor Q, Njeri R, Gwata E, Hoisington D, Njagi I, Silim S and Sharma K. 2008. Evaluation of the shoot regeneration response in tissue culture of pigeonpea (*Cajanus cajan* [L.] Millsp.) varieties adapted to eastern and southern Africa. African Journal of Biotechnology 7(5):587-590.
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105.	1598-2254	Plant Pathology Journal	Osiru MO, **Adipala E**, Olanya OM, Reeder R, **Lemaga B** and KAPINGA R. 2008. Leaf petiole and stem blight disease of sweet potato caused by Alternaria bataticola in Uganda. Plant Pathology Journal 7(1):118-119.
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25.	1613-4516	Journal of Integrative Bioinformatics	JAYASHREE B, Rajgopal S, Dave Hoisington, Prasanth VP and Chandra S. 2008. Webstructure and VisualStruct: web interfaces and visualization for structure software implemented in a cluster environment. Journal of Integrative Bioinformatics 5(1):89. http://journal.imbio.de/index.php?paper_id=89.
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32.	0048-6019	Journal of Research-Punjab Agricultural University	Sandhu JS, Gupta SK, Bains TS, Pal SS and Singh S. 2008. PAU 881 – A high yielding and early maturing variety of pigeonpea *(Arhar*). Journal of Research-Punjab Agricultural University 45: 103.
33.		Journal of Water Management	Suhas P Wani, Sahrawat KL, SREEDEVI TK, Piara Singh, Pathak P and Kesava Rao AVR. 2008. Efficient rainwater management for enhanced productivity in arid and semi-arid drylands. Journal of Water Management 15(2):126-140.
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40.		The Journal of Financial Risk Management	Singh NP and Shunmugam V. 2008. Convergence of futures and spot prices: A co-integration analysis. The Journal of Financial Risk Management 4(4):41-47.
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44.	0567-7572	Journal of Food Legumes (*Formerly* Indian Journal of Pulses Research)	Gupta SK, Sandhu JS and Garg T. 2007. Combining ability analysis in *desi* chickpea. Journal of Food Legumes (*Formerly* Indian Journal of Pulses Research.) 20 (1): 25-28.
45.	0036-8512	Science Reporter	Gurina Bajaj, Kalra N, Chakraborty D, Singh Manish, Mittal RB, Pandey Suraj, SahooRN and Garg RN. 2007. Tropospheric ozone-Impacting Agriculture. Science Reporter 44.
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SNo.	ISSN No.	Journal Name	Journal Article
1.	3973-3094	E-Journal of SAT Agricultural Research	Ashok Kumar A, Reddy BVS, Sharma HC and Ramaiah B. 2008. Shoot fly (*Atherigona soccata*) resistance in improved grain sorghum hybrids. E-Journal of SAT Agricultural Research. 6: 1-4 http://intranet/Journal/Volume6/Sorgum_Millet/Ashok_Shootfly.pdf
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6.	3973-3094	E-Journal of SAT Agricultural Research	Sastry DVSSR, Upadhyaya HD and Gowda CLL. 2008. Seed viability of active collections in ex-situ Genebanks: an analysis of sorghum [*Sorghum bicolor* L. *Moench*.] Germplasm conserved at ICRISAT Genebank. E-Journal of SAT Agricultural Research 6:1-8 http://ejournal.icrisat.org/Volume6/Sorgum_Millet/Sastry.pdf
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Book Chapters

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The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a non-profit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT is supported by the Consultative Group on International Agricultural Research (CGIAR).

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