ICRISAT in West & Central *Africa*
The Seeds of Success Germinated

Archival Report 2005

ICRISAT

International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India
www.icrisat.org

Contents

ICRISAT in West & Central Africa
The Seeds of Success Germinated

Archival Report 2005

Global Theme – SAT Futures
Cynthia Bantilan – Global Theme Leader
Jupiter Ndjeunga – Regional Theme Leader

Introduction

In keeping with the recommendations of the last external review, ICRISAT focused on research programs through four global themes, one of them being Markets, Policy and Impacts. The objective of this global theme is to inform and provide strategic direction and prioritization of research in the semi-arid tropics. It scrutinizes the key driving factors influencing farmer to market linkages, optimal input and output options (including seed systems) and on more effective policy and impact generation. The poor in the semi-arid tropics face a wide range of social and economic constraints, so the theme maintains constant communication with them to understand their needs and seek solutions.

The theme aims to deliver vital information and analytical tools that provide a rational foundation for decisions that affect the welfare of farmers and consumers in the semi-arid tropics. It builds from ICRISAT's strong socioeconomics and policy research rooted from a long tradition of working at the farm level, and strengthened by the participatory and multi-disciplinary approaches to ensure that ICRISAT addresses the pressing concerns in SAT agriculture and the changing external environment both at the micro and the macro-level. With innovative partnerships with other global themes, the NARS and other stakeholders, the theme effectively contributes to the global research agenda by complementing the efforts of national programs to improve the well being of SAT populations in Asia and Africa.

Priority foci

The research agenda of the Global Theme on Markets, Policy and Impacts is focused on three key areas:

- Strategic assessments for agriculture and economic growth in the semi-arid tropics of Asia and sub-Saharan Africa, and implications for agricultural research priorities
- Development pathways and policies for rural livelihoods
- Synthesis studies: lessons learned from impact studies, institutional arrangements and implications for research spillovers across regions

The strategic linkages of the theme with the other global themes target analytical contributions relating to the evaluation of technology investment trade-offs, resource pricing issues, analysis of market preferences and opportunities, collective action, and understanding the uptake process and binding constraints to technology adoption. In particular, linked activities are established on:

- Priority setting, adoption and impact assessment (linked with GTs BT, CI and AE)
- Farmer investment strategies in soil and water management technologies (linked with GT AE)
- Seed systems and technology delivery pathways (linked with GTs BT, CI and AE)
- Markets and product commercialization (market preferred traits, market trends, constraints and synthesis) (linked with GT CI)

The social science team has been successful in using a targeted approach, where resources are directed at specific target areas to draw lessons applicable over much broader areas. It continues to support the institute's targeted efforts for science quality, relevance and impact in the semi-arid tropics. This team has

- generated a large SAT knowledge base
- helped inform decision making on policy issues
- documented impact pathways and impacts generated by ICRISAT-NARS technologies
- built up a network of partnerships as the base for further collaborative studies.

Goal
People-oriented and partnership-based social science research has helped generate tools, lessons, policies 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

Purpose
- Researchers and policy makers in the SAT adopt and implement new tools, policy recommendations and best practices to make efficient choices in support of SAT agriculture
- SAT farmers adopt alternative risk reducing, income diversification and commercialization strategies and innovations for improved livelihoods
- Researchers in the NARS, IARCs and other actors in the research for development continuum adopt innovation systems (institutional arrangements, alliances, and monitoring & evaluation) to promote the learning function and impact

Specific objectives
- Undertake strategic assessments that inform agriculture and economic growth opportunities in the SAT;
- Carry out a combination of sharply focused micro, meso and macro level studies that best inform the overarching and longer-run research priorities in the SAT;
- Synthesize information across countries and regions to draw lessons and international public goods;
- Develop strong links across disciplines in order to translate information and analysis into decision making and resource allocation; and
- Ensure feedback loops from impact assessment to priority setting.

Theme deliverables
- Knowledge on rural investment patterns, market opportunities, commodity outlooks and implications for agricultural research priorities in SAT farming systems
- Micro level database and information on the dynamics and determinants of poverty, development pathways and policies for rural livelihoods
- Policy instruments for technology delivery, market development, and agricultural diversification in the SAT
- Innovative institutional arrangements and mechanisms for technology exchange, market access and targeting of spillovers based on institutional experience
- Synthesized and policy relevant information on technology adoption pathways and impacts
- NARS capacity building and policy communication

Sub-Project: Pro-agricultural development policy environment for food security and disaster prevention & mitigation

Focus: Strategic Assessments

Generic Output: Pro-agricultural development policies promulgated by governments regionally

Output target: Why is agricultural transformation lagging behind in the SAT?

Research led by the Consultative Group of International Agricultural Research (CGIAR) centers, Advanced Research Institutions (ARI), and National Agricultural Research Systems (NARS) have generated a wide range of technologies in West Africa. However, adoption of improved technologies has been low and not on a sufficient scale to lead to increases in agricultural productivity or per capita food production during the last three decades. Lessons from East Asia showed that productivity growth is the entry point to agricultural transformation. Other major ingredients that have contributed to the broad-based growth of Asian economies are the improvement of inputs, credit, and product markets in addition to adequate road infrastructure to ensure households' access for improved farm productivity. Institutions are induced to change by the advent of improved rice and wheat technologies in Asia, as it has enhanced the profitability of innovations.

This study focuses on the assessment of agricultural transformation in the semi-arid tropics of West Africa. It uses a regional survey of rural households in 3 countries to determine factors explaining uptake of improved technologies focusing on fertilizers and improved varieties of sorghum and pearl millet varieties, which are the major cereal crops grown in the West Africa Semi-Arid Tropics (WASAT).

Methodology: The study uses both secondary sources of information and primary data from a regional survey of rural households conducted in Mali, Burkina Faso and Niger in 2000-2001 (ICRISAT/NARS/IFAD, 2000 & 2001). Three types of data were collected at the village, the household and plot. Forty-six (46) villages were chosen using 3 criteria: agro-climatic zone, road and market access. Using agro-climatic zones defined by the length of growing period (LGP), three target regions were defined: (a) the areas with a period of less than 100 days of LGP were considered suitable for pearl millet production (Sahel); (b) areas with a LGP between 100 and 150 days were considered suitable for sorghum (Sudanian), and (c) areas with a LGP of more than 150 days were considered suitable to sorghum and maize production. Villages located at less than 5 km from the nearest markets were defined to have good access to markets, and other villages were considered to have poor access. Similarly villages located at less than 5 km from the main road were regarded as favorably accessible, while villages that were more than 5 kms away were poorly accessible. Overall, 16 villages were selected in Mali, 23 in Burkina Faso and 7 in Niger. Out of the 46 villages selected, 28 had good access to the main road, whereas 16 villages had good access to input or product markets. Thirteen villages were located in the most drought prone areas of the Sahel, with 26 villages in the Sudanian zone and the remaining in the Guinean zone.

In addition, 24 villages were found to be at close proximity to seed multiplication units, and 27 villages were endowed with credit institutions. At the village level, data was collected on rural livelihood assets, which included the institutions and projects operating in the village, the endowments on natural resources, the socio-demographic profile, and important economic activities at the village economies. In each village, an average of 20 rural households was randomly selected using the village census. A structured survey was administered to 983 rural households chosen from the 3 countries in 2000-2001. At the household level, data was collected on the socio-demographic profile, agricultural equipment, land ownership and utilization, livestock and crop stocks, transactions, soil fertility management practices and farmers' perception of soil restoration practices, water conservation methods, and sources of information on agricultural innovations. Similarly data was gathered on village seed markets and its structure, conduct and performance, variety management, and motivations for participating in the seed markets, particularly for sorghum and pearl millet, which are the two most important crops grown in WASAT.

In each household, data was collected on the major communal and individual plots. These included input/output data and plot characteristics such as crop production and plot area, types of crops and varieties used, quantities and types of seeds, and fertilizer used, seed and fertilizer supply sources, plot ownership, farmers' prior knowledge on plot soil fertility and, method and period of application. A K-means cluster analysis was used to classify rural households into wealth status such as the high, middle and low class farmers. Logit models were used to assess the determinants of uptake in fertilizer and improved variety use. Analyses were performed using SPSSPC+ 9.0 (SPSS, 1999) for the cluster analysis and STATA Version 7.0 for regressions analyses (StataCorp, 1999).

Key findings: *Uptake of improved pearl millet and sorghum varieties.* Results from the regional survey of rural households in the WASAT indicate that 33.2% and 20.5% of rural households in Mali claimed to use improved sorghum and pearl millet varieties, respectively. In Niger, about 10.9% and 33.2% have reported using improved sorghum and pearl millet varieties, respectively. The uptake of improved varieties in Burkina Faso is very low. In fact, less than 5% of farmers have reported using improved sorghum or pearl millet varieties.

Adoption rates for improved varieties are increasing, but the rate of productivity gains has been slow. This is due to a combination of factors including the limited productivity gains recorded from using improved varieties, the limited access to information or experimentation on new varieties, and the limited access to seeds of improved varieties. In fact, new varieties derived from agricultural research programs may not be suited to the environments and preferences of small-scale farmers. In other cases, farmers simply do not know about the new varieties or have not tested these varieties. Even if farmers have experimented with the performance of these varieties, few farmers have ready access to quality seeds of most new crop varieties. This is explained by the underdevelopment of national and regional seed markets. Retail distribution channels for seeds are often very few and limited to urban areas.

For the case of sorghum, at sample means, the estimated coefficients indicate that the most important determinants of the probability of increasing uptake are the location in the high rainfall zones (Guinean zone), and the proximity of seed multiplication and distribution centers. The marginal effects of the age of the household head, farm size, location in the Sahelian zone, proximity to input/product markets, and proximity to the road on the probability of uptake are positive but insignificant. Similar results are found for the case of pearl millet. However, the negative effects of access to input/product markets and proximity to the main roads are unexpected. In fact, farmers growing pearl millet are located in the less favorable rainfall zones, where markets are under-developed and the road infrastructure is poor. Crop improvement programs have put less emphasis on "demand-led" breeding where the farmer is the focal point. Farmers like to experiment and should be exposed to a range of choices. It is now common to test a wide range of varieties on the fields of small-scale farmers and review what farmers think of these cultivators.

Such participatory methods have recently been adopted whereby farmers themselves make varietal selections over several generations of breeding. This would undoubtedly improve the likelihood of adoption if the significantly improved seed is ultimately made available. It is increasingly known, however, that one cannot achieve the productivity gains with varieties alone. Improved varieties have to be linked with improved management practices. The uptake of soil fertility and water management practices by rural households is presented below.

Uptake of inorganic and organic fertilizers by rural households in 2000. The use of inorganic and organic fertilizers remains the most popular methods for soil fertility restoration options. In all countries, about 50% of the rural households used inorganic fertilizers and 70% used organic fertilizers. Fallow, crop residues, rotation and association are also methods practiced by farmers.

Farmers are well aware of potential productivity gains derived from using improved management practices. Most farmers have reported declining soil fertility and many of them perceived organic and inorganic fertilizers as being complementary. However the limited use of fertilizers is explained mainly by high fertilizer costs, poor access to fertilizers, and poor access to credit.

Fertilizer use remains extremely low on all fields except those growing a few cash crops. Farmers do not use the research and extension recommendations except for cash crops such as cotton. For example, farmers use 10 kg/ha of fertilizer on sorghum, whereas research and extension recommendations are 100 kg of NPK and 50 kg/ha of urea. National extension recommendations for semi-arid areas continue to call for high rates of fertilizer, manure and insecticide application. Farmers producing a commercial crop are more likely to adopt improved soil and water management practices including the use of fertilizer, timely planting, better ploughing and the application of contours. This implies that crop management advice needs to be more closely linked with efforts to expand commercial production. Blanket recommendations for crop management practices need to be replaced by targeted recommendations suited to each farmer's marketing objectives. This raises questions about how best to provide a wider range of different sorts of extension advice to different farmers.

The results indicate that in Burkina Faso (at sample means), access to markets, proximity to the main road, farm size and the cultivation of cotton are the significant variables with positive impact on the probability of use of inorganic fertilizers. Farmers who are close to markets are likely to apply more fertilizers to derive more surplus for sales. Similarly, farmers located in areas with better access to the main road are more likely to invest in fertilizers because they incur less transport cost in purchasing inputs from the markets. Although not significant, other variables had the expected signs. Similar results were found in Mali.

Conclusions and implications for research and development priorities. This study focuses on uptake of sorghum and pearl millet improved varieties and adoption of soil fertility restorations options in three countries in the semi-arid tropics of West Africa. It identifies constraints to uptake of improved technologies. Results from the regional survey show that sorghum and pearl millet productivity gains have been limited by low performing varieties, poor functioning institutions which are supposed to supply and deliver technologies at low costs, poor functioning credit, fertilizers and seed markets, missing markets and poor road infrastructure.

The agricultural transformation is likely to happen if policy makers could foster investment in road infrastructure to reduce transport or transaction costs and provide an enabling environment for the development of input and product markets. Scientists should continue to develop technologies that could be adopted by farmers for the purpose of high productivity gains. In addition, efforts should be made by scientists to design institutional arrangements that will facilitate technology flow up to the farmers.

Collaborating Institutions and Scientists:

FASID (Japan) : Keijiro Otsuka
ICRISAT : J Ndjeunga, MCS Bantilan

Focus: Rural Livelihoods and Development Pathways

Output target: Longitudinal Village Level Study Surveys: changes, livelihood strategies and outcomes in WCA

This study assesses changes in rural livelihood strategies and outcomes in west and central Africa using the case of 4 villages in Western Niger. During the last three decades, donors and governments have largely invested in agricultural research and development in Niger. These efforts led to the development of a wide range of technologies that have been disseminated through public, non-governmental organizations or parastatal institutions. Yet many of these technologies have limited impact on rural livelihoods and the structural transformation of the economy — the process whereby a predominantly agrarian economy is transformed into a diversified and productive economy dominated by manufacturing services — is still lagging.

Substantial socio-economic research led by CGIAR centers, Advanced Research Institutions (ARI), and NARS have been carried out piecewise and not integrated in a holistic way to account for factors such as the markets, policies and institutions and the livelihood strategies that are constantly changing. During the last three decades, households may have shifted their investment priorities or overall changed their livelihood strategies and formulate new risk coping mechanisms to reach another state of development. It is therefore essential to understand the trends in livelihood strategies and outcomes in order to identify priority research areas, policy and development interventions that will enhance production, productivity growth and sustainable pathways of development.

Understanding development pathways is critical in explaining poverty and its dynamics.
Are poor farmers in the 1980s still poor today or vice-versa? Did rich farmers in the 1980s fall into poverty or vice-versa and what are the factors explaining these trends? The assessment of poverty and its dynamics requires information that is useful to compare past and current poverty indicators and factors explaining thereof. The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) has collected a unique longitudinal data in 4 villages of Niger from 1982 to 1985 (McIntire, 1988) that could be used as baseline for comparison.

There is therefore a need to revisit these 4 villages and gather information in order to identify poverty pathways and factors explaining development pathways. As a first step, a PRA was conducted in order to identify the major drivers of changes that could be hypothesized in the 4 villages in order to formulate research questions and hypotheses to be further tested.

<u>Specific objectives are to:</u>

- identify and assess the potential changes in livelihood assets (natural, physical, natural, social and financial/economic) at village level perceived by farmers
- characterize potential changes in crops, cropping patterns and cropping systems
- assess changes in the access, availability and use of modern technologies in the form of varieties, fertilizers, agricultural equipment or soil and water technologies.
- identify households' income diversification and investment options as well as the linkages between farm and non-farm activities

Methodology. The PRA team was composed of agricultural economists, agronomists and extension agents. The PRA were conducted in April 2004 in Gobery (3-4 April), Fabidji (11-12 April 2004), Sadeizi Koira (18-19 April) and Samari (20-21 April). Analysis and write-up were undertaken in 2004-2005.

Five major PRA tools were used and included: a review of literature and secondary data, the introductory community meeting, the historical profile, the community territory and resource map and VENN diagram. In each village, the team spent 3 days starting with an introductory meeting to discuss with farmers about the procedure to be followed in the diagnostic phase. Semi-structured interview (SSI) was used as stand-alone or along with other tools such as the historical profile, the community territory and resource map or the Venn diagram. Questions were formulated in a logical sequence as we went along based on who? what? why? when? where? and how? In addition, triangulation was used to cross-check farmers' claims. To avoid the dominance of gender, welfare status, old versus youth; opinion leaders and non-opinion leaders, men and women, head of household and heads of farm units; groups were formed to address specific questions.

Key findings: Overall, farmers in the higher rainfall zone have reported significant improvement in their income and well being compared to farmers located in the low rainfall zone who are reporting significant losses in their overall welfare and their inability to secure food. Increased opportunities for income diversification inside and outside the agricultural sector including migration, better access to markets and infrastructure, increased use of fertilizers and agricultural equipment tend to support these claims. However in all the villages, the use of modern varieties and the access to formal credit have not changed and are still very limited. Farmers in low endowed areas are reporting losses in pearl millet and sorghum varieties and their inability to grow crops such as maize. This opens up a range of new hypotheses to be further tested in structured surveys. The impact of market liberalization seemed to have been very limited in rural areas. This research is likely to generate additional information necessary for policy formulation, research and development planning.

Livelihood assets and technologies. There have been changes in the types of crops grown, cropping systems and technological practices by farmers during the last 25 years. The use of modern technologies remains limited despite numerous efforts at developing and disseminating modern technologies by R&D institutions. There is virtually no systematic use of modern sorghum or pearl millet varieties, fertilizers and other inputs such as fungicides, insecticides and pesticides. However, the use of animal traction is one of the most significant break-through. Many more households own animal traction equipment especially in the more favorable rainfall areas. In low rainfall zones, farmers are complaining of loss of some varieties and crops due to the shortening of crop cycle and repeated droughts. The identification of constraints to uptake of modern technologies remains a major challenge for national and international research and development institutions. The potential losses in bio-diversity need to be proven as well as its impact on productivity and resilience. Research and development interventions likely to enhance agricultural productivity are essential.

Income diversification. Income diversification is perceived by households as strategies to cope with climatic, production and price risks. Income diversification strategies change according to agro-climatic zone. In Gobery and Fabidji, the presence of the Dallol (with assured water) has provided opportunities to farmers to diversify within the agricultural sector especially into vegetable production especially during off-seasons. In addition, farmers have also well diversified much into the secondary and tertiary sectors mainly due to market opportunities offered by their proximities to a large market: Fabidji. Processing, handicrafts, short and long-distance trading for livestock or natron exporters, cereal trade, and a range of petty jobs such as groundnut oil processing, vegetable sales, handicrafts are also well developed. Whereas in low rainfall areas of Samari and Sadeizi Koira, there are few opportunities to diversify within the agricultural sector due to poor climatic conditions. Farmers are diversifying outside the sector. Long distance trading of wood, cowpea haulms or millet stalks and migration are the main survival strategies. In all the villages surveyed, income diversification options have changed in response to the development of markets opportunities, better use of resources (i.e. water in the dallol), or low returns to agricultural labor. There is a need to identify households' income diversification strategies and the necessary policy, institutions and technological changes that would affect the rural non-farm economy and translate these into research and development interventions that generate employment and reduce poverty.

Migration. Migration is practiced in all the 4 villages but its importance in improving livelihood outcomes varies by agro-climatic zone. In Gobery and Fabidji, migration tends to move from seasonal to even permanent. It is practiced mostly by the young men in the households. According to groups of farmers interviewed, at least 1 out 3 households in the 2 villages has at least one member in temporary or permanent migration. Revenues from the migration are often shared within the households and are partially used for investment or consumption purposes. Revenues from migration are rarely reinvested in agriculture nut rather in trade. In the low endowed areas of Sadeizi Koira and Samari, migration is a major survival strategy. Every year, at least one member of the household is engaged on seasonal migration. Revenues from migration are mainly used to ensure household food security. Both men and women migrate. Migration patterns have not changed much during the last 25 years but their intensity and importance in livelihood strategy has significantly increased. The returns to migration, optimal migration pathways and its impact on agricultural production and rural livelihoods should be well investigated.

Markets and infrastructure. During the last 25 years, there has been a poor development of input and product markets despite market liberalization in the 1980s and currency devaluation in 1994. Except in Samari where a new market has emerged, in Sadeizi Koira, no market has been developed. In Gobery, the market created some 50 years has not expanded much but the market transactions in Fabidji have expanded considerably. Although all villages are connected to a set of markets, these markets are far away from those villages, thereby increasing trading costs except in Fabidji where transaction costs are low and market transactions have increased considerably. In Gobery, Fabidji and Samari, there are market niches for vegetable crops. Farmers report poor access to and availability of essential inputs such as seed of modern varieties or fertilizers. The role of markets in agricultural transformation needs to be well researched.

Collaborating Institutions and Scientists:
Institut National de Recherche Agronomique du Niger(INRAN): M Zarafi, M Nouhou
ICRISAT : J Ndjeunga, A Amadou

Generic Output: Adoption and impact studies

Output target: Impacts of sorghum and millet research in west and central Africa (WCA): A synthesis and lessons learnt (Linked with GT CI)

Working Paper series no.22 entitled "Impacts of sorghum and millet research in west and central Africa (WCA): A synthesis and lessons learnt" is produced. In a time of increasing scrutiny about the usefulness of investments in agricultural research, impact assessment studies assist to demonstrate the value of continued investments in research. Lessons learnt from impact assessments can be used to improve future research strategies, plans and management. This paper reviews and synthesizes the findings of various studies on the adoption and impact of the research on sorghum and millet technologies in West and Central Africa (WCA). The review covers Burkina Faso, Cameroon, Chad, Mali, Nigeria and Niger, where relatively more breeding research has been conducted. Furthermore, the information is mainly drawn from the diffusion and impacts of varieties generated by ICRISAT and the national agricultural research systems (NARS) of WCA. Findings from reviewed studies show that returns to research (and diffusion) investments are quite high, but the performance varies across countries. These results could be of use to policy makers, donors and other scientists within the region of WCA for priority setting and resource allocation. However, the results of the studies reviewed also indicate that if improved technology is to make a meaningful impact at the farm level, it must be accompanied by at least three complementary factors: 1) an effective extension service, 2) an efficient inputs distribution system, and 3) appropriate economic incentives.

Collaborating Institutions and Scientists:

INRAN, Niamey, Niger	: Issoufou Kapran, Samba Ly, MA Zarafi, Jika Naino
IER, Mali	: Aboubacar Toure
Syngenta	: Niangado
Purdue University	: Williams Masters
WARDA	: Inoussa Akintayo
IAR-ABU	: Aba , Da San San
Consultant, Niamey, Niger	: Ouendeba Botorou,
ICRISAT	: Y Camara, J Ndjeunga, MSC Bantilan, K Anand Kumar, SC Gupta, Eva Weltzein, Fred Rattunde, AB Obilana,

Output target: Impact of input shops on technology uptake in WCA: The example of Niger published by IFPRI/ICRISAT (Linked with GT AE)

Rationale: Niger is one of the poorest countries in the world. Only about one-eighth of the land area is suitable for cultivation, and this portion has fallen in the past several decades due to declining rainfall and land degradation (Abdoulaye and Sanders 2005). One critical manifestation of land degradation is depletion of soil fertility due to declining use of fallow resulting from rapid population growth and limited use of inorganic or organic fertilizers. Land degradation (together with climate change) has led to low and declining crop yields and increasing food insecurity. During the past two decades, yields of pearl millet (the dominant crop) have fallen 1% per year on average (FAOSTAT 2005).

To help address these problems, FAO and the government of Belgium initiated Project Intrants ("inputs project") in 1999, which established a network of input supply shops and inventory credit (warrantage) schemes to promote farmers' use of fertilizer and other inputs and access to credit. The project is also promoting use of fertilizer "micro-dosing", an improved application method in which a small amount of fertilizer is combined with seeds before or during planting, and additional side dressing may be applied to the plant after emergence. In this study we investigate the impacts of access to inventory credit (warrantage), input supply shops, fertilizer micro-dosing demonstrations, and other factors on farmers' use of inorganic and organic fertilizer in Niger, and the impacts on crop yields.

Several hypotheses were formulated:

- H1. By relaxing liquidity constraints and improving marketing of output, availability of warrantage credit should increase adoption of inorganic fertilizer and other purchased inputs, leading to higher yields
- H2. By reducing farmers' cost of purchased inputs, availability of input supply shops should increase use of purchased inputs and increase yields
- H3. Technical assistance promoting fertilizer micro-dosing may lead to either less or more use of inorganic fertilizer, depending on the level of fertilizer used and its profitability prior to such assistance. For households not previously using fertilizer, demonstrations of the effectiveness of micro-dosing may promote increased fertilizer use, while for those who had used fertilizer at larger doses, micro-dosing may reduce use. In either case, the marginal productivity of fertilizer use should increase
- H4. Income generating assets and activities may promote increased use of purchased inputs by relaxing liquidity constraints. The impact of such assets and activities on crop yields is ambiguous, however, since they compete with crop production for labor
- H5. The amount of inputs used per hectare may be lower on larger farms as a result of liquidity or labor constraints. As a result, crop yields may also be lower on larger farms.

Study regions and data: The study was conducted in four regions of Niger where Project Intrants is active: Dosso, Maradi, Tillabery and Zinder (Figure 1). These regions are in the arable dryland zones of Niger, with annual rainfall generally ranging between 200 and 800 mm. Average rainfall is lowest in Zinder and highest in Maradi and Dosso. Soils are generally sandy with low inherent fertility and moisture holding capacity, except in river valleys where clay soils are found. Market access to the capital of Niamey is greatest in Tillabery and Dosso, while Maradi is close to urban markets in Nigeria. About 70% of the population of Niger resides in these regions.

Forty study villages were purposively selected in the four regions, based on access to input shops. Ten villages were selected that have an input shop, and for each of these, three additional villages were selected from 5 to 20 km. away.

In each village, ten households were randomly selected for the survey for a total of 400 households (three sample households did not complete the survey). All plots operated by each selected household were also surveyed.

The farming system in the study regions is dominated by intercropping of millet with various other crops (cowpea, sorghum, peanuts, hibiscus), though some pure stands of crops are also produced (especially of millet). Inorganic fertilizer is used on 23% of the plots surveyed. Inorganic fertilizer is most commonly used on the millet-cowpea-hibiscus intercrop (34% of plots) and least common on peanuts (4%). By far the most common fertilizer used is NPK (15-15-15) (18% of plots); other inorganic fertilizers used include urea and DAP (3%), PST (1.3%) and SSP (0.7%). On plots where NPK is used, the average amount used is only about 11 kg/ha. Micro-dosing is the most common method of applying inorganic fertilizer (90%), while broadcasting and line spreading are used on only 10% of plots.

Organic fertilizer is used on 32% of the plots. Organic fertilizers are most common on intercropped plots. Where organic fertilizers are used, the average amount used is 2.1 MT/ha. Average crop yields in the survey were about 600 kg/ha each for millet, sorghum and cowpeas, across all crop systems. Interestingly, yields are higher in intercrop systems than in pure stands.

Key findings: We find that access to warrantage and input shops and participation in fertilizer micro-dosing demonstrations have increased use of inorganic fertilizer. Access to off-farm employment and ownership of traction animals also contribute to use of inorganic fertilizer. Use of organic fertilizer is less affected by these factors, but is substantially affected by the household's crop mix, access to the plot, ownership of durable assets, labor and land endowments, and participation in farmers' associations. Land tenure influences both inorganic and organic inputs, with less of both on sharecropped and encroached plots.

Inorganic fertilizer has a positive impact on millet yields, with an estimated marginal value-cost ratio greater than 3, indicating significant profitability. Organic fertilizer has a positive impact on millet-cowpea yields. We find little evidence of complementarity between inorganic and organic fertilizer.

Since warrantage, input supply shops and fertilizer micro-dosing demonstrations increase use of inorganic fertilizer which in turn increases millet yields; these interventions indirectly increase millet yields, although the impacts are relatively small. These findings support promoting increased input use through promotion of inventory credit, input supply shops and fertilizer micro-dosing demonstrations. Other interventions that could help to boost productivity include promotion of improved access to farm equipment and traction animals and improved access to land under secure tenure.

We find that access to warrantage and input shops and participation in fertilizer micro-dosing demonstrations have increased use of inorganic fertilizer in Niger. Access to off-farm employment and ownership of traction animals also contribute to use of inorganic fertilizer. Use of organic fertilizer is less affected by these factors, but is substantially affected by the household's crop mix, access to the plot, ownership of durable assets, labor and land endowments, and participation in farmers' associations. Land tenure influences both inorganic and organic inputs, with less of both on sharecropped and encroached plots.

Inorganic fertilizer has a positive impact on millet yields, with an estimated marginal VCR greater than 3, indicating significant profitability. Organic fertilizer has a positive impact on millet-cowpea yields. We find little evidence of complementarity between inorganic and organic fertilizer.

Since warrantage, input supply shops and fertilizer micro-dosing demonstrations increase use of inorganic fertilizer which in turn increases millet yields in pure stands, these interventions must indirectly increase millet yields. However, we do not find significant impact of these factors on millet yields in the reduced form regression; probably because these effects are quantitatively small. We do find significant impacts of access to input shops and fertilizer demonstrations on yields of different millet intercrops (both in production functions and the reduced form regressions), although though effects are mixed, probably because of differential effects of fertilizer on different crop mixes.

These findings support the Projet Intrants approach of promoting increased input use through development of inventory credit and input supply shops and demonstrations of fertilizer micro-dosing. However, the impacts on crop yields appear to be relatively small. Other interventions that could help to boost productivity include promotion of improved access to farm equipment and traction animals and improved access to land under secure tenure.

Collaborating Institutions and Scientists:

IFPRI	: John Pender, E Kato
ICRISAT	: J Ndjeunga, B Gerard
INRAN	: T Abdoulaye

Output target: Report published on early adoption of pearl millet varieties in Niger (Linked with GT CI)

Between 2000/01 and 2002/03, participatory pearl millet variety selection trials were undertaken in 2 regions of Niger, Dosso and Maradi to promote varieties developed by ICRISAT and INRAN during the last 20 years. The Catholic relief Services (CRS) and the offices of the Ministry of Agricultural Development have been involved in the monitoring of PVS trials. However, little is known on farmers' preferences for those varieties, and the constraints to- and level of uptake of pearl millet varieties by farmers. This study investigates on the diffusion of improved millet varieties, to determine the factors affecting adoption, and to propose research and development options to improve their adoption.

Methodology: The study was conducted during April 2005 in the departments of Doutchi, Aguie, Madarounfa in the regions of Doutchi and Maradi where PVS trials were carried out. Data were collected from primary and secondary sources. Secondary sources included published and unpublished information on the socio-economic characteristics of the 2 regions. Primary data were undertaken using structured surveys at village, household and plot levels.

Village level information includes infrastructure and resource endowments. Household surveys included questions on socio-economic and demographic characteristics of households (socio-economic profile, agricultural equipment, and livestock ownership), technologies (exposure, information, and perception), production technologies at plot level (area under improved and local pearl millet varieties, use of fertilizers, yields, cropping systems) and household market transactions. Farmers were selected from 10 districts were 7 pearl millet varieties (ZATIB, HKP, CIVT, P3KOLLO, ICMV IS 89305, ICMV IS 94206, SOSAT C88) were introduced. In each district, 30 households were randomly selected. Thus, a total of 300 households were interviewed.

Collaborating Institutions and Scientists:

Consultant (Niger)	: Quendaba Botoron
Institut National de Recherche Agronomique du Niger(INRAN)	: K Iossufou
ICRISAT	: Y Camara, J Ndjeunga

Output target: Data collection on impacts of sorghum and millet varieties in Northern Nigeria completed (Linked with GT CI)

Rationale: Since the 1990s, ICRISAT and IAR have developed improved pearl millet and sorghum varieties and hybrids suitable to a range of agro-ecologies in Northern Nigeria. These varieties have been disseminated through on-farm trials and demonstrations by agricultural development projects. Seed companies have been involved in the multiplication and marketing of these varieties and breweries have been using sorghum varieties for processing malt. Despite the perceived high level of demand for some of these varieties, little is known on the level of uptake, the determinants of variety uptake and the economic impact of this research and extension investments in Nigeria. This study assesses both the economic impacts of improved pearl millet and sorghum varieties.

Methodology: Data collection was undertaken in July 2005 in Northern Nigeria. A random sample of 840 farmers was interviewed in 6 states in Northern Nigeria (Benin, Gombe, Kano, Kaduna, Katsina, and Jigawa). The sorghum varieties investigated include ICSV 400, ICSV 111, SK 5912, ICSH 89002 NG, ICSH 89009 NG, NSSH 91001 and NSSH 91002 and millet cultivars included SOSAT-C88, GB 8735, EX BORNO, LCIC 9702, LCIC 9703, ICMV-IS 89305 and GWAGWA.

Data were collected at village, household and plot levels. Village level information includes infrastructure and resource endowments. Household surveys included questions on socio-economic and demographic characteristics of households (socio-economic profile, agricultural equipment, and livestock ownership), technologies (exposure, information, and perception), production technologies at plot level (area under improved and local pearl millet varieties, use of fertilizers, yields, cropping systems) and household market transactions.

Output target: Handbook and training module on farmer participation in priority setting for crop improvement published (Linked with GT CI)

The publishing of "Setting Breeding Objectives and Developing Seed Systems with Farmers. A Handbook for Practical Use in Participatory Plant Breeding Projects" provides a major resource for enhancing the effectiveness of participatory selection for crops in WCA, and beyond. This book provides and IPG framework for description and analysis of target environments, production- and seed-systems. It provides a range of methods, approaches and communication tools for breeders and farmers to work together, with practical advice on planning and implementing participatory breeding activities.

Collaborating Scientists:
ICRISAT : J Ndjeunga, Eva Weltzein, Bettina Haussman

Output target: Data collection on impacts of soil and water conservation methods in Burkina Faso completed (Linked with GT AE)

Data collection on impacts of soil and water conservation methods in Burkina Faso completed. A PRA was undertaken with main objective to gather relevant information on soil and water conservation technologies practiced by farmers in Northern Plateau of Burkina Faso, determine the incentives and motivations to use these technologies; pre-assess the impacts and pre-identified the constraints to uptake of these technologies. PRA tools were used to gather information from key resource persons from 2 contrasting villages: Ziga in the Yatenga province and Rissiam in the Bam province.

PRA results show that stone bunds and zaï were the most widely used technologies in the Ziga villages whereas, stone bunds, small dikes, and dikes were the most widely used technologies practiced by farmers in Rissiam. Farmers often used more than one conservation technology to maximize benefits from conservation structures. According to farmers' groups interviewed, there have been impacts due to the use of these technologies and translated by land recoveries, regeneration of land cover, increase in the water table, improvement of households' production and revenues and population fixation. However, constraints to adoption have been reported as insufficient labor, lack of organic manure, lack of equipment and plants.

This PRA was followed by a structured survey in the North, centre-north and centre regions of Burkina Faso. In each region, 7 villages were selected on the basis on population densities, and market access and relative assessment of uptake. In each village, 1 village with high adoption, 2 with average adoption, 2 with low adoption and 2 control villages were purposely selected. In each village, on average 23 households were randomly selected. Therefore a total of 483 households were interviewed. Four questionnaires were developed to gather information at (1) village level, (2) project level, (3) household and plot levels, and (4) research and extension costs. Information will be used to assess impact using the economic surplus and the econometric models.

Collaborating Scientists:
ICRISAT : J Ndjeunga, B Gerard, R Tabo

Output target: Testing and promotion of micro-dosing technology - report completed (Linked with GT AE)

Fertilizer micro-dosing technology was further tested and promoted in Burkina Faso, Ghana and Niger. Yields of sorghum and millet increased by 44 to 120 % while income of farmers increased by 52 to 134 % when using fertilizer micro-dosing and "warrantage" (inventory credit system) than with the earlier recommended and farmer traditional practices. The nitrogen use efficiency (NUE) of sorghum with micro-dosing was twice as great as that of the recommended rate and practice of fertilizer application at Navrongo. It appears that a significant yield increase of millet grain yield from mineral fertilizer application is due to the reduction of vegetative and non mature tillers. Because of the fast mineralization and N leaching at the beginning of the rainy season, the effect of amendments (both mineral and organic) are very spectacular in the case of delayed planting. In the case of labor shortages at first rains or crop failure at an early stage, mineral fertilizer could be very beneficial tool for production recovery. Farmer access to credit and inputs improved substantially through the "warrantage" system. Fertilizer micro-dosing technology has now reached up to 12,650 farm households and efforts are in progress to further scale-up and out the technology to wider areas in several countries.

Collaborating Institutions and Scientists:

TSBF-CIAT	: A Bationo and A Adamou
IFDC	: Arno Maatman and A Konlambigue
Institut National de Recherche Agronomique du Niger(INRAN)	: Annou Garba and Jean Pierre Atindehou
Institut de l' Environnement et de Recherches Agricoles du Burkina (INERA)	: Sibiry Jean Baptiste Taonda, Pale Siebou, Ouattara Korodjouma and Iboudou Blaise
FNGN	: Madibaye Djimadoum
Hunger Project	: Hamadou Tapsoba
ADRK	: Jules Singeogo
Institut d' Economie Rurale (IER)	: Diakala Sogodogo
Projet Intrants FAO	: Daniel Marchal and Bassirou Amadou
Winrock International	: Niels Hanssen and Sako Karamako

Sasakawa Global 2000	: Sandinan Boubacar and Marcel Galiba ADAF-GALLE: Biraima Diall
ICRISAT	: R Tabo, S Koala, MK Diallo, O Hassane, J Ndjeunga, B Gerard

Sub-Project: Crop Improvement and Seed Sector Reform

Focus: Market Studies, Outlooks and Institutional Innovations

Generic Output: Millet, sorghum and groundnut sustainable seed system strategies developed for the formal and informal sector and promoted at regional level

Output target: Market prospects for groundnut in WCA published (Linked with GT BT and CI)

Groundnut trade in international markets account for a mere 4-6% of total world production; while the majority of world groundnut production serves subsistence needs and requirements of domestic markets. In general, recent decades have seen an increase in the consumption of groundnut for all uses. There has been a shift away from its uses for oil and meal (for which there are substitutes, notably soya) and towards confectionary groundnut, for which there are no exact substitutes. However, as product quality standards are far higher for edible groundnut, this trend implies a corresponding increase in product quality (particularly in terms of Aspergillus, the source of aflatoxin.

In general, the European groundnut market has become less diversified and more concentrated over the past decade. It is said that until the late 1990s, large ad small origin shellers/suppliers provided products to large range of small dealers, to serve a range of large and small consumers ie, from end-use manufacturing industries to supermarkets.

Since the early 1970s, groundnut consumption patterns have shifted in West Africa as in other parts of the world. While total consumption in eastern and southern Africa has declined, groundnut utilization in West Africa has increased significantly due to a shift towards edible applications. Since the late 1980s, groundnut has become primarily a food crop rather than oil crop. Between 1972 and 2000, the proportion of West African groundnuts consumed as food as food grew by an astonishing 209%, even as exports declined precipitously during the same period. The decline of African groundnut exports is related to the trend towards production of edible groundnut, which was poorly timed in respect to increasing aflatoxin restrictions as well as increasing industrial substitution by other oils, particularly soybean,

Though all the countries which produce groundnut are prone to aflatoxin infestation, Africa is considered particularly problematic by international buyers, as the production chain in each country (with the exception of south Africa) is fragmented, production systems insufficient to address the problem, afaltoxin monitoring by crop virtually noninexistent, and preshipment inspection services perceived as lacking in reliability.

Unfortunately, international trade in groundnut is based on confidence and reliability in terms of supply as well as product quality. The current EU regulations on aflatoxin have certainly contributed to an increasingly conservative tendency among European buyers, who are unlikely to take any unnecessary risks as regard aflatoxin. An unfortunate and indirect consequence is that for West Africa to re-renter the world groundnut market (and particularly the european market, which offers perhaps the highest potential), export prices would have to compete favorably with Chinese groundnut, which is abundant, cheap and enjoys a favorable reputation in terms of reliable supply and reliable quality.

Recent prices for Chinese groundnut are on the order of $650 per MT – the same price as production of a ton of edible groundnut (arachide de bouche or ARB) under irrigation in Senegal. This means that the current and foreseeable margins of return are not in any case favorable to the re-entry of West African exports on to the world market, even without regard to product quality and perception of international buyers.

On the other hand, though the trade linkages are not as established (or cheap) as between West Africa and Europe, the South African market does not represent a significant potential opportunity for west African producers. Due to a poor harvest in 2003, South Africa has been importing groundnut from Southern Africa and even Argentina at premium prices – over $700 per MT (unsorted and CIF) in Malawi. There may be scope for entry into the South African market once aflatoxin has been addressed by improved management and monitoring of product quality at the crop level.

The primary conclusion of this study is that resources should be devoted to improvement of the production chain of the groundnut sector in each producer country, with initial emphasis on production to satisfy national, sub-regional and even regional demand. With the structural details of such a program would be negotiated on a country-by-country basis – and state intervention is in any case likely to remain limited – common features might include the establishment of public warehouses and/or buying points, at which production would be sorted, graded and tested for Aflatoxin contamination and other parameters of product quality.

In assessing the current and foreseeable market opportunities for groundnut of West African origin, it would be crucial to build slowly and deliberately on existing strengths (including the availability of improved seed through the current project). It needs specific and focused attention to the production chain – specifically cultivation, harvest and post harvest methods which prevent infection of the product by Aspergillus, and therefore ensure product quality.

Collaborating Institutions and Scientists:

Consultant	: E Masters
Former CFC Program Officer	: Mohammed Ramouch
ICRISAT	: BR Ntare, F Waliyar, J Ndjeunga

Output target: Technical paper on groundnut seed supply systems in WCA published (Linked with GT BT and CI)

During the last 30 years, donors and governments have invested more than US$124 million in variety development, seed production and distribution projects in Mali, Niger, Nigeria and Senegal. More than 39 groundnut varieties were developed, adapted, introduced and released. However, the returns to these investments are low due to limited uptake of newly bred modern varieties. This is explained by limited access to seed of new varieties, limited supply of breeder seed, uncertain demand, missing or poorly functional national variety release committee, lack of integration between input and product markets, and lack of enabling policies and institutional environments. There are opportunities to exploit regional seed trade, enhancing the utilization of the large seed infrastructure, improving the interface between the public and local village seed systems and establishing sustainable community based seed systems.

Current practices: In the four countries, the "Ministries of Agriculture" are responsible for seed policies, planning and programs. National agricultural research systems (NARS) are responsible for variety development, breeder seed production and sometimes foundation seed production. Other seed classes are produced either contract farmers, community based groups, or individual farmers. The functional institutional relationship is not different between countries. Private sector involvement in groundnut seed production and marketing remains limited. Farmers still draw most of their planting seed from own stocks or village markets.

Constraints: The major constraints limiting the performance of groundnut seed systems include:
- Limited access to seed of newly bred varieties
- Limited supply of breeder/foundation/certified and commercial seed of varieties preferred by farmers or required by the markets
- Seed production is subsidized and inefficient
- Seed demand is uncertain and thin
- National variety release committees are missing, non-functional or meet irregularly
- Weak integration between seed and product markets
- Lack of enabling policy and institutional environments
- Outlook and perspectives

Opportunities: There are opportunities to build sustainable groundnut seed supply systems around the current availability of human resources (many farmers and farmers' associations trained at seed production techniques, large seed infrastructure – seed conditioning centers ,
- Regional groundnut seed trade
- Large seed infrastructure
- Reinforcing the interface between the formal seed sector and community-based systems and between producers and processors
- Developing sustainable arrangements that operate at low transaction costs such as the promotion local village seed schemes

Collaborating Institutions and Scientists:

Former CFC Program Officer	: Mohammed Ramouch
ICRISAT	: BR Ntare, F Waliyar, J Ndjeunga

Output target: Synthesis report on participatory variety selection in groundnut (Linked with GT CI)

A synthesis report on participatory groundnut variety selection process was also prepared. This report summarizes groundnut participatory variety selection (PVS) trials conducted in Mali, Niger, Nigeria and Senegal. It documents pathways to adoption of improved groundnut varieties, lessons learned and perspectives for enhancing varietal adoption. Two technical papers were prepared for Groundnut, one focusing on seed supply systems and the other on market prospects. The paper on seed supply, summarizes information on the structure, conduct and performance of formal and informal groundnut seed supply systems in 4 countries in West Africa namely Mali, Niger, Nigeria and Senegal. It highlights a range of technical, socio-economic, institutional and policy constraints facing the groundnut seed industry in West Africa and options for sustainability. The paper on market prospects documents the principal groundnut producing countries in the international markets, global market trends and quality requirements, recent trends in production and consumption in West Africa, and strategies for West Africa.

Collaborating Scientists:
ICRISAT : BR Ntare, F Waliyar, J Ndjeunga

Sub-Project: Diversification, Commercialization & IGNRM Systems Management

Generic Output : Crop, tree and livestock system integration promoted for agro-diversity, commercialization and health

Output target: Early diffusion of African market garden units disseminated in Niger (Linked with GT AE)

From June 2002 to May 2003, 827 low pressure drip irrigation systems were distributed and disseminated in Niger by ICRISAT and partners. These systems were distributed in the regions of Agadez, Tahoua, Zinder, Tillabery, Dosso and the peri-urban Niamey. Two types of systems were developed including the Thrifty system (TS) of 80 sq meters and a large commercial system (CS) of 500 sq meters. These systems were targeting two segments of the population based on gender. The small systems were targeted to women who are often excluded from the cash economy in rural and urban areas. The large systems were made to target vegetable producers some of which are located in peri-urban areas where consumers' demand for vegetables are relatively to be higher due to higher urban income.

As a first step to the study, an exploratory study was initiated in the region of Dosso and peri-urban Niamey. Development project partners such as Projet de Dévéloppement Rural Integré de Dosso and the "Ecole de Sante" funded by the Luxemburg government have actively promoted these systems in the region of Dosso and NGOs or ICRISAT in the peri-urban area of Niamey. In the regions of Dosso and peri-rban Niamey, 233 and 326 systems have been disseminated respectively. Since then, there was little monitoring and little was known on the level of uptake and use of these technologies.

Objectives of the research include measuring the level of uptake of drip irrigation systems in peri-urban Niamey and Dosso; identification of the constraints limiting the use of the technology; and recommend policy, institutional, technological and socio-economic options likely to improve uptake of the technology.
Hypotheses

- The economic returns is significantly higher for low pressure drip irrigation than local practice
- The economic returns is significantly higher for those trained than those not trained
- The economic returns is significantly positively correlated with experience in gardening
- Poor access to cleaned water, capital are the major constraints to uptake (fertilizers, capital)
- More than 50% of producers do not have access to cleaned water
- More than 50% of producers cannot sell more than 50% of their produce

Methodology: This study was undertaken in the region of Dosso and peri-urban Niamey. These areas differ significantly by the level of monitoring of the systems. While in peri-urban Niamey, little monitoring and technical support was provided, in Dosso, these systems were not technically and formally supported by any institution.

Prior to the selection of sites, in the region of Dosso, 47 systems were visited out of the 233 systems distributed representing the entire population of AMG from Projet. In peri-urban Niamey, 97 systems -located in a radius of 10 km from Niamey- were visited out of the 326 systems disseminated. A total of 96 low pressure drip irrigation systems purposely selected were evaluated of which 42 thrifty systems and 5 commercial systems in the region of Dosso and

35 small systems and 14 large systems in the peri-urban Niamey. In addition, 9 traditional systems and 13 traditional systems were evaluated in the region of Dosso and peri-uban Niamey respectively.

Structured surveys were used to collect information on production and quantity and costs of input use (water, fertilizers, pesticides, etc..), constraints to uptake of the drip irrigation, farmers' perception of productivity gains etc. Market price data were drawn from the market information systems in Niger (SIMA). A simple enterprise budget was used to assess the economic returns to major resources such as land, labor, water and fertilizers.

Preliminary results: There has been little diffusion of the drip irrigation technology. In effect, only 3 producers out of the 69 interviewed have specifically purchased the drip irrigation systems. However, in environments where monitoring and technical support was provided to producers such as Dosso, out of the 44 systems visited in Dosso, 94% of these were still functioning. In Niamey, Niger where little formal technical support was provided, 58% of these were still functioning.

Results indicate that in general producers perceived that there are significant gains from using the drip irrigation systems. The 4 major constraints reported by farmers are (1) the high set-up costs; (2) poor access to credit facilities to acquire the systems and other important equipment; (3) access to cleaned water and (4) access to vegetable markets. Other constraints include the poor targeting of diffusion points ie. producers testing these systems; poor training at fabricating water tanks that do not leak, especially for small systems; little flexibility of the technology to accommodate different types of crops and the little size of the systems even the commercial ones of 500 square meters.

Due to poor training and little exposure to the technology, many farmers had the perception of low availability of water to vegetables, and had to supply additional water through watering cans leading large waste of water resources. Many producers did use the technology for more than one cropping season limiting their ability to gain from higher prices.

In general, it was found that the economic returns to land for those using the drip irrigation systems was estimated to 507 FCFA/m2 (STD=1020 fcfa/m2) significantly higher than 183 FCFA/m2 (STD=417 FCFA/m2) for those using the traditional practice at 0.076 probability level. In effect, due to the lack of monitoring and evaluation systems, the quality of data collected was very poor justifying these apparent lacks of significant differences between the 2 systems. Other returns parameters were not computed.

Recommendation: There is a strong need to elaborate a sound monitoring and evaluation systems of the AMGs in order to collect good data.

Collaborating Scientists:
University of Mali : Oumarou Adamou Mohamadou
(IPR: Institut Polytechnique Rural de KATi BOUGOU)
ICRISAT : J Ndjuenga, Abdoulaye Amadou

Training. At IPR Katibougou, an MsC student worked on a project report.

Global Theme – Biotechnology
David Hoisington – Global Theme Leader

Introduction

Scientists in the Global Theme continue to achieve remarkable success in a number of projects addressing abiotic, biotic and genetic resource constraints to ICRISAT's mandated crops.

Goal

The goals of this theme are to harness the power of biotechnology to augment the gains achievable through plant breeding and to provide cost-effective diagnostics for critical plant diseases and associated toxins.

Objectives

In its efforts to achieve the overall goal, the Theme focuses on the following two major objectives:

1. To improve the efficiency, effectiveness, speed and precision of plant breeding for abiotic stress tolerance, pest and disease resistance, better agronomic traits, and improved food, feed and fodder quality; and
2. To develop diagnostic tools for the detection of viral infections, toxic contaminants of crops and crop-based products, presence of transgenes, and purity of seed production systems.

The Theme is organized into the following three main Global Projects:

- **Global Project 1:** Improved abiotic stress tolerance, agronomic and quality traits via the application of genomics, genetic engineering and wide-hybridization;
- **Global Project 2:** Applications of biotechnology for improving host plant resistance to insect pests and diseases
- **Global Project 3:** Genetic diversity, Genomic resources and Bioinformatics

Each of these projects depends on the proper application of a range of technologies available within ICRISAT and/or our global partners. Activities within each Global Project are conducted where most effective and efficient – in ICRISAT's laboratories in Asia and Africa, and/or our many partner institutes around the world.

Projects in the Global Theme continue to tap the potential of biotechnology tools for enhancing the speed, precision, efficiency and value addition to many aspects of plant breeding including addressing complex traits that have remained intransigent to conventional breeding. We recognize that biotechnology has enhanced the efficiency, effectiveness, speed and precision of plant breeding; however, breeding for crop productivity in marginal areas requires a complex multidisciplinary collaboration to facilitate the development of effective solutions. Establishing and backstopping such networks is a primary focus for ICRISAT in Africa and Asia. On this basis, a high-throughput DNA marker laboratory has been established at ICRISAT-Patancheru to strengthen our capacity in molecular breeding with particular reference to liberating the value encapsulated in our germplasm collections. Major advances have already been made in the molecular breeding of sorghum and pearl millet and in the development of tools for mapping important traits in chickpea, groundnut and pigeonpea.

We firmly believe that with our "partnership-in-progress" there are good chances for all of us to succeed. The establishment at ICRISAT-Patancheru of the Agri-Science Park and an Agri-Business Incubator strengthen strategic alliances with the private sector for partnerships to facilitate research-for-development and multi-sector collaboration in biotechnology. This leads to a broader scope for applying science expertise and tools to any crop of importance in the Semi-Arid Tropics.

GT-Biotechnology is actively involved in all three Challenge Programs. In the HarvestPlus Challenge Program, we are working on improving the pro-vitamin A content of groundnut and pigeonpea by increasing the ß-carotene level using genetic engineering, enhancing the nutritional quality of pigeonpea for sulfur-rich amino acids using genetic engineering, and improving the micronutrient content in sorghum using genomics. Under the Generation Challenge Program, ICRISAT projects include the assessment of molecular diversity in sorghum, pearl millet, chickpea, pigeonpea and groundnut; marker-assisted improvement of drought tolerance in sorghum, pearl millet and chickpea; genetic engineering of drought tolerance in groundnut; and the development of various bioinformatics tools. In the Water and Food Challenge Program, we are using molecular markers to backcross the stay-green trait into early maturing sorghum varieties for West Africa.

Global Project 1: Improved abiotic stress tolerance, agronomic and quality traits via the application of genomics, genetic engineering and wide-hybridization

Drought is globally the most important constraint to crop productivity and with predictions of greater water scarcity in the future, drought is likely to remain the number one constraint. As options for irrigation are often not available in the semi-arid tropics (SAT), it is critical that genetic enhancement strategies focus on maximizing extraction of available soil moisture and improving the efficiency of water use in crop establishment, growth, biomass production and seed yield. Genetic improvement for drought tolerance has always been a challenge to conventional breeding approaches that rely on selection for yield in drought-stressed environments. The large genotype × environment interaction for yield in natural stress environments often makes direct selection for yield ineffective. Biotechnological tools provide targeted approaches for improving component traits of drought tolerance, which should be more effective than the conventional breeding methods in developing drought tolerant germplasm.

This global project focuses on identifying molecular markers for the quantitative trait loci (QTLs) controlling traits contributing to drought tolerance/avoidance in pearl millet, sorghum, chickpea and groundnut, and on the marker-assisted introgression of these QTLs into adapted cultivars/farmer parental varieties, elite breeding lines. Based on available information on their relative importance in conferring drought tolerance/avoidance, we have selected traits for improvement in each crop, for example, stay green in sorghum, deep and vigorous roots in chickpea, and water use efficiency in groundnut. In pearl millet, we have pursued QTLs associated with maintenance of grain yield under terminal drought situations.

The global project is also evaluating transgenic technology for developing drought tolerant plants in chickpea and groundnut. The genes presently being tested include *DREB1A* and *P5CSF129A*. The transcription factor, *DREB1A* driven by a drought-responsive *rd29A* promoter is expected to enhance tolerance to several abiotic stresses, such as drought, chilling temperature and salinity. The gene *P5CSF129A* increases proline accumulation and improves tolerance to osmotic stress.

Another important abiotic stress being targeted is soil salinity, which is commonly found in arid regions that rely on irrigation for agriculture. We are pursuing efforts to identify sources of salinity tolerance in all five ICRISAT mandate crops. Existing mapping populations have been developed in pearl millet that will be used for identification of QTLs for salinity tolerance. In sorghum, new mapping populations are being developed for this purpose. Similar work will be initiated in ICRISAT mandate legume crops when suitable parents are identified for development of mapping populations.

We are also seeking to improve the ability to obtain and utilize key soil nutrients in our mandate crops. For example, we have found significant variation in phosphorous (P) acquisition ability from low P soils in pearl millet. We are investigating the underlying mechanisms in P acquisition ability of plants and making efforts to identify markers for this important trait.

In the past, the breeding efforts in crop improvement have largely focused on genetic enhancement of yield potential and resistance to biotic and abiotic stresses. The emphasis on quality traits is increasing in recent years and is expected to increase in the coming years. We are presently targeting the improvement of the pro-vitamin A (β-carotene) content in pearl millet, groundnut and pigeonpea; methionine content in pigeonpea; stover ruminant quality in pearl millet; and feed and fodder quality in groundnut and pigeonpea. Marker-assisted breeding will be used for improvement of all these traits, except for β-carotene content in groundnut and pigeonpea, and methionine content in pigeonpea, for which transgenic technology is being used.

The concerted and focused efforts underway will lead to development of diversified breeding populations/lines of ICRISAT mandate crops with improved tolerance to abiotic stresses, improved nutrient uptake and utilization, improved nutritional quality of grain, and improved quality of feed, fodder and stover. We will make these available to all public and private sector plant breeders and seed producers globally, who will, in turn, use these to produce locally adapted varieties with improved tolerances and quality traits for SAT farmers who depend upon our crops for their livelihoods.

Global Project 2: Applications of biotechnology for improving host plant resistance to insect pests and diseases

Insect pests, diseases, and the parasitic weed, *Striga* are serious constraints to increase production, productivity, and utilization of sorghum, pearl millet, chickpea, pigeonpea, and groundnut in the SAT. Crop losses due to these pests have been estimated at over US$ 7.4 billion annually. While *Helicoverpa* control is heavily based on insecticides, chemical control of shoot and panicle feeding insects on cereals is beyond the reach of resource poor farmers in the

SAT regions in Asia, Africa, and Latin America. For many diseases and *Striga,* cost effective technologies are yet to be worked out. Current sensitivities about environmental pollution, human health and pest resurgence are a consequence of improper use of synthetic pesticides. Host-plant resistance, natural plant products, bio-pesticides, natural enemies and agronomic practices offer a potentially viable option for integrated pest management (IPM). They are relatively safe for the non-target organisms and human beings. Use of modern biotechnological tools such as marker assisted selection, genetic transformation and wide hybridization for developing crop cultivars with resistance to insect pests and diseases will have a great bearing on future pest management programs. Insect and disease modeling, decision support systems, and remote sensing would contribute to scaling up and dissemination of the IPM technologies. Current research projects in biotechnology, crop improvement and natural resource management focus on the major pests such as pod borers (*Helicoverpa, Maruca*, and *Melanagromyza*), Fusarium wilt and sterility mosaic in pigeonpea; *Helicoverpa*, Wilt and Botrytis gray mold in chickpea; rossette virus, foliar diseases, aflatoxins and leaf miner in groundnut; *Striga*, grain molds, shoot fly, stem borers, midge and head bugs in sorghum; and downy mildew, stem borer and head miner in pearl millet. IPM promotion and capacity building are significant components of research at ICRISAT. The outputs from this research will lead to sustainable management of insect pests and diseases of cereals and legumes based cropping systems, thereby improving the livelihoods of poor people in SAT.

Global Project 3: Genetic diversity, Genomic resources and Bioinformatics

Plant breeding efforts aimed towards increasing food security require genetic resources as a critical component - both for short-term gains and long-term increase in productivity. The International Agricultural Research Centers have responded to the threat of genetic erosion in economically useful plant species by developing a global network of genebanks for *ex situ* conservation of genetic diversity. Chapter 14G of Agenda 21 of the United Nations Conference on Environment and Development (UNCED) and the Global Plan of Action for the Conservation and Sustainable Utilization of Plant Genetic Resources for Food and Agriculture (GPA) endorsed by the Conference of the Parties to the Convention on Biological Diversity (CBD) underscore the importance of and the responsibilities on the large *ex situ* collections held by the CGIAR Centers, including ICRISAT.

ICRISAT assembled a large collection of germplasm of its mandate crops from threatened areas of biodiversity. The assembled germplasm needs to be maintained using appropriate procedures and through establishment of safe, efficient and cost-effective management systems. While ICRISAT collections represent 70-80% of available diversity in these crops, there is continuing need to rescue germplasm, especially wild and weedy relatives from endangered areas. NARS in developing countries also require assistance in collecting and conserving biodiversity. However, conservation is not the end by itself, but a means of making available diversity for use by the present and future generations. This requires systematic characterization and evaluation of germplasm for special traits. Traditionally, most characterization and evaluation is based on morph agronomic characters that could be easily detected and measured. However, there are many characters that are difficult to identify and are controlled by a number of genes interacting in complex ways. These include yield, time to flowering, resistance to important insect pests, diseases and abiotic stresses and quality parameters. The availability of modern biotechnological tools, particularly molecular markers, provides an opportunity to characterize germplasm for such complex traits.

Large collections of germplasm, which are difficult to handle, can be made more accessible through development of core collections, which are only 10% of entire collection but represent species diversity. ICRISAT scientists have developed core collections of all five mandate crops and finger millet. In the crops where the number of accessions is very large and core subset is also large, ICRISAT scientists have developed a strategy to select a mini-core collection (Upadhyaya and Ortiz 2001). The mini-core collection is 10% of the core collection (i.e., 1% of the entire collection) and contains almost full diversity of the entire collection. We have developed mini-core collections of chickpea (211 accessions, Upadhyaya and Ortiz 2001), groundnut (184 accessions, Upadhyaya et al. 2002) and pigeonpea (Upadhyaya et al 2006). The challenge is now to evaluate the core and mini core collections for useful traits and identify germplasm accessions as diverse parents for utilization in the breeding programs.

Wild and weedy relatives play an important role in sustaining agricultural productivity. In spite of their potential in crop breeding, very few attempts were made to utilize them for improvement of ICRISAT mandate crops, except groundnut. However, developments in biotechnology should provide new opportunities to make greater use of wild species in genetic enhancement.

This project has a global responsibility for effective protection as well as utilization of biodiversity of ICRISAT mandate crops. These primary goals will be achieved with efficient management, conservation, and the enhanced utilization of genetic resources.

Human Resource Development
A short term course on Plant genetic diversity analysis and marker-assisted breeding held at Kamphaeng Saen Campus of the Kasetsart University Thailand during 20 Aug – 04 Sept 2005. This course was funded by Generation Challenge Program. Twenty participants from 10 countries participated in the course

Several Apprentices were given hands on training on basic molecular biology/ biotechnology training through university linked apprentice program, internships.

Several Research Scholars and Research Fellows enrolled for Ph.D. work

A Bio-informatics workshop conducted during 17-21 October 2005

A three-day training course on “Designing and Analysis of Participatory On-Farm Trials held during 25-27 May 2005.

Beneficiaries
National and international public and private sector breeding programs, plus the farmers who adopt new varieties developed by those programs and the rural poor who depend on these crops.

Collaborators
INERA (Burkina Faso); NARI (Eritrea); BECA (Kenya); KARI (Kenya); IER (Mali); INERA (Niger); IAR (Nigeria); ISRA (Senegal); ARTC (Sudan); Networks (CLAN, ECARSAM, ROCAFREMI, SMINET, and ROCARS); and regional fora (ASARECA, SACCAR, CORAF, and FARA); IITA, ILRI and ICRAF and LCRI (Nigeria).

Queensland Department of Primary Industries, Hermitage Research Station, University of Queensland, Melbourne University (Australia); Vrije Universitiet Brussel and Catholique University, Louvain-la-Neuve (Belgium); PBI (Canada); University of Hohenheim (Germany); IGER, JIC, SCRI, University of Birmingham, Centre for Arid Zone Studies (UK); Cornell, Purdue, Texas A&M, Washington State and North Carolina State Universities, University of California-Davis, University of Wisconsin, University of Georgia (USA); CG centers (CIAT, ILRI, IITA and ICARDA).

Global Project 1 : Improved abiotic stress tolerance, agronomic and quality traits via the application of genomics, genetic engineering and wide-hybridization [Project Coordinator: PM Gaur]

Output 1.1.1: Enhanced Drought Tolerance in Pearl Millet and Sorghum

Activity 1.1.1.2 : Marker-assisted breeding for stay-green QTLs in sorghum
Team: CT Hash, V Vadez, FR Bidinger, SMH Rizvi, R Folkertsma, M Mgonja, F Rattunde and S Chandra

Milestone: Techniques standardized for large-scale screening of root traits in sorghum.

The main purpose of experiments conducted was to test whether roots have any role to play in the QTLs thus far identified for terminal drought tolerance in sorghum (QTLs that were detected for the stay-green component of terminal drought tolerance). We used two elite drought-sensitive parents [ISIAP Dorado (partially senescent) and R 16 (highly senescent)], two stay-green donor parents (B35 and E 36-1), and two derivatives of R 16 thought to carry 2 or 3 major stay-green QTLs (RSG 03123 with drought tolerance from donor B35 and RSG 04012 with drought tolerance from donor E 36-1).

In the first experiment, we grew plants in 18 cm diameter and 120 cm deep PVC cylinders, during September-Dec 2004. Twenty plants were grown for each genotype, under well-watered conditions for the first 2 weeks after sowing. Thereafter, half of the plants were exposed to water stress by withholding irrigation while the other half was kept under well-watered conditions (control). One set of plants (5 replicated plants per genotype in stress and control) was harvested at 35 DAS and the second set was harvested at 67 DAS. The second experiment was conducted during March-April 2005. This experiment was basically a repeat from the first experiment, except that cylinders used were 200 cm long (same diameter), and the second harvest was done at 63 DAS. Genotypes ISIAP Dorado, E 36-1, and RSG 04012 were included in the second experiment. At harvest, the entire root system was gently pulled out of the cylinder after washing away the soil, its entire length measured and thereafter sliced in 30 cm portions to measure dry weight and root length density in these different portions.

Data of the first and second experiments were very consistent with each other, despite the difference in cylinder length, and therefore results of the second experiment are discussed. We found that roots of stay-green trait donors and stay-green QTL introgressed materials reached all a length of at least 270 cm in the second harvest under water stress, whereas senescent genotypes ISIAP Dorado and R 16 had a maximum root length of 210 cm. Again, expressed as percentages of roots in the 0-30 cm layer (to compare to shallow rooting), stay-green sorghums had 15-35% of the roots present in soil layers deeper than 150 cm, whereas senescent sorghums had only 5-10% of roots deeper than 150 cm. Interestingly, stay-green and senescent materials did not vary for root length under well-watered conditions.

These results are very encouraging as they show a significant and consistent involvement of roots in the stay-green QTLs associated with terminal drought tolerance in sorghum. The protocol used to pinpoint these differences can be further refined. As an attempt to do so, a third experiment was started with sorghum, where stress was imposed at 21, 35, 49, and 69 (flowering) days after sowing. At each date of stress imposition, one set of plants (5 replicated cylinders per genotype) was pre-harvested and two additional sets were submitted to drought and well-watered conditions. Harvest of the two sets undertaking treatment was done once wilting symptoms were visible on all plants, usually 3-4 weeks after treatment imposition.

V Vadez

Milestone: First products of marker-assisted backcrossing of stay-green QTL from donor E 36-1 into the backgrounds of S35 and IRAT 204 field-tested to assess terminal drought tolerance (2008)

We evaluated sets of progenies from MABC introgression of several putative stay-green QTL into released cultivars ISIAP Dorado (BC_3F_4 lines, with donor parent B35) and R 16 (BC_1F_3 lines, with donor parents B35 and E 36-1) in both supplementally irrigated and dryland environments in the postrainy season of 2004-2005. The objectives were to assess the expression of stay-green in the backcross progenies under postrainy season conditions, to compare the agronomic expression of the recurrent parents and their backcross derivatives, and to evaluate the effects of stay-green expression on grain filling and grain yield under the characteristic post-flowering drought stress of the postrainy season. Environmental (moisture) differences in stay-green expression were strong in both sets of materials; genetic differences in stay green expression were clear in the case of the highly senescent R 16, but less so in the case of the moderately senescent ISIAP Dorado. For example, the percent green leaf area 2/3 of the way through grain filling in the R 16 derivatives ranged from 7% to 29% in the dryland environment, compared to 34% to 57% in the ISIAP Dorado trial (in which stress was interrupted by a rain shower in mid grain filling). None of the backcross progenies expressed the stay-green trait to the same degree as the donor parent B35, but most have only one or two stay-green QTL, in contrast to B35, which has a larger number (six or more).

Many of the R 16 derivatives differed agronomically from the recurrent parent in height and flowering time, and some in grain size and stover yield. The majority were similar in grain yield to R 16 in both environments. However, most of the differences reflect the differences in the donor parents and R 16, and should disappear with further backcrosses. The derivatives of ISIAP Dorado were generally more similar to the recurrent parent (as would be expected from BC_3 materials), except for later flowering, and some tendency for the derivatives to have a greater stover yield and a smaller grain size. Stay-green expression during the second half of the grain filling period was related to relative (dryland environment/supplementally irrigated environment) grain size (*i.e.*, to completeness of grain filling) in both sets of materials: $r^2 = 0.61$ ($P < 0.01$) for R 16 and $r^2 = 0.59$ ($P<0.01$) for ISIAP Dorado. The effect of differences in stay-green expression on grain size carried over into a significant effect on grain yield in the case of R16 ($r^2 = 0.48$) but not in the case of the ISIAP Dorado derivatives ($r^2 = 0.10$). We hypothesize that the difference in stay green effect in the two trials was due to both genetic (R16 is normally considerably more senescent than is ISIAP Dorado) and environmental (the rain shower during mid grain filling in the ISIAP Dorado trial) reasons. Selected R 16 evaluation will be repeated in 2005-2006, and better R 16 derivatives from 2004-2005 trial were backcrossed to R16 twice during 2005 prior to possible re-evaluation during 2006-2007.

FR Bidinger and CT Hash

Milestone: Sorghum stay-green introgression lines derived by marker-assisted backcrossing provided to African national programs in locally adapted, farmer-preferred genetic backgrounds (2008)

Due to lack of adequate SSR marker polymorphism between stay-green drought tolerance donor parent E 36-1 and the two recurrent parents (S35 and IRAT 204), and reduction in the amount of funding provided by granting agencies for activities related to this milestone, we have focused the marker-assisted backcrossing program for the sorghum stay-green trait on donor B35 only.

During 2004 marker-assisted backcrossing of genomic regions associated with the stay-green component of terminal drought tolerance of donor parent B35 was advanced two generations in the genetic background of elite recurrent parent Kapaala = ICSV 111. By the end of 2004, BC_4F_2 seed had been produced for families expected to segregate for four of the six target stay-green QTL in this genetic background (for which suitable BC_3F_1 families were available in 2003) and for the remaining two target QTL, seed had been produced for BC_3F_2 families.

During the first half of 2005, BC_3F_2 and BC_4F_2 plants homozygous for donor parent alleles at SSR marker loci flanking each of six individual stay-green loci (*i.e.*, single-QTL introgression lines for stay-green QTLs *stg*A, *stg*B, *stg*1, *stg*2, *stg*3 and *stg*4) from donor parent B35 in the genetic background of ICSV 111 (released in Ghana as 'Kapaala') and its sub-selection S 35, were identified and their selfed seed harvested. These included ten BC_4F_2 plants expected to be homozygous for *stg*A, three BC_4F_2 plants expected to be homozygous for *stg*B, six $BC3F_2$ plants expected to be homozygous for *stg*1, ten BC_3F_2 plants expected to be homozygous for *stg*2, two BC_3F_2 and seven BC_4F_2 plants expected to be homozygous for *stg*3, and four BC_4F_2 plants expected to be homozygous for *stg*4. The corresponding BC_4F_3 and BC_3F_3 families, along with seed samples of their recurrent and donor parents, were sent to the national sorghum breeding program in Ghana (SARI) in June 2005 in time for initial rainy season seed increase for agronomic and farmer-participatory evaluation under the Water for Food Challenge Program. Further, these progenies were advanced a further generation by selfing at ICRISAT-Patancheru during the 2005-06 post-rainy season to produce seed required for future assessment of their drought tolerance, agronomic performance and grain quality. Marker data generation in 2005 required to identify the putative QTL introgression homozygotes was performed as part of the M.Sc. thesis research program of Mr. Sripathi Venkateswararao. In late 2005 he submitted a thesis to Acharya N.G. Ranga Agricultural University (ANGRAU) India, and this was defended successfully in early 2006.

Similarly, marker-assisted backcross introgression of stay-green QTLs from donor parent B35 into the genetic background of recurrent parent IRAT 204 advanced two generations during 2005, with the marker data generation required being performed as part of the M.Sc. thesis research program of Mr. Sripathi Venkateswararao.

We hosted a Visiting Scientist from the Indian national program (Dr Madhasudhana Rao from the National Research Center for Sorghum) for 3 months to develop marker genotype data for assessing opportunities of MABC to improve stay-green drought tolerance of elite and landrace materials of interest to Indian sorghum breeders, and another from the Universidad Autonoma de Neuvo Leon (Dr F Zavala G) for 1 month to learn how to conduct SSR-MAS for the stay-green trait.

CT Hash

Output 1.1.6: Improved feed and fodder quality

Activity 1.1.6.1: Improved pearl millet stover quality
Team: CT Hash, M Blummel, FR Bidinger, R Folkertsma, M Mgonja, F Rattunde and S Chandra

Milestone: ***Genotype and genotype × environment effects on stover quality documented, heritability of different stover quality components assessed, and sampling methods for efficient assessment of stover quality established in pearl millet (2006)***

Management and genotype effects on pearl millet stover quantity and quality: Farmers have two basic options for improving both the quantity of stover produced and its nutritional quality – intensifying crop management to increase production and/or feed value of stover, and choice of cultivar type and/or specific cultivar to exploit genetic differences in quantity and/or quality of stover produced. We conducted a preliminary evaluation of both options for pearl millet, as baseline information for a funded project on the genetic improvement of millet stover quality.

The most significant management option available to farmers for increasing pearl millet stover digestible dry matter (DDM) yield and stover metabolizable energy (ME) yield is adequate fertilization. Although increased fertilizer application had small, but significant, negative effects on stover digestibility, sugar concentration and ME, these were more than offset by large increases in total stover dry matter production. Higher fertility also had a major positive effect on stover nitrogen concentration, which should have a significant effect on animal weight gain (especially where stover is fed without supplementation with either a concentrate or a higher N legume straw). Increasing plant population, in contrast, had little effect on either stover quality or yield. The low population treatment still produced nearly the same biomass and stover yields as the high population treatment, despite a two-fold difference in plant numbers. Although stover from the lower plant population treatment did have slightly numerically higher values for almost all stover quality traits, but differences were only significant for N % and digestibility, and these had little effect on stover DDM or ME productivity.

Choice of cultivar type (landrace, open-pollinated dual-purpose cultivar, or F_1 hybrid) did have a significant effect on both stover productivity and quality. The dual-purpose cultivars (and the landraces) had higher stover productivity and significantly higher digestibility, sugar concentration and ME than the hybrids, but this was at the cost of a significantly lower grain yield. The most important finding was that there were no strong negative relationships between the most important stover quality traits and either grain or stover yield, however, so there is not bar to combining high grain yields with high stover yields with at least average stover quality. Several dual-purpose hybrids in the trial (notably HHB 60 and the old ICRISAT release ICMH 451), capitalized on this, producing DDM and ME yields on par with the best open-pollinated dual-purpose cultivars and landraces, with a significantly higher grain yield. The results suggest that there is no reason why targeted breeding of dual-purpose hybrids (stover and grain yield) with improved stover quality should not be successful. Such hybrids should also maximize returns to investment in increased fertilization, though increased grain and quality stover yields.

FR Bidinger FR and M Blümmel

Milestone: Additional markers for key components of pearl millet stover quality (digestibility, N content, intake, etc.) identified (2006)

Linkage map construction and QTL mapping: New SSR, EST (EST-SSR and SSCP-SNP) and TRAP markers (developed by the University of Nebraska, USA; JIC, Norwich, UK; and ICRISAT-Patancheru, India) were added into the existing linkage map of the pearl millet mapping population based on cross ICMB 841 × 863B, which was comprised of the previously available polymorphic RFLP and SSR markers. Markers were assigned to different linkage groups based on marker recombination and ordered within linkage groups to minimize the frequency of candidate errors. After removing colinear markers and those exhibiting distorted segregation patterns, seven linkage groups were constructed using 76 polymorphic RFLP, SSR and EST markers.

QTL analysis was performed by composite interval mapping for stover quality traits of individual stover fractions (stem, sheath, and leaf blade) as well as whole stover samples. Stems are a major and important constituent among the different stover fractions because they contribute more mass to the livestock feed. For stem fraction digestibility and metabolizable energy content, a major QTL was identified on LG 2, at a position similar to that for drought tolerance alleles from the 863B parent (suggesting it should be simple to combine improved stem digestibility with greater drought tolerance in the genetic background of elite seed parent maintainer line ICMB 841). Another major stover quality QTL was mapped to LG 5, which controlled significant proportions of phenotypic variation for *in vitro* true digestibility and for metabolizable energy content. In contrast, the ICMB 841 alleles for QTLs on LG 6 were favorable for gas volume, true organic matter degradability, nitrogen content and metabolizable energy content of stover stem and sheath fractions.

T Nepolean, S Senthilvel, CT Hash and M Blümmel

Milestone: Elite hybrid parental lines of pearl millet with improved stover quality through marker-assisted backcrossing available for evaluation (2007)

***Advancing QTL introgression lines*:** During the 2004/05 post-rainy season, 16 F_1 hybrids of selected hybrid seed parent maintainer lines (ICMB 95111, ICMB 95222, HMS 7B and ICMB 93333) and parents of two stover quality mapping populations (ICMB 841, 863B, PT 732B and P1449-2) were grown in the field. Each hybrid combination was backcrossed with the recurrent parent and resulting in a total of 16 F_1 parent × recurrent parent BC_1F_1 combinations. Two plant × plant crosses from each combination were selected to advance the BC_1F_1 generation. Two crosses from each of the BC_1F_1 hybrid combinations were sown and raised during the rainy season of 2005. BC_1F_1 hybrids were backcrossed, plant × plant, with their respective recurrent parents to produce BC_2F_1 seeds. The BC_1F_1 generations of 16 crosses were screened using polymorphic SSR and TRAP markers, to assess their segregation patterns and select the heterozygous QTL introgression genotypes from various crosses for generation advance.

For the putative LG 7 stover quality QTL, RFLP and SSR marker data were used to identify introgression homozygotes for the associated region from donor parent 863B in the genetic background of ICMB 841. Several such plants were identified and their selfed seed harvested for future testcross hybrid production.

The revised QTL analysis reported above indicated that at least some of the introgression lines for the LG 2 drought tolerance QTL of 863B in the genetic background of ICMB 841 are likely to carry a QTL for improved stover quality.

T Nepolean and CT Hash

Milestone: Two cycles of recurrent selection for improved stover quality (using NIRS analysis) completed in two arid zone landrace-based populations in pearl millet (2007)

Evaluation of ICMV 221 cycle 2 FS (full-sib) progenies: We completed the second and final cycle of FS progeny selection for improved stover quality in the released pearl millet variety ICMV 221. The objective of the exercise is to measure the genetic progress that can be made in improving the ruminant nutritional quality of pearl millet stover using simple recurrent selection methodology and rapid near-infrared reflectance spectroscopy (NIRS) assessment of key stover quality parameters. As in the first cycle, there were highly significant differences for all stover quality traits and agronomic variables measured, among the 280 FS progeny evaluated. For example stover *in vitro* organic matter digestibility ranged from 37 to 46%, stover metabolizable energy from 5.2 to 6.7 mega joule kg^{-1}, stover nitrogen from 0.67 to 1.25 %, and stover yield from 123 to 432 g m^{-2}. Selected progenies will be recombined to form both grain and dual-purpose versions of the original variety with improved stover nutritional quality, to compare to the original ICMV 221. Individual progenies will also be used to develop high stover quality trait lines for various research purposes, including evaluating the effect of improving parental stover quality on hybrid stover quality.

FR Bidinger and M Blümmel

Milestones: Stover quality of experimental pearl millet hybrids of BC_5 products evaluated in multilocational field trials (2008)
Stover quality of experimental varieties from selected arid zone populations in multilocational field trials evaluated in pearl millet (2008)

Response to a single cycle of selection for stover yield and quality: We random-mated selected progenies from the first cycle of improvement of the stover quality of the pearl millet variety ICMV 221 (see above) to produce stover quality trait-based experimental varieties to assess the potential for reselecting an existing variety to improve its stover quality. Selection was done jointly for a high or low value of the quality trait, plus grain and stover yield within one SED for mean of the whole set of progenies. In addition we made specific grain or dual purpose versions of the original variety with as good a stover quality as was possible within a high grain or grain + stover yield objective. All six experimental varieties and the C0 and C1 versions of the original ICMV 221 were tested in replicated small plots for productivity and *in vitro* quality analysis by NIRS, and a subset was grown in replicate large plots for *in vivo* quality analysis in a replicated sheep feeding trial.

The reselected grain type experimental variety did not differ significantly from the parent variety, either in agronomic performance (apart from some offsetting changes in yield components) or in stover quality in either the *in vitro* or *in vivo* measurements. The dual propose experimental variety, in contrast, exceeded the parent variety in stover yield by 12% ($P < 0.05$) and in grain yield by 5% (NS). More interestingly, although it did not differ from the parent variety in the *in vitro* quality evaluations, it was significantly better than the parent for organic matter digestibility (56.6% vs. 54.4%) in the *in vivo* evaluation.

Selection for high and low stover digestibility and for high stover nitrogen generally resulted in small and non-significant reductions in both grain and stover yield. The exception was the experimental variety made on the basis of low stover nitrogen, which resulted in a 6% ($P<0.05$) increase in biomass and a 10% ($P<0.05$) increase in grain yield. Selection for and against stover digestibility and stover N% resulted in small, but non-significant, changes in these parameters, in the direction of selection in the *in vitro* stover quality assessment, but few other changes in quality. In the *in vivo* assessment however, the high digestibility selection had a significantly higher digestibility (57.5%) than the parent variety (54.5%).

FR Bidinger and M Blümmel

Global Project 2: Applications of biotechnology for improving host plant resistance to insect pests and diseases [Project Coordinator: HC Sharma]

Output 1.2.1: Marker-assisted selection for enhanced resistance to insect pests and diseases

Milestone: *RILs and backcross populations advanced to facilitate marker-assisted selection for shoot fly resistance (2008)*

Marker-assisted selection for resistance to shoot fly, Atherigona soccata in sorghum. Sorghum RILs [252 RILs from the cross 296B (susceptible) × IS 18551 (resistant)] were phenotyped and genotyped to understand the genetics of shoot fly resistance and locate chromosomal regions harboring putative quantitative trait loci (QTLs) for shoot fly resistance and related component traits [PhD thesis, “QTL analysis for shoot fly resistance in sorghum [*Sorghum bicolor* (L.) Moench”, by SP Deshpande, submitted in 2005 to Marathwada Agricultural University (MAU)-Parbhani, Maharashtra, India]. After genotyping the RIL population with SSR markers, phenotypic observations of off-type progenies were confirmed. As a result, the effective size of the mapping population was reduced to 213 RILs, for which phenotypic screening data (from two field screens for shoot fly resistance conducted at MAU-Parbhani) could be combined with the marker data set (111 SSR loci) for linkage analysis and QTL mapping.

The linkage map for this RIL population covers 2165.8 cM (Haldane units), providing at least partial coverage of all ten sorghum linkage groups, but regions with poor marker coverage remain. Composite interval mapping revealed the presence of putative QTLs for all important shoot fly resistance traits, accounting for 6 to 36% of observed phenotypic variances for these traits. One major QTL for glossiness was detected on LG J, accounting for 33% of observed phenotypic variation. Minor QTLs for seedling vigor, deadhearts , and seedling height were also detected. Co-localization of a QTL for trichome density on the upper leaf surface (explaining 20% of observed phenotypic variation) with a QTL for trichome density on the lower leaf surface (explaining 25% of observed phenotypic variation) indicated similarities in genetic control of trichome densities on either side of sorghum leaf blades. The results obtained largely confirmed the previous information based on the BTx623 × IS 18551 mapping population. It would be desirable to fill some of the remaining gaps in the linkage map, if appropriate markers can be identified, and repeat the QTL analyses with all available shoot fly resistance screening data sets for the 213-entry subset of the (296B × IS 18551)-based sorghum RIL population.

QTL mapping of shoot fly resistance, based on two phenotypic screens conducted at ICRISAT-Patancheru of the sorghum RIL mapping population based on the cross 296B × IS 18551, which had been genotyped previously, was also undertaken [PhD thesis, "Genetic diversity analysis, QTL mapping and marker-assisted selection for shoot fly resistance in sorghum [*Sorghum bicolor* (L.) Moench" by SP Mehtre, submitted in 2006 to MAU, Maharashtra, Parbhani, India] . Analysis of the phenotypic data was performed using the residual maximum likelihood algorithm (ReML), which provides the best linear unbiased predictors (BLUPs) of performance of the genotypes. The BLUPs of 213 uniform RILs, along with their genotypic data from 111 marker loci, were used for QTL analysis. Parental and RIL BLUPs revealed wide variation in phenotypic values for shoot fly resistance and its component traits in each of the screening environments. Wide variation was observed in the RIL population for shoot fly resistance component traits such as leaf glossiness, trichome density (upper and lower surfaces of seedling leaf blades), seedling vigor, oviposition preference, and deadhearts. These traits can be used as simple criteria to select for resistance to shoot fly in sorghum. The genotypic variances for shoot fly resistance traits were significant in each of the screening environments as well as across-environments. Glossiness intensity, trichome density (both upper and lower surfaces of seedling leaf blades), oviposition preference, deadhearts, and seedling vigor showed consistent heritability (broad-sense) estimates in individual screening environments, but low to moderate heritability estimates across environments, indicating that these traits are under genetic control, but there is a substantial role of genotype (G) × environment (E) interaction in expression of these traits.

QTL analysis was performed using the composite interval mapping (CIM) method implemented in PLABQTL version 1.1, which uses a regression approach. This revealed presence of putative QTLs for shoot fly resistance and its component traits including leaf glossiness, oviposition preference, deadhearts, and trichome density. The portion of observed phenotypic variance explained by different putative QTLs varied from 6 to 34%. Glossiness intensity was largely controlled by a major QTL on LG J (= SBI-05), accounting for 34% of observed phenotypic variation, and one minor QTL on LG G (= SBI-10), accounting for 8% of observed phenotypic variation across environments. After adjusting for QTL × environmental interaction, these two QTLs explained 31% of genetic variation in glossiness intensity in this population. Resistant parent IS 18551 contributed to additive genetic effects for increased glossiness at both of these QTLs. For oviposition preference and deadhearts, two common QTLs (one on LG F = SBI-09 and one on LG G) were also mapped in across-environments analysis. Together, these QTLs explained 17% phenotypic variation in oviposition preference and 19% for deadhearts in across-environments analysis. Significant QTL × environmental interactions were observed for these QTLs for oviposition preference and deadhearts. The QTL mapped on LG G for deadhearts and oviposition preference co-localized with a major QTL for trichome density (upper and lower surfaces of seedling leaf blades) and a minor QTL for glossiness intensity. The QTL mapped on LG F for deadhearts and oviposition preference co-localized with a minor QTL for trichome density on the lower leaf surface. For trichome density on the upper leaf surface, one QTL was detected on LG G accounting for 30% of observed phenotypic variance in across-environments analysis. This QTL co-localized with a QTL for trichome density on the lower leaf surface, and explained nearly 27% of observed phenotypic variance across two screening environments. The major QTL for glossiness intensity and a minor QTL for oviposition preference (LG J = SBI-05) and a major QTL for trichome density and minor QTLs for glossiness, deadhearts, and oviposition (LG G = SBI-10) detected in this study have previously been mapped at the same location in another sorghum RIL population derived from the cross BTx623 × IS 18551. This confirmed that these chromosomal regions might be harboring candidate genes contributing to shoot fly resistance in IS 18551.

During 2005, SSR-marker-assisted backcrossing of putative shoot fly resistance QTLs from donor parent IS 18551 into the genetic backgrounds of three hybrid parental lines (20B, 28B, and KR 192) of interest to the sorghum breeding program at the Marathwada Agricultural University-Parbhani, Maharashtra, India, were advanced to the BC_3F_1 seed generation. For this purpose, around 224 BC_2F_1 plants from five populations were genotyped at the seedling stage with 10 SSR marker loci linked to four targeted QTLs (one each on LG A = SBI-01, LG E = SBI-07, LG G = SBI-10, and LG J = SBI-05) associated with shoot fly resistance traits. Nearly 100 heterozygous plants, which had one, two, or more QTL introgression(s), were selected and crossed as a female parent with the selfed progeny of their respective recurrent parents to generate BC_3F_1 progenies.

SSR-marker-assisted backcrossing of putative shoot fly resistance QTLs into the genetic background of the susceptible parents of the two ICRISAT sorghum shoot fly mapping populations, i.e., BTx623 and 296B, were advanced during 2005. By the end of 2005, three of the four target QTLs from donor parent IS 18551 were advanced to the BC_4F_2 seed generation in the genetic background of shoot fly susceptible elite sorghum hybrid seed parental line 296B, and all four QTLs were advanced to the BC_4F_2 seed generation in the genetic background of shoot fly susceptible elite sorghum hybrid seed parental line BTx623. It is expected that the first BC_4F_2 shoot fly resistance QTL introgression homozygotes will be identified by mid-2006.

RT Folkertsma, BVS Reddy, HC Sharma, CT Hash, S Chandra and S Senthilvel

Activity 1.2.1.3: Mapping head bug/grain mold resistance in sorghum
Team : RP Thakur, CT Hash, HC Sharma, BVS Reddy, and HFW Rattunde

RILs developed for grain mold resistance**:** Two grain mold RIL populations; 352 $F_{3:4}$ progenies of IS 23599 (grain mold resistant line) × AKMS 14B (grain mold susceptible line), and 348 $F_{3:4}$ progenies of IS 25017 (grain mold resistant line) × KR 188 (grain mold susceptible line), were advanced to $F_{3:5}$ progenies in the 2004/05 *rabi* season. Limited information available so far indicates that SSR marker polymorphism between parental line pairs of these populations may not be adequate to permit QTL mapping with sorghum SSR markers currently available in the public domain. Assessment of a sample of the RILs for variation in plant height and flowering time, as well as panicle compactness, in an appropriate grain mold screening environment is recommended as previously published attempts in the USA to map QTLs for the related grain weathering complex were largely ineffective as all "grain mold resistance" QTLs identified were either associated with alleles for tall plant height at dwarfing gene loci (that contributed to drier microenvironments for panicles borne by taller progenies in the RIL population) or with grain hardness QTLs.

BVS Reddy, S Ramesh , RT Folkertsma, CT Hash and RP Thakur

Activity 1.2.1.4: Mapping *Striga* resistance in sorghum
Team**:** R Folkertsma, CT Hash and EW Rattunde

Milestone: EST-derived markers closely linked to Striga resistance in sorghum identified (2006)

Sequencing of gene-rich regions of the sorghum genome has moved ahead rapidly, as evidenced by the November 2004 release by Orion Genomics to the public domain of over 500K methyl-filtered sequence reads, predicted to include at least a portion of the sequence of 95% of all sorghum genes (more than 784K sorghum DNA sequences are now available in GenBank). Interestingly, some 25K of the new methyl-filtered sequence reads contain SSR repeat motifs. Thus, the currently available sorghum DNA sequence information would allow substantial expansion of sequence-tagged microsatellite (STMS) marker resources for sorghum, and could provide polymorphic co-dominant PCR-compatible markers in large numbers across the entire sorghum genome. Even more interesting is that by applying simple, inexpensive bioinformatics protocols, we can identify with reasonable certainty where many of these new STMS markers have counterparts in the rice genome sequence, and hence can predict where they will map on the sorghum genome.

Using this approach, (as part of the PhD thesis research program of Mr P Ramu), sorghum EST sequences from The Institute for Genome Research (TIGR) database were searched for the presence of SSRs in their sequences. The non-redundant sorghum EST sequences with SSR motifs were searched against the rice genome sequence in the Gramene database (using BLAST). Among the hits identified, those having the highest score were checked for its location on the rice genome. Nearly 2,000 non-redundant sorghum EST sequences containing SSRs were searched against the rice genome. For each rice linkage group, 50 hits with map positions distributed across the full length of the linkage group were selected. This revealed rice chromosomal locations of similar sequences, allowing selection of a subset of 600 sorghum EST-SSR loci distributed across regions of the sorghum genome that are syntenic with each of the 12 rice chromosomes (50 each). These sorghum EST-SSR loci, if polymorphic in sorghum, are expected to provide coverage across the entire nuclear genome of sorghum. Primer pairs flanking the repeat sequences in each of these 600 sorghum EST sequences were then designed (after masking repeat regions) using the Primer3 program (www.genome.wi.mit.edu). PCR optimization and polymorphism assessment of primer pairs for these 600 candidate sorghum EST-SSR markers were taken up simultaneously using as template DNA samples from the parental lines of several ICRISAT sorghum RIL populations, including those previously used for mapping *Striga* resistance.

During 2005, a subset of the E36-1 × N 13-based RIL population has been used (by PhD student, Kassahun Bantte) to start mapping some of the polymorphic EST-SSR markers. Genotyping has been completed and mapping initiated for about 50 EST-SSR loci expected to map to four of the ten sorghum linkage groups (SBI-01, SBI-02, SBI-03, and SBI-05). Based on the marker data generated, 44 of these EST-SSR markers were mapped across all 10 sorghum linkage groups (not just those actually targeted). Among these 44 newly mapped markers, four were closely linked to the *stg*B QTL on LG B = SBI-02 (which was a primary target of this exploratory mapping exercise). These findings will facilitate future development of additional sorghum EST-SSR markers specifically targeting QTLs for any mapped trait, including *Striga* resistance, for use in marker-assisted selection. With completion of this activity, if we need more SSR markers in a particular region of the sorghum genome, we hope to be in a position to quickly and inexpensively develop them, using the vast amount of sorghum sequence information that is rapidly becoming available.

RT Folkertsma, CT Hash, B Jayashree and BIG Haussmann

***Striga* resistance in sorghum transferred to elite African cultivars using marker-assisted selection.** Marker-assisted backcrossing of *Striga* resistance QTLs from donor parent N 13 into the genetic background of farmer-preferred sorghum varieties from Mali, Sudan, Kenya, and Eritrea were advanced more slowly than planned during 2005. Logistical problems in moving DNA samples, and/or appropriate tissue samples for DNA isolation between national sorghum breeding program sites (where the crossing and backcrossing activities are undertaken) and the BecA facility in Nairobi, Kenya (where the SSR marker genotyping activities are undertaken), are hampering progress towards this milestone.

RT Folkertsma , S deVilliers, D Hoisington, D Kiambi and CT Hash

Arresting the scourge of Striga in sorghum in Africa by combining the strength of marker-assisted backcrossing with farmer-participatory selection. Through this project, NARS in the Kenya, Mali, Eritrea and Sudan are being assisted to strengthen *Striga* resistance of farmer-preferred sorghum varieties (FPSVs) through a combination of marker-assisted backcrossing (MAB) and farmer-participatory selection. The stability of inheritance of the transferred *Striga* resistance alleles in the FPSVs, the actual out-crossing rates in selected FPSVs, and the pollen flow of these FPSVs is being analyzed in order to develop recommendations for variety maintenance and on-farm seed production. To complement the molecular work, a socio-economic and population genetics study of the sorghum seed supply systems in the four target countries is being undertaken concurrently to guide the design of effective seed interventions by partner institutions so that improved materials efficiently reach farmers.

The first generation of backcrosses between F_1 and the farmer-preferred varieties (Hugurtay, Hiryray, Ochuti, Tabat, Wad Ahamat, Tiemarifign, and CSM 335) has been performed and BC_1F_1 generated in Kenya, Mali, Sudan, and Eritrea. In Kenya, 210 BC_1F_1 individuals were genotyped using 3 SSR markers: 63 plants were found to be heterozygous for markers in the QTL target regions – 3 plants contained 3 *Striga* QTLs, 13 had 2 *Striga* QTLs, and 47 had 1 *Striga* QTL. Confirmed hybrids were backcrossed to the FPSV recurrent parent Ochuti to produce the BC_1F_1 generation, which is currently being genotyped. In Sudan, 144 Tabat BC_1F_1 samples were genotyped and 28 plants were found to be heterozygous for markers in the QTL target regions – 5 plants contained 4 *Striga* QTLs, 4 contained alleles of 3 QTLs, 5 had 2 QTLs, and 12 had 1 QTL. Capacity for DNA isolation, quantification, PCR optimization, and agarose/PAGE with silver staining has been provided to the NARS in Mali (UB and IER), and Kenya (KARI-Katumani) through training, provision of equipment, and technical backstopping.

A gene flow experiment was set up to determine the distance of pollen flow using male-sterile lines as receptors, thus eliminating the need of large scale PCR genotyping. The flowering dates of the materials from Sudan, Kenya, and the male-sterile lines were determined and the first pollen dispersal experiment carried out using Ochuti and N 13 pollen donor and recipient, respectively. The experiment is currently being repeated at another site. A field study has been conducted on sorghum indigenous knowledge, farming system, stakeholders' perceptions and seed supply systems in Eritrea, Kenya, and Sudan. A report containing the findings of status of the seed sub-sector in Eritrea, Kenya, and Sudan has been compiled.

D Kiambi

Global Project 3: Genetic Diversity, Genomic Resources and Bioinformatics [Project Coordinator: HD Upadhyaya]

Output 1.3.2: Molecular characterization and validation of mini-core germplasm collections

Activity 1.3.3.3: Phenotypic and genotypic diversity assessment of sorghum germplasm varying in flowering time and stay-green/senescence at maturity

Team: CT Hash, RT Folkertsma, V Vadez, FR Bidinger, D Hoisington, HFW Rattunde, F Sagnard, B Clerget, S Chandra and HD Upadhyaya

Milestone: Allele-mining to develop allele-specific markers for all major flowering genes in sorghum completed (2008)

Genetic materials appropriate for this activity have been included in the composite germplasm set of sorghum that is being genotyped with approximately 50 well-distributed SSR loci in the Generation Challenge Program. However, to achieve this milestone substantial additional special-project funding is required.

CT Hash, RT Folkertsma, V Vadez, FR Bidinger, D Hoisington,
HFW Rattunde, F Sagnard, B Clerget, S Chandra and HD Upadhyaya

Activity 1.3.3.4 : Phenotypic and genotypic diversity assessment of nutritional quality in sorghum and pearl millet germplasm
Team: CT Hash, D Hoisington, BVS Reddy, S Ramesh, KN Rai, VN Kulkarni, EW Rattunde, V Vadez and HD Upadhyaya

Findings from the first two years of phenotypic diversity assessment for grain micronutrient density in sorghum in HarvestPlus, the Biofortification Challenge Program, can be summarized as follows:

- Genetic variability exists for grain densities of Fe, Zn and phytates.
- Broad-sense heritabilities are high for sorghum grain densities of Fe, Zn and phytates.
- There is limited variability for beta-carotene grain density in sorghum, and all materials with detectable levels of this micronutrient in their grain have yellow endosperm. Because of this, we recommend halting conventional phenotypic diversity assessment and marker-based genotypic diversity assessment for this trait in sorghum, allowing the limited available resources to be focused on improvement of sorghum grain densities of Fe and Zn.
- The correlation of sorghum grain densities of Fe and Zn is significant and positive, which will facilitate simultaneous improvement of the grain densities of these two micronutrients.
- There are significant negative correlations of sorghum grain densities of Fe and Zn with grain yield, probably as a result of negative correlation of sorghum grain densities of these micronutrients with grain size.
- No significant interactions of genotype × managed soil fertility (NPK) level was observed for Fe, Zn and phytate grain densities in sorghum

Similarly, findings from the first two years of phenotypic diversity assessment for grain micronutrient density in pearl millet in HarvestPlus, the Biofortification Challenge Program, can be summarized as follows:

- Although there are significant genotype × environment interaction for pearl millet grain densities of Fe and Zn, there were good correlations between two seasons [Fe (r=0.66**) & Zn (r=0.69**)] and genotype rankings for Fe and Zn density were fairly consistent across environments and laboratories.
- There is wide variability for grain Fe and Zn density in pearl millet, and high grain Fe and Zn density is available in elite backgrounds. Almost all micronutrient-dense genotypes identified are derived from '*Iniari*' germplasm.
- As in sorghum, pearl millet grain densities of Fe and Zn are positively correlated, so simultaneous improvement of the grain densities of these two micronutrients should be possible.
- A rapid, low-cost, staining protocol of Fe grain density has been optimized and can now be used for inexpensive high-throughput screening of core collections of sorghum and pearl millet for additional Fe-dense accessions. In pearl millet the aim of such screening would be to identify 'non-*Iniari*' germplasm having high grain density of Fe.

Thus, there are good prospects to increase grain density levels of both Fe and Zn in pearl millet.

Based on the results of the first two years of phenotypic assessment of grain micronutrient densities in these two crops, it appears there are opportunities to:

- use high-throughput methods to screen core collections for additional Fe-dense accessions of sorghum and pearl millet, which are then reasonably likely to also have high grain densities of Zn;
- assess effectiveness of enhancing Fe and Zn density in released OPVs by recurrent selection;
- initiate inheritance studies of grain Fe and Zn density, which can include mapping population development in pearl millet (initially using bulk segregant analysis for grain Fe density)
- initiate studies of nutritional availability of the Fe and Zn in grains of sorghum and pearl millet genotypes that have high grain densities of these micronutrients.

CT Hash, D Hoisington, BVS Reddy, S Ramesh, KN Rai,
VN Kulkarni, EW Rattunde, V Vadez and HD Upadhyaya

Output 1.3.4: Molecular characterization of gene flow

Activity 1.3.4.2 : Sorghum and pearl millet and their wild relatives in Asia and Africa
Team: F Sagnard, HFW Rattunde, EW Rattunde, RT Folkertsma, CT Hash, BVS Reddy, D Hoisington and HD Upadhyaya

Milestone: Sorghum crop-to-wild gene flow in Mali and Kenya

ICRISAT leads a project on the "Environmental Risk Assessment of Genetically Engineered Sorghums in Mali and Kenya". It aims at measuring the realized amount of crop-to-wild gene flow and analyzing the farmers' practices that may limit or favour the in situ genetic introgression between cultivars and wild Sorghum populations. This is a multidisciplinary project involving population geneticists, GIS/remote sensing specialists, molecular biologists, Sorghum breeders, and social scientists from ICRISAT in Mali and Kenya, from IER and the University of Bamako in Mali, from KARI in Kenya that started in March 2005.

We found much morphological evidence of crop/wild introgression occurring in Mali and Kenya. The crosses made on-station between several wild and cultivated sorghums were all successful and produced normally fertile hybrids. However, it seems that the occurrence of wild sorghums and the presence of weedy types in farmers' field differ between regions. In the Soudano-guinean zone of South and South-West Mali, wild and weedy types are widespread in and around farmers' fields whereas weedy sorghums are rare in the Central and Northern part of Mali where they are not mentioned as an important threat for agriculture. The amount of genetic introgression may be variable due to the phenological overlap of wild and cultivated sorghum flowering period. Our partial results show that wild sorghum in North Mali are more genetically differentiated from cultivated sorghum than those from the Mandé region. They also flower earlier than the landraces cultivated in the same villages

F Sagnard, HFW Rattunde, EW Rattunde, RT Folkertsma, CT Hash,
BVS Reddy, D Hoisington and HD Upadhyaya

Output 1.3.5: Assessment of phenotypic and genotypic diversity in sorghum and pearl millet in Western and Central, and Southern and Eastern Africa

Activity 1.3.5.1: Temporal evolution of genetic diversity of Sorghum and Pearl Millet in Niger between 1976 and 2003.

Team: F Sagnard, HFW Rattunde, EW Rattunde, CT Hash, D Hoisington and HD Upadhyaya

Milestone: *Agromorphological and genetic marker analyses of sorghum and pearl millet collection in 79 villages across Niger*

ICRISAT participated in a collaborative project on Sorghum and Pearl Millet agrobiodiversity along with the French Institute for Biodiversity (IFB) including IRD, CIRAD and INRA in 2004 and 2005 to compare the genetic diversity of sorghum and pearl millet collections conducted at a 27 year interval, using both molecular (32 SSR) markers and agromorphological descriptors. The results were expected to provide new insights on the impact of climatic and anthropogenic changes on the evolution of crop diversity in the semi-arid regions.

In Niger, substantial diversity for agromorphological traits and SSR was observed in sorghum. The genetic diversity is highly structured among races and among regions with the Durra race predominant in Eastern Niger and the Guinea race mainly located in the region where the annual rainfall exceeds 600 mm per year. We did not find any evidence of genetic erosion between 1976 and 2003 at the country level despite the occurrence of several drought events and the doubling of the population in Niger during the period of study. The low genetic differentiation (Fst = 0.003) of the two sorghum collections could indicate the strong resilience of agrobiodiversity in harsh environments and support the idea that *in situ* conservation by farmers is an efficient and complementary way to conserve the diversity of crop genetic resources. The data on genetic diversity observed at a more local scale will be analyzed in 2006.

F Sagnard, HFW Rattunde, EW Rattunde, CT Hash,
D Hoisington and HD Upadhyaya

Activity 1.3.5.2: Structuration of Sorghum diversity in Mali in relation to the environmental gradient and the farmers' practices

Team: F Sagnard, HFW Rattunde, EW Rattunde, CT Hash, D Hoisington and HD Upadhyaya

Milestone: *Assessment of inter- and intra-varietal structures of sorghum landrace diversity using agromorphological and microsatellite markers.*

ICRISAT team in Mali participates in the project "Sorghum agrobiodiversity in Mali and Burkina Faso" funded by the French Fund for Global Environment (FFEM). This project promotes plant participatory and decentralized breeding using a large amount of local germplasm as a method to conciliate crop improvement and genetic resource conservation of sorghum in its center of diversity.

The Sorghum genetic diversity is not randomly distributed in Mali along a North-South gradient. Landraces are highly structured according to botanical races and phenology. Traits such as sensitivity to photoperiod and the tillering ability are widespread in the local sorghums. These characters should be linked to adaptation to harsh environments of the semi-arid tropics. The lines produced by the IER breeding program conserve an important part of the local genetic diversity. The within seed lot genetic diversity of 10 sorghum varieties (6 Guinea Gambicum landraces, 3 Guinea Margaritiferum landraces and 1 commercial Guinea Gambicum variety) is more important in the Guinea Gambicum landraces than in the Guinea Margaritiferum landraces and the commercial variety. An average of

1.25 to 3.36 alleles per locus were found. The heterozygote deficit is lower than values that have been previously published for the Durra race sorghum except for the guinea margaritiferum landraces, which indicate a higher outcrossing rate for the Guinea Gambicum sorghums than generally admitted (up to 53 %).

All landraces are highly genetically differentiated (0,19 < Fst < 0,65), even among 2 landraces cultivated in the same field by the same farmer. This is much likely the consequence of repeated bottlenecks caused by sowing seeds collected on a limited number of individuals each year.

F Sagnard, HFW Rattunde, EW Rattunde, CT Hash,
D Hoisington and HD Upadhyaya

Global Theme - Crop Improvement, Management and Utilization for Food Security and Health
CLL Gowda - Global Theme Leader

Introduction

The Global Theme on Crop Improvement, Management and Utilization for Food Security and Health aims to contribute to sustainable growth in crop production, farm income, food security and environmental protection through the development of improved and diversified cultivars, eco-friendly and cost-effective pest management practices, and commercialization of diversified and alternative uses of crop produce.

The purposes of the Theme are:

- To undertake research for genetic diversification and enhancement of ICRISAT mandate crops for high and stable grain and fodder yield with acceptable quality,
- To develop cost-effective and eco-friendly integrated pest management (IPM) technologies,
- To address alternative crop produce utilization strategies, including food and feed safety issues, and prospects for commercialization,
- To increase adoption of improved varieties by farmers through enhanced formal and informal seed-supply systems,
- To develop institutional mechanisms between public and private sector stakeholders to ensure sustainable demand for public sector-bred improved varieties, and
- To accelerate technology exchange and information sharing, using both conventional methods and information and communication technologies (ICT) for capacity building of NARS to achieve on-farm impact and to improve human and livestock health.

The expected outputs (with indicators in Italics) are:

1. Genetically diverse trait-specific populations and breeding lines developed for use in NARS programs *[Increased availability of diverse germplasm sources and breeding materials]*
2. Regionally adapted parental lines, varieties and hybrids developed for SAT regions *[Enhanced and newer options of locally-adapted cultivars]*
3. Effective disease and insect pest management technologies developed *[Increased adoption of cost-effective and eco-friendly IPM packages]*
4. Technologies for improved food, feed and fodder quality and safety disseminated *[Better options for food and feed safety to improve health of humans and livestock]*
5. Crops for diversification and stability of systems enhanced [*Better options for crop diversification and sustaining crop-livestock productivity]*
6. Dual-purpose and forage cultivars of mandate crops evaluated and promoted [*Increased options for raising livestock and crop productivity]*
7. Potential and opportunities for commercialization of diversified alternate crop uses assessed *[Better and novel products, safer food and feed, increased market demand]*
8. NARS capacity and impact accelerated through participatory approaches and technology exchange *[Efficient research methods and technology exchange practices]*

With the considerable genetic resources available at the ICRISAT genebank, and our mandate to provide enhanced breeding material and improved varieties to farmers, crop improvement is a priority activity. Emphasis will be on development of parental lines for cereals and varieties for legumes in Asia, and on varietal development and strengthening participatory breeding and varietal selection approaches in Sub-Saharan Africa. Improved varieties need good crop management to produce high yields, including eco-friendly IPM for crop protection. Resistances to biotic constraints (e.g., pod borers in chickpea and pigeonpea, aflatoxin in groundnut, grain mold and *Striga* in sorghum and downy mildew in pearl millet) will be integrated with other pest management strategies, including bio-pesticides (NPV and bacterial sprays). Opportunities to increase market demand through alternative uses for crop produce, commercialization, and linking income generating industrial utilization strategies with technology development activities will be further strengthened.

The following three Regional Projects focus on research activities in the Global Theme on Crop Improvement, Management and Utilization for Food Security and Health:

1. Improving crop productivity through genetic enhancement and eco-friendly pest management, and enhancing alternative uses of products in Asia (*Coordinator: KN Rai*)
2. Enhancing crop productivity and diversification of income sources of SAT farmers in Eastern and Southern Africa (*Coordinator: Mary A Mgonja*)

3. Increasing productivity and utilization of SAT crops in Western and Central Africa (*Coordinator: Eva Weltzien R*)

Variety Releases
Fourteen varieties were released in six countries (Australia, Ethiopia, Ghana, India, Malawi, Nepal and Uzbekistan). The varietal releases were in sorghum (1), pearl millet (2), chickpea (3) and groundnut (8).

Resource Mobilization
During 2005, the scientists in Crop Improvement and Management (along with scientists from other Global Themes) were successful in getting 41 special projects to augment the core funds of the Institute. The total amount of funds garnered in 2005 was US$ 7.45 million. We also submitted 20 project proposals/concept notes to various donors (details in Appendix 1).

Publications
Books/Book Chapters: 34; Journal Articles: 92; E-Journal Articles: 9; Conference/Workshop Papers: 108; Information Bulletins/Newsletter Articles/SATrends: 30; Methods Manual: 1; Oral Presentations: 6; Posters/Flyers/Success Stories: 28; Public Awareness Articles: 3; Release Proposal: 1; Reports: 10; Student Theses: 7; and Technical Reports: 3

Regional Project 3: Increasing productivity and utilization of SAT crops in Western and Central Africa

The crop improvement team in WCA achieved a very welcome diversification during 2005. A new pearl millet breeder has strengthened activities on a wide scale, and increased our presence and ability to work with farmers, especially in the Sahelian zone of WCA substantially. Similarly a Striga ecologist joined the team in Samanko, Mali, to focus on research efforts on evaluating options for integrating Striga management measures in collaboration with farmers, in both sorghum- and millet-based systems.

Highlights of the 2005 season were the high levels of heterosis found in a wide range of Guinea race sorghum hybrids, tested for the first on a wide scale. For the first time, we succeeded in producing Guinea race hybrid seed in isolation plots, under natural pollen shedding conditions.

Groundnut seed of a wide range of new varieties continues to be in great demand, from research partners, from farmers, and for the first time, from an emerging private seed sector. Thus the first signs of changes in the supply of improved varieties through targeted commercial activities are encouraging. Efforts to develop national Foundation Seed Units are underway that can support these developments in a sustainable way.

Pearl millet improvement research started off with a large-scale germplasm evaluation and multiplication. The germplasm originates from the West-African region, and represents a wide range of agro-ecological zones. New populations are in preparation, and plans underway to classify this material into heterotic groups.

Research on micro-nutrient nutrition of sorghum and pearl millet was established more broadly with support of the Harvest Plus Challenge Program. Nutritionist input is strongly required to achieve appropriate targeting of the work.

Output 3.1: Regionally adapted diverse breeding materials, varieties and hybrids developed

New source materials provide the basis upon which new varieties and hybrids can be developed. Progress is being made on developing new and improved source materials for sorghum in several respects. The original Guinea-race sorghum population has been and continues to be diversified, targeting specific climatic zones and their adaptation requirements, including for the longer-season Guinea zone, in collaboration with Institute of Agricultural Research (IAR), Nigeria. This intensified collaboration with Nigeria was the outcome of intense interactions between Nigerian officials and the ICRISAT team in WCA. Plans for intensifying this collaboration further are underway, along with plans for new projects.

Participatory variety testing, especially for new groundnut and sorghum varieties, is becoming institutionalized among NARS partners. Methodologies are being refined for use in Mali, Niger, Burkina Faso, Nigeria, and Senegal, and for different systems, as well as crop uses. The team has been able to put together major publications on this issue, and more is in the pipeline.

Results of multi-location sorghum trials indicate that progress in increasing grain yields over local varieties, while retaining adaptive characteristics, is actually possible. Most promising are novel shorter height guinea race sorghum varieties, and guinea race sorghum hybrids.

Activity 3.1.1: Develop and improve trait specific populations and breeding lines of sorghum, pearl millet and groundnut

Milestone: Later maturing guinea-race random-mating population of sorghum developed for Northern Guinea zone

A random-mating population was created by crossing a Nigerian Guinea-race sorghum accession IS 7978 with the Guinea Population containing the male-sterile gene ms3. IS 7978 is late maturing (flowering October 18 at ICRISAT-Mali) with large grain size (3.5 g/100 seeds). This new population was included in a five-variety on-farm trial in Kaduna state, Nigeria in 2005. Results obtained from a total of 8 villages indicated that although the grain was often appreciated, the flowering was often too early (dates between 30 September and 18 October frequently recorded). Farmers indicated this population to be of interest in for the more northerly Sudanian zone. Original F_2 seed of this population will be used in 2006 to cross to Kaura and Fara varieties from the Northern Guinea zone to create a later-maturing population.

HFW Rattunde and E Weltzien

Milestone: Guinea sorghum hybrid parents tolerant/resistant to midge identified

Several Guinea-race germplasm accessions from Cameroon have shown consistent high levels of resistance to midge, both per se and in the hybrids they produce. Results from the 2005 Hybrid trial indicated no loss due to midge (0 to 1%) for accessions IS 15302, IS 15629 and IS 30804, all from Cameroon, whereas other accessions of similar maturity had near total loss (IS 26320 (Togo) and IS 7978 (Nigeria) had 84 and 75% losses, respectively). Likewise the hybrids produced with the Cameroon accessions as male parents also showed very high levels of resistance (0 to 2% loss), despite the female parent (IS 3534A) showing 24% loss.

HFW Rattunde and E Weltzien

Milestone: Diversified agronomically superior dual-purpose groundnut breeding lines with improved resistance to foliar diseases and rosette

Groundnut is an important crop for resource-poor farmers in Semi-arid West Africa, who rely on it for their economic prosperity and nutritional welfare. Nutritionally groundnuts are an excellent source of dietary protein, oil/fat, and vitamins such as thiamine, riboflavin and niacin.

Foliar diseases such as rust, early and late leaf spots and groundnut rosette disease cause significant yield losses in groundnut in WCA. In order to stabilize yields and enhance productivity development of high yielding resistant varieties is the most economic approach.

We evaluated 36 advanced groundnut-breeding lines with multiple attributes (dual purpose, tolerant to Aflatoxin contamination and resistant groundnut rosette disease) for resistance early leaf spot. Among 14 early maturing rosette resistant lines, one was highly tolerant to early leaf spot (score of 5 on 1-9 scale) at Samanko in Mali. For the dual-purpose lines, 10 had a score of 4-5 compared to the susceptible check with a score of 8. The six aflatoxin resistant lines were also tolerant to early leaf spot.

We also advanced 71 rosette resistant F_2 populations to F_3 and 47 to F_4. Bulk progenies were selected for further selection and generation advance. These populations were also scored for early leaf spots. Among the F_2 populations, 7 had a score of 5 while in the F_3 populations, 12 had a score of <5. Varieties with high pod and fodder yield with resistance to foliar diseases are expected from these improved breeding lines and populations.

BR Ntare and AT Diallo

Milestone: Multiplication and characterization of pearl millet genebank accessions of diverse geographic origin

One of the objectives of WCA pearl millet improvement program at ICRISAT-Niamey is to better exploit and to enhance access of NARS breeders and farmers to the genetic diversity of pearl millet [Pennisetum glaucum (L.) R. Br.] in its center of origin in West Africa. Therefore, 281 pearl millet accessions from nine countries of West and Central Africa, assembled during joint IRD/ICRISAT pearl millet collections in 1976 and 2003 and geographically covering longitudes from 8.44E to 17.28W and latitudes from 6.49N to 20.26N, were grown for seed multiplication and initial characterization in the rainy season 2005 at ICRISAT, Sadoré (Niger).

The multiplication of materials was performed by controlled pollination (“sibbing”) within each accession, aiming at a minimum effective population size of 60 plants contributing to the next generation. Pollen donors were simultaneously selfed to obtain S_1 seed as an initial step of further inbred line development out of the most promising accessions. Characterization data include days to 50% flowering, plant height, panicle length and diameter, exsertion, form and compactness of the panicle, numbers of selfed and sibbed panicles, and grain weights of selfed and sibbed panicles. The determination of 100-seed weight and grain color is still underway.

Raw data indicate that the germplasm reveals significant variation for all morphological and phenological traits studied: e.g., observations ranged from 40 to 155 days to 50% flowering, 153 to 405 cm for plant height, 18 to 115 cm for panicle length, 1 to 6 cm for panicle diameter, and from minus 23 to plus 12 cm for panicle exsertion. These accessions are therefore a gold mine of variability for future breeding.

Seed multiplication through sibbing was achieved for 248 out of the 281 accessions, with the amount of seed produced ranging from 22 to 2474 g. The effective population size of ≥60 was achieved in 117 accessions (minimum of 30 sibbed panicles). Twenty five accessions were multiplied with an effective population size of less than 20 (<10 sibbed panicles), due to poor germination or lack of adaptation of the accessions. Selfed seed was produced from 232 accessions, with the seed quantities obtained ranging from 14 to 2901 g.

Small amounts of the regenerated seed will be returned to the IRD-Montpellier and ICRISAT-Niamey genebanks for long-term conservation. The complete characterization data shall be linked to the gene banks information systems. The data will mainly be used for further diversity analysis and studies of heterotic grouping of West African pearl millet genetic resources with the final aim of significantly improving pearl millet yield performance and stability in West Africa. The cooperation from IRD-Montpellier and IRD-Niamey (Drs Y Vigouroux, G Bezançon) in providing the original seed of the accessions and extra-large pollination bags is highly appreciated.

BIG Haussmann, SS Boureima and A Boubacar

Activity 3.1.2: Develop hybrid parents adapted to specific zones of cereals cultivation in WCA

Milestone: Superior Guinea-race sorghum R-lines identified

A set of 29 restorer lines of diverse geographic origin was established for creating experimental hybrids. These R-lines were identified based on prior testcross results and chosen to represent geographic and morphological diversity. Twenty restorer lines were identified from accessions in the Guinea-race Core Collection, and nine landraces or bred varieties from Mali. The restorer lines were used to produce hybrids on newly developed A-lines FambeA, IPS001A, and IS3534A. Hybrid trials were conducted in 2005 at ICRISAT-Mali (two dates of sowing), IER-Sotuba, Mali and Bengou, Niger. Later maturing restorer lines of humid West Africa (Nigeria, Cameroon, Togo) origin produced hybrids with the highest grain yields. Restorer lines of intermediate maturity, although not producing the highest yielding hybrids, still provided significantly significant yield superiority over highly adapted check varieties.

A restorer line database with agronomic characterization information and combining ability results of both Guinea-race and inter-racial restorer lines developed by IER, is being compiled jointly with IER. Origin, days to heading and plant height of identified restorer lines used for experimental hybrid production are being documented.

Activity 3.1.3: Participatory testing and release of improved sorghum, pearl millet and groundnut varieties

Milestone: Advanced yield testing of new breeding material evaluated jointly with Malian partners, and with farmer participation

Organized variety testing with farmer participation started in 2003 in 11-12 villages and on 2-3 research stations. The same 32 varieties were grown at each location.

Eight (in 2003) and seven (in 2004, 2005) of the villages were situated in Dioila district, an area of more intensive agricultural production. Many farmers are literate and well organized at a local level. Five sites were managed by the farmer organizations which form part of the Union of Cereal Producers in Dioila district (ULPC). Three were managed by village organizations which were initially formed for the management of cotton production in the respective villages, with whom the researchers had developed good working relationships through a close collaboration with the extension service of the cotton parastatal (CMDT= Compagnie Malienne du Developpement des Textiles). In the Mandé area, villages were suggested by the extension partners, who had longstanding relationships with many villages.

The participating farmers were primarily chosen by the farmers' organizations (Dioila) and the extension services (Mandé). The farmers were responsible for choosing the field for the trial and two local control varieties: one common for the whole village and one of specific interest to the farmer who provided the field. Four farmer participants together with the person providing technical assistance chose the village level check variety, usually one of the dominant varieties in the village used by many farmers. The farmers were involved in the choice of the test entries in the following manner:

Some varieties were retained from a precursor trial. They were retained based on farmers' choice and the yielding ability in the trials.

Farmers involved in the trials came to visit the ICRISAT research station during the pre-harvest period. They were shown the S2- progeny trials from the diversified Guinea-race populations, from which entries for the farmers' trials were to be selected. They scored each plot, using a score from 1-3 with color-coded paper pieces. The preference of farmers was one main criterion to choose varieties for the trials.

Farmers did not, however, visit the IER breeding stations, and thus experimental varieties from IER were chosen by researchers primarily. However, IER also conducts some of its selection program in close collaboration with farmers, and thus some materials have been selected by farmers in other areas of sorghum cultivation. These entries were fixed lines, which had previously been tested in multi-location station trials.

Farmers were responsible for managing the trial field and for visual evaluation for a range of traits identified previously together with them. Farmers received a basal dose of N and P fertilizer, which they applied at sowing time. The seed was treated (if the chemical was available in the local market). Each farmer grew one replication of the 32-entry trial. The 6 row plots of 5 m length were arranged in 4 ranges of eight plots each, and randomized as alpha-lattice designs with 4 plots per block. Students and local extension officers supported the farmers, particularly with sowing, plot identification, recording of observations, decision-making about management, and at harvest. Weighing the yield of each individual plot was a key responsibility of the technical support staff. They further organized the visits of other farmers to the field trials and their evaluation of the test varieties. The researchers contributed to the organization of these visits and organized the testing for processing and culinary qualities

In the other region (Mandé), where agriculture is more extensive and less cotton is grown, the same trials with 32 entries were grown in four villages. Extension agents of a local NGO and the government extension service supported the farmers. The responsibilities were shared in the same manner as described above.

Farmers' visits to the trials were organized at one research station and in at least 10 villages each year. All visiting farmers scored all varieties for their overall performance and acceptability, using a 1-3 scale and paper slips with different colors to signify each score (Christinck et al., 2005, p.96). After harvest, a two-day workshop was organized for each pair of neighbouring trial sites in order to discuss the yield results and evaluate grain and culinary qualities. On the first day the results of the yield evaluations, the farmers' selection, and other key observations were presented to the farmers who had participated in the trials as well other interested farmers from the villages concerned. The results were discussed and four varieties were chosen for the culinary trials the following day. The key activity on the second day was the evaluation of processing qualities and the culinary quality of the four best varieties in each village. All participants could also evaluate the grains of each variety visually, using the same 1-3 scoring system using different colored paper slips.

The four entries selected by the workshop participants for the culinary testing were considered to enter the second stage of testing, but only if their processing and culinary characteristics were found to be acceptable.

After harvest, and after completing the tests for culinary quality, a workshop with all farmers who had participated in the trials and other project activities was organized for each project zone (Dioila and Mandé). Yield data were discussed and varieties finally selected for further testing. Furthermore, changes with regard to trial management, monitoring and responsibilities for the diffusion of results were discussed and decided jointly.

Results of yield trials: The results of the yield trials were very encouraging in all years (2003, 2004, 2005), in the sense that all trials could be harvested and evaluated. Only individual replications of trials had to be abandoned in a few cases.

The seasons were markedly different; in 2003, the rainy season was very good, started early and continued until mid-October in all the project areas. This even led to some difficulties caused by excessive rainfall, such as water logging. In 2004, however, the rainy season started late and ended earlier than expected, as a consequence terminal drought stress occurred, particularly in fields with lower water holding capacities. In 2005, the season started some what earlier than in 2004 and ended earlier than normal, but later than in 2004.

In 2003, varieties could be identified in each village which were more preferred by the farmers than the local check entries. The yield superiority, however, was fairly low, between 10-20% on a variety mean basis for individual villages. A number of new dwarf lines performed relatively well in these trials, and as these are not yet finished varieties, the remaining variability could be exploited in order to further improve the grain yields.

In 2004, some of the new improved varieties showed clearly superior grain yields over the farmers' check entries in both project areas, and also reached high values in the farmers' preference scoring. This was partly due to earlier maturity, an advantage under the end-of-season drought conditions encountered this year. Mean grain yield varied widely between locations, and there was also considerable variability between individual replications within the same village. This made the data evaluation more difficult. The flowering dates were only recorded at the research stations.

There is now increasing interest in the shorter sorghum varieties, as they exhibit better stover quality than the tall varieties that are highly lignified. Farmers are also experiencing that they are easier to harvest, and tend to give higher grain yields.

E Weltzien, HFW Rattunde, I Sissoko and A Christinck

Milestone: Synthesis report on participatory variety selection in groundnut available

Investments by ICRISAT and partners have resulted in the development of a broad range of groundnut varieties. However, farmers have limited access to these varieties. The key is to make available a range of modern varieties and train farmers to efficiently produce seed of selected varieties, using appropriate technologies leading to increase rural incomes.

Over 200 participatory varietal selection (PVS) trials were conducted in 45 locations across four countries: Mali, Niger, Nigeria and Senegal. In each country farmers have selected at least one or two new groundnut varieties. Seed production schemes were initiated in each country to ensure availability of seed of these varieties. The synthesis report will document the PVS process, pathways to adoption of improved varieties, lessons learned and perspectives.

BR Ntare, J Ndjeunga, AT Diallo, HY Bissala and F Waliyar

Milestone: A synthesis report on groundnut seed systems in WCA

The availability and uptake of seed of high quality by farmers is fundamental to the transformation of predominant traditional agricultural production practices to achieve increased stability and sustainable food production in West Africa. New seeds with higher yield potential or ability to relieve constraints faced by farmers in using traditional varieties form part of the improved inputs required to increase crop production.

This technical paper summarizes information on the structure, conduct and performance of formal and informal groundnut seed supply systems in 4 countries in West Africa namely Mali, Niger, Nigeria and Senegal. It highlights a range of technical, socio-economic, institutional and policy constraints facing the groundnut seed industry in West Africa. Low and inconsistent supply of breeder seed, poor seed demand estimation, lack of or non-functional national variety release committees, inappropriate institutional arrangements and the biological features of groundnut have limited private sector entry and the performance of the groundnut seed industry. Options likely to be sustainable should focus on local village seed schemes whereas small-scale private seed entrepreneurs or community based seed systems should be encouraged to become seed entrepreneurs or engaged in the seed industry. There is evidence of vertical integration between inputs and product markets. Appropriate linkages between seed and grain producers, and grain producers and processors are necessary to drive the private sector entry in the seed industry.

J Ndjeunga, BR Ntare, F Waliyar and M Ramouch

Milestone: Technical paper on market prospects for groundnut in WCA published

This is a result of a study commissioned by ICRISAT, with financial support from the Common Fund for Commodities. The paper documents the principal groundnut producing countries in the international markets, global market status trends and quality requirements, recent trends in production and consumption, and strategies for increasing groundnut production in West Africa.

BR Ntare, F Waliyar, M Ramouch, E Masters and J Ndjeunga

Output 3.2: Methodologies for enhancing productivity, adaptation of sorghum pearl millet and groundnut cultivars developed

Basic research into adaptive mechanisms of the local guinea races sorghums is showing more explicitly that not only phonological changes are affected by sensitivity to the photoperiod, but also growth rate changes. However these changes do not affect the whole plant, but rather the above ground dry-matter. It seems that root growth continues unchanged during the various phenological changes of the sorghum plant, in contrast to maize. Research was started to understand better the differential responses of pearl millet varieties to different flowering dates, but also its pattern of root growth.

During 2005 a handbook on Priority setting with farmers for breeding programs and seed system activities was finalized. The book provides basic insights and concepts, but also practical tools for the field, described in sufficient detail, that they can be used directly.

Activity 3.2.1: Design sorghum and pearl millet ideotypes for a regional selection strategy for increasing productivity under production system-specific conditions

Milestone: Testing and grouping Guinea race sorghum and pearl millet, for photoperiod-sensitivity under the newly shown categories

A regional sorghum core-collection of 214 accessions was sown on the 26 June 2004 and characterized for their phyllochron during the life cycle. The goal of the study was to estimate the variability of the rate of development in sorghum, since this character and its evolution during the life cycle of the plant could give insights into how to increase the yield potential of photoperiod-sensitive varieties. The sorghum core-collection managed and studied by CIRAD has been used in this study. This study has largely demonstrated the generality of bilinearity of the leaf appearance rate for long-duration varieties producing more than 22-23 leaves, while the leaf appearance rate remained always constant for short-duration varieties. It showed also that, for sowing dates at the end of June, varieties of the guinea race (including margaritiferum, gambicum and conspicuum) acquired a shorter phyllochron at emergence, than varieties from the caudatum race which were intermediate and varieties from the durra and kafir races which had the longest phyllochron. This suggests that varieties from the guinea race expand their first leaves faster than varieties from the other races, when sown late.

A new series of monthly sowings of 12 pearl millet varieties with a large range of photoperiod-sensitivity was initiated in June 2004. The 18th sowings has been done in December 2005. Current results show patterns similar to sorghum: (i) the duration of the vegetative phase of 9 varieties varies slightly with the sowing date, corresponding with a quantitative photoperiod-sensitivity, while for the 3 other varieties this vegetative phase has been very long for sowings done during the beginning of the year, corresponding with a qualitative or absolute photoperiod-sensitivity; (ii) when more than 25 leaves have been produced by the apex, the rates of development and growth of the plants slowed down considerably and simultaneously; (iii) the rates of development acquired at emergence doubled from sowings done on the summer solstice to those done on the winter solstice. On the other hand, the vegetative phase of the 12 pearl millet varieties tested in Bamako has been minimal for sowings done at the end of June-beginning of July, while this minimum generally occurs for sowings done in October with sorghum. This last observation is contradictory to the current theory, established under artificial lightings, which predicts that pearl millet, a short-day species, must flower later when days are the longest.

B Clerget, HFW Rattunde and B Siaka

Milestone: Enhance knowledge on dwarfing and panicle size x photoperiod-sensitivity interactions

Panicle size x photoperiod-sensitivity interactions in experimental guinea hybrids

Ten experimental guinea sorghum hybrids and their parents were sown on the beginning of June and July to assess the contribution of the yield components responsible for the heterosis observed. The hypothesis is that the heterosis is due to a larger panicles size. Harvest data showed significant heterosis for grain yield of hybrids based on the parent Fambé A. These hybrids had more grains per panicle than their male parents. For July sowings, this larger number of grains clearly results in a better harvest index, thus a larger number of grains per unit of biomass. For the June sowing, on the contrary, the harvest index of the hybrids was generally not better than the parents and the larger grain number appears to be only related with an increase of the total biomass produced by the hybrids. In June sowings, the grain size (100-grain weight) of the hybrids was also slightly larger than that of the parents. On the other hand, no difference was observed between hybrids and parents in the rates of development of the panicle nodes. They remained always equal to the rate of leaf initiation at the time of the panicle initiation. These results show that heterosis depends on the sowing date, as the expression of the yield improvement of photoperiod-sensitive varieties and hybrids varies with the sowing date. It is necessary to understand these variations in order to find better combinations.

B Clerget and S Dagnoko

Comparing the rates of aerial and root development of sorghum and maize

Tropical maize has a much better yield potential than photoperiod-sensitive guinea race sorghum. To compare their developmental strategies, a parallel study of the developments of the aerial plant and of the horizontal and vertical root fronts were carried out with locally cultivated varieties. The rates of development acquired at emergence were similar for both species. Maize expanded 22 leaves at a constant rate of leaf appearance, against 28 leaves for sorghum with a bilinear kinetic. Maize has produced 15.4 t ha^{-1} of total biomass and 7 t ha^{-1} grain within 90 days against 18 t ha^{-1} of biomass, 3.5 t ha^{-1} grain in 130 days for sorghum. The horizontal rates of root growth were 1.2 and 1.8 cm day^{-1} for maize and sorghum, respectively. The maximal vertical rates of root growth have been similar and equal to 2.8 cm day^{-1} for both species. But the strategy to conquer the vertical dimension of soil has been very different between the species: the root tip of sorghum descended quickly at a constant rate from emergence to the 62nd day, time of panicle initiation. It continued its descent at a reduced constant rate (1.2 cm day^{-1}) until grain maturity. Consequently there was no link between the rate of descent of the roots and the rate of leaf appearance, which broke on the 41st day. In maize, the vertical progress of the root tip stopped one week after germination at a depth of 20 cm. It started again only on the 21st day, at panicle initiation time, and definitively stopped on the 56th day, when internodes had finished elongating. It thus appears that (i) the rate of descent of the root tip would be related to the phenology of the aerial plant, but differs with species and (ii) the roots of sorghum continue to go down quickly even after the rate of development of the aerial plant has decreased and the stem has started to elongate. This pattern of root growth may explain the better adaptation of late maturing guinea race sorghums to low fertility soils: during its stem elongation phase, the biomass is synthesized at a lower rate using minerals and water extracted from a larger volume of soil in comparison with maize.

B Clerget

Activity 3.2.2: Refine and adapt methodologies for farmer participation in specific stages of sorghum and pearl millet breeding

Milestone: Handbook on farmer participation in priority setting published

The handbook was published, and has been used as a basis for some training courses. The book is in high demand, and the first edition is nearly out of print.

A Christinck, E Weltzien and V Hoffmann

Output 3.3: Impact-oriented eco-friendly IPM technologies developed

During 2005 research on IPM technologies focused on two of the most complex issues faced by farmers: Aflatoxin contamination of groundnuts, and Striga management in dry-land cereals. For Striga control research on integrating control measures in a farmer participatory, joint learning was designed, and discussed with partners. We are looking forward to its implementation in 2006. For aflatoxin contamination results from widespread on-farm testing and evaluation is now available, and is leading to intense discussion on consequences, among farmers themselves, farmers and processors, as well as consumers.

Activity 3.3.1: Develop and evaluate on-farm integrated Striga control strategies in sorghum and pearl millet (in collaboration with GT AE)

Milestone: Integrated options for Striga control in pearl millet tested and refined in two target production zones

Potential for sesame to contribute to integrated control of Striga hermonthica of pearl millet in the West African Sahel
Striga hermonthica is an important constraint to the production of pearl millet, a staple cereal in many parts of sub-Saharan Africa. Sesame is an important oilseed crop well adapted to the sandy soils of the West African Sahel. Intercropping of sesame and pearl millet has been reported to reduce emerged Striga numbers, but formal research into the potential of sesame to contribute to control the parasite is lacking. Field trials were undertaken to evaluate the potential of sesame grown in rotation with pearl millet to reduce Striga infestation. Emerged Striga numbers and Striga fruiting were strongly reduced on pearl millet following sesame compared to sole millet. To maximize cereal yield, soil fertility enhancement and water conservation are indispensable elements of integrated Striga control. The results can guide future research at a time where sesame is being promoted to diversify agricultural production in the Sahel.

DE Hess, H Dodo and E Weltzien

Integrated Striga management in farmers pearl millet and sorghum fields
A 6-year on-farm trial with Integrated Striga management strategies in Mali and Niger led to very large reductions in the number of emerged Striga plants as well as seed bank densities, when compared to the normal farmers' practice. Although not quantified, farmers are known to adopt parts, if not all of the measures in other fields infected with Striga. More detailed analyses are underway.

DE Hess, R Tabo and E Weltzien

Milestone: Biology of resistance to Striga in sorghum understood

The role of sorghum genotype in the interaction with the parasitic weed Striga hermonthica
The main objective of this study was to find suitable measures for the selection of breeding material (crop genotypes) with superior levels of resistance or tolerance to Striga. The relation between Striga infestation, infection and yield loss and the effect of host genotype on Striga parasitism and reproduction were studied for 4-10 genotypes in agar-

gel, pot and field tests. Striga parasitism and reproduction, and the detrimental effect of Striga on crop yield can be significantly reduced through crop genotype choice. Maximum aboveground Striga number is a reliable selection measure for resistance. Striga flower stalk dry weight can be used to identify genotypes that reduce Striga reproduction. The maximum relative yield loss is a suitable selection measure for tolerance in susceptible genotypes, while for genotypes that are more resistant the relative yield loss per Striga infection seems more appropriate. For these tolerance measures, yield assessment of nearby uninfected controls is indispensable. Chlorophyll fluorescence, more precisely photochemical quenching and electron transport rate, may enable screening for tolerance without this requirement.

J Rodenburg, E Weltzien and D Hess

Combining the strengths of marker-assisted backcrossing and farmer-participatory selection to improve Striga resistance in sorghum

Striga-resistant sorghums would be an important component of integrated Striga management if resistance was available in locally adapted farmer varieties. The application of marker-assisted selection in Striga resistance breeding would greatly accelerate progress since field screening is difficult, complex, and often unreliable; Striga seed is quarantined thus confining tests to areas where Striga is endemic; and because some Striga resistance genes are recessive, increasing the time required for conventional backcrossing. QTL mapping for resistance of sorghum to S. hermonthica was performed using a population of F3:5 lines developed from the cross N13 x E36-1, where the resistant sorghum line N13 is characterized by “mechanical" resistance (Haussmann et al., 2004). Composite interval mapping detected five QTL common across five environments over two years of Striga resistance evaluation, with the resistance alleles deriving from N13. Since their effects were validated across environments, years and independent genotype samples, these robust QTL are excellent candidates for marker-assisted selection. In a three-year project, launched in April 2004, Striga resistance of farmer-preferred sorghum varieties in Eritrea, Kenya, Mali and Sudan will be enhanced through a combination of marker-assisted backcrossing and farmer-participatory selection. The impact of gene flow on the stability of the achieved Striga resistance will be investigated in a complementary study. Simultaneously, a socio-economic study of the sorghum seed supply systems in these countries will be undertaken to guide the design of effective seed interventions by partner institutions so that improved materials efficiently reach farmers. Linkage with technology exchange will boost promotion of the improved varieties as component of integrated Striga control.

RT Folkertsma, BIG Haussmann, HK. Parzies, D Kiambi, V Hoffmann and H H Geiger

Milestone: Quantification of the Striga hermonthica life cycle as a tool for seed bank management

Studies on weed management in cropping systems have shown there are economical advantages in managing long-term weed population dynamics in addition to short-term management to control weeds and prevent crop yield loss. An important component of integrated weed management is monitoring and attempting to predict how cropping systems and control strategies affect long-term population dynamics of weeds. In order to be able to model long term Striga seed bank dynamics, steps in the life cycle such as seed bank replenishment (seed production) and seed bank depletion (seed mortality in the soil), were quantified.

In six field experiments, we tried to: (i) develop a reliable, standardized method for monitoring seed production; and (ii) determine the effect of rainy season length, seed density, host cycle length and several control strategies on aboveground demography leading to seed production. Seed bank germination and depletion of Striga was also measured at a site in Mali and a site in Niger during one rainy season under different crop and fallow systems.

Seed production was affected by rainy season and host cycle length, as well as by different control strategies. A five-fold increase in initial seed density did not affect seed production and data indicated possible density dependence in underground stages, although with a very high variability. There were striking differences in above-ground Striga appearance between years and sites considering small differences in infestation or inoculation levels of (germinable) seeds. Finally, a relation was found between allometric seed production estimates and soil seed content to a depth of 3 cm. Seed production and seed bank dynamics of Striga are affected by season length, host characteristics and should therefore be incorporated into population modeling to support choices of integrated control methods.

Until now it is not clear what influences emergence levels considering certain densities, although rainfall distribution in the first weeks after sowing are suggested to play an important role.

Seed bank depletion was determined using two seed burial and retrieval methods, namely (i) mesh seed bags filled with sand and Striga seeds and (ii) soil inoculation and sampling after which seeds were extracted by means of wet sieving and flotation. Fate of exhumed seeds was assessed by a seed press test in which empty seeds were considered to have germinated.

Seed germination contributed most to seed bank depletion under a variety of vegetative cover types including host crops, non-host trap crops, intercrops of hosts and trap crops and weedy fallow. The soil sampling method and the seed bag burial method yielded similar percentages of seed bank depletion and treatment effects showed similar trends. Combining data from previous studies on seed production with these data on seed losses indicated that seed bank reduction by suicidal germination would only be achievable if seed production and seed bank replenishment are completely prevented. The results raise questions on the specificity of trap crops and whether differences reported previously in seed bank depletion between trap and host crops are simply caused by the prevention of seed production, rather than increased (suicidal) seed germination in the soil.

With the information obtained in this study and from literature, a population model was constructed and parameterized to explore the long-term effects of management strategies on the Striga seed bank through scenario study. The results from this study will aid in assessing and developing promising management strategies for Striga.

TA van Mourik, E Weltzien and R Tabo

Activity 3.3.3: Test options to reduce Aflatoxin contamination in groundnut

Milestone: Integrated technologies to minimize aflatoxin contamination in groundnut out scaling trials established in four countries

Aflatoxin is a toxic substance produced by mold fungi (Aspergillus flavus and A. parasiticus) that can grow on poorly managed agricultural crops, particularly groundnuts. If eaten in sufficient quantities aflatoxin can cause serious sicknesses that can lead to liver and several other cancers. Groundnuts for sale and export should be free from aflatoxin. Therefore appropriate crop management is essential at pre-and post harvest times.

ICRISAT and its partners have developed several technologies that can contribute to reducing risks to aflatoxin contamination. These include genetic resistance and integrated crop management practices, agronomic practices, biological control, and biotechnological interventions. A number of these technologies have been tested on-farm with farmers in Mali. ICRISAT has also developed inexpensive quantitative methods for the detection of aflatoxin in groundnut-based products and feed. The ELISA based diagnostic test is reliable, cost effective and easy to carry out. This can help NARS, NGOs, traders and exporters to undertake large scale testing of groundnut-based-foods and feed for aflatoxin.

Resistant/tolerant varieties: Past research has identified and developed groundnut varieties that are tolerant to Aspergillus flavus invasion and subsequent Aflatoxin contamination. The first task was to expose these varieties to groundnut farmers through participatory on farm trials/demonstrations. In such trials in the district of Kolokani and Kayes, the main groundnut procuring regions in Mali, low levels of aflatoxin contamination were recorded (Table 3.3). Similar trials/demonstrations have been extended to Niger, Nigeria and Senegal.

Integrated management practices: Infection of groundnut pod/kernel by the mold fungi occurs both in pre-and post-harvest conditions. In the pre-harvest conditions, end-of season drought is a major predisposing factor. Technologies to mitigate the effect of drought have been developed. These have been tested in two major groundnut regions of Mali (Kolokani and Kayes). The technologies are: application of lime, crop residues and farmyard manure and their combination. These treatments were applied to a resistant (55-437) and a susceptible (JL 24) variety with farmer participation. Results are presented in Tables 3.4 and 3.5. All treatments, especially, application of lime and farmyard manure significantly reduced aflatoxin contamination, especially in the susceptible variety. On average the application of lime reduced aflatoxin contamination by 84%.

Best-bet harvesting and drying technique: Groundnuts need to be harvested at the correct time. Delays in harvesting result in over maturity leading to fungal infections and subsequent aflatoxin contamination.

Poorly dried groundnuts enhance fungal growth and aflatoxin contamination. Good storage with kernel moisture <10% does not permit fungal growth and aflatoxin contamination. Poor curing can induce fungal growth (aflatoxin contamination) and reduce seed quality for consumption, marketing and germination.

Groundnuts that are allowed to dry well immediately after harvesting tend to develop negligible levels of contamination, where as groundnuts left out but covered with haulms and leaves tend to develop alarming levels of aflatoxin contamination (Table 3.6 and 3.7). The most effective control was achieved through immediate removal of pods from the harvested plants, but this has labor constraints at the time when other farm activities are at their peak. There is a need to explore cheap dryers that can be used by farmers during the harvest period.

Results indicated that proper handling of groundnut during and after harvest will reduce fungal growth and aflatoxin contamination thereby increasing the marketability of groundnuts and increasing sales and income by local groundnut farmers. There is a need for increased awareness for aflatoxin contamination and health hazards.

BR Ntare, AT Diallo, F Waliyar and O Kodio

Global Theme-Agroecosystems
Steve Twomlow – Global Theme Leader

Introduction

Since the EPMR in 1996, the Natural Resource Management Initiative within ICRISAT has been continually evolving in response to the views of the TAC, the Donors,[1] sub-regional organizations and the wider scientific community. The aim has been to ensure a sharper focus on strategic problems through regional and global projects (see Medium Term Plans since 1997). In the process, the four systems projects within the Soils and Agroclimatology Division evolved into four Center-wide projects (CP1 to 4) within the Natural Resources Management Program. In 2001 further restructuring took place. CP1, *Raising soil productivity to help SAT farmers grow their way out of poverty*, and CP2, *Efficient management of natural resources in watersheds*, were consolidated into priority impact-focused research activities within Global Theme 3.[2] CP3, *Farmer participatory approaches to integrated pest and disease management* was divided between three global themes, GT2, 3 and 5. Some of the research programs of 1996 were later completed or discontinued; while some research discarded earlier – for example CP4, the Desert Margins Program – was revived as its relevance to NRM issues in Africa was recognized and funding became available through the Global Environment Fund.

In response to the recommendations of the 5th External Program Review, GT3 and parts of GT5 were merged into the new theme *Land, water and agro-diversity management*, known in short as *Agro-ecosystem development, GTAE*. The new theme will have a greater focus on the African SAT, addressing development goals identified by sub-regional organizations. Subsequently, core resources from Asia have been redeployed in a phased manner to better address the major challenges of land, water and agro-diversity research in Africa.[3] From 2006 there will be no core funds allocated to NRM work in Asia. Component design of Integrated Pest and Disease Management (IPM/IDM) systems remains within the Global Theme 'Crop Improvement', with system testing of integrated components housed within GTAE.

However, given the availability of opportunities for special project funding for NRM in Asia, ICRISAT has continued to pursue these simultaneously; and has created a self-supporting NRM team in Asia. NRM scientists in Asia have continued to contribute to ICRISAT's Integrated Genetic Natural Resource Management (IGNRM) approach; lessons from long-term development programs in Asia are helping to increase the impact of NRM work in Africa. Examples include the watersheds work in Asia; linkage with ASARECA's Soil Water Management Network (SWMnet); and the successes achieved in IPM/IDM research. All these are essential parts of the IGNRM approach to improving food security among smallholder farmers in the African SAT.

In 2005 ICRISAT embarked upon a decentralization program to increase its regional focus in both Africa and Asia. Consequently, GTAE activities are distributed across three regional program: West and Central Africa, East and Southern Africa, and Asia. The agenda reflects the skills and expertise of the respective teams, and addresses research priorities identified by the sub-regional organizations in each region.

Research focus

The broad focus of GTAE reflects the major elements that were addressed within Global Themes GT3 and GT5 and include:

- Income-generating options for managing soil, water and agro-diversity, including systems diversification and integration of livestock and trees
- Low cost, input efficient, practical integrated NRM strategies including targeting of fertilizer (micro-dosing) and/or manure
- Integrating genetic and non-genetic solutions to drought tolerance and water and nutrient use efficiency
- Low cost water catchment and conservation systems
- Managing agro-biodiversity for ecosystem health
- Institutional and policy reforms for water usage and tailoring options for farmers' investment and risk options in sub-Saharan Africa

---

[1]. Since 1996 NMR research funding has shifted dramatically from core budgetary allocations to special project funding.

[2]. GT2 – Global Theme 2, Crop management and utilization for food security and health. GT3 – Water, soil and agrobiodiversity management for ecosystem health. GT5 – Enhancing crop-livestock productivity and systems diversification.

[3]. In response to the 5th EPR recommendations, ICRISAT constituted an Africa Task Force to review its commitments to Africa. The findings were presented for discussion at the Sep 2004 Governing Board meeting.

Gender-sensitive systems diversification options suited to poor farmers (including cash crops, trees, legumes and vegetables) will be assessed and promoted.

Goal, Purpose and Expected Outputs

GTAE goal

Improved rural livelihoods, increased food security and sustainable IGNRM throughout the semi-arid tropics as a result of a greater impact of agricultural research for development.

Intermediate goals

- Partners embrace innovative IGNRM research and development strategies with strong emphasis on improving water and nutrient use efficiency in crop and livestock systems
- Farmers adopt improved technologies for sustainable diversification of crop-livestock systems in SAT of Asia and Africa
- Farmer associations, agribusiness, NARES, policy makers and NGOs promote access, availability and utilization of innovations in a coordinated way along the value chain.

Purpose

- Develop and promote affordable and sustainable soil, water, crop and nutrient management options and integrated approaches to watershed management
- Identify and promote options for systems diversification (high-value crops, trees and livestock) to improve rural livelihood security
- Enhance capacity of R&D partners and regional networks to formulate and implement research for impact
- Develop and promote appropriate methodologies and approaches for agricultural rehabilitation following natural and/or civil disasters including HIV/AIDS.

Outputs [indicators/milestones in brackets]

- Sustainable resource management options to help rural households better meet their livelihood objectives developed and disseminated in Asia and Africa (links to GT Markets and Institutions) *[Socio-economic, agronomic, and cultural constraints/and or facilitating factors in technology adoption/adaptation documented]*
- Soil, water, crops and agro-biodiversity interactions for improved crop-livestock system productivity (INRM) understood in Asia and Africa (links GT Crop Improvement and JIRCAS project in WCA) *[Recommendations for improved water management and nutrient balances in crop/livestock systems adopted and promoted by partners]*
- Resilience of agro-ecosystems enhanced through conservation and diversification of crops in Asia and Africa (links to GT Crop Improvement and GT Markets and Institutions) *[Wider range of crops and varieties promoted and adopted]*
- Alternative methods for scaling up and out, including participatory approaches, simulation and spatial decisions support systems in Asia and Africa assessed and promoted to R&D partners *[Community-based and cooperative enterprises to provide access to input/output markets and knowledge]*
- More effective watershed development and a range of livelihood management strategies for sustainable use of the natural resource base in Asia developed and disseminated *[A range of watershed development options/approaches available for evaluation and implementation by partners]*
- Improved policies and impact strategies for efficient rainwater use and management developed and disseminated in Asia (links to GT Markets and Institutions) *[Institutional innovations and policy options for efficient water use available for partners]*
- Improved (quality and quantity) feed resources through better management practices in mixed systems and access to dual purpose and forage varieties (links to GT Biotechnology and GT Crop Improvement).

Partners and Networks

All GTAE activities are implemented in close collaboration with a very wide range of partners. These include national research and extension services, regional and subregional organizations, research networks, universities, advanced research institutes, sister CGIAR Centers, farmer organizations, NGOs, private sector firms, as well as funding agencies. The watershed consortium in Asia similarly involves a wide range of partners from India, Thailand, Vietnam and China; and the University of Georgia, USA.

Research Highlights 2005

WCA – Diversification and commercialization, IGNRM systems management

A range of crop diversification activities were carried out in 2005. About 500 African Market Garden (AMG) units were disseminated. This low-pressure drip irrigation system – particularly suitable for small-scale farmers – can increase farm profits per unit area up to seven-fold, compared to traditional dryland farming systems. The Sahelian Eco-Farm (SEF) which is an integrated dryland tree-crop-livestock system for millet and sorghum based systems was evaluated in Burkina Faso, Ghana and Niger, in partnership with the NARES and farmers. In Burkina Faso, Mali, Niger and Senegal, seedlings of Pomme du Sahel (*Ziziphus mauritania)* were produced for distribution to producers. Dissemination was done in collaboration with NGOs, government agencies and other projects operating in WCA. In Niger, improved and dual-purpose varieties of millet, sorghum, cowpea and sesame were made available to farmers. In Burkina Faso, sheep fattening practices using cotton cake and *Cassia obtusifolia* were evaluated; and led to significant weight gains.

Fertilizer micro-dosing technology was further tested and promoted in Burkina Faso, Ghana, Mali and Niger. Sorghum and millet yields increased by 44 to 120%; and farmers' incomes increased by 52 to 134% with a combination of micro-dosing and 'warrantage' (inventory credit system), compared with the earlier recommended and farmer traditional practices. In Navrongo, Ghana, sorghum nitrogen use efficiency with micro-dosing was double that under earlier recommended fertilizer application rates. The significant increase of millet grain yield from mineral fertilizer application is probably due to the reduction of vegetative and non-mature tillers. Because of the fast mineralization and N leaching at the beginning of the rainy season, amendments (both mineral and organic) lead to very large benefits in late-planted crops. When there is labor shortage at the first rains, or crop failure at an early stage, mineral fertilizer can assist farmers recover production losses. The warrantage system has substantially improved farmers' access to credit and inputs. Fertilizer micro-dosing technology has now reached up to 12,650 households. Efforts are ongoing to further scale-up and out this technology in several countries.

At the Fakara benchmark in Niger, information on land use and land use change was updated and corrected for previous geographic errors, using high-resolution, pan-enhanced, ortho-rectified Spot 5 images. Three benchmark sites were equipped with Campbell CR10 automated meteorological recording stations to monitor crop water requirement. A network of 60 rain gauges was made operational at the three benchmark sites to characterize spatio-temporal variability in rainfall. A soil map and booklet were produced by INRAN for the Maradi benchmark site. The information will be particularly useful to spatialize water balance and crop growth models at landscape scale.

Data collected in a survey of herders' perceptions of ruminant livestock breeds and breeding management in south-western Niger were analyzed and a paper submitted to the Human Ecology Journal. The study aims to improve our understanding of livestock genetic diversity and strategies for conservation both for present and future use. A participatory ethno-botany survey was carried out on the indigenous knowledge of farmers and pastoralists of local herbaceous and woody plant species. Most of the herbaceous and woody plant species found in the Fakara region were collected and preserved in a herbarium. In the survey, farmers were asked to identify different species and discuss their uses, including forage.

Cowpea varieties with high P use efficiency (PUE: shoot dry matter production/shoot P uptake) and symbiotic N_2 fixation (BNF) were evaluated at ICRISAT-Niamey in 2005. Considerable PUE diversity was found among 140 cowpea germplasm from the IITA and INRAN breeding programs. Although PUE was negatively correlated with harvest index (grain yield/ shoot dry mass x 100) among cultivated varieties ($r = -0.563^{**}$), there was still a wide variation in PUE among varieties with similar harvest index. The $\delta^{15}N$ value also varied from –0.153 to +2.31% in cowpea varieties, indicating that dependency on BNF would vary among cowpea varieties in Sahelian environments. These results suggested that genetic improvement of cowpea varieties with high PUE and BNF would be possible in the Sahel.

The biodiversity garden of the desert margins in ICRISAT Mali has been enhanced by the introduction of new grass and shrub species including : *Combretum glutinosum, Parkia biglobosa, Tamarindus indica, Acacia leata, Cassia sieberiana, Piliostigma reticulatum, Combretum aculeatum, , Leptadenia pyrotechnica, Pergularia tomentosum, Commiphora africana, Combretum micrathum, Blepharis linearifolia, Euphorbia balsamifera, Sclerocarya birrea Cenchrus biflorus* et *Panicum leatum*.

WCA** – **Pro-agricultural development policy environment for food security and disaster prevention and mitigation
In 2004, the SAT region of West Africa (WASAT) experienced drought coupled with locust infestation, leading to severe famine. Cereal grain shortfalls were estimated to be 11% in Niger, i.e. about 250,000 t of grain. In Niger, about 2.5 million people – a quarter of the population – needed food aid. In the regions of Gao and Kidal in northern Mali,

16% of the population was acutely malnourished. Following such crises, governments resort to distribution of food aid; there is no pre-crisis strategy.

ICRISAT, the University of Hohenheim and IFDC have jointly developed a low cost technology –strategic application of small quantities of P – that could significantly increase productivity and help build cereal stocks. However, access to fertilizers (quality, quantity) was a constraint to adoption. The FAO Projet intrants developed a network of input shops and inventory credit schemes to facilitate fertilizer access. ICRISAT projects (USAID Target and CORAF/AfDB funded) have scaled up micro-dosing technologies and monitored efforts to design and build institutional arrangements that will speed adoption. Micro-dosing technology together with the establishment of input shops and inventory credit schemes, could prevent food crises in future.

Studies in Niger, Mali and Burkina Faso during the last 3 years showed that by applying 4 gm of P per hill at planting, i.e. about 20 kg of Di-ammonium phosphate (DAP) fertilizer per ha, farmers could increase yields by 50 to 100% depending on the environment. If only one quarter of Nigerian farmers had applied fertilizer micro-dosing (which would cost about $20 million including fertilizer and inventory credit schemes), donors and governments would have saved up to US$80 million in emergency aid. Consumers would have saved US$70 million in food costs this year, apart from prevention of suffering. This pre-crisis strategy is being shared with policymakers in the CILSS countries. It has also been presented to a forum of decision-makers in Niger.

A study on the impact of input shops on technology uptake in Niger was conducted to investigate the effect of access to inventory credit (warrantage), input supply shops, fertilizer micro-dosing demonstrations, and other factors on use of inorganic and organic fertilizer, and the impacts on crop yields. The study showed that access to warrantage and input shops and participation in fertilizer micro-dosing demonstrations have increased use of inorganic fertilizer. Access to off-farm employment and ownership of draft animals also increases fertilizer use. Use of organic fertilizer is less affected by these factors, but is substantially affected by the household's crop mix, distance to fields, ownership of durable assets, labor and land endowments, and participation in farmer associations. Land tenure influences both inorganic and organic input use: less inputs are used on sharecropped and encroached plots. Inorganic fertilizer increases millet yields, and is highly profitable, with a marginal value-cost ratio greater than 3. Organic fertilizer increases both millet and cowpea yields. We find little evidence of complementarities between inorganic and organic fertilizers. Overall, the study recommended promoting increased input use through promotion of inventory credit, input supply shops and fertilizer micro-dosing demonstrations. Other interventions could include promotion of improved access to farm equipment and draft animals and improved access to land under secure tenure.

This knowledge is being shared in the R&D community. A paper highlighting the major results and policy implications will be presented at the 26th Conference of the International Association of Agricultural Economists, 12-19 August 2006 in Australia.

Impact monitoring is essential for designing R&D policies and interventions. During the last 25 years, ICRISAT developed a range of pearl millet, sorghum and groundnut varieties in the region but little is known of current adoption levels. Studies have been initiated on adoption of pearl millet varieties in Niger, groundnut varieties in Nigeria and impact of pearl millet and sorghum varieties in northern Nigeria.

Setting priorities for R&D requires knowledge of farmers' livelihood strategies and outcomes; factors determining their investment strategies etc. The results from participatory rural appraisals (PRA) conducted in four villages of Western Niger, where ICRISAT collected a panel dataset in 1982-85, are now available. The main objective of the PRA was to understand changes in livelihood strategies and outcomes over the last 25 years and firm up research questions to be later examined using structured surveys. Overall, farmers in the higher rainfall zone have reported significant improvement in income and well-being compared to farmers in the low rainfall zone, who are reporting their inability to secure food. Increased opportunities for income diversification inside and outside the agricultural sector including migration, better access to markets and infrastructure, increased use of fertilizers and agricultural equipment, and project interventions tend to support these claims. However, use of modern varieties and access to formal credit have improved only marginally. Farmers in poorly endowed areas are reporting losses in pearl millet and sorghum varieties and their inability to grow crops such as maize. This opens up a range of new hypotheses to be further tested in structured surveys. This research is likely to generate additional information necessary for policy formulation, priority setting and planning.

WCA – Building partner power

Where possible, R&D capacity of partners is being enhanced through joint action on-the-job, higher degree supervision and by formal training courses. Regional training courses on vegetable seed production, tree propagation techniques, grafting, tree husbandry and nursery management were conducted, benefiting 800 participants from Mali, Burkina Faso and Niger. Another area of capacity building is dissemination, to ensure that research results are translated into relevant development oriented advice and practice. This is particularly important because formal extension services in most WCA countries are extremely weak. Rapid developments in information technologies are creating new opportunities. Research on organizational and institutional options for facilitating these means of knowledge sharing, are being examined.

In 2005, PRAs were completed for Kahe and Gabi radio stations (close to ICRISAT Center at Sadore in Niger). Global PRAs have been undertaken in Niger in Danthiandou (Tillabery Dept) and Zermou (Zinder Dept). Radio Gabi (Maradi Dept) has started broadcasting ICRISAT material. Radio briefs have been developed with FAO which include information on small ruminant nutrition and supplementation; the use of fertilizer micro-dosing to increase millet yields; alternative means of pest control (particularly *Striga*); and information on ICRISAT's VASAT consortia. Supporting videos and extension posters were also prepared. A partnership is being built with FarmRadio Network (Canada) in order to develop scripts on drought preparedness and mitigation.

Theme Profile up to end of 2005

Theme Evolution and Changes in Research Focus since 1996

Since the EPMR in 1996, the Natural Resource Management Initiative within ICRISAT has been continually evolving in response to the views of the TAC, the Donors,[4] sub-regional organizations and the wider scientific community. The aim has been to ensure a sharper focus on strategic problems through regional and global projects (see Medium Term Plans since 1997). In the process, the four systems projects within the Soils and Agroclimatology Division evolved into four Center-wide projects (CP1 to 4) within the Natural Resources Management Program. In 2001 further restructuring took place. CP1, *Raising soil productivity to help SAT farmers grow their way out of poverty*, and CP2, *Efficient management of natural resources in watersheds*, were consolidated into priority impact-focused research activities within Global Theme 3.[5] CP3, *Farmer participatory approaches to integrated pest and disease management* was divided between three global themes, GT2, 3 and 5. Some of the research programs of 1996 were later completed or discontinued; while some research discarded earlier – for example CP4, the Desert Margins Program – was revived as its relevance to NRM issues in Africa was recognized and funding became available through the Global Environment Fund. Other opportunities are beginning to unfold with funding avenues relating to risk management under climate change.

In response to the recommendations of the 5th External Program Review, GT3 and parts of GT5 were merged into the new theme *Land, water and agro-diversity management*, known in short as *Agro-ecosystem development, GTAE*. The new theme will have a greater focus on the African SAT, addressing development goals identified by sub-regional organizations. Subsequently, core resources from Asia have been redeployed in a phased manner to better address the major challenges of land, water and agro-diversity research in Africa.[6] From 2006 there will be no core funds allocated to NRM work in Asia. Component design of Integrated Pest and Disease Management (IPM/IDM) systems remains within the Global Theme 'Crop Improvement', with system testing of integrated components housed within GTAE.

However, given the availability of opportunities for special project funding for NRM in Asia, ICRISAT has continued to pursue these simultaneously; and has created a self-supporting NRM team in Asia. NRM scientists in Asia have continued to contribute to ICRISAT's Integrated Genetic Natural Resource Management (IGNRM) approach; lessons from long-term development programs in Asia are helping to increase the impact of NRM work in Africa. Examples include the watersheds work in Asia; linkage with ASARECA's Soil Water Management Network (SWMnet); and the successes achieved in IPM/IDM research. All these are essential parts of the IGNRM approach to improving food security among smallholder farmers in the African SAT.

In 2005 ICRISAT embarked upon a decentralization program to increase its regional focus in both Africa and Asia. Consequently, GTAE activities are distributed across three regional program: West and Central Africa, East and Southern Africa, and Asia. The agenda reflects the skills and expertise of the respective teams, and addresses research priorities identified by the sub-regional organizations in each region. For ease of reporting, the main body of this report retains the global project structure agreed in 2004 (in late 2005, ICRISAT undertook a series of visioning exercises in response to the new CGIAR Systemwide priorities).

---

[4]. Since 1996 NMR research funding has shifted dramatically from core budgetary allocations to special project funding.

[5]. GT2 – Global Theme 2, Crop management and utilization for food security and health. GT3 – Water, soil and agrobiodiversity management for ecosystem health. GT5 – Enhancing crop-livestock productivity and systems diversification.

[6]. In response to the 5th EPR recommendations, ICRISAT constituted an Africa Task Force to review its commitments to Africa. The findings were presented for discussion at the Sep 2004 Governing Board meeting.

Research Portfolio Changes within ICRISAT for 2006

In the 2006-2008 Medium Term Plan, ICRISAT had restructured both research and administrative departments to more effectively address regional issues. This was in consonance with a paper titled 'ICRISAT strategy to 2010: reaping the seeds of success' developed in 2004 and accepted by the Governing Board. The paper was summarized in the MTP 2006-2008. . The new structure envisaged three mega-projects, each with several sub-projects, as described below.

Improving agriculture in the SAT of Eastern and Southern Africa (ESA)
- Crop improvement and seed sector reform
- Commercialization
- Relief, recovery and food security
- Crop-livestock systems development

Improving agriculture in the SAT of West and Central Africa (WCA)
- Crop improvement and seed sector reform
- Diversification and commercialization, IGNRM systems management
- Pro-agriculture development policy environment for food security and disaster prevention and mitigation
- Building partner power

Improving agriculture in the Asian SAT (Asia)
- Improved germplasm and parental lines of sorghum, pearl millet, pigeonpea, chickpea and groundnut developed and disseminated in Asia and globally
- Efficient and sustainable soil, water, crop and nutrient management, innovative watershed management options, technologies for diversified and sustainable crop-livestock production systems developed and disseminated in the SAT
- Strategies and policies for efficient input and product market linkages for ICRISAT mandate crops developed in SAT Asia
- Institutional and policy recommendations to support livelihoods developed in SAT Asia and globally
- Validated research methods for rainfed agriculture relevant to capacity development of partners in SAT Asia promoted.

ICRISAT also retained its four Global Themes and a Knowledge Management and Sharing Office (KMS). This sub-structure retained the responsibility for ensuring science quality, avoiding disciplinary duplication and encouraging spillovers between regions for the full exploitation of the IPG nature of ICRISAT's research. These themes remain in being and continue their previous roles. They are referred to, in short, as GT Institutions, Markets, Policy and Impact (IMPI), GT Biotechnology (Biotech), GT Crop Improvement (CI), and GT Agro-ecosystems (AE).

The Science Council commentary on this MTP was critical that ICRISAT had not adopted a project structure more in line with their 2005 recommendations – which advised that each project should represent an overall value of $2-3 million, rather than ICRISAT's mega-projects ($8-10 million). We believe this criticism was harsh as ICRISAT was in the process of transition between structures; and the sub-projects themselves essentially met this criterion. However, to avoid misconceptions in the future, though ICRISAT will retain its regional structure for administrative and research directional purposes, it will summarize in the 2007-2009 and subsequent MTPs, its work under 10 projects. These are strictly aligned to those of the CGIAR System Priorities and ICRISAT's new strategic plan. These new projects, their formulation from the mega-projects and sub-projects, their harmony with ICRISAT's global themes and their accordance with the new CGIAR System Priorities are summarized in Table 3.

With a current proposed expenditure of $28-30 million under 10 projects, we expect ICRISAT will have achieved the nomenclature and project size desired by the Science Council in their guidelines for the preparation of the 2007-2009 MTP. It is hoped the Science Council will retain this project structure in its forthcoming guidelines. ICRISAT, as an institution, needs to operate under a stable planning format at least until the next EPMR in 2008. MTP project structures have changed every year since 2002. This continuing flux has a significant cost that detracts from research performance.

Major changes in existing collaborative arrangements including changes in participation in SWEPs and CPs
ICRISAT continues to participate actively in all the current System Challenge Programs, and coordinates the Desert Margins Program SWEP (Project 8 in Table 3). Its contributes to several other SWEPs, principally those on Genetic Resources, AIDS, Water Management, Livestock, IPM and Rice-Wheat in the Indo-Gangetic Plain. ICRISAT continues to be the facilitator for the forthcoming Future Harvest Alliance – Southern Sudan Consortium and, jointly with ICARDA and the Secretariat of the Global Convention on Desertification, is expecting the Drought, Desertification, Poverty and Agriculture Consortium to make further progress in 2006. ICRISAT is also expanding its

collaboration with AVRDC (the World Vegetable Center) by assisting them to open their South Asian regional office within ICRISAT's headquarters at Patancheru; this was done in Jan 2006. ICRISAT's new project structure will also facilitate new and more intimate engagement with the FARA African Challenge Program as three of its ten projects are specifically oriented to sub-Saharan Africa (Projects 3, 4 and 8) and five are globally generic (Projects 1, 2, 7, 9 and 10)

Project GTAE 1: Diversifying income-generation options for improved livelihoods and agro-ecosystem health in semi-arid West and Central Africa

The results reported under this section contribute to ICRISAT's West and Central Africa Regional Research Program, *Diversification and commercialization and IGNRM systems management*

- Output 1.1 Natural resource management options for increased crop production evaluated
- Output 1.2 Simulation and spatial decision support systems to screen the applicability and sustainability of technological interventions developed. Adaptation and validation of DSSAT and APSIM models for pearl millet and sorghum
- Output 1.3 Soil, water, crops and agrobiodiversity interactions within crop-livestock systems
- Output 1.4 Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihoods in the Volta Basin – Project 5 of the Water & Food Challenge Program.

Output 1.1: Natural Resource Management Options for Increased Crop Production Evaluated

Activity 1.1.1: Strategic fertilizer application - On-farm validation trial in the Fakara

Many argue that smallholder farmers in the semi-arid tropics should be encouraged to utilize organic fertility amendments in favor of inorganic fertilizers in the development of sustainable agricultural systems. Organic fertilizers such as cattle manure and crop residues not only improve soil fertility (leading to increased grain yield) but also improve soil structure. Unfortunately, the quantities of organic amendments available at farm level are limited because of competing uses, and cannot meet the current demands for their use as mulch or fertilizer (Baidu-Forson 1995). At the same time, in much of the SAT, use of mineral fertilizer is limited by high price, limited availability and high blanket recommendations. In an attempt to address these problems a series of studies were jointly undertaken by IFDC, University of Hohenheim and ICRISAT scientists based at the ICRISAT Sahelian Center, on the strategic application of small quantities of mineral fertilizer on its own or in combination with organic fertilizers, applied to the planting hills of pearl millet at sowing (Batiano et al. 2003). This technology has shown promising results in on-station and on-farm trials.

The objectives of this study were (i) Evaluate under real conditions the agronomic and economic performance of hill application of different formulations of mineral fertilizer under different manuring practices, (ii) Explain yield response differences by monitoring biophysical parameters and management practices, (iii) Draw recommendations for integrated soil fertility management adapted to soils, risk of drought, and availability of manure.

Materials and methods:
The Fakara region (80 km east of Niamey), an area of 500 km^2, encloses three clusters of villages. The site was selected because of the abundance of biophysical and socio-economic data packaged in a spatial database. The soils are sandy, with low inherent soil fertility and low organic matter content. The predominant crop is millet in a mixed cropping system. Most farmers intercrop millet with cowpeas or with cash crops like sesame. Some well-endowed farmers also integrate crops and livestock systems. Average annual rainfall for the zone is 470 mm.

Experimental sites. From 2003, for three consecutive years ICRISAT conducted on-farm validation trials of the technology. The objective was to take advantage of both natural (on-farm) conditions and better-controlled conditions that would help collect reliable data. The experiment was conducted at three sites with contrasting land use patterns. At Banizoumbou a large proportion of land was fallow in 2004. At Kodey almost all the land was cultivated. Bagoua occupies an intermediary position with regard to fallowing.

Five manuring strata were tested in every year at each site: control (no manure); transported manure; 2 year old corralled plot; 1 year old corralled plot and newly corralled plot were tested in 2003. In 2004 the residual effect of the transported manure of 2003 was added. In 2005 we added the residual effects of the transported manure of 2003 and 2004.

The combination of mineral fertilizer x variety was laid out in a multi-factorial design within each manuring strata in 3 blocks (reps). Three millet varieties were tested: landrace and two improved varieties, ICMV IS 89305 and Zatib. The mineral fertilizer treatments were: control (no fertilizer application), 2 g DAP per planting hill at sowing, and 2 g DAP per planting hill at sowing + 1 g urea per planting hill at tillering. Plot size was 10x10 m.

Sowing occurred after the first major rain (>20 mm) of the season in each year. Sowing dates were 165th DOY in 2003, 180th DOY in 2004 and 155th DOY in 2005 for Banizoumbou; 165th DOY in 2003, 141st DOY in 2004 and 154th DOY in 2005 for Bagoua; 175th DOY in 2003, 142nd DOY in 2004 and 150th DOY in 2005 for Kodey. Planting at Banizoumbou was delayed for more than one month in 2004 compared to the other sites due to the workload. In addition, between day 140 and day 180 no significant rain was received at that site. This delay was a cause for total replanting of all strata at Bagoua except for the one corralled in 2003. Millet was sown in hills at a density of 10,000 hills ha^{-1}. Hills were thinned to three plants per hill two weeks after emergence. The experiment was weeded twice with traditional hand hoes (*hilaire*) in all years. The crop was harvested on 295th DOY in 2003, 259th DOY in 2004 and 260th DOY in 2005 at Kodey; on 287th DOY in 2003 270th DOY in 2004 and 268th DOY in 2005 at Bagoua; 281st DOY in 2003, 287th DOY in 2004 and 278th DOY in 2005 at Banizoumbou.

Observations:
The following phenological data were collected every year: Planting date, days to emergence, number of plants at emergence (counted one week after sowing), number ad dates of weeding, first flower – recorded when 50% of the plants in the plot flower; and days to harvest.

At harvest we collected data on millet dry straw yield. After removal of border rows the heads of the millet hills on the plot diagonals were harvested. The fresh weight of these heads was taken and they were tied and kept in each plot. Then we cut the straw of these hills. The total number of tillers obtained from these hills was evaluated and the number of tillers per hill at harvest calculated based on this count. The fresh weight of the sample obtained was taken and the sample tied and kept in each plot. Thereafter the heads of the whole plot were harvested and the fresh weight taken. The straw of each plot was also harvested and the fresh weight taken. After sun drying the samples, their dry weight was taken and the heads threshed to obtain the grain weight of each sample. We were thus able to calculate the head dry weight, straw dry weight and grain weight per plot.

The number of non-matured hill, the wild type millet hills and the total number of hills harvested was recorded. Hill survival was calculated using the data on number of hills after thinning. The harvest ratio was calculated as a ratio of grain weight and total biomass per plots. All these data were subjected to statistical analysis using Anova, with the statistical package Genstat v8. The analysis was first restricted to the effect of mineral fertilizer. Then the data was analyzed including all strata of organic fertilizers. Finally the three sites were combined for comparison.

Soil samples were collected before the trial and at harvest.

Only grain yield data for 2005 are reported here. Data from earlier years has been reported in previous documents.

Results and discussions:
The rainy season started in early May at all sites. Planting took place by end of May and early June when enough rain was received. Rainfall distribution was normal throughout the season at all sites except for short dry spells of two weeks that occurred at all sites. The longest dry spell, almost four weeks, occurred at Kodey at the end of the season.

The amount of organic amendment remaining on each manuring strata was evaluated using a square shaped placeau of 0.5 x 0.5 m size. The placeau was placed once in each plot in each stratum and all organic material in the square collected. Fecal and herbaceous materials were evaluated separately. The quantity of amendment per hectare remaining in the strata was calculated and the mean values obtained using Genstat v8. The results show high variability among the samples collected on some strata.

In 2004 the quantity of fecal material recorded from the newly corralled plots were 6467, 1521 and 5698 kg ha^{-1} respectively for Banizoumbou, Bagoua and Kodey respectively. But there was a drastic decline in fecal material from the corralled plot after one year, 78%, 44% and 86% respectively. After two years the fecal material almost disappeared – 99% at Banizoumbou and Bagoua and 95% at Kodey.

In all strata, herbaceous material decomposes more slowly than fecal material, although it can be physically destroyed by termites.

Effect of mineral fertilizer and variety on millet grain yield:
Banizoumbou. Grain yield on plots with no organic amendment was low (58-505 kg ha^{-1}), but application of small amount of DAP at planting increased yield by a factor of 2 to 6. In contrast, on plots that received organic amendment, little or no yield increase was seen following application.

Under low soil fertility conditions (no mineral fertilizer, no organic amendment) the farmer's variety performed better than both improved varieties. But the improved varieties were more responsive to mineral and organic fertilizer application (Table 2), indicating the necessity of improving soil fertility when improved varieties are used. There were statistically significant differences due to the application of mineral fertilizer when no organic amendment was applied, or on the plots amended two years earlier with transported manure.

A similar tendency was observed on the newly corralled plot that was not in accordance with our earlier observations in rainy season 2004. The quality of the amendment may explain this, as the manure application rate was the same as in 2004. The highest yield (893 kg ha^{-1}) was obtained with ICMV IS 89305 on the plot corralled two years earlier that received DAP as micro-dose.

Bagoua. Grain yield ranged from 124 to 660 kg ha^{-1}. Apparently soil fertility level at this site was better than at Banizoumbou: for example, variety Zatib yielded 272 kg ha^{-1} from the control (non fertilized) plot, compared to 58 kg ha^{-1} at Banizoumbou.

At this site fertilizer micro-dose application increased grain yield by factor of two on plot not amended with organic fertilizer but also on plots amended with transported manure two years before. Therefore even though grain yield level was low compared to strata that received organic amendment, the effect of mineral fertilizer was more important on plots with potentially low fertility. This is also evident from the anova analysis.

Kodey. Grain yield was low for all treatments. It ranged from 76 kg ha^{-1} for the absolute control to 496 kg ha^{-1} for the plot corralled in 2004. All these values refer to the local variety. Like other sites, yield increased with mineral fertilizer micro dose application. In general, there were statistically significant differences between treatments due to mineral fertilizer application when soil fertility was low. Organic amendment application increased yield on the control plot as well as when mineral fertilizer was applied.

Effect of organic amendment on millet grain yield:
Application of organic amendment doubled grain yield in almost all cases at all sites compared to the control (no organic amendment), except for the new corralled plots at Banizoumbou. The two years old corralled plot at Banizoumbou produced more than the new corralled plot, which is not in accordance with the earlier findings in this study.

Difference in plant growth was observed even during the vegetative phase. The effect of high rate of corralling two years before may have lasted longer. Soil samples collected from all plots will assist in better understanding this trend.

Effect of growing environment on millet grain yield:
As already noted, highly significant differences exist between sites with regards to the effect of the treatments on millet grain yield . There was an interaction between the sites and the organic fertilizer management strategy, which could be due to differences in farmer management, particularly the corralling process. The initial fertility level (which is related to land use pattern, which is quite different at different sites) may also help to explain this interaction. The land at Kodey being more severely exploited than at other sites, grain yield averaged over all treatments at this site was 293 kg ha^{-1} compared to 491 kg ha^{-1} for Banizoumbou.

Summary and conclusions:

Application of mineral fertilizer micro-dose in combination with organic fertilizer, applied with corralling or transported organic waste, significantly increases pearl millet grain yield compared to the absolute control. When compared to organic amendment (without mineral input), yield increase was limited. Yield response was dependent on land history – the lower the fertility level, the higher was the influence of the treatments. The good response of improved varieties depended on favorable soil fertility. At low fertility levels the local variety performed better, indicating that it is better adapted to local conditions compared to the improved varieties.

This study showed that combining organic amendment with mineral fertilizer improves grain yield but not to the extent expected. The corralling process is not labor intensive but its efficiency could be questioned. It may be more suitable to adopt hill application of the organic material coupled with hill application of mineral fertilizer. This would more efficiently use the limited amount of organic material available but also limit the quantity of mineral fertilizer required.

D Fatondji and B Gerard

Activity 1.1.2: Fertilizer micro-dosing and drought tolerant varieties: technology transfer for small scale farmer prosperity in the Sahel

The semi-arid Sahelian zone of West Africa is one of the poorest regions in Africa with one of the lowest human development indices. The climate is extremely harsh – semi-arid tropical with an annual rainfall ranging from 350 to 700 mm, with high inter-annual variability in amount and the distribution, causing large year-to-year fluctuations in millet and sorghum yields and prices.

Collaborative research by various national and international research institutions operating in the Sahel, has developed an effective technique to increase fertilizer use efficiency, reduce investment costs to resource-poor small scale farmers, thereby increasing crop growth and productivity . This strategic application of fertilizer, also known as fertilizer micro-dosing, is based on applying small doses of fertilizer in the plant hill.

During 2002 to 2004, using USAID funds, ICRISAT, in collaboration with its partners – INRAN, Niger; INERA, Burkina Faso; IER, Mali; Projet Intrants FAO, Niger, NGOs from these three countries, TSBF-CIAT and IFDC – have evaluated and promoted this technology in Burkina Faso, Mali and Niger. Encouraging results were obtained from on-farm trials and scaling-up activities.

In all the three countries, over the two years of the study, yields of sorghum and millet increased by 44 to 120% while income of farmers increased by 52 to 134% when using fertilizer micro-dosing and 'warrantage' (inventory credit system), compared to the earlier recommended and farmer traditional practices. Farmer access to credit and inputs was improved substantially through the warrantage system. The technology has reached up to 12,650 farm households in the three countries and efforts are in progress to further scale-up and out the technology to wider areas.

It is in this context that a project proposal was prepared and submitted to CORAF. It was approved for funding, and the project started in June 2005.

Objectives and methodology:
The major objectives of this CORAF/AfDB funded project are to: (i) increase and stabilize production, farm household incomes, and food security; (ii) enable farmers to better manage the natural resource base though adoption of microdosing and better farmer-based cooperatives in Burkina Faso, Niger and Senegal. Farmer field schools were used in the three countries to demonstrate and scale-up the micro-dosing technology. These demonstration trials were managed by farmers with technical backstopping from extension agents, NGO staff and IARC scientists.

Results:
Despite the late approval of the project by CORAF, project partners were able to establish demonstration trials in all three countries. In Niger 36 demonstration trials were established at four sites: Fada Zeno and Konkorido in the Dosso region, Dogueraoua and Guidan Ider in the Tahoua region. Planting dates ranged from 6 May to 17 July 2005 depending on the onset of rains and the logistics on the ground. In Burkina Faso approximately 36 trials were established in the villages of Nagréongo, Malgrétenga, Sarago, V2 and Nagartenga. In Senegal, 34 trials were conducted in the regions of Kaolack, Thiès, and Tambacounda. Data were collected on grain and fodder yields. Data analysis is in progress.

R Tabo (ICRISAT), A Bationo (TSBF-CIAT), F Lompo (CERRA, Senegal),
M Gandah (INRAN, Niger), B Amadou (Projet Intrants FAO, Niger), and
SJB Taonda (INERA, Burkina Faso)

Activity 1.1.2: Combining water harvesting techniques and nutrient management to sustain food production in the drylands of West Africa

In the drylands of West Africa, traditional soil, water, and nutrient management practices are inadequate for sustainable food production. In the past, production was increased by expanding cropped land, but wit increasing land scarcity, further increases are possible only by increasing the output per unit of land.

High inter-annual variability and erratic rainfall distribution in space and time result in water-limiting conditions during the cropping season. In areas with inadequate rainfall or runoff-susceptible land, water conservation and harvesting techniques offer the potential to secure agricultural production and reduce the financial risks associated with purchase of fertilizer. The donor community has put a lot of effort into developing water harvesting techniques (eg Zai system, stone bunds and ridges) in the drier areas. However, results have clearly shown that for high yields, water harvesting techniques must be combined with integrated nutrient management.

The goal of this CORAF/AfDB funded project is to transfer water-harvesting technologies to increase food production in the drylands of West Africa. The project will integrate water and nutrient management techniques into options that address human development needs and environmental challenges. Expected outputs are: adaptation of water and nutrient interaction technologies to farmers' socio-economic conditions and policy environments; demonstration of technological packages on the interaction of water and nutrients; enhancement of stakeholder capacity to adopt water harvesting and soil fertility management technologies.

The project focuses on enhancing rainwater and nutrient use efficiencies and on capitalizing their synergies for increasing crop production and preventing land degradation. In partnership with farmers and NGOs, available soil, water and nutrient management technologies will be assembled and evaluated on-farm and technologies transferred to small-scale farmers.

Results
In Burkina Faso, seven on-farm trials were established in Tougouri in the North West region. In Mali, five trials were conducted in the villages of Mané, Tiébledougou and Daguedougou. In Niger, 21 trials were conducted at four sites: Sina Koira/Kouré in the Tillabery region, Fada Zéno in the Dosso region, Doguéraoua and Guidan Ider in the Tahoua region. Planting dates ranged from 27 June to 27 July 2005. In Senegal, 17 on-farm trials were conducted in the Sibassor and the Toubacouta zones. Data analysis is in progress.

R Tabo (ICRISAT), A Bationo (TSBF-CIAT), F Lompo (CERRA, Senegal), M Gandah (INRAN, Niger), B Amadou (Projet Intrants FAO, Niger), B Kaya (IER/ICRAF, Mali) and K Ouattara (INERA, Burkina Faso)

Activity 1.1.3: Promoting use of indigenous phosphate rock for soil fertility recapitalization in the Sahel

This CORAF/AfDB project aims at demonstrating and enhancing the utilization of indigenous phosphate rock to restore and maintain productivity of soils, increase agricultural production and promote self- reliance of communities in parts of West Africa. The key problem in the selected countries is low agricultural production caused by extremely low amounts of phosphorus (P) stocks in the soils, coupled with low application rates. The proposed solution is to mitigate the problem through 'recapitalization' of soil phosphorus stocks with local phosphate rocks in both processed and unprocessed forms. The project will validate and demonstrate guidelines for direct application of phosphate rock (PR) including the benefits of a one-time (mega dose) application as well as the use of slightly modified forms of PR to support the long-term performance of the unprocessed forms. The major merit of the project lies in the optimized use of PR deposits that occur in many countries in the region as a component of more integrated, self-sufficient and sustainable agricultural practices. The multiple partnership involving CGIAR, ARIs, regional research centers, NARES, NGOS, suppliers/retailers, etc is considered most cost-effective, and will enhance the success of the project. The project will synthesize existing knowledge on PR and validate it so as to optimize use of indigenous PR. This approach aims to add value to past investment in PR research.

Results
In Burkina Faso seven trials were planted on 20 July 2005 in Tougouri in the North West region. In Niger, 40 demonstration trials were established in Fada Zeno and Konkorido in the Dosso region and Dogueraoua and Guidan Ider in the Tahoua region. Dates of planting ranged from 6 May to 8 July 2005. In Senegal, 18 on-farm tests were conducted in the Kaolack region. Data analysis is in progress.

Output 1.2: Simulation and spatial decision support systems to screen the applicability and sustainability of technological interventions developed. Adaptation & validation of DSSAT and APSIM models for pearl millet and sorghum

Activity 1.2.1: Adapt and validate DSSAT and APSIM models for WCA conditions

Activity 1.2.2: Spatial modeling of regional soil water balance from remotely sensed data and indigenous knowledge to predict crop stress and mitigate food deficits in Niger

B Gerard, K Hayashi, D Fatondji, W Payne, J Heilman, M Gandah and C Manyame

Activity 1.2.3: Improving local decision support for crop management options using satellite data and climate forecasts

Activity 1.2.4: Modeling crop production in millet-based systems in the Sahel

P Akponipke, C Bielders (Université catholique de Louvain) and B Gérard (ICRISAT)

Activity 1.2.5: Formalization of economic activities management strategies for local villagers in Niger

Research on this output has been essentially completed, and is described in previous GTAE annual reports.

Output 1.3: Soil, water, crops and agrobiodiversity interactions within crop livestock systems

Activity 1.3.1: Identification and utilization of leguminous and non-leguminous germplasm accessions for sustainable soil fertility management in the Sahel

One hundred forty cowpea varieties, mostly from the IITA and INRAN breeding programs, were evaluated at the experimental field of ICRISAT-Niamey. The varieties had a wide diversity in 50% flowering date. The earliest variety reached 50% flowering at 38 days (DAS), while several varieties did not reach 50% flowering by the final harvesting (92 DAS). Phenology of the varieties affected both grain and fodder yields dramatically. The later-flowering varieties produced more fodder. Varieties that flowered later than 60 DAS hardly produced grain, while the varieties which flowered in 45-55 DAS gave better harvests. Obviously it is difficult to obtain high yields of both grain and fodder from a variety, because there is negative relationship between grain and fodder yields. Therefore breeders have to understand farmers' preferences when they select varieties on the basis of the production type.

Low phosphorus in sandy soils is the most important constraint to cowpea production in the Sahel. Phosphorus uptake in the shoot was significantly correlated with shoot dry mass in the cowpea varieties. When varieties were compared at the same P uptake level, shoot dry matter production varied among varieties. For example, fodder variety 035-84 absorbed 454.9 mg P in the shoot and produced 118.9 g of shoot dry mass, while another fodder variety 078-84 absorbed 432.4 mg P and produced 208.0 g of shoot dry mass. P utilization efficiency among cowpea varieties should be further investigated.

The $\delta^{15}N$ value varied from –0.153 to +2.310% in different varieties, showing considerable genotypic variation in the dependency on biological nitrogen fixation under the Sahel environment. It would be possible to use $\delta^{15}N$ values to select cowpea varieties with higher ability of symbiotic nitrogen fixation. The lowest $\delta^{15}N$ (–0.153%) was measured in IT95K-207-15, a short duration, semi-erect cultivar, followed by IT97K-1101-5 (–0.101%), IT98K-131-2 (–0.021%), 015-84 (+0.026%) and IT99K-213-11-1 (+0.048%)

R Matsunaga and S Tobita

Activity 1.3.2: Integration of indigenous knowledge and scientific information for evaluation of land management in the agro-pastoral semi-arid zone of West Africa

In order to evaluate local soil fertility management practices, 79 households with 259 farms were surveyed in three villages of Fakara area in Niger. Management systems and soil types (indigenous soil classification) were obtained through questionnaires. Soil samples were analysed from 63 farms. Among the surveyed farms, 66% were managed by fallow system, 18% by corralling and 16% by recycling household waste and livestock faeces. Distribution of each management system is shown in Fig 1. Median distances were 676m for the recycling system, 1790m for corralling and 2580m for the fallow system. Thus, the system chosen for soil fertility management depended on the distance from residence to farm. This was confirmed by factor analysis. The results indicated that decision making for soil fertility management was more by distance than by soil type (which reflects fertility level of the farm). It also indicated that geographical distribution of soil nutrients (Bray1-P) showed relatively high concentration in farm plots adjacent to the village and that nutrient concentration tended to decrease in inverse proportion to the distance from residence to farm plot. This information could help to enhance decision making for better soil fertility management in the study area.

K Hayashi, H Shinjo, U Tanaka, A Tahirou and R Matsunaga

Activity 1.3.3: Systems and Crops Diversification Unit

The systems diversification team at the ICRISAT Sahelian Center is comprised of a multidisciplinary team of four permanent scientists and a senior research assistant:

- A Nikiema – Agroforester, specialized in nursery management and fruit tree cultivation
- D Senbeto – Forester, specialized in community based large scale agroforestry and land reclamation projects

- D Pasternak – Agronomy and horticulture
- F Dougbedji – Soil physics and soil fertility
- AVRDC Vegetable breeder (pending)
- L Waltering, research assistant from Holland with an MSc in water management. He has been recruited for a 3-year period.

In addition to the above, three scientists from the ICRISAT Sahelian Center are involved with various crops diversification activities. They are Saidou Koala - soil fertility, Ndjeunga Jupiter - economist, and Tabo Ramadjita, an agronomist. The team has seven permanent technicians and 30 nursery and field workers. This is a very impressive rate of growth from 2001, when operations at ISC started with only one scientist and one field technician.

The objective of the Systems and Crop Diversification Unit is to develop new sustainable irrigated and rain fed production systems and to introduce new crops and varieties. Activities are reported below under various areas: research, training and capacity building, dissemination and resources mobilization.

System diversification
On-station and on-farm research on the Sahelian Eco-Farm (SEF) continued. SEF is an integrated trees-crops-livestock system that provides solutions to most constraints in the current rainfed systems. This technology is expected to lead the transformation of agriculture in semi-arid Africa. All rainfed agricultural research projects carried out by the team are designed to support the optimization of this system. 2005 was a relatively dry year. Nevertheless yields of annual crops in the SEF (millet, cowpea, Roselle) were twice the yields in the 'traditional' control plots.

The performance of eight dual-purpose (grain and forage) cowpea varieties, with and without insecticidal spray, was compared. Four varieties with both high grain and high forage yields were selected for further screening. 60 pilot farmers participated in on-farm trials where four dual-purpose cowpeas varieties were evaluated. 40 new varieties were tested and one variety with very high forage yields was selected for further study.

In 2005 we started research on bioreclamation of degraded lands (BDL) technology. This system is based on planting a wide range of hardy trees, such as *Acacia senegal*, Pomme du Sahel, sweet tamarind, Australian acacias, etc, combined with annual traditional leafy vegetables in a 'guided biodiversity garden'. It is basically an improved fallow system that generates income from the first year after planting and provides a range of services to the community, particularly to women. Two experimental BDL plots were planted and are managed by women.

Effect of Acacia mulch on termite activity, soil fertility and water conservation – bio-test with millet

Exposure of the ferruginous soils of the Sahel to the combination of rain and the sun produces a crust that is impermeable to water and roots of most plant species. In non-crusted soils, mulch prevents the formation of crust, and increases the rate of water infiltration. In crusted soils, mulch encourages the proliferation of termites that in turn build a network of subterranean channels, thus permitting water infiltration and root penetration through the hard lateritic crust. Termites also recycle the organic matter of the mulch, thus making nutrients available to the plant roots.

To study the effect of different types of mulch on soil fertility restoration of degraded land, an experiment was initiated in the post rainy season 2003. The objectives were to study the effect of termites on reclamation of crusted soils, and evaluate the effect of different types of mulch on reclamation of crusted soils and soil water conservation. Millet straw or *Acacia colei* mulch were applied at 4 t ha^{-1}. In some treatments, termite activity was controlled using furadan, applied at the rate of 10 kg ai per ha. Mulch application was renewed for the first time in Dec 2003 and again in Sep 2004. The same design was laid simultaneously on crusted and non-crusted soil. In rainy season 2005, millet was planted in the two fields.

Application of mulch thrice in 2 years improved grain yield under all conditions, indicating that soil fertility had improved. But grain yield on crusted soil was still low, indicating that mulch application for longer periods is necessary. Eliminating termite activity hampered amendment decomposition on both fields. Therefore the contribution to soil fertility improvement was lower.

In addition to the nutrients added through the organic amendments, the termite-dug voids may have improved soil water infiltration and therefore improved the water regime on plots not treated with pesticide, thus increasing yield. We conclude that Acacia sp. as well as millet straw mulch could be used for land rehabilitation. This process could be speeded up by the presence of termites.

Promotion of multi-purpose trees

- The domestication of *Acacia senegal* continued. Ten trees giving about 1kg of gum per year, which is four times the average yield, were identified. These trees were successfully grafted on local rootstock. A one-hectare mother plantation of grafted trees was planted at Sadore.
- A trial comparing the performance of two subspecies of Eucalyptus at four planting densities was planted in July 2005. The objective is to see if *Eucalyptus camaldulensis* sub *cinerea* can replace the current *Eucalyptus camaldulensis* produced in the Sahel.

Cow horn – a new low cost source of nitrogen for crops

Farmers hardly use nitrogen fertilizers in the Sahel due to high price and non availability. Cow horn is animal carcass that contains 15% of N and 36% of organic carbon. As such it is a potential substitute for mineral fertilizers and could also improve soil organic status. The objective of the experiment was to test the effect of different modes of application of cow horn as source of N on sweet corn yield. Less than 2 t ha^{-1} of fresh cob yield was achieved without fertilizer application (Fig 1), indicating that under Sadore conditions it is necessary to apply fertilizer for sweet corn production. Fresh cob production was higher with cow horn (in all modes of application) compared to urea. The highest yield was obtained when the full rate was applied at planting. Urea gave best results when applied in three portions, indicating the readily available nutrients from this fertilizer. The strong response to one application of cow horn shows that nutrient release from this source was slow and probably coincides with the period when the plants need it most. We conclude that cow horn can be used as a source of N and it should be applied at planting. The high carbon and P content could have also contributed to this effect.

Promotion of fruit trees and alternative cash crops

- The hot Habanero variety of pepper gave the best results in a trial as compared to 18 different hot pepper varieties.
- Violet de Galmi, developed by French cooperation some 30 years ago, is the dominant onion variety in dry West Africa. The quality of this variety has deteriorated due to lack of variety maintenance. Seeds of Violet de Galmi are produced nowadays by many local producers. Seeds were collected from 45 seed producers in Niger and evaluated in the field. The six best lines were selected for further evaluation in 2005/06. The final objective is to arrive at a high yielding, high quality Violet de Galmi variety that should further boost regional exports from the dry Sahelian countries.
- Tomatoes do not set fruit during the rainy season, resulting in very high prices from June to November. Xina is among the few tomato varieties that set fruit in the rainy season. However, the fruit quality is very poor and yields are low. There is high variability among Xina tomatoes. This allowed us to select, in 2005, eight individual plants (from among 2000 that were planted) with high yield and quality. The progeny of the eight plants were planted in Nov 2005 to start a screening program for high yielding, high quality Xina tomatoes.
- Collection missions for new fruit trees fruit and varieties were conducted in Australia, Israel, India, Mali and Ethiopia. In addition we received from UC-Davis cuttings of 124 new fig varieties for drying. These collections resulted in the addition of 55 new varieties and species. Sadore probably has by now the world's biggest collection of quality fruit tree species and varieties for the SAT.

Capacity building and public awareness

- Irrigation and Export Development Workshop – a course for the directors of World Bank projects on irrigation and exports for West Africa was conducted in Israel from 27 Feb to 10 March 2005. There were 22 participants from four Sahelian countries.
- A nursery-training course was carried out at Sadore during 19-23 Sep 2005. Thirty-six practitioners from three Sahelian countries participated. Two Israeli nursery experts made up the faculty.
- A course on modern production of fruit trees was given to 30 fruit tree producers in Bobo Dioulasou-Burkina Faso, during 26-30 Nov 2005.
- A vegetable seed multiplication and storage course was given to 40 practitioners from three Sahelian countries during 17-21 Nov 2005. Two Israeli experts conducted the course.
- Four tree-grafting courses with emphasis on the grafting of Pomme du Sahel plants were given to farmers during 2005. A total of 120 farmers participated.
- About 400 farmers from Burkina Faso, Ghana, Senegal, Gambia, Guinea Bissau, Mauritania, Mali, Niger and Chad were trained on installation, operation and maintenance of African Market Gardens.
- Forty farmers from Burkina Faso and Ghana participated in a two-day course on the principles and operation of the Sahelian Eco-Farm.
- Three scientists from KARI, the Kenya Agriculture Research Institute, were trained at Sadore for a period of three months on the whole range of IPALAC activities in preparation for the transfer of IPALAC germplasm and technologies to Kenya.
- Ms Kaisu Lenna Rajala, an MSc student from the University of Helsinki, completed her fieldwork at Sadore on 'Interaction between Leaf Area Index and dry spells on pearl millet yields'.

- Four students from the University of Niamey conducted thesis research under the supervision of IPALAC scientists.

Women's empowerment

Empowerment of women and youth are among the central objectives of the systems and crops diversification team. In 2005 we helped the women of Sadore village to install a 1000m^2 African Market Garden. About 130 women have come together in an association that operates the garden. We are providing close technical supervision, training, marketing and financial guidance to the Association. The lessons learned with this experience will be applied, in the near future, at other sites throughout the region.

The Biodiversity Garden – the heart of the Bioreclamation of Degraded Land system – is especially suitable for operation by women farmers. The crops produced in this system, such as traditional vegetables, forage, fruit, and firewood trees, are traditionally women-managed crops. In most Sahelian countries women are not allowed to own fertile agriculture lands, but they can use degraded lands. The first two Biodiversity Gardens that were planted in Niger are operated by women's cooperatives. IPALAC is negotiating with village authorities for the long-term lease of degraded lands to these women cooperatives. It is hoped that this approach will lead the way for land ownership by women.

Dissemination

- 2005 marked the beginning of large-scale dissemination of new systems and crops that had successfully passed the research phase. Currently the following dissemination activities are under way:
- The USAID-supported African Market Garden (AMG) project for Burkina Faso and Ghana. At the beginning of 2005 some 100 AMGs were installed in Burkina Faso. Another 250 units should be installed by the beginning of 2006: 190 in Burkina Faso and 60 in Ghana. The demand for the AMG is growing sharply in Burkina Faso.
- The joint AMG project between MASHAV and the John Paul II Foundation continued. In 2005 fifty AMG units were installed by the project. This brings the total number of AMGs installed by this project in 8 Sahelian countries, to 280.
- An impact analysis of the first attempt to disseminate the AMG in Niger in 2002/03 was carried out. There was no follow up by the project for more than two years. It was found that whenever dissemination was carried out with the support of responsible NGOs, the adoption rate was almost 100%. When the systems were disseminated to individual farmers the rate of adoption was 60%. These are exceptionally good results, indicating the suitability of this new technology to the local conditions.
- In 2005 we joined hands with PAC, a World Bank project in Niger, and Bio-carbon, a private company, to plant within three years a total of 25,000 ha of *Acacia senegal* plantations throughout Niger.
- The regional tree nursery at ISC produced and disseminated 100,000 trees (mostly fruit trees). In 2005 its area has been doubled to enable the production of 400,000 trees/year from 2006 onwards.
- The *Trees from the Holy Land* project in Tigray-Ethiopia continued. A modern tree propagation greenhouse was installed at Mekele. About 2 ha of *Pinus pinnea, P. halepensis,* carobs, olives, *Tamarix aphylla* and fig trees were planted in various locations in Tigray. However, due to changes in the objectives of REST, our partner NGO in Tigray, it was decided to end relations with this organization, and to partner with World Vision-Ethiopia. This new partnership will start in 2006.

Program development and resources mobilization

- Dates for the Sahel program. The objective is to introduce date palm cultivation to the poor farmers of dry Africa. Dates are planted in AMGs and intercropped with vegetables and fruit trees. Proposals for several regional Dates for the Sahel projects, totalling US$ 17 million, were submitted to the Islamic Development Bank (IDB) and the African Development Bank (AfDB) through the Executive Secretary of the UNCCD. IDB has already approved the capacity building component of the project (US$ 615,000) and will take a final decision on the rest of the project (US$ 13 million) within the next six months. The objective is to install, in 4-5 Sahelian countries, a total of 14,000 AMG units planted with quality date varieties propagated through tissue culture. Youth and women will operate most AMGs. The approval of this program (probably in Sep 2006) and its successful implementation will mark the beginning of mass dissemination of the AMG in West Africa.
- Consultancy to the Govt of Senegal. Prof Dov Pasternak was asked by Dr Abdoulay Wade, the President of Senegal, to serve as an official consultant on agriculture development for Senegal. An official agreement between ICRISAT and the Government of Senegal is in the making.
- Introduction of the AMG and SEF to Nigeria. Prof Pasternak gave a presentation on our activities to the top decision makers of Nigeria. The government of Nigeria requested us to submit proposals for the introduction of the AMG and the SEF to six states in Nigeria.
- Human security improvement in the Mali-Niger border. The regional UN office for West Africa asked us to draw up a program for agriculture development in the border areas between Mali and Niger. The program

(worth about US$ 700,000) will concentrate on *Acacia senegal* plantations and on irrigated forage along the Niger river.

- Domestication of *Jatropha curcas*. Jatropha is a drought-tolerant succulent from Central America. Its seeds contain 30% oil that can be used as bio-fuel, for soap production, and as an insecticide. A proposal on its domestication is being developed, for submission to the Syngenta foundation.
- SEF pilot project. In July 2005, an IPALAC mission traveled to Washington DC in order to explore funding possibilities for a pilot project of the SEF. The World Bank managed GEF, together with TerrAfrica, a new WB program, were very interested in this program. A concept note with a budget of US$ 1million has been submitted for their evaluation.
- Cooperation with US universities. A small project (US$ 50,000) on the processing of Pomme du Sahel fruit, in cooperation with UC-Davis, has been submitted to USAID and approved. The project will start in Jan 2006.
- Participation in regional Challenge Programs. The Volta Basin Challenge Program that is managed by FARA – the umbrella organization of all African NARES – approved a component of SEF research for Ghana and Burkina Faso.
- Cooperation with NGOs and development agencies: Negotiations are underway with World Vision to partner with IPALAC for the dissemination of IPALAC crops and technologies. A program for the dissemination of hundreds of SEF systems in Niger is under development. IPALAC will train some 20 World Vision agents from Mali on both SEF and AMG technologies. A three-day workshop with decision makers of WV in West Africa will be carried out at Sadore. The objective is to expose IPALAC crops and systems to WV leaders, and to generate a plan for mass dissemination of these technologies by World Vision in cooperation with IPALAC. IPALAC is negotiating for cooperation with a range of international NGOs, such as GOAL, CRS and SOS-Sahel, and with FAO, to carry out more widespread dissemination.

D Fatondji and D Pasternak

Output 1.4: Enhancing rainwater and nutrient use efficiency for improved crop productivity, farm income and rural livelihoods in the volta basin – project 5 of the water & food challenge program

In the entire Volta basin, food security is under threat due to low water availability, low and unpredictable rainfall, increasing soil degradation, and increasing population and livestock pressure. Crop failure has become common. The overall research hypothesis of this project is that using a systems approach that integrates water use efficiency, nutrient, soil and crop management, and improved germplasm together with market opportunity identification and rural agro-enterprise development, and empowering rural communities, will result in significant benefits to the rural poor and the environment, which can be scaled out to wider geographical areas.

In this initial stage of this project, efforts were made to understand the biophysical and socio-economic characteristics of the benchmark sites through diagnostic surveys, group meetings and interactions with all stakeholders including farmers, development agencies, policy makers and researchers. Best-bet technologies for soil, crop, nutrient and water management were evaluated in close partnership with farmers. Preliminary and encouraging results have been obtained from these technologies including the SEF and the fertilizer micro-dosing technology.

Activity 1.4.1: Development, evaluation and promotion of improved soil, water and nutrient management practices in Ghana

Participatory Rural Appraisal: The PRA work and related SWOT analyses indicated that all the four target communities have challenges that need to be addressed; as well as strengths and opportunities, which must be optimized to enhance project success. Prominent among the challenges are low soil fertility, inadequate water supply for crop production and for human (in two communities) and animal consumption. These are some of the basic problems the project has already identified and seeks to address. In doing so, however, it is important to identify and collaborate with NGOs that are currently active in the target communities because of their extensive experience in mobilizing rural households.

Another important asset is farmers' appreciation of the fact that application of organic matter such as animal manure, crop residue and household refuse can improve soil fertility and thereby increase crop production. It is important to investigate why the application of organic matter is limited essentially to compound plots. If it is a question of inadequate supply of organic matter, every effort must be made to help farmers to improve upon their current animal husbandry practices, maximize the production of biomass on their farms, increase the quality of organic matter, and even learn to use green manure. The perception that inorganic fertilizers are too expensive and that their continuous use may be detrimental to farmlands is rife in all the four communities visited. Every effort must be made to demonstrate through the on-going farmer participatory research that their fears are unfounded.

Savannah Eco Farm (SEF) in Ghana: Sorghum yield ranged from 2.0 t ha^{-1} in the non-SEF plots to 2.2 t ha^{-1} in the SEF plots. Sorghum yield was not significantly influenced by cropping system or soil conservation method in the first year. Cowpea yield ranged from 640 to 860 kg ha^{-1} in the non-SEF and SEF plots respectively. There were no significant differences between the treatment means. *Acacia coli* had a rapid growth during the rainy season. During the dry season, a number of plants showed die-back from the tip and browning of the leaves along the margins, which was probably due to water stress.

Promotion and evaluation of fertilizer micro-dosing in Ghana: *On-farm trial at Tamale*. Maize yield ranged from 235 kg ha^{-1} in the zero fertilizer to 1635 kg ha^{-1} in the fertilized plots Application of micro-dose of fertilizer at 4 g per hill increased yield 4-fold above the zero fertilizer treatment. The yield response under fertilization was similar on the farmers' variety (micro-far) and the improved variety (micro-imp) – suggesting that farmers were using improved maize varieties from research stations and not local varieties. The recommended fertilizer rate of 60 kg of N per ha significantly out-yielded the micro-dose applications. This confirms the good response of maize to fertilization.

On-farm trial at Navrongo. Millet yield ranged between 335 and 739 kg ha^{-1}. Micro-dose of 4 g per hill increased the yield significantly above the zero fertilizer treatment. The recommended rate of fertilizer of 60 kg per ha more than doubled the yield of millet compared to the control.

Nutrient use efficiency (on-farm trial, maize). The Nitrogen Use Efficiency (NUE) of maize was highest for micro-dose plots with the improved variety. The NUE doubled under micro-dose compared to the recommended rate of application.

On-station trial at Navrongo (sorghum variety Kapaala). Fertilization of sorghum at the recommended rate more than doubled the yield. Grain yield of sorghum under micro-dosing was significantly higher than the control. However, the grain yield was similar for the micro-dose and the recommended rate ($p > 0.05$). The NUE of sorghum under micro-dose was twice as much that of the recommended rate of fertilizer application at Navrongo, 2004.

Activity 1.4.2: Development, evaluation and promotion of improved soil, water nutrient management practices in Burkina Faso

In general markets are held on a regular basis in well-determined places. They function in an informal way with small volumes traded. Isx markets were surveyed, two permanent (Sankariaré and Ouahigouya) and four non-permanent. The frequency of the markets of the northern site (Ziga) is 3 days a week while the market day for the south-western site (Saala) is at a given day of the week, most often on Sundays for the surveyed markets. Depending on the market and the traders, daily taxes of 25 and 50 FCFA are imposed. In 2004 a daily tax of 166,825 FCFA ($330) was collected in the market of Dissin. Part of this money is used to maintain the market. In the urban markets (Sankariaré and Ouahigouya), the traders pay a 'patent' depending on the importance of the market. For example, 30% of the traders of Sankarié pay between 100,000 and 350,000 FCFA .

Urban markets are better organized than the rural ones. Some of the markets have trans-boundary exchanges with the bordering countries. For example, Ouahigouya and Sankariaré have trade exchanges with Mali, Ghana, and Côte d'Ivoire; and the markets of Diébougou and Dissin with Ghana. Cereal grains such as sorghum, millet, maize and rice are the main products sold in these markets. These are followed by leguminous grains like cowpea and bambara nut, sesame and groundnut. Other products such as cabbage, potatoes, onions and pepper, are sold mainly by women.

The average age of the traders is 42 years, although many are younger. In all the surveyed markets the traders are predominantly from the Mossi ethnic group (100% in Ziga and Bougoure, 90% in Ouahigouya, 83% in Dissin and 60% in Diebougou). Most traders have considerable experience but 56% of them did not attend school. In most cases (78%) the original funds to start trading activities came from personal resources.

Activity 1.4.3: Capacity building

The project organized two training courses on DSSAT (Decision Support System for Agrotechnology Transfer) for the project partners. They familiarized themselves with this comprehensive computer model for the simulation of crop growth and yield, soil and plant water, nutrient and carbon dynamics and its application to real world problems. This tool would be useful in scaling-up and out the most promising technologies for soil, nutrient, water and crop management. Exchange visits were also organized for the partners who were exposed to the 'best bet' technologies at different locations.

Conclusions

The biophysical and socio-economic characteristics of the benchmark sites of project in the Volta Basin were documented using diagnostic surveys, group meetings and interactions with all stakeholders including farmers, development agencies, policy makers and researchers. Preliminary results from the on-station and on-farm evaluation of 'best bet' technologies including the Sahelian Eco-Farm (SEF) and fertilizer micro-dosing are encouraging and set the stage for adapting these technologies to the agro-ecological environment in the study sites in the Volta Basin. Project partners have acquired new skills in using modern tools such as DSSAT that will enhance research efficiency and facilitate the scaling-up and out of promising technologies for soil, nutrient, water and crop management. The project will continue to adapt 'best bet' technologies to conditions in the Volta Basin and facilitate the development of local market information systems. It is also recommended that capacity building activities be pursued and linkages be established with other projects operating in the basin.

R Tabo (ICRISAT), A Bationo (TSBF-CIAT), D Fatondji (ICRISAT), O Hassane (ICRISAT),
M Fosu (SARI, Ghana), SK Seraphine (CNRST, Burkina Faso),
K Acheampong (UNU-INRA, Ghana), A Abdou (ICRISAT),
PCS Traore (ICRISAT), S Koala (ICRISAT) and D Pasternak (ICRISAT)

Project GTAE 5. Desert Margins Program Phase 2, 2005-06

S Koala, R Tabo, A van Rooyen and all DMP partners

- Output 5.1 Improved understanding of ecosystem and dynamics with regard to loss of biodiversity (monitoring and evaluation)
- Output 5.2 Strategies for conservation, restoration and sustainable use of degraded agro-ecosystems developed and implemented (testing and implementation)
- Output 5. 3 Capacity of stakeholders and target populations enhanced (capacity building)
- Output 5.4 Sustainable alternative livelihoods
- Output 5. 5 Sound policy intervention/guidelines for sustainable resource use formulated, adopted and implemented (policy and legal framework)
- Output 5.6 Extension of sustainable Natural Resource Management
- Output 5.7 Target populations are involved at each stage of the project's cycle.

Introduction

The Desert Margins Program is a collaborative initiative among nine African countries: Burkina Faso, Botswana, Mali, Namibia, Niger, Senegal, Kenya, South Africa, and Zimbabwe; assisted by five CGIAR Centers (ICRAF, ICRISAT, IFDC, ILRI, TSBF-CIAT) and three Advanced Research Institutes (CEH, CIRAD, IRD). The DMP aims at arresting land degradation in Africa's desert margins and addressing issues of global environmental importance as well as issues of national economic and environmental importance; and in particular the loss of biological diversity, reduced sequestration of carbon, and increased soil erosion and sedimentation, associated with land degradation in these arid and semi-arid ecotones.

The 120 million inhabitants of these countries depend mainly on rainfed agriculture and natural rangelands for their survival. However, their livelihoods are at risk due to land degradation. Furthermore, the problem of biodiversity loss is particularly critical in these very dry areas (200-600 mm annual rainfall), where ecosystems are less likely to recover once they are seriously damaged.

The overall objective is therefore to arrest land degradation in Africa's desert margins through demonstration and capacity building activities. The Global Environment Facility (GEF) increment of $16 million to this project has enabled the program to address these issues during Phase I, with particular emphasis on site characterization, including an inventory of endemic species, evaluation of ecosystem stability, documentation of indigenous knowledge, inventory of endangered species, assessment of biodiversity degradation and regeneration, restoration of biodiversity, characterization of benchmark sites and standardized data collection.

This GEF increment builds on the $15 million commitment from the nine participating countries, and $19 million committed by various donors. The DMP as an action research and development program is divided into three main phases. The first phase (2002-04) concentrated on characterization of the different study sites in order to determine the opportunities, challenges and options to combat desertification. The target ecoregion is the desert margins of sub-Saharan Africa. The immediate beneficiaries of this research are institutions from the participating countries, as the program will strengthen their capacity to design and plan interventions to mitigate land degradation and establish sustainable land use and management practices. These institutions have clearly identified various groups of individuals/organizations who will benefit from the DMP/GEF program. These groups fall into five categories:

- Local communities, pastoralists/agro-pastoralist farmers, through better knowledge on the management of natural resources

- Grassroots organizations (CBOs and NGOs) through access to appropriate technologies to plan and guide sound natural resources management programs among local communities
- Service providers - Government and NGOs involved in policymaking and extension ,through better understanding of biodiversity issues
- Local and international research institutions in terms of improved interaction and linkages with local communities and NARS (target populations)
- The international community involved in development assistance programs, in terms of better policy environment guaranteeing enhanced success
- The end users are village communities benefiting from alternative livelihoods such as the Sahelian Eco-farm, the African Market Garden, and through reclaimed lands planted with *Ziziphus mauritania*, *Acacia senegal* and other species

The main hypothesis of the DMP work is that the desertification trend can be avoided or reversed by adopting resource management policies aiming at both enhancing the resilience of the agro-ecosystem through conserving or strengthening biodiversity, and at improving farmers' livelihoods through options to intensify and diversify mixed crop-livestock productions or to improve rangeland management. Phase I results have shown that there are indeed options for agricultural intensification that would enhance farmers' livelihood and also reverse environment degradation.

The first option tested in the DMP consists in promoting the integration of crop-livestock husbandry at all scales from farm upwards. Such integration improves resource use efficiency and functional stability of the ecosystem, as the tropic systems get more complex. Economy of scale, diversification of products (crop diversification) and a more balanced labor calendar (such as the Sahelian Eco-farm) are the basis for the expected economic benefits. In addition, diversification and strengthening of skills, social networks, cultural values (indigenous knowledge, rural communities' capacity enhancement) will provide further social and cultural benefits.

A second pathway is diversification of crop and livestock production, especially trade-oriented commodities, with a special focus on new fruit trees (figs, Pomme du Sahel, date palm), dual-purpose legume (cowpea) on the crop side, poultry and small ruminants on the livestock side.

The third option consists in promoting input use, such as small amounts of inorganic fertilizers (fertilizer microdose), pesticides for cash crops (especially legumes), and mineral feed supplements for livestock to enhance productivity. All these can have residual and snowball effects on ecosystem productivity.

A fourth option is better integration of woody plant management with both crop and livestock activities (rangeland), with special focus on the biological, economic, social and tenure aspects of traditional agroforestry systems: parkland and field edges (West Africa).

These options need to be adapted to each region (West Africa versus East and Southern Africa) and farm type because farming systems are so diverse in terms of access rights, productive assets, labor availability and skills. Their adoption and development by farmers entail both social and environmental costs that should be evaluated and discussed among development partners and rural communities. There are economic, social and political prerequisites to the adoption and development of these options by farmers.

The use of external inputs as well as the marketing of cash crops, livestock products, wood and related products, depends on the market situation, national and international regulations. Access rights and tenure systems depend on social institutions and laws which are in turn influenced by the regional and global political environment. Strong complementary expertise of partners does exist to successfully undertake the testing and promotion of these options:

- ICRISAT in crop biodiversity and natural resource management
- ILRI in pasture lands restoration
- ICRAF in agroforestry systems
- TSBF/CIAT for soil fertility management
- IFDC for integrated soil nutrient management
- ARIs in model development and upscaling
- Specialized NGOs in medicinal plants
- NARS in local expertise on all these areas

This synthesis report summarizes progress made during the first year of Phase II while taking into account the achievements of Phase I (see Appendices 3 and 4). The diversity in agro-ecological systems even in the desert margins is significant, but this apparent challenge allows us to analyze a range of different issues in relation to differences in policy, land use, access to markets in a range of agro-ecological conditions across the nine DMP countries.

Output 5.1: Improved understanding of ecosystem and dynamics with regard to loss of biodiversity (monitoring and evaluation)

This component aimed at improving knowledge about the physical processes leading to biodiversity loss in the drylands, in particular the relative importance of human and climatic factors, the development of quantitative indicators of biodiversity loss, and improved monitoring techniques. Most activities undertaken under this output have been completed during Phase I. The major highlights of Phase I are summarized below:

Soil and vegetation inventories, including biodiversity have been widely investigated across the project sites (Kenya, Zimbabwe, Burkina Faso, Mali, Niger). However, levels of detail, coverage and the amount of data gathered have varied across countries. The project was successful in generating consistent baseline data across all DMP countries. Some countries have even begun modeling climate change, hydrological cycles (Kenya, Zimbabwe, Burkina Faso, Senegal, Mali, Niger), and are studying the impact of land use on the resource base, including levels of degradation, soil fertility, and changes in biodiversity and land cover. We are now planning to organize a technical conference to synthesize lessons learnt during Phase I and generate regional perspectives (West, East and Southern Africa) on the impacts of land use and climate change on the resource base. Socio-economic changes taking place in the project sites have been documented and recommendations are being formulated on potential measures for adapting to climate change, including lessons learned from indigenous knowledge and best practices in agriculture, pastoralism and agro-forestry (Kenya, Burkina Faso). Furthermore, the project has made linked together all projects operating at the same sites for information sharing to derive best practices across the eco-regions of West, East and Southern Africa.

During Phase II, some activities started in Phase I are being pursued. For example new findings have been identified to better characterize ecosystem stability. In Burkina Faso, some insect species (*Charaxes epijasius)* have been identified as potential bio-indicators for land and biodiversity regeneration. Similar work has been done in South Africa, Namibia and Botswana. In the land rehabilitation front, scientists aided by rural communities have shown that land cover could be regenerated after a very short period using the half-moon technology. Land vegetative cover was 24% on control plots versus over 82% on plots treated with half moons on lateritic or silty glacis. With the help of rural communities medicinal biodiversity has also been restored using Ikat at some benchmark sites.

The biodiversity garden of the desert in Mali has been enhanced by the introduction of several new grass and shrub species: *Combretum glutinosum, Parkia biglobosa, Tamarindus indica, Acacia leata, Cassia sieberiana, Piliostigma reticulatum, Combretum aculeatum, Leptadenia pyrotechnica, Pergularia tomentosum, Commiphora africana, Combretum micrathum, Blepharis linearifolia, Euphorbia balsamifera, Sclerocarya birrea Cenchrus biflorus* et *Panicum leatum*.

A biodiversity assessment manual has been developed and published by ICRAF. A data analysis workshop was organized with participants from Burkina Faso, Mali, Niger and Senegal. A strategy for upscaling adoption of *Ziziphus mauritania* in the Sahel has been developed for Burkina Faso, and can be applied in other DMP countries.

An excellent study covering general household information and population demography, security of land tenure, rangeland and livestock resources, farming practices, marketing, knowledge base of population, institutional support, access to credit, coping strategies, infrastructure, finances, education and health, labor, and monitoring system has been conducted in Namibia. *Livelihoods in the Eastern Communal Areas (Otjozondjupa and Omaheke regions), Namibia: A baseline for future reference* is a combination of a desk study and the results of extensive qualitative interviews in all nine pilot areas. A series of posters on "Socio-economic survey of the eastern communal lands of Namibia", focusing on all nine pilot areas has been developed and distributed to communities and development agents. The challenge now is how target populations and decision-makers can use this socio-economic data for improved decision-making at different levels.

A field guide for local level monitoring in the western parts of the project area has been developed. About 100 farmers from four pilot areas have been trained in the use of the field guide. Most of these farmers are in the process of implementing the local level monitoring system. The project has provided considerable backstop support to the newly trained farmers in implementing the system. A first combined session with selected farmers was held where results from the system were synthesized, analyzed, and constraints in implementation were discussed.

The success and applicability of the *EcoRestore* DSS done in Namibia depends largely on the ability to regularly update the existing database. DMP Namibia supported the Namibia Agricultural Union in conducting 54 additional case studies for inclusion in the DSS. The School of Environment Sciences and Development of Northwest University (Potchefstroom campus) has been contracted to incorporate these case studies into the existing database. FIRMs (Forum for Integrated Resource Management) have been established in all nine pilot areas and are at different levels of operation. In most pilot areas integrated workplans have been developed and incorporated into the constituency development plans of the different regions. A very successful donor conference was held in Okakarara where priorities of the pilot communities were discussed and financial support for their workplans have been solicited. One of the major challenges in Phase II will be to ensure that the newly established FIRMs in each of the nine pilot areas becomes fully operational.

Four conservancies (economically based system of sustainable management and utilization of game in communal areas) have been officially established and gazetted in the pilot areas during 2005.

South Africa has selected two provinces, i.e. Northwest and Northern Cape as they border Botswana and Namibia (two DMP countries); and teamed up with these two countries to enhance its field work. Such work included data analysis, flora and fauna surveys, and population mapping and socio-economic inventory. This led to better exchange of knowledge between stakeholders on assessment of soil degradation and integrated biodiversity management (soil and vegetation) with a resulting reduction in grazing pressure on the land; better understanding of ecosystem stability; and greater stakeholder participation in the three countries. Farmers' indigenous knowledge related to sustainable use of *Rooibos* tea has been documented, and farmer experimentation to restore biodiversity in *Rooibos* plantations enhanced. More endangered plant species have been identified and farmers made aware of species diversity. The teams also organized a workshop to record farmer practices in adaptation to climate change. Transects were set up to monitor grazing impact on biodiversity and restoration (Mier). A simplified quantitative vegetation change measurement system for application by extension agents and farmers, is under development by IES in Zimbabwe.

Climate-forcing gas emissions and development of carbon and nitrogen budgets for land-use systems have been documented in Senegal and Mali in collaboration with CEH. The influence of land use on the emissions of greenhouse gases from soils, in particular nitrous oxide and methane, the evaluation of biodiversity and biophysical sustainability indicators for desert margin ecosystems, the development of C sequestration model for evaluation of species' potential for carbon trading will be the emphasis of the collaboration between ARIs and IARCs through the Scientific and Technical Advisory Team (STAT) soon to be established. Activities will cover the following:

Climate-forcing gas emissions from land use options in Mali
Emission inventories are key to global modeling studies and environmental policy development. Reasonable estimates of sources, strengths and distribution as well as trends in time, is a prerequisite for selecting cost-effective environmental policy packages and carrying out realistic studies on projections of future emissions. Quantification of above-ground carbon dioxide sinks and sources has so far received the major international effort; but soils are now being recognized as a major under-researched component in the system.

There are large uncertainties in the current annual emission figures for nitrous oxide (N_2O) and methane (CH_4) from soils. It has been estimated, for example, that the uncertainty in the current global emission of N_2O from agricultural sources may be larger than 100% (Olivier and Berdowski 2001). Agriculture is by far the largest source of N_2O, contributing 85% to the global anthropogenic total in 1995; with synthetic fertilizers and animal waste contributing approximately equal amounts to direct N_2O emissions. There are very few data on emissions of these gases from sub-Saharan Africa or dryland agroecosystems.

Soil emission fluxes are tightly linked to land use management through the impact of natural and synthetic fertilizer application, tillage, irrigation, compaction, planting and harvesting. The aim of our study is to measure nitrous oxide and methane emissions from a range of land management options in dryland African agroecosystems. Carbon and nitrogen budgets will be evaluated in a cereal/legume field trial in Mali in which N_20 and CH_4 emissions are being measured. Additional measurements by CEH will include estimation of microbial biomass and microbial activity. This work will improve our understanding of soil nutrient dynamics: turnover of litter and organic matter, and the relationship between soil microbial activity and the emission of climate-forcing gases.

Biodiversity and biophysical sustainability indicators for desert margin ecosystems
This activity has commenced with a desk study of the current state of knowledge of soil quality assessment and evaluation of sustainability of land-use systems in the desert margins. The study has generated a review paper on the potential of carbon management to improve biological condition in land use systems in dryland sub-Saharan Africa (Hall, N.M., 2004, in preparation). This review highlights the need for further research into useful indicators of soil biological condition as a prerequisite for evaluating sustainability of land-use in the desert margins. CEH is following up on this identified research need by developing a relevant research program with ARIs and NARS.

Development of C sequestration model for evaluation of species' potential for carbon trading
CEH work also begins in Senegal with an analysis of carbon sequestration in tree biomass and soils. This work builds on former collaboration with ISRA (Dakar) on the biomass production and nutrient use of nitrogen fixing trees (Deans et al 2003). The DMP collaboration will involve development of protocols for assessment of carbon stocks in forest systems. CEH intends to use baseline information on common tree species in the West African parklands to

develop a C sequestration model that can be used to evaluate species' potential for adoption in carbon trading projects.

There has been increasing interest in the potential revenues that smallholder farmers and village-based communities may derive from the trading of carbon credits accrued through tree carbon sequestration, either through the Clean Development Mechanism, or through voluntary trading mechanisms. This work will commence with an evaluation of carbon sequestration in woody biomass and soils at a forest field station in Senegal. It is proposed that the model be field tested in village based systems in Phase II with an evaluation of existing carbon resources. While this may present an alternative livelihood option in dryland agroecosystems, a study of livelihood risks and benefits of tree planting for carbon sequestration would be integrated in this study.

Some agroforestry technologies have been promoted at most DMP benchmark sites for the involvement of rural communities such as shown in Table 1. Up to 12623 Ziziphus tree seedlings have been produced and planted in more than 25 ha.

In Niger, more than 1000 ha of rehabilitated lands have been planted with grasses and 50,000 seedlings of Ziziphus and Acacia senegal planted at the project sites with the participation of rural communities.

A manual or guide on birds found in the benchmark sites has been produced and will be published. The fertilizer microdosing technology is being promoted in Mali, Burkina Faso and Niger. New activities have been established aimed at providing alternative livelihoods to rural communities bordering the habitat of the last remaining giraffes of West and Central Africa as well as to provide more browse to the giraffes.

In Senegal, agroforestry technologies are being upscaled, with over 350,000 tree seedlings of *Ziziphus mauritania* produced, new home gardens and the African Market Garden established in rural communities, and a number of sites put under 'mises en defens' and/or natural communal reserves by over 20 rural communities using the local development plans approach. This follows a technology transfer model developed by the program and its partners as described in Fig 1. In this model, local experts play a key role and are used as change agents.

The Program in Zimbabwe has identified, through extensive participatory approaches, a number of alternative livelihoods and is currently building on these at the sites. These include production and marketing of Mopane worms, livestock, crops and cropping systems. Interventions include policy reviews regarding their adequacy, knowledge of such policies and contribution by community groups. Consultations with partners confirmed opportunities and challenges previously identified through PRAs and biophysical assessment. Participatory processes were used to identify community interest groups and assess intervention needs. Additional studies were conducted to gather information on indigenous knowledge and practices: Mopane worms, woodlands and grasses, animal disease control, and use of wetlands. Areas of critical degradation were identified at village level in the three sites and degradation processes discussed. This improved the understanding of degradation levels and processes at both community and institutional levels.

Output 5.2: Strategies for conservation, restoration and sustainable use of degraded agro-ecosystems developed and implemented (testing and implementation)

Activities under this output concentrated on:

- Documenting best-bet practices
- Piloting the selected technologies identified during phase I
- Promoting their adoption and implementation by communities at DMP benchmark sites
- Enhancing indigenous knowledge

Development of more efficient farming systems

The African Market Garden (AMG) is a low-pressure drip irrigation system particularly suitable for small farmers. It has all the advantages of conventional drip irrigation systems at a fraction of their cost. The AMG can increase farm profits per unit area over traditional dryland farming systems by a factor of seven. Over the last three years, ICRISAT has disseminated 1500 AMG units in eight countries of West and Central Africa and the effort is continuing through an ongoing project in Burkina Faso and Ghana (see West Africa section for more details).

The Sahelian Eco-Farm (SEF) is an integrated dryland tree-crop-livestock system designed to address the major constraints in millet based production systems. Three versions of the SEF are under investigation. The system is still under development in partnership with the NARES of Burkina Faso (INERA) and Ghana and with pilot farmers in Niger. Results of four years of research at Sadore, Niger, demonstrated that the SEF could increase farm profits per unit area by a factor of five as compared to the traditional system. ICRISAT is proposing to study mechanisms for large-scale dissemination (see West Africa section for more details).

Crop diversification: activities involve improvement of traditional crops and native plants and identification of new income-generating crops:

- Domestication of *Acacia senegal*, the Gum Arabic producing tree
- Promotion of traditional vegetables
- Selection of dual-purpose cowpea varieties
- Promoting Roselle (*Hibiscus* sp) as a cash crop for export
- Production of watermelons on stored soil moisture
- Pomme du Sahel: introduction of domesticated *Ziziphus mauritiana*
- Dates for the Sahel
- Introduction of new species and quality varieties of fruit trees
- Heat tolerant quality vegetable varieties.

Diversification with medicinal and aromatic plants: initiatives are planned in Zimbabwe and Senegal to identify and re-popularize sustainable indigenous land use practices. A number of activities are planned to help communities improve their management of soil and water resources, retain soil fertility, avoid soil erosion, and make best use of water resources (Zimbabwe, Burkina Faso, Senegal, Niger). The DMP will take the latest lessons from the field, indigenous knowledge and scientific research from across the region to update and rationalize approaches to water and soil management at project sites. Rural development initiatives are planned to help local communities build the capacity to organize themselves into collectives and cooperatives, increase productivity and add value to farm output (Kenya, Burkina Faso). Finally there are a number of baseline activities to rehabilitate pastoral areas, encourage natural regeneration of over-used species, and to re-forest degraded areas and stabilize sand dunes (Burkina Faso, Senegal, Niger). The DMP will build on the foundations laid by the community development and rehabilitation activities, building on the broad base of experience.

At the country level, the focus was on piloting the selected technologies identified during Phase I, promoting their adoption and implementation by rural communities involved in DMP benchmark sites, and enhancing indigenous knowledge. In Burkina Faso, vast areas of degraded lands have been rehabilitated using the half moon technology and sand dunes have been stabilized. The following photographs show some of the rehabilitation work in the four benchmark sites, Banh, Tougori, Katchari and Oursi in northern Burkina Faso, where degraded land was rehabilitated using the Delphino plow. Furthermore, over 80,000 tree seedlings have been produced and planted into these regenerated degraded lands in Burkina Faso. In Niger, a similar approach was adopted. In South Africa, higher crop and vegetable yields from the household food gardens established in the Paulshoek target area resulted in better income generation and livelihoods, as well as increased community participation. Vegetable and legume seeds were produced and distributed to farmers. Dialog was established with NGO representatives on the implementation of the household food garden model to other communities. Many courses and workshops were presented to farmers and community members to build capacity and skills.

Output 5.3: Capacity of stakeholders and target populations enhanced (capacity building)

Initiatives undertaken in 2005 at project sites were planned to encourage the development of (as opposed to the modification of) new rural enterprise and livelihood ventures. Both Kenya and Burkina Faso have begun to promote alternative rural enterprise, by making rural credit available to provide seed finance for new ventures, renewable sources of energy for rural initiatives, and business development support for new enterprises. In Senegal activities focused on the domestication of wild fruit, for commercialization.

Over the last year a range of capacity building activities have been undertaken with DMP stakeholders. Training needs were first assessed and prioritized in order to tailor training activities to users' needs. For example, ICRAF is finalizing their report on a workshop entitled 'Agroforestry in the Sahel: present status, needs and perspectives' during which training needs were identified in close consultation with the major players in West and Central Africa. CIRAD has circulated a survey questionnaire to all DMP partners asking about their training needs in terms of capacity/governance building for Natural Resource Management. The focus will be on environmental, socio-economic and policy evaluation. This will strengthen local capacity for evaluating NRM options and policies, and for devising policy scenarios. This would also strengthen the capacity of NARS scientists to estimate the economic impact of a given technology and fine-tune their interventions accordingly.

Since Phase II focused on technology dissemination, TSBF-CIAT/AfNET, in collaboration with DMP, organized a training workshop to create awareness and develop researchers' skills in farmer-participatory research and scaling-up of promising innovations. DMP partners from Burkina Faso, Kenya, Niger, Senegal, South Africa and Zimbabwe attended. Partners from Burkina Faso, Kenya, Niger and Senegal also participated in a training workshop on

‘Assessing crop production, nutrient management, climatic risk and environmental sustainability with simulation models’. They familiarized themselves with DSSAT (Decision Support System for Agrotechnology Transfer), a comprehensive computer model for the simulation of crop growth and yield and plant water, nutrient and carbon dynamics. IFDC organized a training workshop for 350 pilot-farmers and 50 national extension agents from Burkina Faso on large-scale dissemination of Integrated Soil Fertility Management technologies. Another IFDC workshop on ‘CASE’ and technical options for cropland forage production was attended by 50 participants in Burkina Faso. CASE promotes commodity chain development and the agro-input sector. DMP-Niger scientists took part in a training course on monitoring and impact studies of projects in Segou, Mali.

In the area of postgraduate training, students from the University of Niamey worked on their MSc theses on documentation of indigenous knowledge of livestock genetic diversity in south-western Niger under the supervision of DMP-ILRI scientists.

DMP has also undertaken in-country and cross-country training activities. Scientists from South Africa attended a training workshop in Namibia, organized by the DMP-Namibia. They acquired hands-on experience of the FIRM (Forum for Integrated Resource Management) and the Local Level Monitoring (LLM) programs that are used by the DMP in Namibia. A PhD student from DMP South Africa visited Burkina Faso, Mali, Niger and Senegal to document and evaluate restoration and NRM technologies in these countries. DMP South Africa also supported training and capacity building workshops for farmers and the youth of formerly disadvantaged schools in the Mier target area in the Kahalari. In addition small livestock breeding and management training courses were given to farmers and land users in the Mier region. DMP South Africa has developed a training manual for production of organic *Rooibos* seedlings. Through training (technical and institution-building) at grassroots level, the capacity of resource users and service providers to sustainably manage their natural resources was enhanced. In Mali several women were trained in tree grafting and management of nurseries. In Burkina Faso, 48 farmers from 15 villages in the department of Banh were trained in grafting and production of Pomme du Sahe” and in the use of drip irrigation. In Senegal producers were trained in the techniques of grafting *Ziziphus mauritania.* In Niger, tourist guides were trained and provided with tourist maps. IRD has provided training to DMP Burkina partners in microbial ecology.

ICRISAT carried out a number of field trainings during the year. A nursery-training course was held at ICRISAT, Sadore for 36 farmers from Burkina Faso, Mali and Niger. A course on modern production techniques of fruit trees was given to 30 producers in Bobo Dioulasso, Burkina Faso. A course on multiplication and storage of vegetable seeds was given to 40 practitioners from the DMP countries in West Africa. Four tree-grafting courses with emphasis on the grafting of Pomme du Sahel plants were given to 120 farmers. About 400 farmers from Burkina Faso, Ghana, Senegal, Gambia, Guinea Bissau, Mauritania, Mali, Niger and Chad were trained on installation, operation and maintenance of African Market Gardens. Forty farmers from Burkina Faso and Ghana participated in a two-day course on the principles and operation of the Sahelian Eco-Farm. Three scientists from DMP-Kenya were trained at Sadore for a period of three months on tree grafting, African Market Garden, and other relevant technologies.

Output 5.4: Sustainable alternative livelihoods

This component will identify, inventorize and document economically viable livelihood options. It will create an environment conducive to the adoption of improved plant nutrient technologies through programs that promote more efficient procurement, distribution and marketing of inputs and also enhance utilization of farm outputs through the development of micro-enterprises. It will increase local awareness and use of indigenous dryland products, improve processing and marketing, develop markets for non-timber forest products and other dryland products, and implement pilot schemes with alternative crop technologies that have proved successful elsewhere. Overall, it aims to examine ways to add value to farm outputs in order to increase the farmer’s income. Activities included two broad areas: Livelihoods options and empowerment of communities.

Land degradation control and conservation of biodiversity require that rural communities are provided with alternative means of survival if they are to protect natural resources. Rural communities depend on both farm and non-farm income. Farm income is often generated from crops, natural (wild) trees and livestock. There is need to characterize current livelihood strategies pursued by households so as to design livelihood options which are most likely to improve rural welfare.

Alternative livelihood options are critically important to reduce the stresses on natural resources in the desert margin areas of sub-Saharan Africa. A number of such options have been developed, as described below.

African Market Garden
The AMG is set within the context of multiple farming systems with emphasis on social, economic and gender at the community and household levels. A socioeconomic survey was conducted by DMP researchers in collaboration with local NGOs, development partners and farmers associations, to assess the different components necessary for

successful introduction of the (AMG). The results showed that potential beneficiaries of the technologies included women who are traditional market gardeners and who could manage the small units promoted by the program.

Sahelian Eco-Farm
The SEF is an innovation that was recently developed at the ICRISAT Sahelian Center (ISC) in Niger in collaboration with NARES partners. It aims at addressing the multiple problems, biophysical and economic, of smallholder farmers in semi-arid areas. The SEF combines the use of live hedges of *Acacia colei*, earth bunds that turn into micro-catchments or 'demi-Lunes', high value trees such as the domesticated *Ziziphus mauritania* planted in the demi-Lunes, a perennial grass such as *Andropogon gayanus* planted on the earth bunds, and annual crops, each planted in half or a third of the field in rotation each year.

Poultry production, consumption and marketing survey in Kajiado district, Kenya
The survey illustrated the role of chickens in the lives of Maasai, former pastoralists, now largely sedentary. Huge opportunities exist to improve the livelihoods of these people using chicken production. Many other people in the desert margins may benefit from improved rural chicken production and we should build on these initiatives.

Bee keeping in Marsabit district, Kenya
A survey was conducted, through focus group discussions, on bee-keeping and honey production in the Southern rangelands of the Ndotto mountain ranges in Marsabit district. The survey clearly showed the need for training on modern honey production techniques: the current system is based on indigenous skills that require enrichment. A follow-up action plan has been agreed upon between the community and the project. Another survey on the potential of bee keeping in the pastoral Ngurunit area gave similar results. Bee keeping is an option worth pursuing and already makes a contribution in providing extra income for poor people. Investments from the DMP in this area could have significant long term impact, especially if developed in such a way as to include women in the production and processing cycle.

Interventions on crop production in Turkana district, Kenya
The economic importance of crop production among the pastoral Turkana community was revealed during site characterization. The need for technical interventions became apparent during the characterization feedback workshop. A detailed assessment of the farming systems including production techniques, constraints, indigenous knowledge, crop varieties and cropping season dynamics and opportunities was conducted following the recommendations of the feedback workshop.

Sustainable rooibos tea production in Namaqualand, South Africa
Rooibos tea is an indigenous tea to the dry, winter-rainfall areas of the semi-arid Western Cape province in South Africa. Increased rooibos tea production and harvesting through DMP research and development activities contributes to rooibos tea certification and international marketing.

Output 5.5: Sound policy interventions/guidelines for sustainable resource use formulated, adopted and implemented (policy and legal framework)

Incentives for farmers and rural communities to conserve and sustainably use natural resources are influenced by a variety of social, economic and political factors. These include micro and macroeconomic policies, legal rules of access to resources, direct public investment, and institutional mechanisms in place to support these policies. The DMP work will be synchronized with existing work on policy reform to avoid any duplications, and will focus mainly on informing policy debate. Activities focused on two broad areas: documenting existing policies and developing policy documents.

The Kenya government is in the process of developing a policy for the Arid and Semi Arid Lands (ASALs). Various consultative meetings in which members of the DMP have participated have been held. The National Policy for Development of the ASAL areas of Kenya was prepared in 1992 and the government in collaboration with UNDP is currently updating and reviewing the document. Discussions have been held between stakeholders; and an expert workshop and two regional workshops have been held and the output incorporated in a draft national policy in Dec 2003. The document has been forwarded to the Kenya government for ratification and implementation. A second policy document known as the Soil Fertility Initiative for Kenya has been prepared. Discussions have been held between stakeholders; several expert workshops have been held and the output incorporated in a draft national policy.

In all the four countries in WCA, efforts were made by DMP partners to document exiting policies, through literature review and secondary data collection. In general, policy guidelines follow the general framework of the decentralization process that is being implemented in the four countries. More authority is being given to local and communal structures in managing natural resources.

DMP Namibia contributed to a study to assess to what extent the current policy, legislative and planning framework is conducive to the implementation of better land management, particularly biodiversity conservation and combating of desertification. Since the 1996 policy analysis, there have been many positive changes to the policy environment. Several environmental policies, that reflect global thinking regarding sustainable natural resource management and utilization (guided largely by the principles enshrined within the UNCCD, UNCBD and other agreements), have been formulated. Favorable sustainable development statements now appear in many other sectoral policies. The Namibian DMP team continuously contribute to these developments. A comprehensive analysis of policies concerned with environmental issues has been summarized in CD-Rom format in South Africa. This will be updated again during 2005.

The DMP coordinator in ESA initiated a series of studies with country partners, illustrating the impact of different environmental and agricultural policies at various cross border locations in the ESA region using remote sensing techniques. This work will continue and also be incorporated in country level policy debate. With partners in West Africa this work may be extended to include similar analysis there.

Output 5.6: Extension of sustainable natural resource management

This component fosters improved and integrated soil, water, nutrient, vegetation, and livestock management technologies to improve the productivity of crops, trees, and animals to enhance food security and ecosystem resilience. It will ensure the integrated management of biological diversity by households and farmer associations so as to improve incomes. It will enhance NARS capacity to identify, in collaboration with farmers, NRM technologies including strategies for promoting conservation, restoration and sustainable use of degraded ecosystems. Impact can only be achieved if scaling-up and out of promising technologies is done using effective approaches and methodologies. Activities cover two areas: promoting soil fertility management, and support to NARS.

While much work has been done in this area, it is essentially the focus of the second phase. During the first phase of the project, various soil, water and nutrient management strategies and alternative livelihood options were tested in the benchmark sites in Burkina Faso, Mali, Niger and Senegal, with the active participation of farmers as described under outputs 2 and 4. Good results were obtained from these experiments. Kenya has collaborated with TSBF with on-farm trials to test the soil/water/nutrient management model. In Zimbabwe soil fertility management options were identified in a series of PRAs in the target areas. The shortfalls and achievements are identified in a participatory manner and future testing and adaptation will be done. Projects focusing on integrated land and pastoral spaces are being implemented in Tsholotsho and Matobo districts in Zimbabwe. Namibia is currently in the process of developing a Country Pilot Partnership (CPP) for Integrated Sustainable Land Management. This multi-sectoral forum will, once operational, replace the Napcod steering committee as the national stakeholder forum for land and water . The Namibian DMP team contributes significantly to these initiatives that greatly support the national processes. In South Africa presentations were made at the Western Cape Poverty Indaba and the National LandCare Conference on the importance of using local knowledge in development interventions, based on research undertaken during the DMP project. Both fora were attended by a wide range of decision makers, NGOs, and members of the public. The LandCare conference was attended by NARS and agricultural extension services, where the DMP South Africa team made a substantial contribution.

Once again, notable work is being done and needs to be publicized in a coherent way that allows comparisons and drawing of lessons. Partners should be encouraged to provide detailed reports on both the methodologies used and the approaches for implementation in order to create the synergies expected from the DMP. This information is available at country level and a few well focused activities should be able to crystallize this into a form available to a much larger audience. During Phase II, emphasis will be placed on disseminating the most promising of these technologies through appropriate and effective methods for scaling up and out. Active farmer participation in these activities will be paramount. Equally important will be the contribution of co-funded activities and projects.

Output 5.7: Target populations are involved at each stage of the project cycle

This component covers activities intended to guarantee the participation of all stakeholders – and especially the most vulnerable groups – in the design, implementation and follow-up/evaluation of the project. It has established a permanent dialog framework using participatory tools. It is evaluating the existing interface between experts and rural communities in order to identify effective mechanisms and constitute working groups, especially of women, and promote effective linkages between researchers and rural communities at all project sites.

- Activity 7.1 Participation of vulnerable groups
- Activity 7.2 Permanent dialog framework
- Activity 7.3 Scientific team exchanges

Most DMP partners have made substantial efforts to include vulnerable groups in project activities. The plight of the largely neglected San community in Zimbabwe is taken into consideration; while bee-keeping and poultry provides huge opportunities to empower women in Kenya.

A large number of scientific exchanges took place in the first phase of the project. Kenya, being very active in this regard, had scientists visiting DMP sites in Niger where they were trained in various aspects of natural resource management. The potential of scientific exchange teams is clearly illustrated by the exchange visits between South Africa and Botswana during the external evaluation of the project in those two countries. Much more serious attention needs to be focused on activities where information and technologies can be shared between study sites, especially between countries.

In WCA, various group discussions were held in villages, where all stakeholders interacted on the implementation of the project. This is a critical aspect as the rural communities have to be involved in the entire process of project design and execution so as to enhance adoption of the technological options proposed. Exchange visits should also take place among target communities. Such successful visits took place in South Africa between small-scale farmers in Namaqualand and the Kalahari. These events should be clearly documented and evaluated in order to determine their impact and to develop a format that would enhance the heuristic value of these events.

The use of internet technology

Output 7 strives also to engage stakeholders and establish a permanent dialog framework. The internet cannot replace person-to-person contact, but it can be a valuable supplement to it. In the First DMP Steering Committee meeting, the use of the internet as one part of a DMP communication strategy was recommended. To meet this recommendation we have begun a DMP website (tied to ICRISAT’s website) and a bi-monthly newsletter. Many of our partners in Africa have limited access to the internet, so the strategy is taking this into account, utilizing low-bandwith and asynchronous communications such as email, clear and informative web pages, and an email newsletter.

The website describes the DMP’s mission, history, achievements, activities, partnerships, and current news and events. As it matures it will also become an important venue for sharing the results and meaning of our research, such as reports of studies, policy analyses and recommendations, training materials and so on. We are planning to also add a private area to the website (DMP partners only) to facilitate project tracking. The newsletter links to stories on the website, serving to remind people of the web resource, which results in greater awareness of the full scope of DMP activities.

This website is designed not only to share information among DMP partners in the field, but also with the wider stakeholder community and public including development investors, decision and policy-makers, and those in civil society globally who want to learn more about sustainable agriculture in the desert margins. It is important for the DMP not to become too inward-looking; we want the wider world to know what we are doing, understand and appreciate it, and hopefully, join in. Increasingly, people are turning to the web to seek information and we want to be sure the DMP can satisfy this need. Over the long term we believe this will help increase and sustain support for the DMP.

In addition to the main website at www.dmpafrica.net, DMP partner CIRAD has established a ‘Sahel DMP blog’ where they post summaries of events and documents in the West African countries. This blog is in French and gives particularly thorough coverage of the Francophone DMP countries.

Conclusions

- The Desert Margins Program in SSA is well established and recognized as a viable program in all the participating NARS. Collaboration between parastatals, NGOs and the private sector (to a lesser degree) is well established. Most target communities are well informed and provide local support and play an active part in the project.
- Highlights include the preparation of the different site characterization reports. These will be finalized at country level and then compiled. The final document will illustrate, within the regional context, the salient issues pertaining to the loss of biodiversity and the dynamics of desertification.
- A further highlight is the work being done in certain countries to foster alternative livelihoods. These will make a significant contribution in the areas where they are being implemented, but the potential impact can be improved with appropriate information flow. Direct communication of these positive results will greatly increase impact especially if reinforced with clear concise fliers and coverage in the DMP newsletter.
- Desertification is a multi-dimensional problem, with many conceivable causes and a network of consequences that encompass a wide range of spatial and temporal scales. Biodiversity loss is one component process of dryland ecosystem degradation. Degradation and restoration of a landscape are two sides of the same problem, involving both natural and social forces.

- Results of Phase I show that in spite of the wide amplitude of the inter-annual changes in production and species composition, natural vegetation in the desert margins of the Sahel as a whole is remarkably resilient to droughts, as demonstrated by the spectacular spontaneous ‘regenerations’ of northern Sahel rangelands following the droughts in 1973-74 and 1983-84 in the Gourma region in Eastern Mali.
- Based on the sole criterion of species richness, floral and faunal biodiversity in the desert margins of the Sahel appears relatively low in comparison with other arid or semi-arid zones such as the Karoo-Namib in southern Africa and the Horn of Africa. The low level of endemism in the flora as well as the fauna is probably due to the amplitude of fluctuations in environmental conditions at the present time and during the whole quaternary, and the relative homogeneity of the soil background. Some species are locally rare, either because they are close to the limits of their distribution area or because of the small extent of their specific habitat, eg wetlands or rocky outcrops.
- Inter-annual fluctuations in herbage production and species composition of the vegetation in the region could be explained by the variable pattern of rainfall distribution from year to year and from site to site.
- Progressive loss of soil fertility and fragmentation of the landscape converge to erode diversity, either because they lead to disappearance of habitats, or to severe reduction in population (i.e. the species remnants are too small and isolated to maintain the specific biomes), or because they promote a few ‘invading’ species to the detriment of the others.
- Rapid rural population growth as well as urbanization, have profoundly changed land use patterns and challenged the resilience of the system. Following the population increase, land cropped expanded rapidly since the 1950s without much intensification of the production system.
- The simultaneous expansion of cropped area and livestock populations in the region have aggravated the shortage of quality grazing resources, particularly in the late dry and early wet seasons. The grazing pressure on rangelands during the growing season (when livestock are excluded from croplands) has increased considerably. Thus, mobility is important for livestock production in the desert margins of the Sahel, for example wet season transhumance to the arid north. This was highlighted by the results of the bio-economic model validated with Fakara village databases in Niger.
- The spatial distribution of grazing pressure, and the associated forage uptake and excretion deposition, depends largely on the land use but also on the location relative to water points, village, camps and cattle paths.
- Options for agricultural intensification are emerging that could improve livelihoods and also reverse environmental degradation. These include promoting fruit trees, medicinal plants, integration of crop and livestock husbandry, diversification of crop and livestock production (especially trade-oriented commodities), increased use of inputs (fertilizer microdosing), and better integration of woody plant management with both crop and livestock activities.
- Building up of livestock capital is key to achieving food self-sufficiency and improving livelihoods. This in turn requires optimization of crop-livestock interactions within farm and at regional scale.
- Farmer feedback on the technological options tested by the project has been highly positive.
- The lack of technical information is the first constraint identified by the farmers as limiting technology adoption. This includes information on markets as well as technical information on production, and conservation. Thus, local means of information transmission, such as radio, are critical. Cost is another major constraint given especially for the technologies that require some external inputs.
- Rural credit and saving banks such as the warrantage scheme being tested in West Africa, are the most important communal institution the farmers would like to strengthen. Input shops for crop and livestock husbandry are also considered important.
- The key issues for future phases of the project, is farmer empowerment for natural resource management. This will require farmers’ associations and associated services to take on major responsibilities.
- Areas of weakness include the paucity of socio-economic information in some of the site characterization reports, mismatched methodologies, lack of effort in the policy and legal output, and insufficient cross border collaboration.
- A wealth of information has been gathered. This should now be collated by experts in different fields in order to produce the global benefits that donors require. For example, as a series of working papers to be distributed to partners and to the wider R&D community. An active DMP website will also help access and deposit information. The DMP newsletter will also greatly facilitate communication between partners.
- In summary, the DMP will continue to grow during the second phase, and will have significant impact if all partners contribute, and grow in their role as facilitators of change in the desert margins of Africa. The DMP is a significant institution, and small site-specific incremental changes will gradually accumulate into global differences.

Knowledge Management and Sharing @ ICRISAT
V Balaji - Head

Virtual Academy for the Semi-Arid Tropics

Project led by ICRISAT with the participation of ILRI and IWMI

Summary

- *Workshop on tech-mediated ODL was organized*: domain experts in agri. and vet. sciences were engaged in a weeklong workshop and partnered in learnings on development of content for e-learning and learning content management systems.
- *Addakal Hub has been strengthened*; new capacity strengthening processes in relation to extension have been put on stream; a new infrastructure for video conferencing has been donated by two national agencies; the women volunteers in Addakal on this project have been honored with the Fellowship of the National Virtual Academy by the President of India
- *Rapid Rural Appraisal in Kahe and Gabi Hubs Completed*: There is a clear picture of information needs of the communities now available.
- *New Partnerships Developed*; with the well-known Indian Institutes of Technology System, in applying GIS at a micro-level, in the use of semantic web technologies and in the use of weather sensors; also with Microsoft Community Affairs to extend the hub operations.
- Preparatory consultations organized for **Setting Up Online Grids of Educational and Extension Materials and for Capacity Strengthening**.
- The pilot learning program on drought awareness in Maharashtra organized with a new, non-traditional partner (MKCL) had nearly 30000 registrants over six months and concluded in June 2005.
- VASAT materials along with a significant volume of online materials were contributed to the CG-OLR repository.

A number of invited presentations were made in national and international meetings; young scholars presented some of these.

Engaging the ODL Partners: a preliminary workshop

During late 2004, VASAT was engaged with the emerging ODL programs of Indian agricultural universities. In a workshop in January 2005, the universities expressed the need to train their ODL faculty in the use of Learning Management Systems (LMS). VASAT agreed to organize such a training workshop. The COL came forward to extend additional support in terms of human resources.

As a forerunner to the workshop for the ODL partners, a 5-day training workshop on *Instructional Design and Learning Management Systems* was organized on pilot basis in April 2005 for the scientists and communicators of the National Institute of Hydrology, partner in the VASAT coalition. This course aimed to orient the scientists and communicators to the field of technology-mediated self-instructional learning modules. The course also exposed them to learning content management systems (LCMS).

ODL Workshop for the University Partners

ICRISAT partnered with the Commonwealth of Learning (COL) in organizing a training workshop on Learning Management Systems for four state agricultural universities in India, who are partners in the technology mediated open and distance education (TechMODE) initiative. The workshop events took place in three phases: (a) Planning (meeting in Chennai on 2nd Nov); (b) LMS Workshop (multiple institutions as resources persons; 6-10 Dec); (c) Online forum to use LMS and provide support, and to develop an investor-oriented proposal for adoption of TechMODE more extensively. The workshop was effective, and has catalyzed the formation of an active group among the SAU's in India, and more universities have expressed interest in partnership. Audio and video conferencing systems were used extensively to facilitate the participation of ARI resource persons. Erik Duval, advisor to the CG-OLR project, served as a resource person via video. Feedback from the participants overwhelmingly rated the workshop experience as superior. The online discussions hosted with about thirty participants from India, Canada, the USA and Belgium are continuing.

Extension Workshops and Hub Management Training

Three kinds of interactions took place on the project during the year, and they were on different planes and to different degrees of technology mediation. The rural hub (or, the village resources centers as some partners called it) was the centerpiece in all these efforts.

Initial interaction on extension bordered on the traditional methods. There was no technology mediation, and the audience received a direct exposure to a new practice with an expert facilitating that process. Two such conversations, one on micronutrients and another on improved practices in pigeonpea cultivation were carried out for farmers from the Addakal hub region in the second half of 2005. They were organized on 30 farms in quick response to strong demands from the field because the area experienced unusually good rainy season.

The second one involved some technology mediation. We had experimented with the use of an online content management system (CMS-Acado, accessible via the Internet) to support interaction of farmers with experts. The hub operators and village level volunteers played an important role. The farmers posed questions seeking practical solutions and the village network operators conveyed these into the CMS via the Web. Experts would study and provide the answers to these queries. In the experiment, we first strengthened the capacity of these intermediaries (all women) to get the very basic science of cultivation so that the farmers' queries were supplemented adequately with much agronomic and environmental data. The expert time needed to provide a satisfactory answer was reduced from seven days (included the waiting period for supplementary information) to a low of 14 hours on an average, leading to almost immediate yet exhaustive solutions. This showed the viability of the approach to capacity strengthening we have followed.

The third kind of interaction involved significantly more of technology mediation. We used two-way satellite-based video-conferencing systems to interact with several rural hubs in different linguistic regions. This was carried out in association with two national organizations: the M S Swaminathan Research Foundation and the Indian Space Research Organization. These two organizations have set up a pilot system for rural video conferencing and VASAT partners have organized rural extension activities using this arrangement. Encouraged by the value of combined information that VASAT partners were able to provide to the rural users, the MSSRF-ISRO project leaders decided to establish a permanent expert center at ICRISAT that would serve to deliver new information and instruction to rural hub users.

LO repository and Trials on Rapid Production of Content

The VASAT scholars have been working on the use of three different LMS online and have been assessing their use for two purposes: for their use in creation of locally relevant extension materials; and to strengthen the capacity of rural hub operators in supporting farmer-expert interactions. A tool for rapid localization of relatively complex online material was designed and developed in 2005. Further work on rapid localization resulted in the development of a blend of online tools and procedures that use a global specification such as SCORM and the freeware, Reload Editor. A number of tests have been carried out in the ODL workshops with this blend. The trials were successful as evident in the way the participants in these programs were able to use it with ease.

RRA and Rural radio Activities in Kahe and Gabi, Niger

Rural radios are surely a development factor in West Africa. In Niger, many different partners joined their efforts through the CPRP to determine what are the key factors for the success of rural radios. VASAT-WCA aims at using these radios to share timely information and courseware with producers in remote areas. This need to be achieved with a close and continuous assessment of population needs in term of information. This information shall differ depending on the location, ethnic groups, water supply and agricultural activities.

Launching of VASAT-WCA on September, 10th with Chairman & DG of ICRISAT, Members of the Board, the Chairwoman of Communication Council of Niger and communities from the surroundings villages.

Rapid Rural Appraisal (RRA)

VASAT-WCA core group performed two RRA in each pilot site. Information needs of Kahé and Gabi population were reported. These RRA could also map information flows as perceived by community

Concerning the RRAs, the core group was firstly trained in performing the RRAs and spent three days on each site in order to gather information. Results were compiled in two different reports and discussed with the expert groups.

Training

Following RRAs, a training program for pilot station was established. Radiostaff have been trained in community broadcasting techniques, writing for community radio, internet-radio interface and station maintenance. In partnership with UNDP and DGCD project, two volunteers of each radio had been initiated to computer with a private firm from Niger. Radio staff also received training on management of documentation center and weather forecast instrumentations on site.

Technical Assistance

One of the main challenges of VASAT in West Africa is to ensure that our stations are functional at the technical level. Sand and dust are enemies of technological devices and therefore we must find ways and means to fight against them. Moreover, rural radios in Niger need great support in term of technical assistance in order to make them functional. Our pilot stations received their computer but are still meeting energy problems. Solar panels were increased on both sites and batteries were changed, antennas have also been reoriented in order to reach a greater number of producers.

Content Development
On site content were developed as well as with the expert groups. Following demand from Kahé village chief a special program has been realized on *Striga* in collaboration with ICRISAT scientists. Radio staff came to Sadoré to realize their interviews with the scientists. Moreover, radio staff in collaboration with ICRISAT technicians developed a program on insects invading millet fields and ways to control in local language. VASAT-WCA initiated visits of ICRISAT Sahelian Center by Kahé villagers, radio staff realized interviews on-air to collect more data about information needs of the population towards sustainable resource management and system diversification. Radio staff from Kahé also developed a special program to present VASAT and ICRISAT.

Monitoring and Assessment
A special monitoring of broadcast program is being organized between VASAT, UNDP, projet intrants/FAO, SNV, UNICEF and the Decision support system project led by Bruno Gérard of ICRISAT in order to harmonize our interventions among rural radios in Niger. Different meetings were held and the Core group is validating the document.

Broadcasting is usually developed following the agricultural calendar. Broadcast program in Kahé has been improved, involving 6 hours a week dedicated to VASAT. Farmers' voice developed a special edition on ICRISAT and VASAT and the Herders' voice is lead by interviews with herders in local languages.

Partnership
Stronger partnership is developed with Agrhymet who already developed training modules on climate changes. Farm Radio (www.farmradio.org) based in Canada already developed agricultural and NRM broadcast, lyrics are available on the web. CPRP (Comité de pilotage des radios de proximité) propose a program for sustainability of rural radios in Niger with SNV. This program will reinforce existing rural radios in Niger and identify key points for success of rural radios

Potential partners in Burkina Faso include CIERRO (Centre interafricain d'études en radios rurales). In Mali, VASAT-WCA could be anchored in partnership with Africare and ARCOM.

Resource Mobilization
Project for fundings has been sent to CORAF. VASAT-WCA was involved in the concept note of a FIDA project involving ICRISAT-Mali, DGCD, PRONAF, FAO, CRS, Care and farmers' organizations. In collaboration with INRAN a project proposal was sent to McKnight Foundation.

Media
Different activities were held in order to demonstrate the benefits of VASAT-WCA to rural population. Radio Alternative / Niger realized an interview on-air with the operations manager of VASAT-WCA to inform the population of the existence of VASAT-WCA and its aim to help rural communities in the Sahel. Kahé villagers visited the Sahelian Center by group of 5 people during a month. ICRISAT gave them improved *Ziziphus* plants for their own uses in the village. VASAT main pages of the web site has been translated into French and sent to India for access by French-speaking communities of the Sahel. VASAT flyer is available in French for West Africa and our French-speaking partners. Finally, a special edition of ''Les Échos du Sahel'' focussed on rural radios and VASAT-WCA.

Significant Outcomes
Adarsha Mahila Samaikya (Adarsha Women's Association ***www.aadarsha.org****):* Capacity of AMS members to deliver complex information and training to rural clients enhanced.

Unanticipated Changes: Three of the individual members of the AMS who joined the VASAT capacity strengthening processes have gone on to become Fellows of the National Virtual Academy for Rural Prosperity during 2005. A total of 1100 nominations of rural young leaders known for contributions to improving local capacities was considered in a multi-tier review at the national level, and identified 155 individuals eligible for induction as Fellows. The three Fellows were inducted by the President of India ceremonially. This level of national honor for our partners was not anticipated in the earlier stage of the project. Evidence for it is in the form of Fellowship certificates provided by the National Academy. This has led to a very large number of young members seeking to join the VASAT activities at the village level.

The Maharashtra Knowledge Corporation (MKCL ***www.mkcl.org****), Pune, India:* During December 2004, the VASAT group engaged with the MKCL in a series of discussions on making use of their technical capabilities in building a paradigm of drought-related mass education in India. The MKCL made use of various “literacy” modules of VASAT on NRM and drought in delivering an awareness course on drought matters to students affiliated to the National Service Scheme in various colleges of the University of Pune. Three drought-prone rural districts (Pune, Ahmednagar and Nashik) were covered and 150 colleges joined the program. VASAT content advisor helped the MKCL in customization of the generic drought-literacy module to suit the milieu in Maharashtra, and the MKCL’s multi-media group added its own voice-over audio-track in Marathi to the module. The customized module was expected to be of four learning hours in duration. Starting in January 2005 the awareness course was delivered to the NSS learners during their rural camps, and by late July 2005, the MKCL recorded the participation of 32,000 learners. Here is an example of how a partner organization with an IT-education focus was able to harness its network and capability to foster awareness on drought among a large number of learners.

Using ICT to Enhance Food and Livelihood Security in Afghanistan through Increasing Farm Profitability: a joint project of ICRISAT and the Afghanistan Ministry of Agriculture, Animal Husbandry and Fisheries

The project was started in December 2004 and was launched officially in Kabul in March 2005. A special agreement was signed with the Minister for the implementation of this project. The Ministry completed staff recruitment, has set up a project office, has enhanced local infrastructure and has built new capacity among 75 members of staff. The extended locations have been identified as Herat (W Afghanistan) and Mazar-e-Shariff (North) with the Ministry office in Kabul serving as the node. Project staff based in the Ministry visited ICRISAT for training in advanced network techniques and visited two ICT4D project sites in India. The steering committee meeting was held and a number of valuable suggestions were received. Outlines of a blueprint for infrastructure have been developed. By December 2005, a web site of the Ministry with a focus on commodity prices has been developed and is available in the two official languages of Afghanistan. A unique email domain for the Ministry has also been established.

Appendix 1. List of Special Projects funded during 2005

GT-SAT Futures

Africa
The governments and NARS of the SAT countries in sub-Saharan Africa benefit from this global theme research to plan their future agricultural strategies. Research benefits are expected to accrue to agricultural universities and NGOs, private sector, and farmers' organization. In particular, research managers, scientists, and partners are directly collaborating to improve priority setting, resource allocation, and improve research efficiency; development investors to better develop interventions; and policy makers to better understand the consequences of policy and institutional constraints; and farmers in the SAT.

The principal partners in these projects are NARS social scientists and other researchers from other disciplines who participate in project and survey implementation and training workshops. They include Ministries of Agriculture, [including AREX (Zimbabwe); Kenya Agricultural Research Institute (KARI), Burkina Faso, Mali, Tanzania, Mozambique, Malawi, Niger, Nigeria]; Universities of Zimbabwe, Nigeria, Ouagadougou and Pretoria; System-wide programs (SLP, CAPRI and PRGA, SWIHA), networks (ASARECA, INTSORMIL, SADC-FANRE, CORAF, ROCARS, ROCAFREMI, ECARSAM); economists, policy makers, and think-tanks for development policy analysis in Mali, Burkina Faso, Niger, Kenya, Senegal, Nigeria, Ethiopia, and Zimbabwe; World Bank, FAO, CIRAD, NRI (UK), and FASID (Japan), Michigan State University, Agricultural University of Norway. The main partners in impact assessments are national program partners and CGIAR collaborators (IFPRI, IWMI, ILRI, ICRAF, CIP, IITA, ICARDA, WARDA) through SPIA. Our main collaborators in the innovations systems research include private sector grain processors in ESA and WCA, NGOs (World Vision and CRS) and farmers' organizations. Economists, policy makers, and think-thanks for development policy analysis in Mali, Burkina Faso, Niger, Kenya, Senegal, Nigeria, Ethiopia, Zimbabwe are part of the evolving network of social scientists working with GT-MPI in sub-Saharan Africa.

GT-Crop Improvement

Sl. No.	Title of the Project	Donor	Amount (US$)	Scientists involved
1	Diversification of pearl millet hybrid parents	ICRISAT-Private Sector pearl millet hybrid parents research consortium	333,000	KN Rai, CLL Gowda and Team
2	Diversification of sorghum hybrid parents	ICRISAT-Private Sector sorghum hybrid parents research consortium	158,000	BVS Reddy, CLL Gowda and Team
3	Diversification of pigeonpea hybrid parents	ICRISAT-Private Sector pigeonpea hybrid parents research consortium	89,500	KB Saxena, CLL Gowda and Team
4	Development of salinity-tolerant sorghum and pearl millet cultivars for enhanced productivity on saline lands	OPEC Fund for International Development	35,000	BVS Reddy, KN Rai, Vincent Vadez and CT Hash
5	Development of micronutrient and ß-carotene-dense for sorghums	HarvestPlus	55,000	BVS Reddy and Team
6	Improved livelihood opportunities through watersheds	APRLP/TATA Sujala	139,000	SP Wani, BVS Reddy and others
7	Enhancing yield and stability of pigeonpea through heterosis breeding	ISOPOM	415,996	KB Saxena and Team
8	Enhanced utilization of sorghum and pearl millet grains in poultry feed (CFC/FIGG/32)	CFC/FAO	1,509,000	BVS Reddy, P Parthasarathy Rao, KN Rai, CLL Gowda and F Waliyar
9	Protecting crops and Promoting businesses:	ICRISAT-Private Sector Biopesticides	22,000	OP Rupela, GV RangaRao and CLL

Sl. No.	Title of the Project	Donor	Amount (US$)	Scientists involved
	Eco-friendly materials for protecting crops of SAT farmers in partnership with Private-sector Biopesticides Manufacturers	Research Consortium		Gowda
10	Exploring soil biology to understand high yields due to SRI method of cultivation	WWF-ICRISAT Dialogue Project	12,300	OP Rupela and SP Wani

GT- Agroecosystems: Special projects, 2003 to 2005

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
1	Fertilizer micro-dosing for small farmer prosperity in the Sahel	2001-04	USAID (Target)	250	TSBF-CIAT	IFDC, FAO-Projets Intrants, INERA, IER, INRAN, NGOs	Burkina-Faso, Mali and Niger
2	Enhancing rainwater and nutrient use efficiency for improved crop productivity , farm income and rural livelihoods in the Volta Basin	2004-09	Water Challenge Program	1500	CIAT and TSBF-CIAT	INERA, SARI, SAFGRAD, UNU, ZEF	Burkina-Faso and Ghana
3	Improved livelihoods in the Sahel through the development and implementation of household level bio-economic decision support systems	2003-07	DGCD (Belgium)	323	ILRI	UCL, FAO-projet intrants, Farmer federations Mooriben and Fuma, Agrhymet, CRESA, INRAN, Aquadev, ACMAD	Three benchmark sites of 500 km2 in Niger (Niamey, Maradi, Zinder
4	Impacts of climate change (Fakara pilot site)	2003-04	ACDI through Agrhymet	152	ILRI	FAO-projet intrants, Mooriben, Agrhymet, CRESA, INRAN,	Fakara benchmark site
5	Erosion of agrobiodiversity of pearl millet and sorghum in Niger	2004-05	FFEM (coordinated by IRD)	NA	None	IRD, INRAN, Univ Paris VI	Niger
6	Improvement of fertility of sandy soils in the semi-arid zone of West Africa through organic matter management	2003-10	JIRCAS (Japan)	4000	ICRISAT, ILRI, TSBF-CIAT	INRAN, Univ. of Tokyo and Kyoto	Fakara benchmark site

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
7	Spatial modeling of regional soil water balance from remotely sensed data and indigenous knowledge to predict crop stress and mitigate food deficit in Niger	2002-04	USAID Linkage Grant	70	None	Texas A&M Univ	Fakara Benchmark site + upscaling
8	Measuring and assessing soil carbon sequestration by agricultural systems in developing countries (Soil Management CRSP/USAID Collaborative Project)	2002-06	CRSP/USAID	NA	ILRI	IER;SARI;ISRA; U. Florida;U. Hawaii	Burkina Faso, Ghana, Mali, Senegal
9	Bytes for bites: translating climate forecasts into enhanced food	2002-04	START	23		IRI, INERA AGRYHMET,	WCA
10	Introduction of the African Market Garden to the semi arid tropics of West and Central Africa	2004-07	USAID/WARP	750	None	APIPAC, INERA, SARI	Burkina Faso and Norh Ghana
11	The Sahelian Eco-Farm. on farm research	2004-07	USAID/WARP	120	INRAN, SOS-Sahel,	PDL Gaya, MOA-Niger	Niger
12	Development of gum arabic in Niger	2004-07	USAID/Africa	300	GTZ, Italy cooperation	PDL Gaya, MOA-Niger	Niger
13	Supporting AMG projects in the Sahel	2005-08	USAID/GDA	500	APIPAC,INERA, SARI	PDL Gaya, MOA-Niger	Niger, Burkina, Ghana
14	IPALAC -crops and systems diversification	2001-06	Finland, IPALAC	1,000	INRAN, ILRI, IER, INERA, ISRA,	Numerous NGOs	West Africa SAT
15	IPALAC -crops and systems diversification	2001-06	MASHAV-IPALAC	500	INRAN, ILRI, IER, INERA, ISRA,	Chatholic NGOs, Numerous NGOS	West Africa SAT
16	Vegetable production in the Sahel	2002-05	IDRC	200	INRAN,ILRI ISRA,INERAIER	West Africa SAT	
17	Intensification of onion production	2004-06	PPEAP	50		INRAN	Niger
18	New approaches for technology, policy, drought prone areas in Zimbabwe	2001-04	Rockefeller	154	None	Arex	Zimbabwe
19	Soil fertility in the communal farming lands in Zimbabwe	2002-07	WOTRO	50	None	Wageningnen Agricultural Univ	Zimbabwe

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
20	Improved fertilizer recommendations and policy for dry regions of southern Africa	2003-06	ACIAR	300	None	CSIRO; Limpast, Progress Mills, Limpopo Dept Agric, Omnia Fertilizers Ltd, Land	RSA
21	Technical support and monitoring of seeds relief in Hwange dist	2004-05	Echo Funds	55	None	COSV/AREX	
22	Increasing the impacts of soil fertility research in Southern Africa	2004-07	IDRC	315	None	NASFAM, LIMPAST,Reapers, Ominia Fertilizers ltd, Depts Agric, REX, CARE, WVI	Malawi, RSA, Zimbabwe
23	Recovery and growth of smallholder agriculture in the rural communities of dryland Zimbabwe	2004-07	DFID	1,800		AREX, CARE, WVI, OXFAM, CRS	Zimbabwe
24	The challenge of integrated water resource management for improved rural livelihoods: managing risk, mitigating drought and improving water productivity in the water scarce Limpopo Basin	2004-09	WFCP	150	IWMI	WaterNet, Unesco-IHE, CARE, NUST, U. Zimbabwe, AREX, ARC, Universidade Eduardo Mondlane, INIA, U. Pretoria	Mozambique, RSA, Zimbabwe
25	Smallholder crop livestock systems	2004	SLP	40	ILRI/IWMI	SWMnet, AARNet and JKUAT	Eastern and Southern Africa
26	Institutionalised scaling-up and uptake promotion of outputs from soil and water management research in East and Central Africa	2004-05	DFID-NRSP	178		SWMnet, EIAR (Ethiopia), KARI (Kenya), ARTC (Sudan); DRT (Tanzania)	Eastern and Southern Africa
27	Productivity of water in agriculture and interacting systems: approaches and options for East Africa	2003-04	CA on water	175	IWMI	Sokoine Univ, Mekelle Univ, Univ of East Anglia	Eastern and Southern Africa
28	Identifying systems for carbon sequenstration and increased productivity in SAT environments	2000-04	NATP, New Delhi, India	151	None	CRIDA, NBSS&LUP, CRIDA	India
29	Combating land degradation and increasing productivity in Madhya Pradesh and Eastern Rajasthan	2002-07	Sir Dorabji Tata Trust	1,023	None	IISS, NGOs, CRIDA, CAZRI, JNKVV, RAU	India

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
30	Improved livelihood opportunities through watersheds	2002-04	DFID through Andhra Pradesh Rural Livelihood Programme (APRLP)	844	IWMI, ILRI	CRIDA, ANGRAU, NRSA, KVKs, NGOs, FTCs and WWF, India	India
31	Will climate forescatsing and new knowledge tools help resource-poor farmers from debt to prosperity? Farmers participatory approach to manage climate variability	2002-04	START	20	None	ANGRAU, IITM, India; APSRU, Australia	India
32	Validation of drivers for bright spots in the area of watershed management and joint forest management in India (Comprehensive Assessment of Water Management in Agriculture)	2002-04	CA	433	None	CRS, GVT, FORWARD, DOA in India and Nepal	India, Nepal
33	Enabling rural poor for better livelihoods through improved natural resource management in SAT India	2003-04	DFID/NRSP/CRIDA	42	None	PROVA, DAE, BARI	Bangladesh
34	Promotion of rainfed rabi cropping in rice fallows of India and Nepal - Phase II	2002-05	DFID/CAZS, UK	17	IWMI	NCAP, ICAR	India
35	Improvement of rainfed cropping systems in the high Barind tract of Bangaldesh	2002-05	DFID/CAZS, UK	625	IWMI, CIMMYT, ICARDA	IISA, Austria, UNESCO-IHE, Netherlands; NBSS&LUP, CRIDA and NCAP, India; VASI, Vietnam; UFS-RAPIDS, RSA	India
36	Water scarcity and food security in tropical rainfed water scarcity systems: a multi-level assessment of existing conditions, response options and future potentials	2003-05	IWMI/CA Prog.	1	None	CRIDA	India
37	Participatory watershed management for reducing poverty and land degradation in the semi-arid tropics	2003-05	ADB	1,300	IWMI	CRIDA, IISS, JNKVV, NRSA, ANGRAU, BAIF, APRLP, DWMA,	India, Thailand, Vietnam, China

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
						Govt. of A.P., and MVF, India: DOA, LDD and KKU, Thailand; VASI, Vietnam; GAAS and YAAS, China; UGA, USA	
38	Developing community-based water energy services and markets	2003-06	USAID	150	IWMI	ITDA, Govt. of A.P.,SuTRA, CEAD, NGOs,	India
39	Watershed research at ICRISAT: innovation histories and experiences of action learning in practices	2004-05	IPGRI	15	None	None	India
40	IPM of chickpea in Nepal	2004-05	UK/DFID/CPP	177	None	NARC, NGOs	Nepal
41	Making the best of climate – Adapting agriculture to climate variability	2005-08	ASARECA-CGS	450	None	Univ of Nairobi, EARO, FOFIFA, SOMEAH, SWMnet	Nairobi
42	Preparation and startup Phase of IMAWESA Project	2005-06	IFAD	100	None	SWMnet	Nairobi
43	Dry season feeding of livestock in the SAT of Zimbabwe	2005-08	BMZ/GTZ	220	None	AREX/LPD	Zimbabwe
44	ICRISAT/ILRI livestock scoping study in southern Africa	2005-06	ICRISAT Core ICRISAT DMP ILRI	60	ILRI	Country consultants????	Mozambique, Zimbabwe, Zambia, Botswana, Namibia
45	Desert Margins Program	2002-08	UNEP/GEF	16,000	ILRI, TSBF/CIAT, IFDC, ICRAF	ARIs (CEH, IRD, CIRAD), NARS of BF, Mali, Niger, Senegal, Kenya, Botswana, Namibia, Zimbabwe and South Africa	WCA, ESA
46	Combining water harvesting techniques and nutrient management to sustain food production in the dry lands of west Africa	2005-08	CORAF/AfDB	155	TSBF-CIAT	INRAN, IER, INERA, CERAAS/ISRA, Projet Intrants FAO, EGAT, CARITAS-Kaolack	Burkina Faso, Mali, Niger, Senegal
47	Fertilizer micro-dosing and drought tolerant	2005-08	CORAF/AfDB	195	ICRISAT, TSBF-	INRAN, INERA,	Burkina Faso, Niger and

No.	Project title	Period	Donor	(US$) '000	CGIAR partners	Other partners	Location
	variety transfer technology for small farmer prosperity in the Sahel				CIAT	CERAAS/ISRA, Projet Intrants FAO, GADEC, UGPM	Senegal
48	Promoting use of indigenous phosphate rock for soil fertility "recapitalization" in the Sahel	2005-08	CORAF/AfDB	155	ICRISAT, TSBF-CIAT	INRAN, INERA, CERAAS/ISRA, Projet Intrants FAO, UNICOM, Groupement Nabonswinde de Tougouri	Burkina, Niger and Senegal
49	Dry season feeding of livestock in the SAT of Zimbabwe	2005-08	BMZ	186	ILRI	MRS, AREX, DLPD, DMP	Zimbabwe
	Start-up phase for Project on improved management of agricultural water in ESA	2005 - 2006	IFAD-ASARECA	90		SWMnet	East and Southern Africa

ICRISAT projects 2006-2009

	Expenditure Estimate, $	System Priority	Global Theme	Corresponding MTP 06-08 sub-project	Associated CPs & SWEPs
1. Improving policies and facilitating institutional innovation, markets and impact to support the sustained reduction of poverty and hunger in the SAT	4.1 m	5	IMPI	WCA D & C part, WCA Policy ESA Commercialization Asia market linkages, policy	SW HIV/AIDS Program
2. Sustaining biodiversity of sorghum, pearl millet, small millets, groundnut, pigeonpea and chickpea for current and future generations	2.1 m	1	Biotech & CI	ESA Crop Imp. (part) WCA Crop Imp. (part) Asia Biotech (part) Asia Impr. Germ. (part)	Generation CP SW Genetic Resources Program
3. Producing more and better food at lower cost of the staple cereals and legumes of the WCA SAT (sorghum, pearl millet, groundnut) through genetic improvement	3.0 m	2	Biotech & CI	WCA Crop Improvement	SW Livestock Program Africa CP, Harvest+ CP Water and Food CP
4. Producing more and better food at lower cost of the staple cereals and legumes of the ESA SAT (sorghum, millets, groundnut, pigeonpea, chickpea) through genetic improvement	3.0 m	2	Biotech & CI	ESA Crop Improvement	Water and Food CP FARA Africa CP
5. Producing more and better food at lower cost of staple cereal and legume hybrids in the Asian SAT (sorghum, pearl millet, pigeonpea) through genetic improvement	2.2 m	2	Biotech & CI	Asia Biotech Asia Improved Germplasm	Harvest Plus CP
6. Producing more and better food at lower cost of staple	2.8 m	2	Biotech & CI	Asia Biotech Asia Improved	Generation CP Harvest Plus CP

	Expenditure Estimate, $	System Priority	Global Theme	Corresponding MTP 06-08 sub-project	Associated CPs & SWEPs
open-pollinated cereals and legumes in the Asian SAT (sorghum, millets, pigeonpea, chickpea, groundnut) through genetic improvement				Germplasm	RWC SWEP IPM SWEP
7. Reducing rural poverty through agricultural diversification and emerging opportunities for high-value commodities and products	2.7 m	3	AE	ESA Crop-livestock WCA Diversification (part) Soil water manage in Asia (part)	DMP SWEP SW SLP
8. Poverty alleviation and sustainable management of water, land, livestock and forest resources, particularly at the desert margins of the Sahel and the drylands of ESA	2.8 m	4	AE	Desert Margins Program Systemswide ecoregional program (SWEP)	
9. Poverty alleviation and sustainable management of water, land, livestock and forest resources through sustainable agro-ecological intensification in low- and high-potential environments	4.1 m	4	AE	ESA Relief, Food Sec. WCA Diversification (part) Soil, water management in Asia	Water and Food CP FARA Africa CP
10. Virtual Academy for the African and Asian SAT	<1.0 m	0 Blue Sky	KMS	WCA Partner power Capacity development in Asia	
	Total 28 m				

Appendix 2: List of Scientists

GT- SAT Future Scientists

Name	Discipline	Location	Country
B Ntare	Plant Breeding	Bamako	Mali
B Gerard	Farming Systems	Niamey	Niger
R Tabo	Agronomy	Niamey	Niger
Jupiter Ndjeunga	Socioeconomics	Niamey	Niger
Youssouf Camara	Socioeconomics	Niamey	Niger
Margaret Louffen	APO	Bamako	Mali

GT-Crop Improvement Scientists

Name	Discipline	Location	Country
B Clerget	Plant Physiology	Bamako	Mali
BR Ntare	Plant Breeding	Bamako	Mali
HFW Rattunde	Plant Breeding	Bamako	Mali
Eva Weltzien	Plant Breeding	Bamako	Mali
SS Boureima	Consultant	Niamey	Niger
B Haussmann	Plant Breeding	Niamey	Niger
Jupiter Ndjeunga	Socioeconomics	Niamey	Niger
R Tabo	Agronomy	Niamey	Niger

GT- Biotechnology Scientists

Name	Discipline	Location	Country
HFW Rattunde	Plant Breeding	Bamako	Mali
F Sagnard	Principal Scientist (CIRAD, ICRISAT)	Bamako	Mali
EW Rattunde	Plant Breeding	Bamako	Mali

GT-Agroecosystems

Location	Discipline	% time core	Special Projects	% time
Saidou Koala	Soil science	0	DMP coordinator	100
Bruno Gerard	Farming systems	50	DGCD-Decision support	50
Dov Pasternak	Crop diversification	78	AMG and New Sahel	22
Jupiter Ndjeunga	Socio-economics	10	Groundnut Seed Project	10
R Tabo	Agronomy	0	DMP, USAID target, WFCP	100
Philippe Delfosse*		0	DGCD - Groundnuts	20
Ousman Youm*	Entomologist	50	IFAD	50
Youssouf Camara	Socio-economics		PDF	100
Mamby Fofana*	Forestry		USAID Gum Arabic	100
Pierre S Traore	GIS	90	EURD-Niger Panel	10
Fatondji Dougbedji**	Soil science	100		
Augustine Ayantunde	Animal science		DMP-ICRISAT/ILRI/	100
Hayashi Keiichi	Soil science	0	JIRCAS	100
Ryoichi Matsunaga	Crop physiology	0	JIRCAS	100
Albert Nikiema	Agroforestry		USAID	100
Akira Kamidohzono	Soil science	0	JIRCAS	100

Location	Discipline	% time core	Special Projects	% time
Lenardt Woltering	Hydrologist	0	Dutch JAPO	100
Visiting Scientists				
Debesaye Senbeto	Forestry & land degradation		USAID Gum Arabic and DMP	100

* Youm left 2004, Delfosse left end 2004, Mamby Fofana left Dec 2005
** Dougbedji, Senior Scientific Officer

KMS Experts and Managers

Name	Discipline	Location	Country
Marie-Julie Menard	Project Manager, VASAT-WCA (50% to VASAT; balance contributed to DMP and CO activities in WCA)	Niamey	Niger
Harou Rabe	IT Administrator, ICRISAT, Niamey	Niamey	Niver

Time Contributions from Experts in Global Themes and Corporate Offices

1	Rex L Navarro	Director, Communication Office (contributes to VASAT – 8% time)
2	Farid Waliyar	Principal Scientist, GT-BT and Advisor to DG, 8% time on MoAL project in Afghanistan
3	S Koala	Regional Director, WCA: VASAT-WCA Oversight