Seven seasons of learning and engaging smallholder farmers

in the drought-prone areas of sub-Saharan Africa and South Asia through Tropical Legumes

2007-2014

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

CGIAR
RESEARCH PROGRAM ON Grain Legumes

Citation: Monyo ES and Varshney RK, eds. 2016. Seven seasons of learning and engaging smallholder farmers in the drought-prone areas of sub-Saharan Africa and South Asia through Tropical Legumes, 2007–2014. Patancheru 502 324, Telangana, India: International Crops Research Institute for the Semi-Arid Tropics. ISBN 978-92-9066-568-7. 236 pp.

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2007 – 2014

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Project:
Tropical Legumes II
(TL II)

This work has been undertaken as part of the CGIAR RESEARCH PROGRAM ON Grain Legumes

Investor:
Bill & Melinda Gates Foundation

Partners:

ICRISAT INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

CIAT

IITA Research to Nourish Africa

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Abbreviations and Acronyms

ASA	Agriculture Seed Agency
AYT	Advanced Yield Trials
ADD	Agriculture Development Division
ACOS	Agricultural Commodities and Supplies
APSSDC	Andhra Pradesh State Seed Development Corporation
ADP	Area Development Program
BARI	Bangladesh Agricultural Research Institute
BECA	Biosciences Eastern and Central Africa
BSM	Bruchids and Stem Maggots
BILFA	Bean Improvement for Low Soil Fertility in Africa
BS	Breeder Seed
CIAT	International Centre for Tropical Agriculture
CCAFs	Climate change Agriculture and Food Security
CBOs	Community Based Organizations
CBB	Common Bacterial Blight
CRV	Central Rift Valley
CS	Certified Seed
CRS	Catholic Relief Services
DARS	Development of Agricultural Research Services
DIVA	Diffusion of Improved Varieties in Sub-Saharan Africa
DRD	Department of Research and Development
ECABREN	East and Central Africa Bean Research Network
EIAR	Ethiopian Institute of Agricultural Research
ELS	Early leafspots
FPVS	Farmer Participatory Varietal Selection
FTC	Farmer Training Centre
FRG	Farmer Research Group
FCU	Farmer Cooperative Union
GRV	Groundnut Rosette Virus
GENSTAT	General Statistics
IAR	Institute of Agricultural Research
ICRISAT	International Crops Research Institute for the Semi-Arid tropics
IER	Institut d'Economie Rurale
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IBP	Integrated Breeding Platform
INERA	Institut de l'Environnement et Recherches Agricoles
IVT	Intermediate Variety Trials
ISRA	Senegalese Institute for Agricultural Research
KARI	Kenya Agricultural Research Institute
KSSC	Karnataka State Seed Corporation
MARS	Marker Assisted Recurrent Selection
MABC	Marker Assisted Back Crossing
MAC	Mid Altitude Climbers
MASA	Malawi Seed Alliance
MAS	Marker Assisted Selection
MSSCL	Maharashtra State Seeds Corporation Limited

NARI	Naliendele Agricultural Research Institute
NARS	National Agriculture Research systems
NASFAM	National Association of Smallholder Farmers Malawi
NASAARI	National Semi-Arid Agricultural Research Institute
NADDS	National Agricultural Advisory Services
NARES	National Agricultural Research and Extension systems
NaCRRI	National Crops Resources Research Institute
NARO	National Agricultural Research Organization
NPTs	National Performance Trials
NSC	National Seed Corporation
ODK	Open Data Kit
OUAT	Odisha University of Agriculture and Technology
PVS	Participatory Varietal Selections
PICS	Purdue Improved Crop Storage
PHI	Pod Harvest Index
PABRA	Pan African Bean Research Alliance
PYT	Preliminary Yield Trials
QDS	Quality Declared Seed
QTL	Quantitative Trait Loci
QA	Quality Assurance
QC	Quality Control
RECODA	Research Community and Organizational Development Associates
RILS	Recombinant Inbred Lines
RARS	Regional Agricultural Research Stations
SARI	Savanna Agricultural Research Institute
SSA	Sub-Saharan Africa
SOCADIDO	Soroti Catholic Diocese Development Organization
SNP	Single Nucleotide Polymorphism
SABRN	Southern Africa Bean Research Network
SNNP	Southern Nations, Nationalities, and Peoples'
SFCI	State Farms Corporations of India limited
SMD	Sterility Mosaic Disease
SRC	Soybean Resources Centre
TL II	Tropical Legumes II
TAs	Traditional Authorities
TNAU	Tamil Nadu Agricultural University
TLS	Truthfully Labeled Seed
TASO	Tanzanian Agricultural Society
VECO	An NGO
WCA	West Central Africa
WACCI	West Africa Centre for Crop Improvement
ZARDI	Zonal Agricultural Research and Development Institute

Foreword

This publication represents an important record of the work and achievements across seven years of the Tropical Legumes II (TL II) project supported by the Bill & Melinda Gates Foundation. The TL II project is being executed by ICRISAT in collaboration with a broad range of partners including two other CGIAR centers, ie, the International Center for Tropical Agriculture – CIAT and International Institute of Tropical Agriculture-IITA, as well as National Research Institutes of fifteen partner countries across sub–Saharan Africa (Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda and Zimbabwe) and South Asia (Bangladesh and India).

The legume crops featured in TL II, such as groundnut, common bean, cowpea, chickpea, pigeonpea and soybean, are critically important to the livelihood of smallholder farmers for a number of reasons. They represent the most affordable source of protein and micronutrients available to the rural and urban poor and are especially important for the hundreds of millions of women and children living in these geographies. The nutritional value of these crops is attributable to their high nutrient composition (eg, protein, complex carbohydrates, essential minerals and fatty acids), as well as properties that promote nutrient absorption and reduce gut inflammation. These crops also helps in intensifying the staple cereal, roots and tuber cropping systems as catch, relay and intercrop options, by providing nitrogen and other soil health benefits associated with crop rotation to the subsequently grown crops. The legume grains contain 2-3 times higher protein content than the starchy staples that form the bulk of the diets of smallholder and urban poor families, thus, providing them with the critical nutritional and health benefits. As the legume crops are largely grown by women, improvements in their productivity bring them additional income. Legumes also help in diversification of the food production and income streams of the smallholder farmers. Hence, this lead to risk mitigation associated with staple crop price fluctuations that in turn buffer the farm from catastrophic disease, pest infestations and climate-related production disruptions of the staple crops. Thus, legumes contribute significantly towards the achievement of the Foundation's core goals of reducing poverty, improving food security, improving nutrition and health, women empowerment and sustenance of the natural resource base.

The TL II project has been focused on developing and disseminating improved legume varieties across the 15 partner countries. Now in its 7th year, the project has achieved a number of notable successes in terms of development, release and dissemination of new varieties that have put money into the hands of farmers. The farmer participatory trials and training efforts conducted by the project directly reached more than 280,000 farmers over the course of the two phases of the project. ICRISAT economists have estimated that the expected increase in the added value of productivity gains in the rural areas of the TL II target regions will amount to about $1.3 billion over the ten year period from 2007 to 2017. Further, the total amount of seed produced during the two phases of the project was sufficient to cover more than 2 million ha with the funds provided under TL II and more than 6.5 million ha with project and partners' investment catalyzed by the project. The project also made a strong contribution towards the capacity building by training 37 MSc and PhD students since 2007, with 22 more currently being trained.

I want to congratulate the volume editors, Emmanuel Monyo and Rajeev Varshney, and their team for the outstanding effort in bringing together the various country level perspectives in a highly readable document. We are proud to have supported the people and institutions across Africa and South Asia who contributed to this work.

Jeff Ehlers
Program Officer
Bill & Melinda Gates Foundation

Executive Summary

Tropical Legumes II (TL II) is a Bill & Melinda Gates Foundation sponsored project implemented by three International Agricultural Research Centers – International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Centre for Tropical Agriculture (CIAT) and International Institute for Tropical Agriculture (IITA). The project aims to improve the livelihoods of smallholder farmers in the drought-prone areas of Sub-Saharan Africa (SSA) and South Asia (SA) through improved productivity and production of six major grain legumes – chickpea, common bean, cowpea, groundnut, pigeonpea and soybean. The project activities were implemented in Burkina Faso, Ghana, Mali, Niger, Nigeria, Senegal, Ethiopia, Kenya, Malawi, Mozambique, Tanzania, Uganda and Zimbabwe in SSA, and India and Bangladesh in SA.

The project has been running for the past two phases: Phase I (2007 – 2011) and Phase II (2012 – 2014).

The project is designed to help the smallholder farmers to overcome constraints, such as drought, pests, diseases and lack of improved seed varieties. TL II is expected to enhance the productivity by at least 20% through increased adoption covering 30% of legume area, strengthening national breeding programs and generating at least $1.3 billion in added value. This has resulted in significant achievements. The active breeding programs are now in place in all 15 countries. New seed varieties (163) have been released and are fast replacing the old ruling seed varieties. Thirty seven national partners were trained at MSc and PhD levels. As a result of the enhanced skills and knowledge of seed value chain actors, seed production significantly increased by 221% (from 139,048 to 446,359 tons) over the project period. The program adopted an inclusive approach for the poor, especially women, through promotion of various innovative approaches, such as small seed packs, seed loans and decentralized production schemes.

Since 2007, dissemination of improved varieties has been adopted on at least 2 million hectares and more than $448 million has been generated from the project funding and nearly $976 million from the project and investment partners. Even when using the adoption rates data from adoption and expert opinion surveys, the aggregate gross benefits from TL II-related modern legume varieties is **estimated at about $978 million**, which is still far above the total TL II investment grossly compounded at $48 million. In effect, for each dollar invested, the project generated $9 with direct project investment or $20 with partnership's investment and again $20 when using adoption rate based estimate.

These successes and associated challenges will be discussed in detail in subsequent chapters of this book.

Enhancing market opportunities, policies and partnerships along the legume value chain to increase the income and nutritional security of smallholder farmers in drought-prone areas of Sub-Saharan Africa and South Asia

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Summary

During the last seven years, the baseline studies and situation analysis conducted in phase I and the early adoption studies conducted in phase II of the Tropical Legumes II (TL II) project provided a range of useful insights guiding technological development and adaptation, as well as scaling-up of promising options to the wider target domains beyond the pilot areas of the project. The socioeconomic studies provided critical feedback information to the breeders and other technological development and dissemination partners on the end user-preferred traits, priority development and technology uptake constraints, as well as early impact indicators. Adoption of more promising grain legume varieties is mostly limited by the lack of access to information on available varieties, availability of varieties with desirable production and consumption attributes, and inadequate seed supply. The major drivers of dissemination of research products and adoption by farmers have been characterized as follows: farmers' access to new information and awareness; expected benefits and local availability of new technologies; market access and opportunities (performance of input and output value chains); and access to credit and other policies to enable farmers' investment in new technologies. The uptake of technologies by farmers largely depends on whether a particular technology addresses the key production constraints faced by the farmers and has the traits that are highly preferred by the various end users. A growing volume of empirical work has demonstrated that farmers are unlikely to adopt new varieties that do not meet their own criteria or address major production constraints. While the institutional and policy factors may hinder the uptake of otherwise profitable varieties and practices, addressing the needs and priorities of smallholder farmers, especially women, present the necessary conditions for greater technology uptake and its impact.

The major institutional constraints for the adoption of improved grain legume technologies relate to the weak extension services and lack of physical and economic access to improved seed varieties. The poor access to improved seeds, in terms of both information on availability of seeds and its delivery, is one of the major constraint to the smallholder grain legume productivity in Sub-Saharan Africa (SSA). A number of constraints have led to the diminished interest of the existing seed systems (eg, commercial seed companies) to provide small-scale farmers with access to improved seed varieties for grain legumes. Firstly, the public-sector seed production has not been able to meet the demand for the new seed varieties and initial quantities of high-quality seeds because of the prioritization of more commercial crops, such as hybrid maize, for the foundation seed stocks. The private sector also has shown little interest in entering the legume seed industry due to low profitability (as the farmers recycle varieties multiple times once they receive the initial germplasm). The high protein and oil content of soybean makes it difficult to maintain the seed viability over a long period of time. Many grain legumes also have a high seeding rate and low multiplication ratios. Groundnut, for example, has a high seeding rate but a low multiplication ratio and this poses challenges in producing large quantities of seed and distributing it to producers who are widely scattered in the rural community.

The observed low private-sector participation in the seed systems may indicate a market failure and the need for stronger public support for legume seed production and distribution, at least in the early stage until demand is high to attract private sector seed companies. On the other hand, it is important to build on the strengths and adaptability of the informal approaches and enhance the opportunity to increase both seed supply and quality through the participation of local seed producers, farmer groups, and agro-dealers with capacity building and monitoring to produce and market quality seed. The importance of quasi-formal or market-based channels increases with the availability of new farmer-preferred varieties that creates incentives for the emergence of markets and trade in the supply of the new seeds.

The use of farmer participatory variety selection (PVS) in grain legume improvement under the TL II project has increased the level of awareness about the performances of new varieties among the farmers. The adoption of new varieties by the farmers has been enhanced by their involvement in the breeding activities.

The IFPRI global futures for agriculture (IMPACT) model customized for legumes in targeted locations showed an increased demand and supply of legume crops, both globally and regionally, by 2050 in the pessimistic/optimistic framework under some climate change scenarios. The option of upgrading the value chain for some legume crops has been identified. In some countries, pilot experiments have been set up for testing the upgrading options and are found to be relatively successful.

Key achievements

Adoption and impacts of modern varieties

The adoption of modern varieties developed and disseminated during the period of implementation of TL II project has shown a significant increase. Table 1 presents the trends in adoption from 2007 onwards. In West Africa, studies on adoption of cowpea and soybean varieties conducted in Nigeria showed an increase by 49% and 17%, respectively, in the project sites. An early adoption and impact study conducted in July – August 2013 on cowpea and soybean varieties in Mozambique showed an estimated increase in its adoption by 11% and 8%, respectively. In Malawi, adoption of soybean varieties was estimated to be about 22% of the cropped area in the project sites.

In Niger, an adoption study on groundnut varieties carried out in 2011 in the Dosso region showed an increase in the adoption by 14% from 2008 to 2011 resulting essentially from TL II intervention on variety promotion and seed production schemes. Similarly, in Nigeria, a nationwide household survey data from 2,732 households was used to assess the drivers of exposure, adoption and impacts of modern groundnut varieties (SAMNUT 21, 22 and 23) which were disseminated under the TL II project on household poverty and food security. The results showed that adoption was largely explained by knowledge of known modern varieties, age and education of household head, total work force and household size. This was consistent with many other legume adoption studies. In addition, access to seed was a significant constraint for adoption. The current adoption rate increased from 6.15% of farmers in 2008 to 22.44% in 2012. Using the treatment effect estimation framework, the potential adoption rate for groundnut was estimated to be 78.44% leading to an adoption gap of 55.99% of farmers. This implied that there is potential to increase the adoption of modern groundnut varieties based on awareness or promotion. There was significant impact of groundnut varieties on food security and little impact on poverty suggesting that there is a need for increasing the adoption to attain poverty impacts.

In Tanzania, an impact assessment of modern groundnut varieties was carried out using a sub-sample of the TL II baseline sample as well as additional households within the districts of Kondoa, Karatu, Babati and Arumeru. The results indicated that the positive attributes of the improved varieties went beyond

Table 1. Adoption of modern legume varieties developed or adapted under TL II project.

			Year					
Crop	Country	Indicator	2008	2009	2010	2011	2012	2013
Groundnut	Niger	% farmers	13.0			55.0		
		% area	3.0			17.0		
	Nigeria	% farmers	6.1				22.4	
		% area	2.0				13.0	
	Mali	% farmers	3.0					
		% area	0.3					
	Karnataka	% area	0.0		8.0			
	Tamil Nadu	% area	0.0		1.0			
	Malawi	% farmers	52.0		64.0			84.0
Common beans	Uganda	% farmers						
		% area					13.2	
	Tanzania	% farmers					23.4	
		% area					18.3	
	Ethiopia	% farmers	10.0				43.4	
		% area					38.7	
Cowpea	Mozambique	% farmers	25.0				36.0	
	Nigeria	% farmers	26.0		75.0		18.0*	
Soybean	Mozambique	% farmers	22.0				30.0	
	Malawi	% farmers	23.0				45.0	
	Nigeria	% farmers	53.0		80.0			
Chickpea	Andhra Pradesh	% area	47.0		55.0			85.0
	Karnataka	% area	0.0		52.0			65.0
	Bangladesh	% farmers				75.0		
	Ethiopia	% farmers		63.0				
Pigeonpea	Karnataka	% area	3.0		31.0			
	Maharashtra	% area	3.0		40.0			
	Tanzania	% farmers	23.2		45.4		49.6	

*Nationwide survey
Sources: Numerous survey results from several TL II countries

the pure yield increase to include soil fertility improvements and food security. These results were confirmed by nationwide estimates based on related projects that showed that the improvements made in the seed system paid-off way beyond the narrow intervention regions and are successfully creating nationwide linkages. International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) efforts in Tanzania included several other projects that were estimated to have an internal rate of return (IRR) between 13.5% and 25.5% based on the observed optimistic or pessimistic assumptions.

In Ethiopia, adoption of new improved bean varieties released between 2003 and 2011 was analyzed based on 600 sampled households selected from the major bean producing regions of Oromiya and Southern Highlands of Ethiopia. The estimation indicated that adoption of varieties released between 2003 and 2011 increased from less than 10% in 2008 to 43.4% of the bean area in 2012. In comparison to 2008, the number of bean varieties released during 2003 – 2005 that were utilized by the farmers of Ethiopia increased from two in 2008 to seven varieties. This was due to the increased capacity in seed production and delivery at country level. Out of 48 varieties released between 2003 and 2012 (PABRA database, 2014), 16 varieties have been taken up by the farmers and are currently diffusing in the farming communities. As a result, the ruling varieties have decreased in their relative importance, being replaced by new varieties. The varieties released between 2008 and 2011 accounts for 4.4% of the bean area in the study regions.

In the Southern Highlands of Tanzania, the analysis of adoption was based on 750 households from 75 villages across the bean growing areas of the region. The results showed that about 23.4% of the households have adopted varieties released between 2002 and 2010. Of these, 15% replaced their traditional varieties with new ones while 8.4% have adopted partially (plantation of new varieties alongside other varieties that they were growing before the implementation of the project). In terms of area, varieties released since 2002 are grown on 18.3% of the bean area as varieties between 1970 and 2000 continue to dominate (occupying 46.58% of the area).

In Uganda, the analysis was based on the data from a national representative sample of 1,800 households collected under the "Diffusion of improved varieties in Sub-Saharan Africa project". The adoption of new improved varieties occupies a smaller area share of about 13% because of the partial adoption by majority of the farmers. The other reason may be the late entry of Uganda into the project in phase II. Because of this, Uganda was found to be least benefited from TL II project seed dissemination effort at the time of the survey in 2012. Across the three countries, adoption of improved bean varieties is largely explained by adaptability to the physical environments. The amounts and distribution of rainfall is a major determinant of improved bean varieties, with higher diffusion in moderate to high rainfall zones than in semi-arid areas. In general, the poorer households in South Tanzania and Uganda are less likely to adopt new improved varieties, due to accessibility constraints (ie, lack of cash to buy seeds, less informed about the benefits of the varieties, etc). The cost of learning about the agronomic performance of the variety, its market demand and stability under weather fluctuations might also exclude the poorer households from adopting new varieties. Table 2 summarizes the major constraints facing legume farmers in the TL II project countries.

Factors like low exposure, low access and availability of seed of modern varieties still remain a major farm level constraint to the adoption of modern varieties. The main sector level constraints are the low awareness to aflatoxin contamination, inconsistent and unreliable supply of grain legumes and higher prices and capacity of national partners in socioeconomic research (Table 2).

Use of new approaches to assess impacts and modern ICT tools

A combination of with or without and before or after approaches were used for the project and non-project households to control for selection biases that arise when participation in the program by individuals is related to unmeasured characteristics that are themselves related to the program outcome under study. This is the case for impact studies of cowpea and soybean in Mozambique; soybean in Malawi; and groundnut in Niger and Nigeria. This method ensures that impacts can be largely attributed to project interventions.

ICT tools and technology for both data collection and information dissemination was successfully piloted in Kenya and Tanzania. Through collaboration with CCAFS, a team from Eastern and Southern Africa (ESA) region was able to film an episode featuring healthy groundnut production for the popular Kenyan TV show *Shamba shape up*. The show is aired in Kenya, Tanzania and Uganda in both English as well as the local language Swahili and is being watched by more than 7 million people across the three countries. Even though all the people who watch the show are not groundnut farmers, the awareness about Aflatoxin is also important on the consumer side and will create demand for quality attributes. Furthermore, survey implementation using tablet computers was piloted in ESA during the adoption tracking survey of modern varieties of chickpea in Ethiopia using the open source app ODK. The use of tablets has improved the data quality but also reduced the time lag between survey implementation, data availability and the results generation.

Table 2. Constraints faced by smallholder legume farmers at farm, sector and country levels.

Country	Crop	Constraint level		
		Farm	Sector	Country
Uganda	Groundnut		• Lack of awareness about aflatoxin contamination • Unreliable supply	
Tanzania	Pigeonpea	• Poor soil fertility • Increased soil erosion	• Inconsistent quality	
Malawi	Groundnut	• Inadequate seed supply	• High priced seed	• Weak extension
Odisha	Groundnut	• Poor seed storage mechanisms		
Bihar	Chickpea	• Low seed availability • Low exposure of farmers to modern varieties		
Andhra Pradesh	Chickpea	• Need for mechanically suitable cultivars • Low output prices		
Karnataka	Chickpea	• Recurrent drought • Low exposure of farmers to modern varieties		
Tamil Nadu	Groundnut	• Drought • Low seed availability		
Maharashtra	Pigeonpea	• Drought as an issue		
Bangladesh	Chickpea	• Poor awareness • Need for introduction of cultivars suitable for rice-fallow		
Uganda	Common beans	• Declined soil fertility • Diseases		
Tanzania	Common beans		• Low capacity for impact assessment within NARS	• Low prices • Climatic shocks
Ethiopia	Common beans	• Pests and diseases • Labor availability at peak period	• Low capacity for impact assessment within NARS	• Poor infrastructure
Mali	Groundnut	• Non availability of seeds • Poor soils • Low yielding varieties • Late maturity	• Awareness regarding aflatoxin contamination • Low value addition	• Low capacity within NARS • Climate change
Niger	Groundnut	• Non availability of seeds • Poor soils	• Awareness regarding aflatoxin contamination • Low value addition	• Low capacity within NARS • Climate change
Nigeria	Groundnut	• Non availability of seeds • Lack of money to buy seeds • Low yielding varieties • Poor soils	• Awareness aflatoxin	• Low capacity for impact assessment within NARS • Climate change

Markets, policies and institutions

Understanding legume value chains

A pigeonpea value chain assessment survey was conducted in Tanzania. The main findings were that there was massive growth in the pigeonpea sector in Tanzania in recent years and that it is now the third biggest supplier in the world. However, the sector heavily depends on two dominant trading houses that handle the bulk of the exports to India, which is the major market for Tanzanian pigeonpea. Besides being an important cash crop for Tanzanian farmers it is also widely consumed and thus, contributes to the local diet and food security. In addition, the incorporation of improved varieties and management practices was reported to almost quadruple the revenues from pigeonpea production.

In Malawi, although the groundnut export volumes remained lower than the 1980s levels, the review showed that Malawi maintains a comparative advantage in groundnut production and competitiveness in exports. This suggests that there is scope for increasing groundnut exports once the required quality standards are adhered to. The soybean producers are beginning to respond to the growing market price incentives, with over 75% of the soybean produced being marketed. In West Africa, the competitiveness of groundnut in the domestic, regional and international markets has been limited by the low productivity, aflatoxin regulations and stricter grades and standards.

In 2012 in Niger, participatory value chain analysis was performed in four villages of western Niger (Moussa Dey, Guidan Gaba, Sambera and Gaya). Five upgrading points were identified as follows: (1) the lack of consistent supply of high quality grains to the processors; (2) the lack of appropriate equipment to process groundnut into oil, cakes or pastes; (3) the lack of training in business and marketing skills; (4) the lack of access to credit for working capital or trade; and (5) the poor trader linkages for product selling. A pilot economic experiment was set up with the objectives to reduce drudgery and assess the impact of processing machines on the livelihood of women processors essentially focusing on constraints (2) and (3). These villages were selected based on the large volume of groundnut oil, cakes and pastes processed. Four other villages were selected as control sites with similar socioeconomic characteristics as the project villages but where groundnut is processed by hand. The households are being monitored for finding the amount of time invested by women in processing groundnut and the corresponding revenues derived from it. The preliminary results showed that decorticators helped the women save the processing time on an average of 2.7 minutes per kg of decorticated groundnut and reduce costs by 2.5 FCFA (West African CFA franc) per kg of decorticated groundnut. In addition, the use of processing equipment, especially milling, reduced the time by 0.75 minutes and costs by 6.25 FCFA per kg. For oil extraction, processors gained on average 5.5 minutes and 18.75 FCFA per kg of shelled groundnut that are processed. The use of both the decorticators and oil processing machines by processors contributes to reduced labor time by 22.2 minutes and costs by 27.5 FCFA per kg of shelled groundnut. The labor time and revenues generated by the women are being currently monitored in both the project and non-control villages.

Lessons learned

Specifically, the following major lessons can be drawn from the empirical work undertaken under Objective 1:

- While the baseline surveys conducted at the beginning of phase I of the TL II project showed continued dominance of old improved varieties introduced several years ago, the early adoption studies conducted in phase II showed an increase in the adoption of new varieties disseminated through the project following farmer-participatory varietal selection (FPVS) (see Table 1).
- While adoption of improved varieties is still low in many countries, an increasing share of the legume area is under the improved varieties in the FPVS sites of the project where farmers gained initial access to the varieties. The variety dissemination is likely to have occurred through farmer-to-farmer exchange of seeds.
- Where increased adoption of improved varieties has occurred, early adoption and impact studies showed positive and significant farm level impacts of adoption on grain yields and incomes. For example adoption of improved soybean varieties in Mozambique increased the grain yields by 43% and income by 56%.
- Most legume producers sell at the farm gate, but producer prices at the time of harvest are generally two to three times lower than prices at the time of planting. As a result, farmers receive a lower share of the final price paid by consumers.
- In view of the growing trader penetration into the rural areas for product assembly, most farmers sell at the farm gate and thus, the farmers have better access to output markets than to input markets, such as for improved seed.
- Lack of access to improved seed was found to be the major reason for non-adoption of improved varieties of legumes, whereas lack of access to capital (ie, cash, credit, etc.) was the main reason for non-adoption of improved varieties of maize due to the greater private sector participation in the maize seed industry.
- Assessment of farmer preferences for varietal traits showed greater preference for soybean varieties with higher yields, but low yields of existing varieties are mainly a result of poor agronomic practices and low input use.
- Demand for certified seed is driven largely by subsidy programs and donor-funded projects, indicating the lack of sufficient sustainable demand for seed that is needed for creating the conditions for sustainable seed supply through private sector participation.
- In view of the growing private sector investments in the ICT sector, the studies found high levels of mobile phone reception and ownership in all project countries. This holds potential for enhancing farmers' access to price information and improved technology for increased commercialization of legume production.

Challenges/Gaps and future outlook

The following are the major gaps in knowledge and practice that should be addressed in the third phase of the project:

- Lack of rigorous evidence on adoption and impacts of improved varieties on poverty and food security outcomes using nationally representative household surveys;
- Lack of a sound methodology or protocol for identifying improved varieties in farmers' fields;

- Lack of evidence on household level consumption and demand for legumes among different income and social groups to help establish the role of legumes in the diets and livelihoods of the poor in Africa;
- Need for the evaluation of upgrading options for legume value chains to identify and promote interventions that increase the inclusiveness, competitiveness and incomes of smallholder farmers,
- Identify ways for increasing awareness of farmers about new seed varieties and strengthening seed delivery systems to reach farmers who continue to rely on low-yielding local varieties;
- Gender-differentiated evaluation of technology choices and demand for variety traits to better understand and target new technologies and establish effective impact pathways; and
- Improved understanding of the changing roles of men and women in legume production and marketing to provide insights into technology development and institutional innovations.

Policy-makers need to be informed on the impacts of new varieties and opportunities that grain legumes present for addressing issues, such as rural poverty and supplying food to rapidly growing urban populations aiming at the promotion of this important social objective. Evaluation of the impacts of legume technologies on poverty reduction and food security has so far been limited. A lot of empirical work in the past has failed to move beyond the estimated economic surplus and returns on research investment. A comprehensive study on the long-range impacts of legume technologies will provide the necessary information base for identifying further research needs and for developing policy recommendations that can foster change towards more sustainable production and marketing systems.

The underdeveloped input and output markets and poorly functioning value chains reduce competitiveness of legumes relative to other food crops (eg, maize, rice, etc) and undermine adoption of new varieties. In particular, market access is important for wider adoption of new technologies of legumes. Firstly, these crops are grown in marginal areas where markets are thin and segmented and poorly linked with deficit regions. Secondly, poor grain quality, unreliable supply and high costs to end users reduce the farmer's share in the consumer's price. Thirdly, poor market integration and lack of market information means that both the producers and buyers face high market risks. This implies that increasing production is difficult to sustain under low and inelastic demand that often causes price collapse when local markets fail to absorb surplus production (eg, following good rains or adoption of new varieties). Unless technology promotion is supported by market development, the risk of price collapse and poor access to input and output markets will slow down the adoption of new technologies.

Investment in market institutions and upgrading value chain to reduce transaction and marketing costs and better provision of market information can increase the trade and stimulate consumer demand. This can improve responsiveness of market players (including producers, traders, consumers, etc) toward price and income and therefore to increase demand and expand markets for these crops. But this would require careful understanding of the consumer choices, end user preferences, processing options to improve product quality and reduce family food processing time and development of suitable models for linking farmers to markets. There is also increasing evidence that innovative institutional arrangements can help remedy market failures and improve market opportunities for the poor. If market linkages and competitiveness can be improved through institutional innovations, a significant segment of legume producers in SSA and SA could be benefited from existing as well as new market opportunities.

Enhancing groundnut productivity and production in Eastern and Southern Africa

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Summary

The Tropical Legumes Project is a research and development approach that is complementary to the CGIAR Research Program being implemented by a global consortium of partners. The project targets production of legumes that have high nutrient content and possess commercial potential to fight hunger, increase income and improve soil fertility for the resource-poor farmers. The groundnut improvement and seed systems under the Tropical Legumes II Project is implemented by ICRISAT with full participation of four national program partners in Malawi, Mozambique, Tanzania and Uganda. There is strong involvement of public sector, private sector and non-governmental organizations that assure relevance and effectiveness in delivery of groundnut innovations. These technologies must inter alia secure harvests against drought and outburst of major pests and diseases, in the process guaranteeing high yields and quality. In addition, the program seeks to strengthen the capacity to deliver seeds of new varieties and build capacity of partners to utilize integrated legume innovations for research and production purposes. The key achievements of the program over the last seven seasons include:

1. **Improved access to seed**. Increased adoption of improved varieties by farmers, in some cases, new varieties accounting for up to 40% of cropped area in the case of Malawi. This has led to improved productivity from about 450 kg ha^{-1} in the pre-TL II period to about 800 – 1,000 kg ha^{-1} in 2013[1].
2. **Benefits from farmer participatory research**. By engaging farmers during the pre-release variety selection, breeding programs have been able to better target varieties to both the ecological and market needs. In all anchor countries, an average of five new varieties were released including on-the-shelf material.
3. **Stronger regional breeding pipelines**. In both phases of the project, the ICRISAT regional program has been strengthened through both human capital and infrastructure development over the seven seasons. Accordingly, the program has provided over 2,500 new breeding lines to the partners of anchor countries, such as Tanzania, Malawi, Mozambique and Uganda as well as spill over countries (non anchor countries – Sudan, DR Congo, South Africa and Zambia).
4. **Strengthening of seed system**. A semi-commercial to commercial seed systems that link breeders to smallholder seed producers and marketers run on the basis of a revolving fund has been explored in Malawi. This system provides over 50% of the legume seed used in Malawi. Based on working through farmer organizations, alternative pro-poor seed delivery scheme in all partner countries have facilitated access to good quality seed.
5. **High net impacts**. The farmer field schools have delivered improved groundnut seed to more than 100,000 households in Malawi and Tanzania over the past three years. At the current production levels, it is estimated that the total seed produced in these countries if availed in 2 kg small seed packs would benefit a total of 17,096,425 individual farmers.

1. More details can be found from ICRISAT Groundnut R4D Impact Assessment Report 2013.

Key achievements

Crop improvement

Development and research context

Groundnut (*Arachis hypogaea* L.) is a major valuable and versatile grain legume crop that contributes tremendously to economies and livelihoods of smallholder farmers in Eastern and Southern Africa (ESA). The crop plays an essential role in determining the economies and livelihoods of smallholder farmers contributing to their household nutrition and food security, as well as soil health. The crop is well adapted to low rainfall an increasing phenomenon especially now, with the threat that is posed by climate change[2]. This resilient crop, thus, continues to form part of the adaptability strategies to an ever-present threat to their livelihoods that is now predicted to have even more severe effect[3]. The ESA region has 2,631,167 ha of groundnut cropped area, with four CGIAR Research Programs (CRP) and TL II anchor countries accounting for 76% of the total cropped area (2,003,035 ha)[4]. The yield of groundnuts in the region is limited by four major constraints that are as follows: (i) Low productivity with yields hovering around 400 kg ha^{-1} in most countries compared to 1,700 – 2,500 kg ha^{-1} possible from elite varieties; (ii) Obsolete varieties, such as *Chalimbana* in Malawi, *Bebiano blanco* in Mozambique and *redmwitunde* in Tanzania are still common, highlighting the importance of limited access to improved seed varieties. A recent impact assessment study in Malawi showed that the proportion of recycled seed used by farmers ranged from 30% for new varieties to over 62% for old obsolete varieties[5]; (iii) Biotic stresses still impede production, with major diseases, such as rosette, early leafspots (ELS), rust and contamination of grain with *Aspergillus*-produced aflatoxin, being common. Under severe epidemics the entire crop may be lost to disease though in majority of years approximately 30% yield loss from all diseases combined is common. It has been estimated that in Malawi alone, approximately $12 million produce is lost annually from the combined effect of ELS and rosette; (iv) In addition, drought due to the erratic rainfall has affected the groundnut production agro-ecological zones in the three target countries. Thus, strategic investment in groundnut research for development (R4D) will go a long way in unlocking potential of the crop to contribute to economic growth with more direct impacts on livelihoods and ecological services, especially improvements in the agro ecological productivity.

Groundnuts production trends in target countries

In general, groundnut production has been increasing in the region especially after the intensified investments in groundnut research for development activities (Figure 1). In each of the anchor countries, the yield increase ranges from 25% in Mozambique that has just released new varieties in 2011 to almost 90% in Tanzania between 2007 and 2012. In particular, Tanzania has been very successful due to its official policy on production and use of Quality Declared Seed (QDS) produced under supervision by the National Seed Agency. The increase in production is attributed to adoption of new varieties. In Malawi, recent impact studies showed that up to 80% of the planted groundnut area is under two main improved varieties, CG 7 and *Nsinjiro*, with average yields on-farm of 560 kg ha^{-1} well above the 1980s average yield of 368 kg ha^{-1}.

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2. World Bank, 2012. 4°C. Turn Down the Heat. Why a 4°C Warmer World must be Avoided. A Report for the World Bank by the Potsdam Institute for Climate Impact Research and Climate Analytics. World Bank Washington DC, November 2012.
3. IPCC 2014. Intergovernmental Panel on Climate Change report. Climate Change 2014: Impacts, Adaptation, and Vulnerability. Working Group II Contribution to the IPCC 5th Assessment Report — Changes to the Underlying Scientific/Technical Assessment.
4. FAO Stat, 2014. Production statistics, Food and Agriculture organization of the United Nations, Rome, Italy.
5. Davies Ng'ong'ola et al., 2014. Adoption of groundnut production technologies by smallholder farmers in Malawi. Impact assessment study Groundnut investments in Malawi from 1982 – 2013.

In Malawi, the averagely lower yield compared to national averages of 1,000 kg ha^{-1} is indicative of the need to target deployment of genotypes to different agro-ecological needs. Whereas, better endowed agro-ecologies like the Central plateau (comprising Mchinji, Dowa, Dedza, Lilongwe) and high altitude areas of Rumphi, Shire Highlands, and Phalombe managed above 1 ton ha^{-1} on farmer's fields and could utilize full season varieties like CG7 and *Nsinjiro* for maximized production. The need for early maturing or short duration varieties for the low altitude short season agro-ecologies is normally found in Chitipa, Karonga, lower Thyolo, Mangochi, Machinga, Balaka, Neno, Chikwawa and Nsanje (whose productivity was less than 0.75 t ha^{-1} in 2008). Deployment of relevant genotypes has improved productivity in some of these areas although full-scale adoption is still limited (Table 3).

Table 3. Groundnut productivity in major groundnut producing agricultural development divisions of Malawi in 2012.

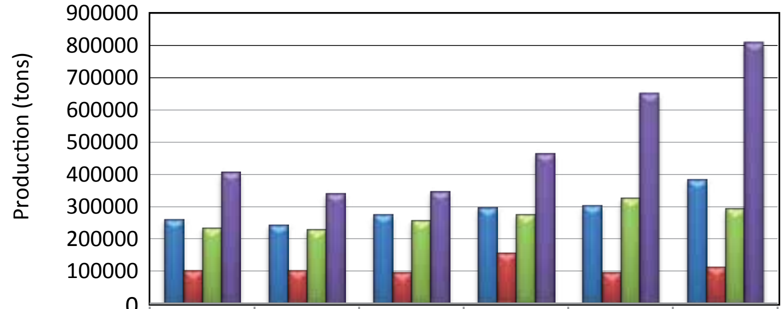
Agriculture Development Division	Productivity (kg ha^{-1})
Shire valley	620
Blantyre	990
Machinga	609
Lilongwe	1,266
Salima	972
Kasungu	1,123
Mzuzu	820
Karonga	990

Source: Ministry of Agriculture and Food Security Malawi.

In Tanzania, groundnut is grown by smallholder farmers with the major growing regions being Mtwara, Tabora, Shinyanga, Kigoma, Dodoma and Mwanza. The area under groundnut in Tanzania is estimated to be 810,000 ha with a rate of growth of 4.63% per annum. The current national average yield[6] is 721 kg ha^{-1}. There has been tremendous increase in the yields with more than 90% increase in production over the last seven years. The yield still hovers around 545–723 kg ha^{-1}. The production has been extensively weather dependent, marked by sharp declines in production during the drought years (2008 – 2009 and earlier in 2000). In order of importance, the largest groundnut production regions of Tanzania are Shinyanga, Dodoma, Tabora and Mtwara accounting for over 60% of the national production. Mtwara and western Shinyanga have slightly better rainfall distribution and can accommodate some of the medium duration Virginia groundnuts whereas Spanish early duration varieties are more adapted to the rest of the country.

The growth and production trends of groundnuts in Mozambique have been reported. The data shows that while the areas under the crop remain relatively stable at about 280,000 ha, the productivity still remains low with declining yields that might be due to the limited access to improved seed varieties. Five new varieties were released in 2011 but they are yet to spread out in part due to a compromised seed system. About 99% of the area under groundnut is cultivated by small-scale peasant farmers on traditional farms and the crop is important both as a subsistence food crop and source of cash and oil (Diop et al. 2003[7]). The oilseed sector in Mozambique has expanded, especially through the interventions of various NGOs, principally in Manica, Zambezia and Nampula[8], which takes lead in

6. Ministry of Agriculture Food Security and Cooperatives (MAFSC 2011). Proceedings of the seed industry stakeholders' workshop held on 3rd June, 2011 at Naura springs hotel, Arusha, Tanzania.
7. Diop, N., J. Beghin, and M. Sewadeh. 2003. Groundnut Policies, Global Trade Dynamics and the Impact of Trade Liberalization. Mimeo. The World Bank, Washington, D.C.
8. Diagnostic Trade Integration-Mozambique, 2004. Crop subsector analyses results of trade transport facilitation audit. Study Volume 3.



	2007	2008	2009	2010	2011	2012
Malawi	261810	243215	275176	297487	304868	384869
Mozambique	102932	102520	97000	157685	95700	112913
Uganda	235000	229636	257967	275767	327000	295000
Tanzania	408058	340770	347970	465290	651397	810000

Figure 1. Groundnut production in TL II anchor countries during 2007 – 2012.
Source: FAOSTAT 2014

production of the crop. The main varieties are farmers' local varieties, such as *Bebiano blanco* and newer varieties, such as *Mamane* and *Nematil*. The main challenge to increase productivity is access to seed. For southern Mozambique (Inhambane, Gaza and Maputo), the focus is on high yielding short duration varieties (90 – 110 days) with resistance to ELS and rust. For northern Mozambique (Nampula, Zambezia, Cabo Delgado), the major focus is on medium-duration varieties (110 – 130 days) with resistance to rosette and ELS. For the whole country, the strategy is to provide varieties and agronomic packages targeting reduction of aflatoxin contamination.

Seed systems

Improving groundnut seed systems

The access to improved seed variety is fundamental for the development and growth of the agricultural sector worldwide. In general, the legume seed systems in ESA are improving, especially under TL II project. This weakness is conditioned in part by non-competitive public sector-led seed production systems and low interest by the private sector to invest in a crop characterized by high seed rates (approx. 100 kg ha^{-1}), low seed multiplicative ratio (approximately 1:10) and high opportunity for seed recycling by the farmers. TL II investments sought to develop efficient seed systems for reaching smallholder farmers in drought-prone areas of SSA and SA. The outcomes of investments in ESA are highlighted below.

Planning for success through country seed strategies and road maps

Strategic planning. One of the major achievements of TL II has been the development of Country Seed Strategies and Road Maps to guide production and distribution of improved seed by all anchor countries. Each strategy clearly defines and sets targets for groundnut seed production for the various classes of seed (breeder, foundation, certified or QDS); partnerships for producing, marketing and delivering the seed to farmers; capacity strengthening entry points and critical challenges and opportunities to be harnessed per country.

Strengthening seed production and delivery strategies. In order to ensure sufficient seed production, TL II has supported production of all classes of seed. The highlights are provided below.

1. Breeder seed. In all anchor countries, most of the varieties are released by public research agencies. Yet these research bodies are under resourced to produce breeder seeds more effectively. Therefore, the project has invested in strengthening NARI production of breeder seed. Two models are being used, ie, (i) National Agricultural Research Systems (NARS) alone and (ii) NARS + ICRISAT. The NARS + ICRISAT model is being used to inject up to 0.5 tons of breeder seed upon request to NARS partners in addition to what NARS have produced. Using this approach, Malawi produces about 27 tons of breeder seed (*Nsinjiro, CG 7, Chitala, Kakoma* and *Baka* and *Chalimbana* 2005) up from about 0.5 – 1 ton in 2007. Similarly in Tanzania, breeder seed production of Pendo was spread across three major research stations and one FTC producing 5 tons per year. A similar strategy is being used in Uganda with about 8 tons of seed produced, of which 4 tons come from TL II support, up from a case of less than 0.5 tons in 2007.

2. Foundation seed. Two strategies are being used for foundation seed production. The first is the use of contract farmers with proven track record as implemented in Malawi and Uganda and use of Farmer Field Schools and farmer groups as implemented in Malawi, Tanzania and Mozambique. In both the cases, the farmers are trained on seed production and they annually receive infusions of seed from the breeder. The smallholder farmers initially receive seed grants and following successful payback can be given even more seed to produce on a contractual basis. The farmer groups for Malawi are those linked to the National Association of Smallholder Farmers Malawi (NASFAM) whereas those for Tanzania are linked to the Agricultural Seed Agency (ASA). Another successful foundation seed provision scheme in Malawi is the seed revolving fund scheme run by ICRISAT (Figure 2). This was initiated by ICRISAT in 2001 through a one-time financial grant from USAID and is still running with further support from Irish Aid. The scheme has since grown and is supported by an alliance of seed producers that now accounts for 54% in total of legume seed produced in Malawi. Since its inception, the scheme has delivered more than 1,200 tons foundation seed and more than 200 tons breeder seed. Currently, the scheme produces

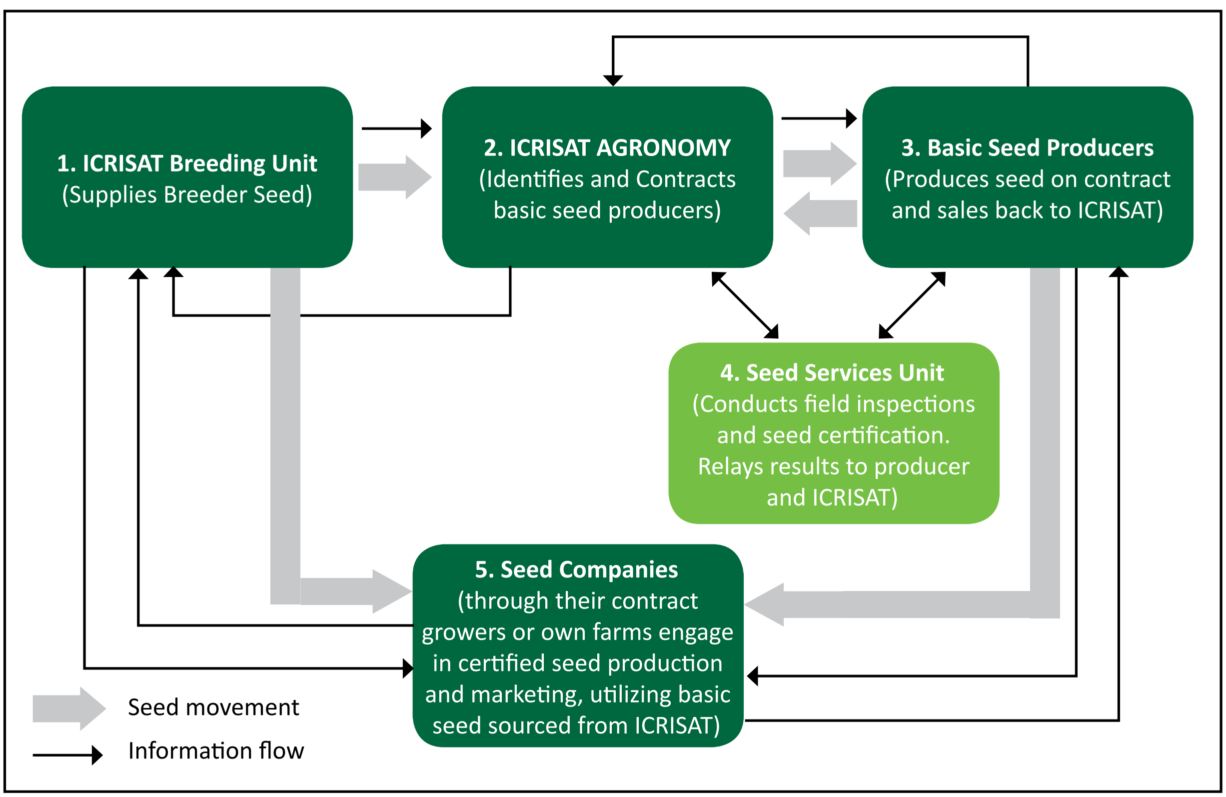


Figure 2. The Malawi model of the seed revolving fund.

about 200 tons foundation seed and 50 tons of breeder seed annually. By 2011, the scheme was able to supply the seed requirements of 156,250 farmers. Taking cognizance of the fact that the groundnut farmers obtain a majority of seeds from other farmers, this reach can easily be multiplied five-folds.

The scheme is funded through a revolving fund that grows based on the sale proceeds of the foundation seed to selected local seed companies and a few NGOs working on food security, who in turn produce and sell certified seed to the government and farmers. The fund has been growing and expanding to other orphaned crops.

3. Certified seed. TL II partnered with farmer organizations like NASFAM in Malawi and farmer cooperatives in Tanzania for commercial production of certified seed. The seed from farmers' field is used either directly by the farmer organizations or feeds directly into Government programs such as the government input subsidy programs of Malawi. This model is now replicated in Zambia. In order to ensure sustainability, the private seed sector is slowly getting involved. In Malawi, the demand created by the Government input subsidy program has attracted SEEDCo, one of the largest seed companies in the region, into groundnut seed production and marketing. Recently, Tanzania has found apparent involvement of certified seed marketing agencies, such as the ASA that sells about 100 tons of certified seeds per year.

4. Alternative seed production, distribution and marketing arrangements. In order to improve the reach of new varieties, TL II explored alternative seed production systems that depend on farmer level but research supported seed production. A combination of farmer groups and farmer field schools were engaged in seed production. In 2013, the Tanzanian farmer groups produced 17,542 tons of seed, followed by 16,253 tons produced by Malawi, about 363 tons by Uganda and 66 tons by Mozambique. In Malawi, more than 450 farmers were involved who were linked to the NGO named as CARE, 233 farmers were linked to NASFAM, and 73 linked to the Millennium Villages project. Similar approaches are being used in Uganda with NASAARI partnering with Government Programs (District Farm Offices or National Agricultural Advisory Services), local companies and civil society such as Plan International, VECO, for seed production and making it available to the farmers.

1. **Strengthening diffusion, marketing and institutional arrangements for seed**. In order to improve the diffusion of technologies, the TL II harnessed complementary investments in all anchor countries and successfully built upon earlier lessons that were learnt while working with the farmer groups.

    - **Tanzania experience**. Farmer-marketing groups were established in districts of Tanzania – Mpeta, Mnanje B and Likokona – while seed production groups have been established in three districts of Malawi – Mchinji (19), Nkhotakota (28) and Zomba (3). In addition to the supply of the required variety and class of seed to the growers and traders, they were supported by capacity building and farmer-friendly literature in vernacular on Integrated Crop Management and seed production, processing, storage and marketing skills (especially for the traders and seed entrepreneurs). Seed marketing is handled by ASA in Tanzania. These agencies offer smallholder farmers seed production contracts to produce certified seed, which is then bought back by these agencies. The national seed services of each participating country do independent inspections for quality assurance.

    - **Malawi experience**. In collaboration with NASFAM and Millennium Village Project and other complementary projects (McKnight Foundation supported), there are now about 200 seed production groups with community seed banks in Mchinji, Kasungu, Mzimba Nkhotakota Dedza and Zomba. The groups in Mchinji are already mature and are regularly producing seed on contract for ICRISAT and other interested NGOs and private sector. Others are still at seed production level and dependent on project-based support market to sell their produce as seed, otherwise, they sell most of what they produce as grain. In addition, 150 farmers in Kasungu from Traditional Authorities (TAs) Kaomba, Mwase and Njobwa in collaboration with ICRISAT and CARE were issued with groundnut breeder seed of ICGV-SM 90704 and ICGV-SM 99568 to produce foundation seed under the formal contract. Around 135 smallholder contract growers produced each 0.5 ha seed but organized themselves into a farmer cooperative in order to take care of the costs involved in delivery of a contract.

- **Uganda experience**. A multi-pronged approach is being used in Uganda involving community-based organizations that already have farmer groups such as Soroti Catholic Diocese Development Organization (SOCADIDO); farmer self help groups such as Patongo women's group as well as through Government supported rural interventions that require collective action through the National Agricultural Advisory Services (NAADS). The TL II trained community organization extension agents provide seed and complementary training to produce it by NASAARI. These are generally being contracted to produce seed for government, private sector or distribution within the community.

2. Improving capacity to produce, deliver, store and market seed. A number of activities have been conducted to improve production, delivery and marketing**.**

- **Production**. By 2010, 527 officers, farmers and seed producers, 57 technicians, 141 extension officers and 46 farmer research group leaders were trained in seed production in Tanzania and Malawi. In addition, a groundnut seed production manual for Malawi was produced while a similar manual for Tanzania is available in Swahili. In Uganda, a similar document has been produced. In each anchor country, at least 1,000 – 3,000 information leaflets are distributed during each growing season. In addition, over 6,000 farmers (3,635 women and 2,365 men) have been trained towards the use of improved technologies (improved varieties and integrated crop management – time of plantation, plant population, weed management, harvesting and post-harvest technologies including storage and management of aflatoxin contamination).
- **Engaging private sector**. In Malawi, under the umbrella of Malawi Seed Alliance Trust (registered in 2014), an alliance of local seed producers and marketers, created to sustain availability and increased uptake of legume foundation seeds by local seed companies and entrepreneurs. The current membership of MASA endorses 14 small seed companies and smallholder producer groups. MASA provides branding that allows the seed to be marketed commercially in Malawi. MASA brands are packaged as small seed packets of 5 and 10 kg suitable for the smallholder farmers. In Uganda and Tanzania, the seed companies are being engaged albeit at ad-hoc basis because of the weak demand from the seed companies to engage in legume seed. A similar scenario exists in Mozambique.

3. Local-level awareness of released varieties (demand creation). A number of activities to popularize the released varieties were implemented in all anchor countries. These are highlighted below.

- **Annual farmer field schools, farmer field days and seed fairs.** In Malawi, 20–50 farmers' field days are conducted annually by NARS and ICRISAT with partners since 2007 for skill upgradation of the farmers and stakeholders on improved varieties and integrated crop management while soliciting feedback to improve focus of the breeding program. The farmer field schools have also become an important tool for technological awareness. There are over 400 active farmer field schools in the project sites of Malawi. In Tanzania, the field days (19 per season), open days and seed fairs (two per site per season) and farmer field schools (80 in Tanzania) became tools for regular project monitoring of activities. In Tanzania, for example, over 100 extension officers and policy makers (40 women and 60 men) have been exposed to improved groundnut varieties. Seed fairs have been organized in Tanzania creating awareness for about 2,000 farmers per fair. Furthermore, in Tanzania, more than 3,000 booklets describing good agronomic practices and methods for good quality seed production were produced and disseminated. In Uganda and Mozambique, open days and field days were also implemented. In 2012, season field days were implemented at project action sites (Acholi bur), national agricultural show and seed fair.

- **Publicity**. Flyers for crop production, aflatoxin management and seed production were developed and translated into vernacular in Tanzania, Malawi, Uganda and Mozambique (at least 4,000 flyers were distributed annually during the field days). These flyers carried messages on description of released varieties, new promising materials under farmer evaluation and results of participatory variety selection from previous seasons. Television and radio broadcasts with live interviews and newspaper articles about the new varieties were also used. The access to benefits by partner communication platforms, such as NASFAM, MASA, etc, increases the reach of information flow. Complementary newsletters became a norm throughout the project sites in Malawi and Tanzania.

Adoption and impacts

Household adoption tracking. Household surveys were conducted in Malawi; based on three rounds (2008, 2010 and 2013) of surveys covering the project areas, progress in adoption is clearly emerging. The adoption rates showed a steady increase, starting from 31% to more than 40% for CG7 (Table 4). Furthermore, the share of the low yielding but formerly widely popular local variety *Chalimbana,* which used to be grown by more than half of the farmers in Malawi, was down to 22% in 2013, showing a good progress in replacing old material in farmers' fields. Partnering with TL II, in-depth studies have also found profound indications of impact achieved on households' incomes, poverty reduction and gender equity attributable to groundnut research in Malawi.

Table 4. Progress of groundnut adoption in Malawi.

	Total		
Crop varieties grown by the farmer	2008	2010	2013
	% of farmers planting		
CG 7	31	39	42
JL 24 (Kakoma)	1	0	4
Chalimbana 2005	11	4	15
Chalimbana	44	34	19
ICGV-90704 (Nsinjiro)	2	17	17
Kalisere	6	3	1
Manipintar	5	3	2

Testing modern ICT tools – Technology for outreach or information. With modern technology penetrating the rural areas, new modes of communication with farmers are made available. Therefore, one of these new avenues was tested in phase II of the project. To raise awareness on aflatoxin contamination among groundnut farmers, ICRISAT's Dr Samuel MC Njoroge, went on Kenya's highly popular farming TV show, *Shamba Shape Up*, in the second episode of the TV show's fourth season titled 'Healthy Groundnuts'. Dr Njoroge advised the farmers on groundnut production and also suggested improvements that will not only result in higher yields, but also reduce aflatoxin exposure.

With over seven million viewers across the three countries in Africa, *Shamba Shape Up* is a widely viewed channel by the smallholder farmers. For farmers in Kenya, the TV show offers additional support by providing free-of-charge information flyers that can be requested by sending a text message. The farmers can also pose queries through text messages to which the experts would respond in less than

48 hours. Aiming at rapidly growing rural audience of East Africa, the makeover style TV show focuses to give both the farmers and audience the tools they need to improve productivity and income on their farms. The show's team visits a farm each week in different areas of the country and involves experts from partner organizations who specialize in the topics covered in the episode. A team from ICRISAT ESA worked with Dr. Njoroge and the show's production company, mediae.org, on planning the episode's content and messaging. The program with Dr Njoroge can also be viewed online at: http://youtu.be/X8H9ETNeieA. The data generated from this exercise is helping the ICRISAT team to further improve aflatoxin-related messaging.

The program was sponsored by the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) with funding support from Tropical Legumes II project. The features parts of an animation were produced by the Innovative Communication Media and Methods project, funded by the McKnight Foundation. This highlights the synergetic effects of various projects for wider spread of the results. Besides its initial release in Kenya, the program will also be aired in Tanzania and Uganda in both English and Swahili.

Strengthening of groundnut breeding pipelines

Participatory variety selection underpinning variety relevance and adoption

Methods. Under TL II project, the FPVS is being used to improve the adoption of new variety by the farmers. FPVS is being used to: (i) identify local and market selection criteria for candidate groundnut varieties; (ii) determine the performance of promising varieties for release and (iii) identify farmer and market-preferred material from the pool of candidate lines for variety release. In general, about 10 candidate varieties, each of mainly Spanish and Virginia groups are being used. In all anchor countries, the methodology used to elicit farmer selection criteria is the same though the number of varieties used varies. The entries were selected based on seed yield and a multiple of other desirable agronomic traits, such as seed color, size, shape and maturity range from trials planted on-farm during agreed upon days (Appendix 2). FPVS were set up following the mother-baby approach in which the researcher-managed trial (the mother plot) and farmer-managed plots (baby plots) were taken into consideration. The number of mother plots contained all test lines including a local check while the baby trials usually contained three test lines. The mother trials varied according to the number of villages while the baby plots were determined by the farmers willing to test lines and seed availability. The pair-wise comparisons and matrix ranking techniques were used to elicit variety preferences by the farmers based on identified local evaluative criteria. In addition, the farmers were given the opportunity to select materials according to their own composite of preferred traits and criteria to gain better understanding of the farmer selection criterion.

Main achievements

1. **Tanzania**. Using this approach the new lines, ICGV-SM 99555 and ICGV-SM 99557, were confirmed as better material than Pendo released prior to TL II. The output traits, such as confectionary market demands as determined by pod filling, grain size and attractiveness of grain were identified and used to inform breeding activities. In the recent past (2012 – 2013) cropping season, 25 farmer research groups (FRGs) comprising 20 farmers each of 25 selected villages (total 12,500 farmers) participated in paired comparisons of three released varieties (Pendo, Mangaka and Mnanje) against a local variety in project districts of Southern (Masasi, Nanyumbu, Tandahimba and Tunduru), Central (Bahi Kondoa and Manyoni), Western (Nzega) and Lake Zone (Bukombe). In addition, 40 new candidate varieties were put under PVS, which involved 8,000 farmers in all the above project action districts of Tanzania. These PVS will lead to the release of next generation of new varieties for Tanzania.

2. **Malawi.** PVS is being implemented now as a routine part of the breeding program. During the 2012 – 2013 season, for example, a total of 25 PVS trials were conducted in over 20 sites in 10 districts (Lilongwe, Kasungu, Mzuzu, Salima, Machinga, Blantyre and Shire Valley Agricultural Development Divisions (ADDs), including new districts of Lilongwe and Mzimba). FPVS involved trials comprised six advanced (Spanish and Virginia) lines in each set tested against two popular varieties (CG7, Nsinjiro or Chalimbana 2005 for Virginia and Kakoma or Chitala for Spanish) in each case in paired comparisons as mother trials. FPVS trial results revealed that the farmers were excited with the new advanced lines due to the various attributes provided by the promising lines. The preferred attributes ranged from high yield, heavy pod load, resistance to diseases (rosette and leafspots), early maturity and good pod filling under limited moisture conditions. Chalimbana 2005 was the most promising variety alongside the older varieties, such as CG7 and Nsinjiro, particularly for export market qualities. The groundnut traders and processors cited the roundish wedge-shaped nuts and uniform grain shape characteristic of Nsinjiro as the reason for preference due to anticipated ease of blanching. PVS top ranked materials, ICGV-SM 96714 and ICGV-SM 99537, have been recommended for release whilst others (four Spanish (ICGV-SM 96714, 99567, 99537, 01514) and three Virginia (ICGV-SM 01708, 01728 and 01711) were identified for their superior performance. These farmer-preferred materials have now been pipelined for National Performance trials and subsequent variety release.
3. **Mozambique.** In Mozambique, FPVS trials were conducted in Nampula, Zambezia and Inhambane and five varieties each of Spanish and Virginia-type were identified. Through PVS, farmers' view points on candidate groundnut varieties were solicited. The current focus of the work is to popularize the released materials, such as ICGV-SM 99568, ICGV-SM 01513, ICGV-SM 01514, CG 7 and JL 24 as well as the new materials.
4. **Uganda.** FPVS has been implemented in various agro-ecologies (major groundnut producing zones), parts with a major focus in the eastern and northern parts of the country. The test materials include nine sets with a total of 35 entries from ICRISAT and eight sets NARO initiated efforts to improve a susceptible ICRISAT derived material S1 or CG 7 (ICGV-SM 83708) using another ICRISAT derived material ICGV-SM 91707. Other materials under PVS include ICGV-SM 06525, ICGV-SM 06629, ICGV-SM 06637, ICGV-SM 08528, ICGV-SM 08556, Baka and Kakoma. These new options will expand the repertoire of improved groundnut materials for use in diverse agro-ecologies of the country and region.
5. **Spill over to other countries.** The approach has also been tried in spill over countries, such as Zambia, where five new candidate lines have now entered national performance trials following successful FPVS. The varieties for release were also identified in Malawi – which should be released before the end of fourth year of the project.

Fast-tracked release of *'on-the-shelf'* varieties expands options for farmers

Prior to the TL II period, variety release was slow with many of the released material unavailable to the farming communities in some cases. More than 148 groundnut mother trials and 440 baby trials in the first four years of the program in Malawi; 60 mother trials and 300 baby trials in Tanzania and 48 mother trials and 162 baby trials in Mozambique underpinned variety release (Table 5). In comparison to the pre-TL II period in the selected countries, (anchor and spill over countries) the program has supported the release of 22 new varieties.

Stronger capacity of the regional program to breed for common needs

Regional operations. ICRISAT maintains a regional groundnut improvement centre at its Lilongwe Station that is based at Chitedze Research Station in Malawi. ICRISAT takes leadership in the development of new populations that underpin the extensive variety selection currently being implemented in all anchor countries. A major contribution of TL II to the regional groundnut breeding efforts has been strengthening of breeding pipelines in anchor countries in the short term via breeding line access and medium to longer term via sharing of material for use by NARS breeding programs.

Table 5. Trends in groundnut variety releases prior to and during the seven seasons of TL II.

Country	Breeding line/Germplasm	Released name	Year of release
Malawi	ICGV-SM 83708 (ICGMS 42)	CG 7	1990
	ICGV-SM 99568	Chitala	2005
	ICGV-SM 90704	(Nsinjiro)	2000
	ICG 12991	(Baka)	2001
		Chalimbana 2005	2005
	Chalimbana	Chalimbana	1968
	ICGV-SM 08501		2014
	ICGV-SM 08503		2014
	ICGV-SM 01731		2014
	ICGV-SM 01724		2014
	ICGV-SM 99551		2014
	ICGV-SM 99556		2014
	ICGV-SM 01514		2014
Mozambique		Babianco Branco	
	ICG 12991	Nematil	2002
	ICGV-SM 90704	Mamane	2002
	ICGV-SM 01513		2011
	ICGV-SM 01514		2011
	ICGV-SM 99541		2011
	ICGV-SM 99568		2011
	CG 7		2011
Tanzania	Robut 33-1 selection	Johari	1985
	ICGMS 33	Pendo	1998
	ICGV-SM 99555	Naliendele 09	2009
	ICGV-SM 99557	Mangaka 09	2009
	ICGV-SM 01711	Nachingwea 09	2009
	ICGV-SM 01721	Masasi 09	2009
	ICGV-SM 83708 (ICGMS 42)	Mnanje	2009
Uganda	ICGV-SM 83708 (ICGMS 42)	Serenut 1R	1999
	ICGV-SM 90704 (Igola-2)	Serenut 2 /Igola 2	2002
	ICG 12991 (Igola-1)	Serenut 4T	2002
	ICGV-SM 93535	Serenut 5R	2010
	ICGV-SM 99566	Serenut 6	2010
	[a]SGV-S1R x S2	Serenut 7T-14R	2011

[a]These are derivatives from the cross involving ICGV-SM 83708 (CG7) and ICVG-SM 90704.

Strengthened capacity at ICRISAT. The main focus of the R4D work in Malawi is variety development, germplasm sharing and management and support to developmental partners. The highlights of the major impacts include:

(i). Input traits: Stress tolerance breeding. Breeding populations ranging from $F_2 – F_7$ are currently being evaluated. Most of these populations were generated from crosses between adapted Malawian, Tanzanian, Zambian, Zimbabwean, Nigerien, Malian and Senegalese varieties and disease resistant accessions or elite ICGV-SMs lines. There are currently 12 populations for ELS ranging from $F_2 – F_7$, 13 populations for rust resistance ranging from $F_2 – F_7$, 10 populations for GRV ranging from $F_2 – F_7$, nine populations for aphid resistance (F_6) and six populations for aflatoxin (F_2). The program currently maintains more than 3,500 progenies for rust, 1,500 for ELS and 400 for rosette from segregating populations ($F_3 – F_6$) developed for variety improvement through pedigree breeding.

(ii). Output trait: Oil content and confectionery traits. Other populations being evaluated were derived from crosses between high yielding genotypes, high oil content (CG 7) and bold seeded genotypes (Chalimbana). The details of populations developed are presented in Appendix 3.

New sources of traits identified under TL I are being used for further hybridization and quantitative trait locus (QTL) mapping. They are presented below:

- **Sources of rust resistance**: 92R/70-4, ICGV 94114, ICGV-SM 86021 and ICGV-SM 02536 that combines rust and ELS. Additional rust resistant lines found from the germplasm reference set includes: ICGV 02194, ICG 11426, ICGV 01276 and ICGV 02286.
- **Sources of rosette resistance**: ICG 14705, ICG 15405, ICG 13099, and ICG 9449 identified from the groundnut reference set.
- **Sources of ELS resistance**: ICG 5663, ICG 4156, ICG 721 and ICG 9905.
- **Sources of drought resistance**: ICG 14390, ICG 14778, ICGV SM 00537 and ICGV SM 03535 identified from field trials.

Germplasm transfers. Over the past seven seasons of TL II, about 2,500 new breeding lines have been availed to NARS in the anchor countries, Tanzania, Malawi, Mozambique and Uganda as well as spill over countries (non anchor countries – Sudan, DR Congo, South Africa and Zambia). The trial sets usually include: Elite short-duration groundnut variety trials (25 genotypes), Elite Virginia bunch drought resistant groundnut variety trial (20 genotypes), Elite Spanish bunch rosette resistant groundnut variety trial (25 genotypes), Elite Spanish bunch drought resistant groundnut variety trial (20 genotypes) and Elite rust resistant groundnut variety trial (16 genotypes), etc. For Malawi, these trials are established at Chitedze, Chitala, Kasinthula and Ngabu. In Mozambique, trials are usually conducted from Nampula, Zambesia, Chokwe and Inhacoongo (Inhambane); whereas in Tanzania trials are conducted at Naliendele, Nachingwea, Hombolo, Makutopora, Bihawana and Tumbi Research Stations. The trials are jointly monitored by ICRISAT and concerned NARS and data reported in appropriate annual planning and review meetings for the project. For the entire period, over 450 international/regional trial sets including varieties and advanced/elite lines were distributed. In addition, the groundnut reference set (259 varieties) and recombinant inbred lines (RILs) (300 varieties) were distributed for drought and disease phenotyping in Malawi and Tanzania in conjunction under TL I. The performance of some of the trial sets selected from the partner research stations has been highlighted in Appendix 4.

Capacity building

There has been infrastructure development in all participating countries for the active breeding program. In Tanzania, greenhouse facilities now exist for disease screening, refrigeration of samples (seed and disease), rainout shelter and a Leaf Area meter for drought screening and Spad meter for chlorophyll measurements in drought screening trials. In Malawi, the NARS have similarly been equipped with a rainout shelter, two glasshouses, one portable weather station and irrigation pump to help them maintain offseason breeding nurseries. Two collaborators from Malawi (Mr Wilson Chafutsa) and Tanzania (Juma Mfaume) were trained at MSc level. Wilson is now in-charge of the seed certification lab of Malawi while Juma is a breeder at Naliendele Research Institute. Training on groundnuts hybridization techniques, design of experiments and statistical data analysis, disease screening and use of the infector row technique benefited seven research technicians from Malawi (3), Tanzania (2) and Mozambique (2). Three scientists, one from each of the partner countries, attended the statistical data analysis training conducted at ICRISAT Malawi.

Lessons learned

Groundnut improvement

1. **Improving R4D efficiency**. Scientist-farmer partnership in agricultural research and development is crucial in bringing about desired changes in the agricultural research and production scenario in the country. There is a need for faster varietal testing and release systems to enhance the spectrum of varieties available to the farmers.
2. **Targeting and adoption**. Advocacy of new varieties and technology by the farmers is essential to bring about changes in the existing policies and large-scale adoption.
3. **Impact orientation**. Sustained seed support is essential for large area coverage by FPVs and resultant enhanced productivity in groundnut.
4. **High performing genotypes could be targeted for regional release**. Many of high performing genotypes are generally good performers across the region. There is need to develop a mechanism if possible, for regional release to overcome or at least minimize "slowdown" due to national institutional challenges.
5. **Strengthening capacity via mentorship**. Each of the countries is unique in their right in terms of capacity and throughput. Exploring opportunity for mentorship amongst regional scientists over and beyond the planning meetings is worth considering, especially supporting development of leadership skills, which are needed to push things through government systems. Tanzania, which is one of the high-flying project partners, is successful because the country's focal point has good leadership qualities, which is used to mentor other younger scientists.

Seed systems

1. **Marketing-related issues.** The input and output markets continue to emerge as a challenge to full utilization of the potential of legumes by smallholder farmers.
2. **Impact orientation**. The project interventions that focused on pro-poor seed production and delivery systems have a better chance of surviving beyond the lifespan of the project.
3. **Catalyzing seed production**. The contract seed production is profit-motivated as farmers look at seed production as an enterprise; sustainable seed production by smallholders stand a better chance of success if complemented by functional seed and product markets for the legumes.
4. **Limited capacity a challenge**. Limited number of research and seed technicians available in ESA hampers progress of seed dissemination.
5. **Smallholder seed entrepreneurs**. The business-oriented smallholder farmers performed better in seed production, seed storage and seed dissemination than food security-oriented farmers. Hence, efforts should be made for inclusion of such groups into the seed systems.

Appendixes

Appendix 1. Participating districts, wards and villages implementing TL II activities in Tanzania.

District	Ward	Participating Villages
Masasi	Chiungutwa Lisekese Chigugu Lukuledi	Chiungutwa, Mpeta and Maugura Sululu Nangose Chigugu and Mandiwa Chikowete and Namichi
Nanyumbu	Mangaka Maratani Mikangaula Likokona	Likokona Mnanje-B Mikangaula Nanyumbu Nahawala
Tunduru	Mlingoti Mashariki Mlingoti Magharibi Namasakata Kidodoma Ligunga Mbesa Nandembo Nakapanya	Sisi kwa Sisi Mkwajuni and Kangomba Amani and Mchenga Legeza Ligunga Mbesa Naluwale Rwanda
Mtwara	Naliendele Ufukoni Mkangala Mikindani Ziwani	Naliendele Mbaye and Mbawala chini Mji mwema Ziwani Mkwajuni and Kangomba Amani and Mchenga Legeza Ligunga
Chamwino	Muungano Buigiri Mvumi Makulu Mvumi Iringa Msanga Idandu Msamalo	Muungano Buigiri Mvumi makulu Mvumi Iringa Msanga Ndembwe Chinangali
Bahi	Bahi	Bahi
Kondoa	Mondo	Mondo

Appendix 2. Farmer participatory selection and demonstration sites across various agroecologies of Uganda during the 2013 growing season.

Location	Region	PVS/Multiplication	Demo	Intention
Bukedea	Eastern Uganda	Serenut 5R and Serenut 6T	Serenuts 1-14 series	Demonstration, PVS, yield stability; multiplication
Isingiro	South Western	Gweri red; Serenut 3 and Serenut 5R	Serenut 1-14 series	PVS, demonstration of rosette and leafspot resistant technologies
Patongo		Serenut 5R and Serenut 6T	Serenut 1-14 series	Wide adaptability; yield stability; multiplication
Lyantonde	South Western	Gweri red and Gweri tan; SGV 99046; Serenut 3 and Serenut 5R	Serenut 1-14 series	Demonstrate leafspot and rosette resistant technologies
Maraca	South Western	Serenut 5R, Serenest 7-14	Serenest 1-14 series	Demonstrate leafspot and rosette resistant technologies
Hoima	Western			Wide adaptability; yield stability
Mukono	Central Uganda			Wide adaptability; yield stability
Rubirizi	South Western Uganda	Gweri red and Gweri tan (4 entries); Serenut 5R and S3	Serenuts 1-14 series	Demonstrate leafspot and rosette resistant technologies
Pajule	Northern Uganda	Gweri red and Gweri tan (4 entries); Serenut 5R and S3		Wide adaptability; yield stability; Demonstration
Prison Masindi	Western Uganda	Gweri red	Serenuts1-14 series;	Wide adaptability; yield stability; Demonstration
Acholibur	Northern Uganda	Gweri red and Gweri tan (4 entries); Serenut 5R and S3		Wide adaptability; yield stability; PVS, Demonstration
Alito	Northern Uganda	Gweri red and Gweri tan (4 entries); Serenut 5R and S3		Demonstrate leafspot and rosette resistant technologies
Aduku	Northern Uganda		Serenuts S1-14 series	Demonstrate leafspot and rosette resistant technologies
Nakabango	Eastern Uganda			Rosette disease resistance confirmation at this hot spot in addition to yield stability
Abi	North Western Uganda		Serenuts S1-14 series	Wide adaptability, yield stability; Demonstration
Ikulwe	Eastern Uganda		Serenuts S1-14 series	Demonstration; Wide adaptability; yield stability
Kuju	Eastern Uganda			Wide adaptability; drought tolerance; yield stability
Ngetta	Northern Uganda			Wide adaptability; drought tolerance; yield stability
ZOA	Northern Uganda		Serenuts S1-14 series; Gweri red and tan; Serenuts 5R and 6T	Demonstrate groundnut technologies; PVS; Multiplication

Appendix 3. Populations developed being evaluated at different stages at ICRISAT Malawi.

Priority stress	Generation	Remark
Early leafspot	F_7	Introgressed to Zimbabwe variety
	F_7	Introgressed to Indian variety
	F_6	Introgressed to Malawian variety
	F_6	Introgressed to Tanzanian variety
	F_6	Introgressed to Tanzanian variety
	F_6	Introgressed to Tanzanian variety
	F_6	Introgressed to Nigerian and Senegalese variety
	F_6	Introgressed to Nigerian variety
	F_6	Introgressed to Malian and Senegalese variety
	F_2	Introgressed to Zambian variety
	F_2	Introgressed to Zambian variety
	F_2	Introgressed to Zambian variety
Rust	F_7	Introgressed to Zimbabwean variety
	F_7	Introgressed to Malawian, Zambian variety
	F_7	Introgressed to Malawian, Zambiam variety
	F_6	Introgressed to Senegalese variety
	F_6	Introgressed to Nigerian variety
	F_6	Introgressed to Nigerian variety
	F_6	Introgressed to Tanzanian variety
	F_6	Introgressed to Malawian variety
	F_2	Introgressed to Zambian variety
GRV	F_7	Introgressed to Malawian variety
	F_6	Introgressed to Tanzanian variety
	F_6	Introgressed to Nigerian variety
	F_6	Introgressed to Malian and Senegalese Variety
	F_6	Introgressed to Senegalese variety
	F_2	Introgressed to Zambian varieties
Aphid	F_6	Introgressed to Tanzanian varieties
	F_6	Introgressed to West African varieties
Aflatoxin	F_2	Introgressed to Zambian varieties other regional varieties

Appendix 4. Performance of Elite groundnut varieties at select Research Stations (Tanzania 2009 – 2010).

Cultivar	Naliendele	Nachingwea	Ilonga	Hombolo
CG 7	532	510	1,880	654
ICGV 90087	720	280	1,133	416
ICGV 90092	481	225	573	375
ICGV 94114	720	582	867	561
ICGV-SM 01711	627	422	1,000	765
ICGV-SM 02501	626	623	633	558
ICGV-SM 03701	683	370	900	526
ICGV-SM 86201	700	148	1,500	620
ICGV-SM 90704	692	582	967	512
ICGV-SM 99568	600	175	1,300	383
PENDO	723	718	2,533	763
Mean	646	421	1,208	557
CV%	24.7	35.7	37.6	28.5
LSD	272	256.1	978.6	270
$P \leq 0.05$	NS	**	*	NS

Appendix 5. Seed delivery plan, 2014 – to cover the required area (20% of national area under groundnut for Malawi).

Summary			Area to be covered (20% adoption)		Seed Production (tons)					
					Breeder seed 2012		Foundation seed 2013		Certified seed 2014	
Ecology (Zone)	Demand (ha)	Promising Varieties	Total (ha)	Per variety (ha)	Area (ha)	Production (kg)	Area (ha)	Production (tons)	Area (ha)	Production (tons)
Mid Altitude	216,000	CG7	216,000	129,600	155	139,648	29	26,054	20	18,000
		Nsinjiro		64,800	6	5,000	21	18,737	18	16,000
		Chalimbana 2005		10,800	13	11,848	9	8,000	3	3,000
		ICGV-SM 01711		10,800	6	5,000	3	3,000	3	3,000
Lowland	54,000	Kakoma	54000	27,000	0	400	1	1,250	0	400
		Chitala		27,000	16	13,970	9	8,000	3	3,000
Total	270,000		270,000	270,000	195	175,866	72	65,041	48	43,400

Enhancing groundnut productivity and production in West and Central Africa

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Summary

Globally, groundnut is one of the important grain legumes with Asia and Africa being the main producing continents. West and Central Africa (WCA) accounts for almost 70% of groundnut production in Africa. The crop plays an important role in ensuring livelihood of the farmers and significantly contributes to the export sector of the countries in the region. The groundnut productivity in the region is limited by the number of abiotic and biotic stresses, such as drought, foliar diseases, rosette and aflatoxin contamination. The gap between potential and realized yield is large in subsistence farming. Improving productivity at the farm level and bridging the yield gap require varieties that have farmer- and market-preferred traits, including those that enhance and stabilize productivity, increase profitability of the crop and thereby the income of smallholder groundnut farmers. ICRISAT has been working with national partners in the region since the 1980s to improve groundnut productivity. Consequently, improved technologies were developed and promoted. The ICRISAT – WCA groundnut improvement program participated in TL II funded by the Bill & Melinda Gates Foundation to enhance groundnut productivity and production in the region. The project is built on the achievements made by ICRISAT and partners in groundnut improvement in the last 30 years. The TL II project had two phases that lasted seven years (2007 – 2014), and this report highlights the progresses made during both the phases in WCA. During phase I of the project, Mali, Niger and Nigeria were the target countries. Burkina Faso, Ghana and Senegal were included during phase II. The report focuses on three aspects: firstly, socioeconomics or targeting studies, which were mainly conducted during phase I; secondly, variety development activities conducted during both phases I and II; and thirdly, seed systems activities conducted during both phases I and II.

Key achievements

Crop improvement

The project was implemented in three countries (Mali, Niger and Nigeria) during phase I, with the addition of three other (Ghana, Burkina Faso and Senegal) during phase II. The major activities focused on farmer PVS, breeding lines development and capacity building. Significant achievements were made in all the areas.

Farmer PVS

The demand for improved groundnut varieties will increase if varieties are developed with producer- and consumer-preferred traits. Therefore, improving the performance of varieties accounting for all significant traits will contribute to the productivity and profitability of groundnut production in West Africa. PVS using the mother and baby trial approach has been used to assess farmers' trait preferences for varieties and increase farmers' exposure to new groundnut varieties. PVS were carried out at various locations in each country. The PVS started with 18 locations (six locations each in Mali, Niger and Nigeria) during the 2007 – 2008 cropping season and expanded to various locations over the years. In Mali, three pilot sites were identified in each region: Diankoute Camara, Sadiola and Dialafra in Kayes; Marako, Diorila and Faladie in Koulikoro. In Niger, the experimental sites were Doula, Guida Gaba, Koma Beri, Tanda, Tounga and Wassangou in the Dosso region. In Nigeria, the pilot sites were located in the states of Jigawa, Kano and Kastina that account for more than 50% of the total groundnut production. In each of the pilot sites a mother trial was set up in a randomized complete block design of five varieties with five replications (four new varieties and a local check). The plot size for each variety was 10 x 10 m per replication. The mother trials were implemented collectively by farmers selected by the village chief or farmers' associations. The PVS sites for Burkina Faso included Boulgou, Kouritenga and Koulpelego (Eastern region); Sanmatenga, Bam and Namemtenga (Northern region); and Boulkiemdé, Ziro and Sissili (Western region) while sites for Ghana included Wungu and Wulugu (Northern region); Sandema and Paga (Upper East); and Lawra and Tumu (Upper West). In Senegal, sites were spread in four regions: Baba Garage (North region); Darou, Paoskoto, Kayi, Nganda (Central region); Sinthioumaleme (Eastern region); and Sedhiou (Southern region).

Based on the PVS trials, the national program in Niger released four varieties (RRB, ICG 9346, J11 and Fleur 11) in 2010. In Nigeria, three short-duration rosette resistant varieties were released: SAMNUT 24 in December 2011 and SAMNUT 25 and SAMNUT 26 in December 2013. In Mali, eight varieties, including ICGV 86015 and ICGV 86124, were selected by the farmers for various regions and effort is being made for its official release. In Senegal, six varieties were released since 2007 while four varieties were released in Ghana during the same period. The released varieties as well as varieties proposed for release showed a yield advantage of up to 42% over the local varieties grown by the farmers with some of the varieties yielding over 3 t/ha in some of the locations. The on-farm trials by ISRA facilitated wide adoption of the extra-early maturing varieties (75 – 80 days) in Louga in the Northern region of Senegal where groundnut is grown by almost all the households with active participation of women. Farmer meetings were also organized in all the villages aiming at exposure to the new released varieties. The average yield for selected varieties included in PVS trials for the Kayes region of Mali from 2008 – 2010 is shown in Table 6.

In a particular year, 400 – 1,500 farmers directly or indirectly participated in the trials in each participating country. Participation of technology transfer/extension institutions and farmers organizations facilitated the access of farmers to new varieties, management practices and information dissemination. In Niger and Mali, groundnut farmers, especially women, are keen to adopt new improved varieties. Various pathways were used to share information, methodologies and outputs among the stakeholders. This was achieved through hosting workshops, annual planning sessions, progress reports, user-friendly brochures and flyers, on-farm and on-station field days, farmer-to-farmer visits and radio and television coverage. Each year, over 5,000 farmers were made aware of the availability of new improved varieties.

Table 6. An example of mean pod yield (kg ha^{-1}) of PVS varieties averaged over 2008 – 2010 from Kayes region in Mali.

	Diankounté Camara				Sadiola				Dialafra			
Variety	2008	2009	2010	Mean	2008	2009	2010	Mean	2008	2009	2010	Mean
Fleur 11	690	1,450	1,480	1,206	1,520	3,000	2,800	2,440	1,100	749	1,650	1,166
JL 24	550	990	1,450	997	1,700	2,800	2,800	2,443	1,100	646	1,015	920
ICGV86124	700	1,600	1,675	1,325	1,900	3,800	3,500	3,067	1,220	611	1,850	1,227
ICGV86015	550	1,700	1,380	1,210	2,200	3,600	3,150	2,983	1,180	589	1,750	1,173
Check	760	890	950	867	1,610	1,100	1,100	1,270	760	400	1,120	760
Mean	650	1,336	1,387	1,224	1,802	2,860	2,670	2,444	1,072	660	1,477	1,070

Breeding line development

Significant achievements were made in developing new breeding lines and it's sharing with the national partners. The intensive hybridization program was initiated at ICRISAT – Mali with various trait-specific (productivity, aflatoxin tolerance, rosette, drought, early maturity, early leafspot (ELS), late leafspot (LLS)) segregating populations developed over the years. The crossing program utilizes local or popular (ruling) varieties, improved varieties and newly identified sources of variability. Some of the parent varieties include ICG 7878, ICG 7, ICG 6222, ICG 4440, ICG (FDRS) 4, ICGV 00350, ICGV 86124, ICGV 91114, 55-437, J11, JL 24, Fleur 11, 47-10 and ICIAR 19 BT. Over the years, ICRISAT supplied more than 2,400 trait-specific advanced breeding lines (resistance to aflatoxin contamination, foliar diseases, rosette, early and medium maturing, confectionery types and drought tolerant) to the national programs of the project target countries and other countries in WCA (Table 7). Currently, ICRISAT – Mali groundnut breeding program is making selections on newly developed populations (more than 150) that are found at various stages of selection, from F_1 to F_6. Besides, over 700 advanced breeding lines are available from the breeding program that will be evaluated for yield and other traits in observation nurseries as well as replicated trials. These breeding lines will also be shared with NARES for evaluation in multi-location trials. Further, 179 lines are being genotyped and phenotyped for ELS-QTL analysis for marker-assisted breeding. The breeding program utilizes off-season seed increase under irrigation and main season evaluation of breeding materials for the traits of interest.

Table 7. Number of groundnut breeding lines distributed to NARES in WCA

	Years						
Countries	2008	2009	2010	2011	2012	2013	2014
Burkina Faso	–	–	–	–	74	–	58
Ghana	–	36	–	55	4	–	–
Niger	67	457	–	20	–	297	–
Nigeria	241	–	256	22	253	–	–
Senegal	–	–	–	5	43	3	–
Mali	380	19	–	–	46	–	–
Others	–	47	26	–	–	3	–
Grand Total	688	559	282	102	420	303	58

The distribution of advanced breeding lines to NARES partners is a continuing process. ICRISAT will continue to develop new populations for specific traits and their combinations (high yield, drought tolerance; disease resistance including ELS, aflatoxin and rosette; and human nutrition including oil content, Oleic to Linoleic acid (O/L) ratio). The program will benefit from the achievements of TL I and TL II to move forward with implementing integrated groundnut breeding in the region. The technological advancements including phenotyping platforms, genotyping tools (molecular marker-assisted selection, marker-assisted backcrossing, whole genome sequencing and genotyping by sequencing) and bioinformatics/data analyses and management tools will be utilized for increased efficiency of the breeding program. Efforts are going on to digitize the data collection and analysis process using hand held Samsung Galaxy Tabs and Panasonic Tough pads.

Seed systems

ICRISAT seed systems strategy in WCA is two-fold.

1. Improving access to seed for smallholder farmers that concentrate on subsistence production through the enhancement of local village seed systems;
2. Exploiting market niches where farmers produce for the commercial market by developing seed markets. Research on seed systems include: (a) identifying seed supply constraints and recommending options to improve its efficiency; (b) carrying out a range of market experiments to uncover the demand for seed and farmers' willingness to pay for seed; (c) to test a range of seed production and delivery options; and (d) search for options to scale-out and scale-up alternative technologies for seed production and delivery schemes. Alternative seed supply systems were characterized and tested, and cost-effective systems identified.

Identification of constraints for groundnut seed supply and delivery systems

The major constraints limiting the performance of groundnut seed systems in West Africa 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;
- Subsidized and inefficient seed production;
- Uncertain and thin seed demand;
- Missing, non-functional or irregular meetings of the National variety release committees;
- Weak integration between the seed and product markets; and
- Lack of enabling policy and institutional environments.

Strategies to enhance seed production and delivery schemes

To search for strategies to enhance seed production and delivery schemes, data on costs of seed production and delivery by all institutions involved in the seed chain were gathered. Basically, two schemes were pursued: the public seed multiplication and delivery scheme (NARES and traditional extension services) and community-based organizations (CBOs) including farmers' associations and small-scale seed producers. The results showed that seed production through the public sector institutions is very high. Direct foundation seed production through NARES in their farms and managed by NARES personnel is very costly, that is about $3.28 per kg. However, the seed production through contract growers can significantly reduce the cost of production. Farmers' associations and small-scale producers can produce high quality foundation seed at lower costs, ($1.10 per ha). The major cost items in seed production are manual harvesting, weeding, seed and land preparation. Opportunities for mechanization should be explored.

Based on the analysis of costs involved in seed production and delivery systems in West Africa, it is clear that the production of Breeder Seed should remain as the responsibility of NARES. However, the commitment of the government to support NARES in the production of breeder seed is considered essential. Revolving fund schemes within NARES should be supported by the government to ensure sustainability. The production of Basic Seed could be facilitated through contract farming with small-scale seed producers or farmers' organizations with technical backstopping from NARES. The production of certified seed should be entirely the responsibility of farmers' organization and small-scale seed producers.

Table 8. Trend in groundnut seed production (in tons) in Mali, Niger and Nigeria, Burkina Faso, Ghana and Senegal (2007 – 2013).

	Year							
Country	2007	2008	2009	2010	2011	2012	2013	Total
Mali								
Breeder	–	3.2	3.0	1.7	1.8	1.3	11.5	22.5
Foundation	–	6.3	5.1	8.6	28.2	32.7	34.5	115.4
Certified/QDS	1.2	28.3	57.5	79.4	72.0	88.0	120.0	446.4
Subtotal (1)	**1.2**	**37.8**	**65.6**	**89.7**	**102.0**	**122.0**	**166.0**	**584.3**
Niger								
Breeder	0.1	0.7	0.2	0.5	0.3	5.5	2.0	9.3
Foundation	0.9	7.7	10.4	14.2	13.3	20.8	23.0	90.3
Certified/QDS	–	11.8	27.0	25.7	62.6	147.6	215.0	489.7
Subtotal (2)	**1.0**	**20.2**	**37.6**	**40.4**	**76.2**	**173.9**	**240.0**	**589.3**
Nigeria								
Breeder	–	–	1.0	0.4	0.8	1.7	0.5	4.4
Foundation	–	1.3	10.8	2.8	–	4.5	4.0	23.4
Certified/QDS	0.8	20.3	41.0	88.5	111.6	945.9	1,061.8	2,269.9
Subtotal (3)	**0.8**	**21.6**	**52.8**	**91.7**	**112.4**	**952.1**	**1,066.3**	**2,297.7**
Burkina Faso								
Breeder	–	0.7	0.8	0.7	0.7	0.8	1.0	4.7
Foundation	–	6.0	8.0	7.0	7.5	8.0	10.0	46.5
Certified/QDS	–	80.0	78.0	71.0	75.0	77.5	85.0	466.5
Subtotal (4)	–	**86.7**	**86.8**	**78.7**	**83.2**	**86.3**	**96.0**	**517.7**
Ghana								
Breeder	–	1.2	1.1	0.9	1.8	1.6	1.4	8.0
Certified/QDS	–	9.5	12.0	14.5	11.8	12.7	10.3	70.8
Subtotal (5)	–	**10.7**	**13.1**	**15.4**	**13.6**	**14.3**	**11.7**	**78.8**
Senegal								
Breeder	–	–	–	19.0	20.0	15.0	18.0	72.0
Foundation	–	–	–	280.0	400.0	200.0	83.0	963.0
Certified/QDS	–	–	–	1,851.0	2,159.0	2,229.0	2,483.0	8,722.0
Subtotal (6)	–	–	–	**2,150.0**	**2,579.0**	**2,444.0**	**2,584.0**	**9,757.0**
Grand total	**3.0**	**177.0**	**255.5**	**2,465.9**	**2,966.4**	**3,792.6**	**4,164.0**	**13,824.5**

Efforts were made to enhance seed production of various classes (breeder, foundation and certified/ quality declared seed) and delivery schemes. A total of 15,112 tons of quality seed of all classes were produced (Table 8) during the project of which 121 tons were breeder seed, 1,239 tons were foundation seed and more than 12,465 tons were certified/QDS.

Marketing strategies for tested seed

Developing a major marketing strategy for tested seeds include the sale of small pack groundnut seed. This scheme was largely successful. More than 10,000 small pack seeds were sold. The farmers revealed their preference for smaller pack sizes ranging from 0.5 kg to 1 kg of treated seeds. However, major differences in sales/profitability were found on the positioning of selling points, the level of knowledge of agro-dealers and small-scale retailers on marketing and business skills and agro-ecological zones. Sale were found to be lower in drier areas as compared to the less dry ones.

Training in seed production, marketing and management skills

More than 1,000 farmers and extension agents were trained on seed production techniques every year. And more than 55 retailers or local seed producers from Mali and Niger were trained in small-scale seed marketing and business skills with the technical backstopping from WASA-SEEDS. During the implementation of the project, Mr Diarra Mahamadou registered and obtained his MSc degree from the University of Ouagadougou, Burkina Faso. His thesis topic focused on the “Adoption of improved varieties in project sites in Mali”.

Development and dissemination of information themes or programs

Supply and access to information by smallholder farmers remain a major constraint to adoption of technologies in West Africa. The baseline studies revealed that many smallholder farmers are not aware of new technologies and varieties. Even when they are aware of they do not have information on the modern varieties or seed supply sources. In an attempt to reduce the information constraints, the TL II project has contracted with rural radios in the intervention sites to offer information on technologies and innovations to smallholder farmers. Thus, four radio programs on crop management and seed production were developed by the RADIO Faraa in Gaya district and Radio Rounkououm in the Doutchi district of Niger. In addition to the information on crop management and seed production, during the small pack sales between April and June each year, information on improved varieties were also disseminated to the smallholder farmers. The supply of information has impacted the sales and access to seed by farmers in and around the project sites.

Adoption and impacts

This section summarizes the TL II project achievements targeting the promotion of groundnut varieties and drawing lessons from interventions in Mali, Niger and Nigeria. The groundnut outlook (ie, trends and market prospects) were studied and better understood; project sites were thoroughly characterized and varieties and traits preferred by farmers were identified. Adoption of improved groundnut varieties has increased as a result of farmers’ exposure and access to seed of improved varieties.

In addition, a total of four reports have been generated:

a. Outlook for groundnut trends and market prospects in West and Central Africa;

b. Characterizing village economies in major groundnut producing countries in West Africa: Cases of Mali, Niger and Nigeria;

c. Farmer preferences for groundnut traits and varieties in West Africa: Cases of Mali, Niger and Nigeria; and

d. Early diffusion of groundnut varieties in the Dosso region in Niger.

A synopsis of results from the reports is presented below.

Outlook for groundnut trends and market prospects in WCA

WCA lost its world groundnut production and export shares during he last four decades. The groundnut production shares declined from 27% to 20% whereas groundnut oil export shares decreased from 55% to 24%. Senegal remains the lead groundnut oil exporter (19% of world exports) in WCA, followed by Nigeria (1.20%). Senegal exports significant amount of groundnut cakes accounting for 10% of the world total. WCA’s contribution to confectionery groundnut exports fell by half from 43,956 tons to 27,495 tons from 1979 – 1981 to 2005 – 2007, respectively. Although its global share declined, groundnut production in WCA has been increasing since 1984 by about 4.6% annually due to the area expansion. Senegal and Nigeria remain among the largest world groundnut producers. Groundnut still remains a major source of employment, income and foreign exchange in many WCA countries. Therefore, there is a need to reassess the market prospects and highlight opportunities for the region to regain its market share. The competitiveness of WCA groundnut in the domestic, regional and international markets has been limited by the low productivity, aflatoxin regulations, and stricter grades and standards. Relative prices of groundnut oils are higher in the international markets making these products less competitive as compared to the oil palms, cotton oil and other oil fruits. There are market niches for confectionery groundnut. Access to this market would require knowledge of market requirements, especially EU markets. To regain its competitiveness, significant increase in the groundnut productivity and production, promotion of technologies to reduce aflatoxin contamination and establishment of grades and standards are needed.

Baseline surveys in project countries

Three baseline studies were carried out from November 2007 to February 2008 in program and non-program sites in Mali, Niger and Nigeria, where the TL II project started its activities in 2007. A purposive random sampling was used to select program sites: Kayes and Koulikoro from Mali, Dogondoutchi, Dosso and Gaya from Niger, and Jigawa, Kano and Katsina from Nigeria. Next to every selected program site was a non-program site (a neighboring village) or the non-intervention area. In each program site, 10 on-farm trial participants were selected from the population of participants and five non-trial participants were selected from the population of non-participants. In case the number of on-farm participants was less than 15 farmers, enumerators were asked to survey all on-farm trial participants with the remaining unchanged. In total, 298 non-trial participants and 494 trial participants were surveyed.

The survey results indicated that groundnut was planted in about 36% of total cultivated area in Mali, 15% in Niger and 34% in Nigeria. Groundnut contributed to 64% of household cash revenues in Mali, 66% in Niger and 54% in Nigeria. It accounted for 28% of the total value of crop production in Mali, 31% in Niger and 23% in Nigeria. No statistical differences were found between the program and non-program villages. The groundnut market participation was very high where many households sold groundnut in Mali and Niger and many purchased groundnut in Nigeria. In Mali, 46% of households were net-sellers with no differences between the program and non-program sites. In Niger, about 79% of households were net-sellers of groundnut with high rates in program versus non-program sites. In Nigeria, 72% of households were net-buyers of groundnut with significantly more households buying groundnut in program versus non-program sites. Gender wise, 85% of private or individual plots belonged to women in Mali and 35% in Niger. In Nigeria, there was little participation of women in groundnut production activities. However, women were largely involved in local groundnut processing activities. There were no differences based on program and non-program villages.

Modern groundnut variety uptake in surveyed sites was estimated to be less than 5% except in the Dosso region in Niger, where this was estimated to be 14% of the groundnut planted area. The survey results showed that about 40% of groundnut area was planted with the variety 47-10 in Mali. In Niger, 47% of area was planted with the variety 55-437 and in Nigeria the variety ex-Dakar (ie, 55-437) was planted on 41% of groundnut area. These are ruling varieties introduced at colonial times in the 1950s. Households sourced planting seed from past harvests, village markets, other farmers, family and parents. However, majority of the seed was sourced from the past harvest accounting for 80% in Mali, 86% in Niger and 71% in Nigeria. The major constraint in using improved varieties that has been reported by the farmers is the non-availability of seed for 83% in Mali, 60% in Niger and 56% in Nigeria. The households have little access to seed of the varieties released less than 20 years ago. Lack of cash was cited as a major constraint in Niger and Nigeria. Low grain and haulm yields, lack of information on crop management, fitness in association and undesirable color were also cited as the major constraints in Nigeria. The use of other inputs (credit, inorganic and organic fertilizers) remains limited in the surveyed areas where, on an average, farmers used less than $20/ha of inputs in Mali, $21 in Niger and $123 in Nigeria.

The major lessons drawn from the study include:

1. Groundnut is a major source of cash for smallholder farmers in WCA;
2. Groundnut is a major source of cash for women farmers;
3. Many households participate in the groundnut markets compared to other crops such as cereals;
4. Old ('ruling') varieties are still dominant;
5. The use of inputs, such as fertilizers in groundnut cultivation is very limited; and
6. Majority (71 – 86%) of the households still draw their seed from past harvests.

Recognizing farmers' preference for traits and varieties

The PVS trials revealed that the farmers were able to discriminate most of the major plant and seed traits. The trials enabled assessment of farmers' preferences for plant and seed traits of selected varieties using structured surveys administered to a panel of farmers in each of the pilot sites. The color of the leaves, maturity (short cycle), number of pods, pod size, constriction, pod yield, pod filling and taste were the important attributes explaining farmers ranking for varieties in Mali. In Niger, the color of the leaves, the number of pods, pod filling, pod beak, and pod yield were the most important traits sought by the farmers. In Nigeria, plant vigor, plant maturity, plant type, number of pods, pod size, haulm yield and pod yield were the important traits. For some traits, varieties selected for the PVS were similar or identical restricting the farmers to differentiate between the varieties based on those characteristics. The varieties selected by farmers can be site-specific, and attributes such as color of leaves, pod reticulation and pod beak tends to get neglected. The lessons learned include: (1) a better choice of varieties for PVS with different traits and (2) the need for targeting varieties to recommendation domains.

Early diffusion of groundnut varieties in the Dosso region, Niger

The contribution of groundnut to cash income of smallholder farmers has significantly increased in the surveyed areas that are attributed by the increase in the total value of groundnut sales. Sixty-six percent of household cash revenues contribution of groundnut during 2007 – 2008 has increased to 83% in 2009 – 2010. No statistical differences were found between the program and non-program villages. The groundnut market participation has also shown an increase. About 79% of households were net-sellers of groundnut in 2007 – 2008 against 93% in 2009 – 2010 while 39 and 42% of households were net-buyers of maize and pearl millet, respectively.

The uptake of modern groundnut varieties in the Dosso region in Niger has increased significantly from 14% (2007 – 2008) of groundnut area planted with improved varieties to 64% (2009 – 2010). Variety RRB accounted for more than 90% (ie, 56%) of the area covered with improved varieties. The use of other inputs (credit, inorganic and organic fertilizers) has not improved in the surveyed areas. But access to seed has significantly improved as a result of building seed supply systems in the project sites. Access to major productive resources is still limited for women, and female farmers still plant less groundnut area (0.77 ha) than men (0.94 ha). In particular, female farmers have almost no access to organic fertilizers. About 2.5% of surveyed female farmers used manure in their fields against 22% for men.

Capacity building

NARES in WCA lack human resources and infrastructure to execute an efficient groundnut breeding program. These weaknesses have limited the flow of improved varieties and farmers continue to grow old varieties that were developed or introduced more than half a century ago. One of the objectives of TL II project has been to enhance the capacity of some of the NARES to breed groundnut with multiple attributes.

Degree training

Ms Nana Mariama Idi Garba of INRAN, Niger, completed her MSc program in breeding at the University of Niamey in 2010. Mr Mamary Traore, IER-Mali, completed his MSc from the University of Ouagadougou, Burkina Faso in 2012. Mr Coulibaly Adama completed his PhD from Ghana in April 2014. Mr Adama Zongo from Burkina Faso and Mr Ousmane Sanogo from Mali started their PhD research on groundnut breeding in 2013. In addition to the graduate students, three undergraduate students conducted their final year bachelor's degree thesis work on groundnut breeding. These included Mr Prosper Gassinta and Mr Harara of the Polytechnic of Katibougou, Mali and Mr Youssouf Camara from the University of Niamey, Niger. Two PhD students (from Niger and Nigeria) at the West Africa Center for Crop Improvement (WACCI), University of Ghana, were also mentored to formulate and present their thesis research project proposals on groundnut breeding.

Non-degree training

NARES staffs managing the groundnut breeding programs were offered hands-on training on breeding principles and ways to manage a breeding program including priority skills such as hybridization, data capture and analysis. At the start of the project, ICRISAT – Mali conducted two day in-country training workshops in Mali, Niger and Nigeria on breeding methods and data capture. A total of 15 (five in Mali, two in Niger and eight in Nigeria) participants benefited from the training. A methods manual was prepared. A training module on crop management and seed production was also produced. This was shared with the project staff in the partner countries. A 10-day intensive training workshop on groundnut breeding methods and techniques was held at ICRISAT – Mali from 26 January to 6 February 2009 where four scientists from Nigeria, two from Mali and one from Niger were involved. The course covered a range of topics where a technical guide for groundnut breeding technologies of 10 training modules was compiled in English and French. Two technical guides in groundnut breeding and PVS were prepared and their soft copies were made available to the participants. The project also contributed to the training of research technicians from IER (Mali), INRAN (Niger) and ICRISAT – Mali in data capture and analysis using the GENSTAT statistical program from 9 – 20 February 2009. A total of 33 participants attended the training program. A breeder and pathologist from the six project countries (Mali, Ghana, Burkina Faso, Nigeria, Niger and Senegal) were involved in the one week training at ICRISAT – Mali conducted in October 2013 on groundnut breeding techniques and disease management. The phenotyping workshop was attended by 12 participants involving senior breeders, plant pathologists (Ghana, Nigeria and Senegal) and senior research assistants (Burkina Faso, Niger and Mali).

Physical capacity building

The phenotyping facilities (laboratory and field) in Mali, Niger and Nigeria were rehabilitated. In Mali, a half-hectare plot at the same research station of IER was fenced for drought and foliar disease screening or phenotyping. In Niger, the irrigation system at Maradi was rehabilitated to enable phenotyping for drought stress, generation advance and assurance of production of breeder seed. This involved purchase of two immersible water pumps and regeneration of wells to ensure constant water availability and an 18 KVA generator to ensure electric power supply. The pathology screen house was also rehabilitated to ensure disease phenotyping and maintaining inoculums for target diseases and insect pests. Other infrastructure improvements included: renovation of the seed store, purchase of laboratory equipment, such as electronic balances, refrigerator, plastic sheeting, groundnut sheller, a motorcycle, a digital camera and office furniture. In Nigeria, screen house phenotyping facility for groundnut rosette disease and raising the aphid vector needed rehabilitation. The genotyping facility was enhanced by the purchase of an Alpha merger mini analysis system, digital thermal printer, alpha InfoTech computer and high gloss thermal paper. At the beginning of the project, no hybridization activity was conducted at any of the participating NARES. After the training of technicians in managing crossing blocks and the rehabilitated facilities, hybridization has been initiated at INRAN (Niger) and IAR (Nigeria).

Farmer's Training

Before the implementation of the PVS trials, a 1- to 2-day training session was conducted for the participating farmers in the respective locations. Group meetings were also held during field monitoring by the project staff. More than 2,000 persons including farmers and extension agents have benefited from the training by the end of 2009. In 2010, a total of 150 women from the farmer groups in five villages in Sanakoroba district of Mali participated in a pre-sowing 2-day training program in good practices of producing groundnut. In November 2013, a total of 48 women from farmer groups were trained in seed entrepreneurship including postharvest seed management, marketing, book keeping and related financial or business management aspects. In addition, 10 village agents (all men) and two staff (one woman and one man) of PLAN – Mali also benefited from the training. ICRISAT – Mali provided the required facilities. IER – Mali facilitated training of 75 farmers on integrated crop management at the sites in the Kayes region where demonstration plots were established.

Apart from the training, efforts were made to enhance the farmers' awareness of improved varieties through various pathways such as hosting workshops, annual planning sessions, progress reports, user-friendly brochures and flyers, on-farm and on-station fields days, farmer-to-farmer visits and radio and television coverage. Simplified brochures on varieties grown and crop management were prepared in French for eventual translation into the local language – Bambara for Mali. The field days targeting a range of clientele (farmers, researchers, development partners and private sector) were organized by ICRISAT and NARES in each country. On an average, 30 – 300 persons participated in the open field days every year and the events were well covered on state as well as local television and radio channels in each country. During the 2010 crop season, for example, six field days or farmer meetings were held in Nigeria at eight demonstration trial sites and one at Samaru, before the harvest. A total of 932 farmers, all men, participated in the field days. The number of participants ranged from 87 to 264 per location. IER – Mali organized an on-farm field day at Sadiola with 94 farmer participants. An on-station field day at *Same*, chaired by the regional governor attracted 150 participants. During all these events, the participants were familiarized with new varieties and other productivity enhancing technologies. A documentary film of 20 minutes was prepared in Niger based on the activities in the pilot sites to raise stakeholders' awareness of newly released varieties. This is expected to reach a wider audience.

Lessons learned

- The release of new breeding lines remains a very slow process, particularly in Mali. This is largely due to variety release committees not meeting or the NARES partners not being aggressive enough to promote new varieties through nationally coordinated trials and on-farm validation tests. However, through PVS the variety release process can be fast-tracked.
- The major challenge faced by the women groundnut farmers is the limited access to good land and farm equipment to reduce drudgery in the production and processing of groundnut.
- The project involves many sites, of which some are situated in isolated locations, making coordination and monitoring a challenge.

Constraints

The main constraints cited by the partners are as follows:

- Lack of reliable transport to monitor activities, thus, limiting the spread of activities;
- Lack of suitable cold storage to maintain seed in good conditions before planting;
- Poorly motivated technicians;
- Difficulty in identifying candidates for the graduate degree training programs and delays in starting the course work;
- A lack of a critical mass of scientists in Niger and Mali to carry out the groundnut breeding activities;
- Fund disbursement procedures coupled with different accounting systems in the NARES has created challenges that can have a negative impact on the full implementation of the project. This was the case for Nigeria.

Enhancing groundnut productivity and production in Bangladesh and India

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Summary

Bangladesh: In phase II, a total of 131 PVS trials were conducted in nine districts. Two short duration high yielding varieties, BARI Chinabadam-8 and BINA Chinabadam 4, were identified to replace an obsolete groundnut variety, Dhaka 1. New crosses involving nine parental lines were made, and promising selections were made from the evaluated breeding populations (F_2 to F_5). Previously, 72 lines were received from ICRISAT – India and were evaluated. The superior lines were selected for early maturity, large seed size and high yield as edible types.

India: The TL II project was conducted in two phases and this report highlights the progress through 2008 to 2013. In phase I, Karnataka and Tamil Nadu were included while in phase II, Bihar and Odisha were added along with the phase I states. Through PVS and paired comparison (PC) trials conducted over years, a number of promising varieties were identified. The farmers' preferred varieties in Bihar were ICGV 02266 and ICGV 91114 in Araria and Purnea districts and ICGV 93648, ICGV 89280 and ICGV 91114 in Jehanabad and Nawada districts. The Farmers' in Araria also preferred Dh 86 for spring season cultivation. ICGV 91114, GPBD 4, ICGV 00350, Chintamani-2 and R2001-2 in Karnataka and ICGV 02266 in Odisha have been identified as the most promising varieties by the farmers. In Tamil Nadu, a Virginia bunch variety, ICGV 87846 (CO 6) and a Spanish bunch variety, ICGV 00351 (CO 7) have been released for cultivation. Other varieties selected through multilocation evaluations were CTMG 6, CTMG 7 and Dh 236 in Karnataka; ICGV# 02266, 07220, 04623, 07213 and 10004 in Odisha; ICGV# 01263, 96155, 02266, 03128, 06146, 07018 and COG 0402 in Tamil Nadu, which will be entered in states or national trials for further evaluation. UAS Dharwad and UAS Bangalore identified 10 and 24 varieties, respectively from the international trials. Tamil Nadu Agricultural University (TNAU) identified seven varieties either with resistance to drought or high oil types. To support breeding programs, ICRISAT made over 900 crosses and provided project partners 192 sets of international trials, 449 advanced lines and 236 trait-specific breeding populations. The participating centers also generated their own breeding populations involving ICRISAT-bred varieties and made large number of single plant selections and bulks for further evaluations.

Seven scientists from Bangladesh were trained on various aspects of groundnut breeding, including integrated molecular breeding. In India, a manually operated rainout shelter for phenotyping drought tolerance, equipment for measuring drought tolerance, and sprinkler irrigation systems for screening for resistance to foliar diseases were established at some of the centers in Karnataka and Tamil Nadu. Six students (three each for PhD and MSc) have successfully completed their research and submitted their thesis under this project. A total of 10 scientists or technicians received hands-on training on groundnut breeding, screening for resistance to virus diseases, data management and statistical modules and on integrated molecular breeding.

Background

Bangladesh: Groundnut is the third important oilseed crop in Bangladesh and is mainly consumed as roasted nut (*badam*) or as confectionary item. The acreage and production in 2011 was 87,576 ha and 139,333 t, respectively, accounting for 11% and 17% of total oilseed cropped area and production in Bangladesh, respectively (DAE, 2012). Groundnut is the principal crop of Char land and is cultivated in the Char areas that generally remains submerged in water throughout the rainy season (June to September). The soils in Char agro-ecologies are highly prone to soil erosion and are characterized by sand to sandy-loam type, low soil-water holding capacity and poor nutritional status of soils. Most of the areas consist of riverbed and riverine region. In every 3 – 5 years, the Char area is increased by 36,000 ha, which should be considered for crop production. Groundnut is cultivated in post-rainy season. The major groundnut growing districts are Dhaka, Mymensingh (Dhaka division), Comilla, Chittagong, Rangamati (Chittagong division), Sylhet (Sylhet division), Jessore, Rajshahi (Khulna division) and Rangpur (Rangpur division). The key constraints to groundnut production include lack of quality seed production and supply, cultivation of obsolete variety (Dhaka 1), drought, poor soil fertility coupled with low input use, lack of awareness on production technology and trained manpower and lack of storage facilities. Dhaka-1, an age-old variety, is preferred by farmers for its early maturity. Bangladesh participated in TL II phase II project (2011 to 2013) to strengthen its groundnut breeding program and identify promising varieties for cultivation.

India: Globally, India holds the second position in terms of total groundnut production. Groundnut oil accounts for the third largest oil produced in India after rapeseed and soybean oil (FAO Stat, 2012). The groundnut acreage in India declined by 30.1% from 8.3 m ha in 1991– 1993 to 5.8 m ha in 2009 – 2011. However, the average productivity increased by 28.5% from 924 to 1188 kg ha^{-1} during the same period, which led to 10.4% decline in total production from 7.7 to 6.9 million tons. The groundnut cropped area during the rainy season declined by 29% while the post-rainy season cropped areas reduced by 38.5% during the same period. The linear productivity growth was higher (18 kg per year) in post-rainy season than the rainy season (14.5 kg per year). The decadal-wise linear growth in nation's productivity was in increasing trend (7 kg/year in 1970 – 1980 to 26 kg/year in 2000 – 2010) over the last four decades period. Several reasons contribute to low productivity, which includes abiotic and biotic stresses, lack of access to quality seeds and other inputs and improved technologies. However, there exists an enormous potential to improve the groundnut yields in the country through adoption of improved varietal technology by the farmers and quality seed supply.

In Bihar, groundnut is mainly grown in Araria, Purnea, Nawada and Jehanabad districts. Two crops, namely *kharif* and spring or summer, are commonly grown. The spring or summer groundnut is fully irrigated while *kharif* crop is rain-fed. The production in *kharif* is hampered by heavy rainfall. Some districts (Nawada, Jehanabad, Gaya and Rohtas) receive less rainfall therefore, providing a good scope to cultivate groundnut as seed crop with yields of about 1 ton ha^{-1}. Short duration varieties with resistance to foliar diseases and some level of tolerance to drought with seed dormancy are needed. R 20 is the most commonly grown and preferred cultivar. In Karnataka, the major groundnut producing districts (with more than 40,000 ha) are Chitradurga, Tumkur, Bellary, Gadag, Koppal and Bijapur. The groundnut yields are low as the crops suffer from moisture stress and susceptibility to insect pests and diseases. Groundnut is also grown as post-rainy season irrigated crop (with more than 20,000 ha) in Bagalkot, Bijapur, Yadgir and Raichur districts. TMV 2 is a widely grown cultivar. Other varieties introduced and popularized in the state are GPBD4 and ICGV 91114. The groundnut production in Odisha is about 79,000 t, with major produce (68.5%) from post-rainy season crop after paddy with an average productivity of 1,189 kg ha^{-1}. TMV 2, AK 12- 24, Smruti and Kishan are the most popular varieties. In Tamil Nadu, groundnut is grown in about 0.38 m ha with a production of 1.06 t. The state recorded highest productivity (2,751 kg ha^{-1}). About 62% of the crop acreage is under rainfed conditions. The most commonly grown varieties include TMV 7, VRI 2, VRI 3, Co Gn 4 and TMV Gn 13.

The Bill & Melinda Gates Foundation supported TL II project ran for six years in two phases in the selected states in India and three years in Bangladesh. In phase I, the states of Karnataka and Tamil Nadu were included while in phase II, Bihar, Karnataka, Odisha and Tamil Nadu were included from India. Bangladesh was included in phase II. This report details the progress achieved towards developing or identifying improved groundnut varieties and capacity building (both human capital and infrastructure development) to support the development of improved varieties.

Key achievements

A. Crop improvement

PVS

Bangladesh

PVS were conducted in Jamalpur, Mymensingh, Kishoregong, Lalmonirhat, Kurigram, Pabna, Panchagarh, Noakhali and Cox's Bazzar districts. Four early maturing groundnut varieties were evaluated in 131 trials, and two varieties (BARI Chinnabadam 8 and BINA Chinnabadam 4) were identified, which produced 28 – 58% greater pod yield over local control that were found suitable for cultivation.

India (Bihar)

PVS trials involving eight Spanish bunch varieties were conducted in four villages each in Araria, Purnea, Jehanabad and Nawada districts. A total of 80 PVS trials in 2012 and 40 paired comparisons (PC) trials in 2013 were conducted. In Araria and Purnea, ICGV 02266 emerged as a preferred variety and recorded a 25% pod yield increase over the local check. ICGV 93648 and ICGV 91114 were farmer-preferred varieties in Jehanabad and Nawada districts. Dh 86 is also preferred by farmers of Araria district for spring cultivation.

Karnataka

UAS, Bangalore: A total of 625 PC trials of the improved varieties (ICGV 91114 and Chintamani 2) with local variety (TMV 2) were conducted in the farmers' fields in four districts. ICGV 91114 on an average across 429 demonstrations produced 25% greater yield over TMV 2 (average pod yield, 1,323 kg ha^{-1}) (Table 9) while Chintamani 2 showed 29% greater pod yield over TMV 2 (average pod yield, 1,379 kg ha^{-1}) (Table 10).

Table 9. Performance of ICGV 91114 and TMV 2 in PVS and PC trials in four districts of Karnataka, 2008 to 2013, rainy seasons.

			Pod yield (kg ha^{-1})		
Season	Name of the trial	No. of demonstration	ICGV 91114	TMV 2	Superiority over TMV 2 (%)
2008 rainy	PVS	9	1,073	1,076	–
2009 rainy	PVS	12	1,490	1,180	26
2010 rainy	PC	33	823	640	28
2011 rainy	PC	150	1,825	1,423	28
2012 rainy	PC	100	1,734	1,521	14
2013 rainy	PC	125	1,645	1,257	31
Total / Mean		429	1,649	1,323	25

PVS = participatory variety selection; PC = paired comparisons

Table 10. Performance of Chintamani-2 (KCG-2) in PVS and PC trials in three districts of Karnataka during rainy season.

Season	Name of the trial	No. of demonstration	Pod yield (kg ha^{-1})		
			Chintamani 2	TMV 2	Superiority over TMV 2 (%)
2008 rainy	PVS	9	1,527	1,076	42
2009 rainy	PVS	13	1,593	1,180	35
2011 rainy	PC	50	1,921	1,381	39
2012 rainy	PC	75	1,875	1,652	14
2013 rainy	PC	125	1,698	1,257	35
Total / Mean		272	1,777	1,379	29

PVS = participatory variety selection; PC = paired comparisons

UAS, Bangalore: A total of 100 frontline demonstrations (0.4 ha each), involving ICGV 91114, Chintamani 2 and TMV 2, were conducted at farmers' fields in Chitradurga, Tumkur, Chikballapur and Kolar districts. ICGV 91114 and Chintamani 2 on an average produced greater pod yield of 23% and 19%, respectively, over TMV 2 (Tables 11 and 12).

Table 11. Performance of ICGV 91114 in frontline demonstrations in four districts of Karnataka.

Season	Name of the trial	No. of demonstration	Pod yield (kg ha^{-1})		
			ICGV 91114	TMV 2	Superiority over TMV 2 (%)
2011 rainy	FLD	20	1,700	1,425	19
2012 rainy	FLD	20	1,773	1,458	22
2013 rainy	FLD	10	1,896	1,432	32
Total / Mean		50	1,768	1,440	23

FLD = Frontline demonstrations

Table 12. Performance of Chintamani 2 in frontline demonstrations in four districts of Karnataka.

Season	Name of the trial	No. of demonstration	Mean pod yield (kg ha^{-1})		
			Chintamani 2	TMV 2	Superiority over TMV 2 (%)
2011 rainy	FLD	20	1,757	1,472	19
2012 rainy	FLD	20	1,709	1,468	16
2013 rainy	FLD	10	1,800	1,475	22
Total / Mean		50	1,746	1,471	19

FLD = frontline demonstrations

UAS, Dharwad: The FPV trial in 2011 rainy season was conducted on 96 farmers' fields in Badami, Bagalkot and Bilagi in Bagalkot district. ICGV 00350 produced an average of 13% greater pod yield over TMV 2 (pod yield, 1,145 kg ha^{-1}) (Table 13). In 2012 rainy season, the PC trial was conducted on 20 farmers' fields in Bagalkot district. ICGV 00350 on an average produced 19% greater pod yield over

Table 13. Average performance of ICGV 00350 and TMV 2 in farmers' fields in Bagalkot district, Karnataka during the rainy season, 2011.

Panchayat	No. of farmer	Pod yield (kg ha^{-1}) ICGV 00350	TMV 2	Superiority over TMV 2 (%)
Badami	43	1,302	1,150	13
Bagalkot	28	1,261	1,125	12
Bilagi	25	1,307	1,158	13
Total / Mean	96	1,291	1,145	13

TMV 2 (pod yield, 1,902 kg ha^{-1}). In 2013 rainy season, PC trial was conducted on seven farmers' fields in Bagalkot district. ICGV 00350 on average produced 10% greater pod yield over TMV 2 (pod yield, 1987 kg ha^{-1}).

ICGV 00350 in 2009 and 2010 rainy seasons produced 43 – 78% greater pod yield over TMV 2 (Table 14) in large scale (0.4 ha) field trials in Bagalkot while in 2008 rainy season, it produced 226% greater pod yield over TMV 2 due to heavy incidence of foliar diseases. ICGV 00350 was most preferred by the traders.

Table 14. Performance of ICGV 00350 in PVS trials conducted at Badami, Bagalkot and Bilagi, in Bagalkot district, during the rainy seasons of 2009 and 2010.

2009 rainy

Variety	Mean pod yield (kg ha^{-1}) Badami (2 villages and 10 farmers)	Bagalkot (2 villages and 6 farmers)	Bilagi (3 villages and 4 farmers)	Average pod yield (kg ha^{-1}) (7 villages and 20 farmers)	Superiority over TMV 2 (%)
ICGV 00350	1,655	2,700	2,670	2,172	78
TMV 2	899	1,643	1,380	1,218	

2010 rainy

Variety	Mean pod yield (kg ha^{-1}) Badami (76 trials)	Bagalkot (102 trials)	Bilagi (14 trials)	Average pod yield (kg ha^{-1}) (192 trials)	Superiority over TMV 2 (%)
ICGV 00350	1,482	1,482	1,478	1,482	43
TMV 2	1,028	1,039	1,057	1,036	

UAS, Raichur: On an average, ICGV 00350 and R2001-2 produced 114% to 116% greater pod yield over TMV 2 (Table 15). However, both the varieties have some drawbacks from farmers' perspectives: no fresh seed dormancy in ICGV 00350 and low shelling turnover (%) in R2001-2. ICGV 00350 was also evaluated in PVS trials during 2010 rainy season in Raichur district. On an average, ICGV 00350 produced 44% greater pod yield over TMV 2 (pod yield of 937 kg ha^{-1}) (Table 16).

Table 15. Performance of selected varieties in paired comparison trials, 2012 rainy season, Raichur district, Karnataka.

	Pod yield (kg ha^{-1})				
	Taluk				
Varieties	Raichur	Deodurga	Lingasugur	Mean	% increase over TMV 2
ICGV 00350	976	1,147	945	1,023	114
TMV 2 (C)	467	543	425	478	
R 2001-2	1,015	1,236	915	1,055	116
TMV 2 (C)	512	488	466	489	

Yield levels are low in Raichur and Lingasugur due to low rainfall

Table 16. Performance of ICGV 00350 and local check, 2010 rainy season, Raichur district, Karnataka.

	Pod yield (kg ha^{-1})				
	Taluk				
Varieties	Raichur	Deodurga	Lingasugur	Mean	% increase over TMV 2
ICGV 00350	1,456	1,163	1,425	1,348	44
Local check	959	890	964	937	

Odisha

OUAT, Bhubaneswar evaluated three varieties (ICGV# 00308, 02266 and 07213) together with control (Smruti) in PVS trials in target districts, and farmers identified ICGV 02266 as the best performing variety.

Tamil Nadu

A Virginia bunch variety, ICGV 87846, which was evaluated in PVS and PC trials in 985 trials during 2008 – 2013 rainy seasons in Namakkal district, produced an average of 41% greater pod yield over local control (1,066 kg ha^{-1}) (Table 17). A Spanish bunch variety, ICGV 00351, was evaluated in 731 PVS and PC trials in Erode district during 2008 – 2013 rainy seasons and in 720 PVS and PC trials in Thiruvannamalai during 2009 – 2013 rainy seasons. In Erode district, ICGV 00351 produced 30% greater pod yield over TMV Gn 13 (pod yield, 1,340 kg ha^{-1}) (Table 18) while in Thiruvannamalai district, it produced 20% greater pod yield over TMV Gn 13 (pod yield, 1,587 kg ha^{-1}) (Table 19). Both the varieties have been released as CO 6 (ICGV 87846) and CO 7 (ICGV 00351) for cultivation in these districts in Tamil Nadu.

Table 17. Performance of ICGV 87846 in on-farm trials in Namakkal district of Tamil Nadu, from 2008 to 2013 rainy seasons.

Season	Name of the trial	No. of trials	Mean pod yield (kg ha^{-1}) ICGV 87846	Mean pod yield (kg ha^{-1}) Local	Superiority over local (%)
2008 rainy	PVS	90	1,630	869	88
2009 rainy	PC	237	1,019	646	58
2010 rainy	PC	198	1,985	1,457	36
2011 rainy	PC	150	1,984	1,634	21
2012 rainy	PC	160	1,340	888	51
2013 rainy	PC	150	1,245	954	31
Total / Mean		985	1,503	1,066	41

PVS = participatory variety selection; PC = paired comparisons

Table 18. Performance of ICGV 00351 in on-farm trials in Erode district, Tamil Nadu, from 2009 to 2013 rainy seasons.

Season	Name of the trial	No. of trial	Mean pod yield (kg ha^{-1}) ICGV 00351	Mean pod yield (kg ha^{-1}) TMV Gn 13	Superiority over TMV Gn 13 (%)
2009 rainy	PVS	107	1,185	868	37
2010 rainy	PC	103	2,227	1,717	30
2011 rainy	PC	150	2,302	1,837	25
2012 rainy	PC	221	1,343	894	50
2013 rainy	PC	150	1,853	1,576	18
Total / Mean		731	1,746	1,340	30

PVS = participatory variety selection; PC = paired comparisons

Table 19. Performance of ICGV 00351 and TVG 004 in on-farm trials in Thiruvannamalai district, Tamil Nadu, from 2008 to 2013 rainy seasons.

Season	Name of the trial	No. of trials	Mean pod yield (kg ha^{-1})			Superiority over TMV GN 13 (%)	
			ICGV 00351	TMV Gn 004	TMV Gn 13	ICGV 00351	TMV Gn 004
2008 rainy	PVS	99	1,429	1,270	996	43.5	28
2009 rainy	PVS	81	1,580	1,417	1,293	22.2	10
2010 rainy	PC	90	1,890	2,235	1,888	–	18
2011 rainy	PC	150	2,313	–	1,903	21.5	–
2012 rainy	PC	150	1,998	–	1,585	26.1	–
2013 rainy	PC	150	1,885	–	1,643	14.7	–
Total / Mean		720	1,901	1,636	1,587	20.0	3

PVS = participatory variety selection; PC = paired comparisons

1. Multi-location testing

Karnataka

UAS, Bangalore evaluated seven varieties across locations and seasons in Chitradurga, Tumkur, Chikballapur and Kolar districts for identification of superior varieties. In 2011 rainy season, CTMG 6 and CTMG 7 produced 65% to 83% greater pod yield over TMV 2 (pod yield of 1,647 kg ha^{-1}) while in 2013 rainy season, these two varieties produced 49% to 62% greater pod yield over TMV 2 (pod yield, 1,761 kg ha^{-1}). The international trials were also evaluated by the university for the two rainy seasons. In IMGVT, ICGV# 06046, 06049 and 06122 produced 22% to 26% greater pod yield over control Chintamani 2 (pod yield, 2.52 tons ha^{-1}) while ICGV# 07286 and 07403 in IDGVRT produced 19% to 43% greater pod yield over Chintamani 2 (pod yield, 2.15 tons ha^{-1}). In IFGRVT, ICGV# 06139, 06145 and 06146 produced 44% to 63% greater pod yield and had similar rust and LLS disease score as of Chintamani (pod yield, 2,109 kg ha^{-1}; disease score, 2).

UAS, Dharwad evaluated seven Spanish bunch varieties for pod yield and agronomic traits during 2012 rainy season. The pod yield ranged from 3.48 tons to 4.49 tons ha^{-1}, Dh 236 being the highest yielder and resistant to rust and LLS. It produced 16% greater pod yield over TMV 2 (pod yield of 3,479 kg ha^{-1}). The international trials were also evaluated by the university. ICGV# 07211, 07214, 00338 and 07213 in ISGVT produced 12 – 25% greater pod yield over JL 24 (2.86 tons ha^{-1}), ICGV 07211 and ICGVT 07213 being the resistant varieties to rust and LLS. The pod yield of ICGV 99160 in IMGVT was comparable to control, GPBD 4 (3,409 kg ha^{-1}); however, it showed greater 100-seed weight (51 g) than control (35 g). In ICGVT, ICGV 06189 produced 18% greater pod yield over TGLPS 3 (3.63 tons ha^{-1}). It showed 6% and 20% greater SMK% and 100 seed weight over TGLPS 3 (SMK, 88%; 100-seed weight, 54 g). Four varieties in IFDRGVT yielded at par and had similar disease score as of GPBD 4 (pod yield, 3.8 tons ha^{-1}; rust and LLS score, 2).

Odisha

OUAT, Bhubaneshwar identified ICGV 07220 as a drought tolerant variety and ICGV 10004 as an early maturing variety.

Tamil Nadu

TNAU identified ICGV# 01263, 96155 and 02266 as drought and foliar diseases resistant varieties and ICGV# 03128, 06146, 07018 and 07222 as high oil producing varieties.

All these varieties identified from multi-location or international trials will be further evaluated in state or national trials to identify promising varieties for release.

2. Generation of new breeding populations

During the period of 2007 – 2013, ICRISAT made a total of 919 crosses to generate breeding populations for early to medium duration, resistance to aflatoxin and foliar diseases, tolerance to drought and heat stress, confectionary and oil types, seed dormancy and minerals (Fe and Zn) dense types. In Karnataka, UAS Bangalore made 26 new crosses to generate breeding populations' specific to high yield, tolerance to drought, resistance to foliar diseases, early maturity and high shelling out-turn. The segregating generations (F_2 – F_7) involving 102 crosses were advanced and selections were made. UAS Dharwad selected 138 single plant selections for drought tolerance and 180 for early maturity and resistance to foliar diseases. In addition, 34 single plants and 23 bulks with confectionary characteristics were made. The marker-assisted backcross breeding has been initiated to select for rust resistance. BC_1F_2 generation was checked through MAS to pick up the segregants containing simple sequence repeats (SSRs) associated with rust resistance. UAS Raichur made 40 new crosses to generate foliar disease resistant breeding populations. In addition, 221 single plant selections and 12 bulks were advanced combining high yield, early maturity, resistance to pest and diseases, better pod or seed characteristics and high oil types. Bihar Agricultural University, Sabour made 10 crosses, evaluated segregating populations (F_2 – F_4) and made promising selections. OUAT Bhubaneshwar made 10 crosses, evaluated segregating populations (F_2 – F_7) from 32 crosses and made promising selections.

3. Distribution of advanced lines and breeding populations

During 2007 – 2013, ICRISAT provided the partners with 192 sets of trials (short to medium duration, confectionary types, and resistant to aflatoxin, drought and foliar diseases). In addition, ICRISAT supplied 449 advanced lines and 236 trait-specific breeding populations for local adaptation and selection by the project partners.

B. Seed systems

The project was implemented in two phases, in partnership with Indian universities, such as Tamil Nadu Agricultural University, University of Agricultural Sciences – Dharwad (UAS – D), University of Agricultural Sciences – Bangalore (UAS-B), University of Agricultural Sciences – Raichur (UAS – R), Bihar Agricultural University, Orissa University of Agriculture and Technology – Bhubaneshwar and Bangladesh Agricultural Research Institute (BARI) – Bangladesh. Phase I was implemented in Karnataka and Tamil Nadu, India and phase II involved Odisha and Bihar, India and Bangladesh along with the phase I states. To foster growth and continuity, NGOs and farmer organizations were also included by the partner countries.

NARS ensured the availability and accessibility of breeders' and basic seeds to feed into both the formal and informal seed chains, which are considered to be important in groundnut production given the bulky nature of seed and low seed multiplication ratio. For these obvious reasons, formal seed chain of groundnut often falls short to meet the groundnut seed requirement in both these countries. Besides the capacity enhancement, infrastructure at SAUs was improved to undertake and handle seed production in large quantities. This has resulted in increased production of early generation seeds that were fed to seed chain. During 2008 – 2014, 8,124 tons of early generation seeds (NS, BS, FS) were produced by NARS partners, of which 8,088 tons was produced in India and 36.6 tons in Bangladesh. The groundnut farmers generally replenish the seeds after 3-4 crops, so saving own seed by farmers and farmer-to-farmer seed exchange is promoted to achieve enhanced adoption of new varieties.

Promoting adoption of new varieties through small seed packets has proven to be a successful model for groundnut production in India and Bangladesh. The small packs approach is increasingly gaining popularity as the most efficient and cost effective means of reaching more farmers with affordable quantities of seed and a wide range of preferred varieties. A total of 11,460 seed packets were distributed in four states in India during phases I and II, and 290 packets were distributed in Bangladesh during phase II. Reaching out to 11,500 farmers though small seed packets of new groundnut varieties is the most significant achievement towards adoption of new varieties.

Two alternate groundnut seed system models were developed and promoted in two states of India, ie, Karnataka and Tamil Nadu during phase I. The first model is the Panjabrao Deshmukh Krishi Vidyapeeth (PDKV) model that engages farmers in informal seed multiplication. Improved varieties in 2 kg packs are distributed to farmers who then multiply the seed over the two seasons, producing 20 kg in the first season and subsequently 200 kg in the second season. This generates enough seed to plant 1 ha area by the third season. In the third season, the farmers save 2 kg seeds from the selected plants and the cycle is repeated. This model enables the farmers to attain seed self-sufficiency sustaining high adoption rates among them.

The second seed system model, is semi-formal, and was implemented successfully in Karnataka state. In this model, the University supplies basic seed to farmers, who either offered land for certified seed production for the formal seed chain or Truthfully Labeled Seed (TLS), which was produced without certification but monitored by the University, NGOs and farmer associations. A similar model was also used in Tamil Nadu. The semi-formal seed systems were found to be very successful in meeting local groundnut seed demand. In Tamil Nadu, the transport cost of 100 kg of pods alone is about ₹ 700, which is 20% of the cost of seed. Thus, the alternate seed systems reduced the costs of seed transportation by more than 10%.

The semi-formal model was implemented in the five districts including Erode and Thiiruvannamalai districts of Tamil Nadu and Bagalkot, Hiriyur and Raichur districts of Karnataka; and linkages were established between formal and informal seed sectors through supply of basic seed by the University. In Karnataka state, additional linkages were also facilitated through certification of seed production plots by the state seed certifying agencies. This seed was procured by state seed corporations or State Department of Agriculture. One hundred kg of basic seed of the variety ICGV 87846 was supplied to Agri-Business Incubation (ABI) Program of ICRISAT, Krishi Vignan Kendra – Sandhiyur and Regional Research Station – Vridhachalam for further multiplication and distribution of seeds to the farmers through this system. Similarly, 100 kg seed of ICGV 00351 was also supplied to ABI program of ICRISAT during 2010 rainy season. (Source: Tropical Legumes II project (2012) – Four Seasons of Learning and Engaging Smallholder Farmers: Progress of Phase I).

The support for both the formal and informal seed systems led to the increased production of certified and truthfully labeled (TL) seeds in the target sites. During 2008 – 2014, a total of 16,570 tons of CS and TL seeds were produced that accounted for 96 tons of its produce from Bangladesh in phase II. The quality seed of improved varieties can cover 138,000 ha of cropped area (@120 kg ha^{-1} seed rate used by farmers). The process of support to seed systems has also enhanced the collaboration between the TL II Project, NARS and farmer organizations.

C. Adoption and Impacts

Under TL II project, Raichur and Chitradurga districts in Karnataka and Erode and Thiruvannamalai districts in Tamil Nadu were chosen for introduction of new varieties and technologies. In each of these four districts, three villages were selected for intervention and were designated as “adopted” villages and three more villages were chosen as non-intervention villages and were designated as “control” villages. From each of the adopted villages, a sample of 30 farmers was chosen while this number was 15 in case of the control villages. Thus, in each of the two states, a sample of 180 farmers was drawn from the adopted villages while 90 farmers were chosen from the control villages. A baseline survey was conducted during 2007 – 2008, immediately after the cropping season to assess the socioeconomic status of the farmers, adoption and yield levels and benefit cost ratios of groundnut vis-à-vis other competing crops. The FPVS trials were conducted during the 2008 – 2009 rainy season in the so called adopted villages. Some new varieties were tested vis-à-vis the ruling varieties in the region to assess their comparative performance. The farmers were asked to rank the varieties based on the traits preferred by them. The varieties so selected by the farmers were taken up for seed multiplication. The farmers were supplied with small quantities of seed so that they will multiply the seeds and bulk the supply so that they can gradually switch over to the preferred varieties. In 2009 – 2010, an early adoption survey was commissioned to assess the dent created by the new varieties and prediction of any improvement in their yields and incomes due to such adoption.

Adoption of improved cultivars during baseline survey, 2007 – 2008

In Raichur, groundnut is grown in both rainy and post-rainy seasons, with more predominance in post-rainy season. Groundnut was grown only in the rainy season under rain-fed situations in case of Chitradurga district. The baseline sample villages in both the districts were completely dominated by single variety, ie, TMV-2 (nearly 90%) during the baseline survey of 2007 – 2008. The variety R 2001-2 that was released a few years ago failed to make any dent despite its high yield potential. This variety has undesirable pod characteristics that have led to its low market preference. Similarly, ICGV 91114 has not made any head way, despite some desired characteristics like short duration, tolerance to drought, moderate levels of resistance to rust and leafspots and good pod and kernel traits, mainly due to the lack of support from the seed production and distribution chain.

The baseline sample villages of Erode and Thiruvannamalai districts of Tamil Nadu are dominated by groundnut cultivation (>80%). In Erode district sample, CO-2 is the most popular variety in both the adopted and control villages. It occupied 52% of the groundnut area of the sample farms from the adopted villages. Its share was slightly lower at 48% in case of the sample farms of control villages. VRI-2 was the next most popular variety in Erode district, occupying 33% area in the adopted villages and 34% in the control villages. TMV-2 covered 9% area in the adopted villages and 13% in the control villages. In Thiruvannamalai district sample, POL-2 was the most preferred variety in the adopted villages, with a share of 55% in terms of total groundnut area. TMV-7 was also popular with a 44% share. The remainder of 1% area was under JL-24. The ranking order of varieties was similar in the control villages of the same district. POL-2 was the dominant variety in control villages with a share of 59% in the groundnut area of the sample farms. TMV-7 stood next with a 40% share. JL-24 had the remaining share of 1% area under it.

Adoption of improved cultivars during early adoption survey, 2009 – 2010

Karnataka

Just as in case of baseline survey year in Raichur district, the dominance of TMV-2 remained intact in the 2009 – 2010 period also. Nearly 95.4% groundnut area covered by TMV-2 and the remaining 4.6% covered by TL II introduced new varieties (R2001-02 and ICGV00350) during 2009 – 2010. This low adoption in Raichur might be due to inability of the farmers to access the information about new cultivars and developing a conviction about their superiority. Similarly, the stranglehold of TMV-2 was evident in Chitradurga district during early adoption surveys. Nearly 90.8% of total groundnut area in the sample villages was under TMV-2 and only 9.2% area was covered with project introduced varieties (ICGV 91114 and R2001-2).

Table 20 summarizes the cost of production of groundnut per quintal that has reduced from ₹ 2,145 to ₹ 1,983 between the baseline and early adoption surveys for the pooled sample. However, the unit cost reduction is much higher in case of Raichur sample (₹ 305) than Chitradurga sample (₹ 19). Overall, the productivity per ha has gone up nearly 29.7% which translated into unit cost reduction of 7.6% for the pooled sample.

Table 20. Unit cost reduction in groundnut cultivation, Karnataka sample.

Item	Raichur sample	Chitradurga sample	Pooled sample
Cost of production in baseline (2006 – 2007) ₹ per 100 kg	2,429	1,861	2,145
Cost of production in early adoption (2009 – 2010) ₹ per 100 kg	2,124	1,842	1,983
Reduction in cost of production (₹)	305	19	162
Percentage of reduction in unit cost of production (%)	12.6	1.0	7.6

Tamil Nadu

In Erode district, CO-2 occupied 48.1% of the cropped area in 2007 – 2008 and it was followed by VRI-2 (33.5%) and TMV-2 (10.4%). JL-24, TMV-7 and TMV-1 occupied minor areas. In 2009 – 2010, VRI-2 covered 62.5% area, followed by CO-2 (32.7%) and TMV-7 (1.9%). There was a token presence of new varieties in less than 1% area. In Thiruvannamalai district sample, POL-2 and TMV-7 were the farmer-preferred varieties during the period of 2007 – 2008, occupying 56.6% and 42.3% areas, respectively. The remaining 1.1% area was under JL-24. In 2009 – 2010, the same varieties held sway over the groundnut farmers in the sample. POL-2 covered 64.5% area and TMV-7 had 21% share in the groundnut cultivated area. CO-2 accounted for 13.8% share. The new varieties had a token adoption in 0.7% area. Thus, new varieties failed to make a dent in the groundnut areas of the sample farmers, even though there was a churning between the old varieties. The cropped and groundnut areas decreased and the farmers seemed to shift to a more profitable crop in the absence of sustained efforts for popularizing the high yielding new varieties.

However, the new varieties offer a prospect for drastic reduction in unit cost of cultivation even in nominal terms because of their yield potential. In Erode district, cultivation of TVG0004 can bring down the unit cost of production by 39% as compared to CO-2. In case of ICGV00351 in Thiruvannamalai district, the reduction in unit cost of production would be more modest by 4.3% when compared to that of POL-2.

D. Capacity building

1. Human capital development

Bangladesh: Two breeders and one pathologist were trained on various aspects of breeding and diseases resistance screening. Four breeders participated in the training program on molecular breeding in Netherlands and Spain that was arranged by the Generation Challenge Program (GCP).

India: In phase I, one PhD student from TNAU Coimbatore and one MSc student from UAS Raichur completed their dissertations on groundnut research. Six researchers from Karnataka and Tamil Nadu received hands-on training on groundnut breeding and production technologies. Two scientists from TNAU Coimbatore were trained on use of marker-assisted breeding in groundnut at ICRISAT. **In phase II,** two students from Bihar have submitted their MSc thesis, one on heat tolerance in groundnut and another on root rot disease of groundnut, to BAU, Sabour. A scientist received hands-on training on breeding, screening for resistance to virus diseases, statistical modules, data management and integrated molecular breeding. From UAS Dharwad, a scientist and technician were trained on various aspects of integrated breeding (including molecular breeding) in groundnut. Four scientists from TNAU were trained on integrated molecular breeding and pre-breeding while a technician was trained on integrated legume crop management. Two students submitted their doctoral thesis on groundnut breeding. Researchers from India participated in the training program on molecular breeding in Netherlands and Spain that was arranged by GCP.

2. Infrastructure development

At TNAU, Coimbatore, the foliar disease screening facility was strengthened by installing a sprinkler system while at Tindivanam rain-out shelter were made for screening for drought tolerance and equipment for measuring drought tolerance traits were provided. Similar facilities were also established at UAS Raichur, Karnataka.

E. Lessons learned

- Feedback from the farmers helped the researchers in identification of farmer-preferred traits to breed new varieties;
- Participation of farmers in FPVS provided sense of belonging and ownership of the varieties by the farmers facilitating fast spread of new varieties;
- Capacity building and support to improve infrastructure development provided boost to adoption of new technology by the project partners;

- Distribution of seeds of promising varieties through 'small seed packet' has been a successful model for adoption of new groundnut varieties; however, our experience shows that for better adoption, seed packet should contain at least 10 – 20 kg seeds;
- Alternate seed systems adopted in the project have been very successful; however, these should be region specific considering local conditions of production, storage, seed laws and partners involved in the seed production and distribution chain;
- Increased collaboration seen between the TL II Project, NARS, civil society, farmer organizations, seed companies and traders;
- Adoption of improved varieties and integrated crop management technologies should go hand in hand for enhancing groundnut production and profitability; and
- A strong variety pipeline will be needed to replace the old and obsolete varieties with new varieties, matching the demand from farmers and the industry.

Enhancing cowpea productivity and production in drought-prone areas of sub-Saharan Africa

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Summary

Cowpea is one of the most commonly grown and consumed legumes in the dry savanna regions of SSA. Its drought tolerance ability enables it to adapt to the dry savanna agroecology, where the crop is produced in bulk. The global cowpea grain production has increased from about 1.3 million metric tons in the 1970s to over 5 million metric tons in the 2000s (FAO, 2012). West and Central Africa contribute to about 95% of the global cowpea production. According to the baseline studies conducted in the sub-regions, demand will grow faster at the rate of 2.7% than supply at 2.5% annually from 2007 to 2030 (Abate 2012). An increase in the productivity will bridge the gap between demand and supply. The average grain yield of the crop is about 495 kg ha^{-1}, which is lower than the potential yield of 2,500 kg ha^{-1} obtained under experimental conditions. There is ample opportunity for lifting the grain yield above the level obtained presently from the farmers' fields. Cowpea is attacked by several insect pests (aphids, flower bud thrips, legume pod borer, and pod sucking bugs), several diseases (viral, bacterial, and fungal), and two parasitic flowering plants (*Striga gesnerioides* and *Alectra vogelii)*, which considerably reduces the yield. Despite its adaptation to drought-prone areas, cowpea grain yield could be adversely affected by drought occurring at different stages of the crop's lifespan. The rainfall pattern in the dry savanna regions is becoming more unpredictable at both the beginning and the end of the cropping season. Given that cowpea is grown purely under rainfed conditions, the development and deployment of more drought tolerant varieties of the crop would help farmers in obtaining better and more stable grain yield. The main purpose of this project is to enhance the cowpea productivity in the dry savanna regions of SSA through genetic improvements.

Targets achieved so far in this project

- Recently selected cowpea breeding lines were evaluated for their drought tolerance and those with enhanced drought tolerance were selected with farmers' involvement. The selected varieties outperformed farmers' own varieties at all locations.
- More than 200 kg seeds of the selected lines were produced and used annually in the trials in at least 30 communities in phase I and 50 communities in phase II per target country.
- Over 1,200 germplasm lines were screened for drought tolerance. Out of this, the best 20 were selected and used in making crosses to existing lines with preferred traits of farmers and consumers.
- Over 200 populations segregating for drought tolerance and resistance to *Striga* were generated. About 361 advanced lines were selected and are being evaluated.
- DNA markers (single nucleotide polymorphisms, SNPs) associated with drought tolerance, bacterial blight, and *Striga* resistances as identified in the TL I project at UC Riverside were validated at IITA.
- Marker-assisted backcross was initiated to introgress *Striga* resistance into the well adapted released varieties that are susceptible to *Striga*. This lead to the generation of back-cross disease-resistant variety, ie, BC2F1.
- A total of 18 new varieties were released in the participating countries.

- A report on assessment of gaps with collaborating scientists, extension agents, and farmers' skills was produced.
- Early studies on the adoption of improved cowpea varieties were carried out in Nigeria.
- Support for upgrading the drought screening sites was provided in each country based on their needs.
- Seven national programs are now active in breeding cowpea with drought tolerance ability.
- Two stakeholder and community workshops per community were conducted each year. In phase I, 100 workshops were held each year for farmers involved in FPVS across five countries. In phase II, 350 similar workshops were organized. At least 1,892 farmers participated in FPVS in identifying the drought tolerant lines possessing desirable traits in five countries during phase I of the project. Out of all the participants, 734 were female and 1,158 were male farmers. In phase II, more than 4,500 farmers participated in PVS from the seven participating countries out of which 33% were female farmers.
- Fourteen graduates have been or are being trained at MSc (10) and PhD (4) levels on plant breeding.
- Each NARS cowpea breeder in five countries (Mali, Niger, Nigeria, Mozambique and Tanzania) received a Samsung Galaxy 10.1 tablet for use in data capture and analysis.
- NARS breeders were trained in molecular breeding and data collection and analysis with electronic data-capture devices such as tablets.

Background

Cowpea breeding sites and activities

The project was implemented in 5 countries during phase I, (2007-2011) and in 7 countries during phase II (2011-2014). Phase I target countries included Mali, Mozambique, Niger, Nigeria and Tanzania. In phase II, Burkina Faso and Ghana joined the list.

Three activities were carried out in both phase I and phase II. Phase I activities included: (a) testing the existing cowpea varieties and lines for their drought tolerance, (b) creating segregating populations for drought tolerance and attendant traits, and (c) strengthening the capacity of the NARS scientists. In phase II, the activities conducted were: (a) selection of the segregating populations and evaluating the lines with enhanced drought tolerance ability and other desirable traits, (b) marker-assisted backcrossing (MABC) to transfer *Striga* and flower thrips resistance to the farmer-preferred varieties, and (c) capacity building of the stakeholders in the NARS.

Key achievements

Crop improvement

Testing existing cowpea varieties and lines for their drought tolerance

Several cowpea breeding lines on the shelves at NARS and IITA breeding nurseries were tested for their drought tolerance on-station (Table 21). Sixteen common elite lines (IT00K-1263, IT99K-1122, IT96D-610, IT98K-491-4, IT89KD-288, IT98K-311-8-2, IT98K-166-4, IT99K-216-24-2, IT99K-7-21-2-2, IT98K-412-13, IT98K-390-2, IT98K-628, IT97K-819-118, IT99-529-1, IT97K-1069-6, and IT98K-128-3) were tested in all the participating countries. These 16 lines were from the early maturing, dual purpose, *Striga*-resistant, and medium maturing breeding nurseries at IITA.

Table 21. Number of improved cowpea breeding lines tested across countries.

	In country developed breeding lines	IITA developed lines	Total
Mali – IER	5	43	48
Mozambique – IITA and IIAM	0	16	16
Niger – INRAN	11	25	36
Nigeria – IAR	48	20	68
Tanzania – ARI	4	16	20
IITA – Kano	0	78	78

Several lines were selected through FPVS and later evaluated in multi-locations for their adaptation and possible release. For example, the cowpea line IT97K-499-35 was selected by farmers in Nigeria and Mali for its drought tolerance and *Striga*-resistance in Mali. Cowpea line IT97K-499-38 was selected in Niger for its good yield performance. In East Africa, the cowpea lines IT00K-1263 and IT99K-1122 were selected by farmers in Tanzania for their drought tolerance and earliness (IT99K-1122) while IT00K-1263 was the most preferred line by the farmers in Mozambique.

Evaluation of breeding lines for resistance to bacterial blight and viruses

A set of 50 breeding lines including the above-mentioned 16 lines were shared with NARS and tested to determine their resistance to the bacterial blight and viruses in the greenhouse at Ibadan. The results showed that some of the lines were resistant to bacterial blight as well as virus diseases. The following breeding lines IT00K-1263, IT99K-1060, IT99K-1122, and IT99K-1111-1 were found to be highly resistant to bacterial blight. The local line Danila, also a drought tolerant variety, showed high level of resistance to the disease. Cowpea breeding lines resistant to three important viral diseases (*Cowpea aphid-borne mosaic virus* (CABMV), *Cowpea mild mottle virus* (CPMMV), and *Cowpea mottle virus* (CPMoV)) included IT98K-133-1-1, IT99K-573-1-1, IT98K-390-2, IT98K-1092-1, IT97K-1069-6, IT04K-405-5; IT00K-901-5 and IT98K-412-13 breeding lines.

Evaluation of breeding lines for phosphorus-use efficiency

A greenhouse experiment was conducted using a mixture of subsoil and acid-washed sand to evaluate variations in phosphorus use and response efficiency. The genotypes varied both for the number of nodules and for the response to phosphorus application. Nodulation was highest in dual purpose lines such as IT98K-166-44 but the response to phosphorus application was higher in IT89KD-288 than IT98K-166-44. There were highly significant ($p \leq 0.001$) interaction between genotype and phosphorus, which had an effect on the utilization of P for shoot development. The IT89KD-288 was the most efficient and IT99K-7-21-2-2 was the least efficient genotype under the low phosphorus conditions. Among the early maturing lines, genotype IT03K-351-1 formed the largest nodular tissue under low phosphorus conditions and was least dependent on high soil available phosphorus for nodule formation and development. In other genotypes, nodulation was relatively low under low phosphorus conditions, however, the increase in nodule/mass development in response to the high soil available phosphorus ranged from 83 to 515%. The genotypic differences in phosphorus utilization under both low and high phosphorus conditions were not extensive ($P \leq 0.05$) even though IT00K-1263 genotype appeared to have performed better under low phosphorus conditions than most of the other genotypes within the early maturity group.

Conventional Breeding – Development of drought tolerant varieties

Screening of germplasm lines for their drought tolerance

About 1,288 germplasm lines, maintained at the IITA, were evaluated for their drought tolerance at Ibadan during the dry season in 2008. Drought stress was imposed by withdrawing the irrigation from the 5th week after sowing. On an average, the drought condition reduced the number of days to flower by 12 d, and the mean grain yield per plant also got reduced by 67.28% (Fatokun et al. 2012). A few of the cowpea lines stayed green for up to 6 weeks after irrigation was stopped even though some of them produced no pods when the study was terminated. Further evaluation in the screen house of 142 selected drought-tolerant lines helped to identify 20 lines that were used as parents for developing breeding lines with enhanced drought tolerance. Seven of these lines included Danila, TVu 557, TVu 1438, TVu 4574, TVu 6443, TVu 14676, and TVu 11982.

Screening of germplasm lines for their aphid resistance

Aphid (*Aphis craccivora*) is one of the major insect pests of cowpea at the seedling stage, which could lead to a total crop loss in drought conditions. Several cowpea breeding programs have observed that varieties developed with aphid resistance are showing susceptibility or allowing the development of aphid colonies. We have screened a number of cowpea germplasm lines but found very low levels of resistance. Cowpea's wild relatives were also screened for resistance to this pest and three of them (TVNu 1158; TVNu 432 and TVNu 912) were identified to be cross compatible with cowpea. They were detected with moderate to good levels of resistance to aphid (Abate et al. 2012). Efforts are on to introgress the resistance genes into some of the farmers' preferred crop varieties.

Making crosses and developing segregating populations

At vegetative and flowering stages, the best-identified germplasm lines with enhanced drought tolerance ability were crossed to one another and to the improved breeding lines selected by the farmers through PVS. Over 200 cross combinations were generated to produce several segregating populations. These have currently been advanced to F_{10}, F_9, F_8, F_7, F_6, and F_5 generations depending on when the crosses were made. Additional crosses have been made during the phase II of the project at IITA and in several NARS cowpea breeding programs.

Selections were made from these segregating populations for plants with superior drought tolerance ability, resistance to *Striga* parasite, and farmers' and consumers' desirable key traits. A total of 361 advanced lines (in F_7-F_{10} generations) were selected from more than 7,000 families and evaluated in three different environments between 2012 and 2013. Following the analysis of the data collected from these environments for desirable key traits, the best 50 lines were further evaluated during the 2014 cropping season by using FPVS.

Molecular Marker Assisted Breeding – Development of *Striga*-resistant varieties

Cowpea SNP marker conversion and validation:

Some molecular markers, developed under TL I project, were found to be associated with the desirable traits in cowpea at UC Riverside that were validated at the IITA facility, BecA, Nairobi. Allele-specific primers were designed to capture SNPs linked to important traits like *Striga*, Macrophomina/*CPMVnewb, Macrophomina, Gy-1, Gs-4, Gs-2, Flow-5, Flow-1/2, Drought, DLS-5/6, DLS-4,DLS-3, DLS-1/2, CoBB-3, CoBB-2/DLS-4, CoBB-2, CoBB-1/CPMVnewb, CoBB-1, Dehydrin, CPSMV, and CPMVnewb. The SNPs were mined from the HarvEST: Cowpea v1.18 software. To design allele-specific PCR (AS-PCR) primer of extra 3' mismatch, WebSNAPER (http://ausubellab.mgh.harvard.edu/) was used. Primers without extra 3' mismatch were designed by using DNASTAR Lasergene Software (www.dnastar.

com/). Polymerase chain reaction (PCR) was performed using AccuPower® PCR PreMix (www.bioneer.com). All the selected AS-PCR primer sets were optimized and validated. Ten SNPs, potentially linked to CoBB-1,*CPMVnewb, DLS-1/2, Macrophomina, SUR, Drought, Gy-1, CoBB-3, and *Striga*, were converted to agarose gel assay. Information about SNP genotype was provided by the presence (scored as 1) or absence (scored as 0) of the PCR amplification product from AS-PCR primers (Fatokun et al. 2012). The converted SNPs covered several regions of the cowpea genetic map ie, LG 3 (0 ~ 1.3cM), LG 7 (13~17.8 cM), LG8 (0~1.3cM), LG9 (3.4~7.3cM), and LG10 (40.8~41.7cM), where genes for several important traits may be present. AS-PCR primers were also designed and tested with a cowpea breeding population. Of the 57 SNPs, targeted using mismatch approach, 10 gave robust AS-PCR products, which is a success rate for marker development. Allele-specific amplification was observed in one of the two alternative alleles at SNP sites. In this study, we found AS-PCR to be an efficient, cost-effective, and reliable way for SNP validation.

Implementation of Marker-assisted Backcrossing for *Striga* resistance:

Marker-assisted backcrossing (MABC) strategy, using foreground and background selections, started during phase II of the TL II project. F1 and BC1F1 were generated from crosses between improved and adapted *Striga*-susceptible lines and *Striga*-resistant lines. The main objective of this activity was to introgress *Striga* resistance genes into two released varieties IT89KD-288 and IT93K-452-1 with the farmer preferred characteristics that are susceptible to the prevalent *Striga* strains in Nigeria. Two *Striga* resistant gene donors IT99K- 573-2-1 and IT97K-499-35 were used in these crosses. F1s were generated in 2012 and BC1F1 were obtained in early 2013. Two backcross populations, about 100 plants in each, IT93K-452-1/IT97K-499-35//IT93K-452-1 and IT89KD-288/IT97K-499-35//IT89KD-288 were planted in screen house at Ibadan campus in March 2013. Fresh leaf samples were collected in April and sent to LGC Genomics for genotyping. Amplification of the DNA samples was found to be very poor. Hence, a second set of leaf samples were quickly collected and sent to LGC Genomics in late August and the results were obtained in early October. Analysis of the genomic data identified the BC1F1 plants with Striga resistance allele that could be used to generate BC2F1. Phenotyping of BC2F1 was conducted in Kano to cross IT93K-452-1/IT97K-499-35/IT93K-452-1 while the leaf samples were sent for genotyping. The generated BC3F1 was selfed and phenotyped. The identified resistant lines were evaluated for grain yield across different locations.

FPVS

The FPVS approach was used during both the phases of fast-tracking release of cowpea breeding lines ie, 'on-the-shelf' improved lines in phase I and the variety development activities in phase II. In all the target countries involved in objective 3, the breeders, technicians, and extension agents interacted with farmers of several communities during every cropping season. The farmers got opportunities to learn the procedures for PVS and implement it with eagerness. It should be noted that the farmers enthusiastically accepted the proposal of employing their farmlands for demonstrations. Table 22 summarizes the list of varieties selected by farmers and quantities of seed produced during the two phases of the project.

Number of farmers involved in PVS

During both the phases of this project, our target was to involve at least 1000 farmers per year in FPVS. In phase I, the targeted number of farmers in Nigeria (465) and Mozambique (753) was smaller but it was reversed in phase II with 1,408 farmers in Nigeria and 1,322 farmers in Mozambique. In phase I, a total of 1,892 farmers participated in PVS, which was organized in Mali, Niger, Nigeria, Mozambique, and Tanzania. Out of them, 734 were women representing almost 39% of all the involved farmers. In phase II, 25% of a total of 4,500 farmers under FPVS were women.

Seed systems

Seed multiplication

Each year, seed of the lines selected through FPVS in the previous year was multiplied and used for on-farm trials in several communities of the targeted countries. Table 22 summarizes the quantity of seed produced for farmer-preferred lines. In addition, seeds of some lines recommended for variety release were also multiplied and submitted as required by the national variety release committees.

Demonstration plots

Demonstration plots were established in 15 communities for phase I and 50 communities for phase II on a per-country basis (Table 23). At least two lines (an improved and a farmer's own) were planted in each demonstration site on a 20 x 20 meter plot for each line. The lines considered for these demonstration plots were selected by farmers during FPVS conducted in the previous year. Generally in phase I, two planting dates were used with two to three weeks gap in between the dates. The gap was implemented to ensure that the plants in the second planting date experienced terminal drought. In phase II, a single delayed planting date was usually used.

Storage of cowpea seed using the hermetic storage technique

The Purdue Improved Cowpea Storage (PICS) technology was promoted in cowpea communities across WCA sub-region. During the community workshops, the use of PICS technology in cowpea seed storage was demonstrated in countries like Burkina Faso, Ghana, Mali, Nigeria and Niger.

A survey on the adoption of PICS bags was conducted in Feb 2014 in 10 communities of Burkina Faso and the results showed that 60% of farmers have only heard about PICS bags, whereas only 12% of farmers were using PICS bags to store cowpea. In Ghana, the communities involved in demonstrations were also introduced to various storage methods, including PICS.

Cowpea variety released

TL II Project accelerated the process of crop variety release in some of the targeted countries. NARS breeders and variety release/registration committees were encouraged to consider this important step to increase crop production and productivity. TL II supported the evaluation of improved lines and the conducting of committee meetings on variety release/registration. Eleven new cowpea varieties were released officially during the first phase of TL II in Mali, Niger and Nigeria (Table 24). In the early part of the second phase, seven additional varieties were released in Nigeria, Mozambique and Tanzania. More such lines are still to be released in other participating countries on the basis of their performance across different locations within each country.

Capacity building

Workshops

Stakeholders' meetings

During phases I and II, stakeholders met each year at the sub-regional levels of WCA and ESA. In phase I, meetings conducted in WCA region were in Niamey (2008), Maradi (2009), Kano (2010), and Ibadan (2011) while in ESA region the meetings were hosted in Lilongwe (2008), Dar-Es Salam (2009), Nampula (2010), and Lilongwe (2011). In phase II, annual meetings were held in Niamey (2012) and Accra (2013) in WCA region, and in Nampula (2012) and Kampala (2013) for the ESA region. Both sub-regions had their 2014 annual meeting in Nairobi in the month of March. All collaborators from the NARS, extension

Table 22. Quantities of seed of the selected lines produced in the last four years of the project.

Countries	Years	Varieties	Quantities (kg)
Total		-	
Burkina Faso	2010		
	2011	-	
	2012	KVx 442-3-25, KVx775-33-2, IT98K-205-8, IT99K-573-2-1	450
	2013	KVx 442-3-25, KVx775-33-2, IT98K-205-8, Nafi, IT99K-573-2-1	465
Total			915
Ghana	2010	-	
	2011	-	
	2012	IT86D-610, IT97K-390-2, IT98K-128-3, IT9K-311-8-2, IT98K-491-4, IT98K-628, IT99K-216-24-2, IT99K-529-2, IT99K-1122	350
	2013	Songotra, Padi-tuya, Apagbaala, Baawutawuta, SARVx-09-001, SARVx-09-002, SARVx-09-003, SARVx-09-004	311
Total			661
Mali	2010	IT97K-499-35, IT89KD-876-30	2,585
	2011	Jiguiya, CZ1-94-23-1, CZ1-94-23-2, Fakson	
	2012	Jiguiya, Korobalen,Sangaraka	2,118
	2013	KPR1-96-54; KPR1-96-73; CZ06-3-1, CZ06-1-05, CZ06-2-17, CZ06-4-16, CZ06-1-12, CZ1-94-23-1, CZ1-94-23-2, IT93K-876-1-2; IT93k-876-30, IT90K-372-1-2, Sanoudaoulen, and M'Barawa,	1,812
Total			6,515
Mozambique	2010	IT-18, IT00K-126-3, IT97K-1069-6, IT-16 and IT98K-390-2	5,570
	2011	IT18, IT00K-1263, IT97K-1069-6, IT16 and IT98K-390-2	200
	2012	IT18, IT00K-1263, IT97K-1069-6, IT16, IT98K-390-2, IT98K131-2, IT98K-128-3	3,200
	2013	IT-16, IT-18, IT-1263, IT-1069, IT-96D-610, Sudan-1, IT99K-529-1, IT-98K-131-2, IT97K-390-2 and IT99K-573-1-1	2,750
Total			
Nigeria	2010	IT00K-1263, IT99K-216-24-2, IT99K-7-21-2-2, IAR-00-1074, IT97K-819-118, IT96D-610, IAR-1050, IT97K-499-35	435
	2011		
	2012	IT99K-573-1-1, IT89KD 288, IT93K-452-1, IT97K-499-35, IT99K-216-24-2, IT99K-241-2, IT89KD-391 and IT99K-7-21-2-2	1,200
	2013	IT99K-573-1-1; IT90K-277-2; IT99K-216-24-2; IT89KD-288; IT98K-409-4; IT96D-610; IT98K-491-4; IT99K-7-21-2-2; IT98K-131-2; IT99K-573-2-1; IT98K-131-1; IT89KD-391; IT97K-568-18; IT93K-542-1; IT98KD-391; IT06K-292-10; IT81KD-994; IT97K-499-35; IT98K-412-13; IT98K-241-2	3,420
Total			5,055
Tanzania	2010	IT00K-1263 IT99K-1122	2,327
	2011		
	2012	IT00K -1263, IT99K-1122, IT99K-7-21-2-2, IT99K-573-1-1	795
	2013	IT00K-1263; IT99k-1122	465
Total			3,587

Table 23. Number of demonstration plots established per country in phase II.			
Countries	Year	No. Communities	No. Demonstration plots
Burkina Faso	2011	-	-
	2012	10	50
	2013	10	50
Total		20	100
Ghana	2011	-	-
	2012	3	50
	2013	5	10
Total		8	60
Mali	2011	10	60
	2012	2	28
	2013	10	15
Total		22	103
Mozambique	2011		
	2012	25	304
	2013	41	500
Total		66	804
Niger	2011		
	2012	10	50
	2013		
Total			
Nigeria	2011	68	289
	2012	83	313
	2013	74	437
Total		225	1039
Tanzania	2011		
	2012	10	50
	2013	35	450
Total		45	500

services, NGOs (such as SNV, World Vision, CRS, CLUSA and Africare), and Save the Children and seed companies like Alheri Seeds and Maina Seeds were invited. They actively participated in the meetings where the previous year activities were reviewed and plans for coming season were fine tuned.

Farmers' workshops

Community workshops for demonstration plots (two per year), and PVS workshop (one per year) took place in both WCA and ESA regions during the first and second phases of the TL II project. At least, 6,392 farmers participated in PVS workshop and 600 community workshops were organized during the seven-year period of the project. Each community workshop comprised two parts, where the first part intimated farmers with the implementation of the demonstration plots and the second one discussed the feedback on the performance of the lines tested. In the case of PVS workshops, farmers were exposed to the principles of PVS.

Scientists' workshops

During phase I, scientists developed common protocols for establishing the demonstration plots and conducting PVS workshops. Some scientists attended the drought phenotyping workshop organized in 2008 at ICRISAT, Patancheru, India. During phase II, scientists participating in TL II project also contributed in the data management and Quality Assurance/Quality Control (QA/QC) organized in collaboration with the Generation Challenge Program (GCP). The importance and opportunity to perform

Table 24. Cowpea varieties released in different countries.						
Variety code	Local name	Year released	Country	Location	Average on-farm yield (Kg ha^{-1})	Yield advantage over check (%)
IT97K-499-35	Jiguiya	2010	Mali	Sahelian Zone (Mopti and Ségou)	1.000	70
IT93K-876-30	Fakson	2010	Mali	Sahelian Zone (Mopti and Ségou)	1.500	80
CZ1-94-23-1	Gana Shoba	2009	Mali	Sahelian Zone (Mopti and Ségou)	1.500	65
CZ11-94-5C	Cinzana Telimani	2009	Mali	Sahelian Zone (Mopti and Ségou)	1.000	60
IT-16	IT-16	2011	Mozambique	Northeast & central	650.000	100
IT00K-1263	IT-1263	2011	Mozambique	Northeast & central	800.000	150
IT97K-1069-6	IT-1069	2011	Mozambique	Northeast & central	800.000	150
IT97K-499-35	IT	2009	Niger	Maradi and Zinder	800.000	300
IT97K-499-38	IT	2009	Niger	Maradi and Zinder	700.000	200
IT98K-205-8	IT	2009	Niger	Maradi, Zinder, and Dosso	800.000	300
IT99K-573-1-1	IT	2010	Niger	Maradi	500.000	100
IT97K-499-35	Sampea-10	2008	Nigeria	Northern guinea/ Sudan Savanna region	835.000	60
IT89KD-288	Sampea-11	2009	Nigeria	Northern guinea/ Sudan Savanna region	800.000	56
IT89KD-391	Sampea-12	2009	Nigeria	Savanna region	900.000	71
IT98K-573-1-1	Sampea-13	2011	Nigeria	Northern guinea/ Sudan Savanna region	750.000	55
IT98K-573-2-1	Sampea-14	2011	Nigeria	Northern guinea/ Sudan Savanna region	700.000	50
IT99K-7-21-2-2-1	Vuli-AR1	2013	Tanzania	Singida, Dodoma, and Iringa regions	700.000	20
IT99K-573-1-1	Vuli-AR2	2013	Tanzania	Singida, Dodoma, and Iringa regions	800.000	37

QA/QC were introduced during the workshop. The use of IVIS in managing cowpea pedigree information was also demonstrated. There was discussion on generating and using electronic field books. In WCA, a brief introduction about molecular breeding was staged. Major breeding methods (MABC, MARS, etc.) and the availability of the support tools through the integrated breeding platform (IBP) were presented. The use of tablets in generating electronic field books and capturing data from the field were demonstrated.

Degree-related and short term training

Several training activities were carried out during both phase I and phase II of TL II. Graduates from different participating countries were trained at MSc and PhD levels either fully (registration fees and research fund covered) or partially (only research fund covered) under the project (Table 25). In addition, some technicians received training in field screening for drought tolerant crops.

Table 25. List of students trained in plant breeding during phase I and II of the TLII project.

Countries	Name of students	Degree	Research topic/thesis title
Burkina	Lalsaga Joel	PhD	Marker-Assisted Recurrent selection in cowpea. (Ongoing)
Ghana	Haruna Mohammed	PhD	Physiological and Molecular characterization of cowpea (*Vigna unguiculata* (L.) Walp.) germplasm collection in northern Ghana. (Ongoing).
	Grace Adusei	MSc	Responses of Cowpea genotypes to low soil phosphorus conditions. (Ongoing)
Mali	Siaka Dembele	MSc	Screening for virus resistance in cowpea. (Completed)
Mozambique	John Bulassi Kaunda	MSc	Completed
	Henriques Victor Collial	MSc	Completed
Niger	Abdou Souleymane	MSc	Screening cowpea for aphid resistance. (Completed)
Nigeria	Kayode E Ogunsola	PhD	Reactions of cowpea lines to single and multiple viruses. Awaiting oral PhD examination
	Oladejo Samuel Atanda	PhD	Breeding for thrips resistance in cowpea (*Vigna unguiculata* l. Walp) (Ongoing)
	Auwalu Umar	MSc	Genetics of duration of cooking time. (Completed)
	Habibu Aliyu	MSc	Aphid resistance in cowpea. Completed
	Jonathan Joseph Iduh Otene	MSc	Growth responses of selected cowpea varieties under water stress condition. (Completed)
	AK Olomide Oluwatosin	MSc	Nitrogen use efficiency in selected cowpea varieties under low phosphorus soils of Nigeria. (Completed)
Oluwaseyi Toyinbo		MSc	Path coefficient analysis of cowpea. (Completed)
Tanzania	Didas Kimaro	MSc	Completed

Infrastructure development at NARS

During the first phase of the project, support was provided to the target countries for improving their irrigation facilities in locations like Cinzana station (Mali), Gurue (Mozambique), INRAN Maradi (Niger), Minjibir (Nigeria), and ARI-Ilonga (Tanzania). Such irrigational assistances created opportunities for the breeders to conduct off-season activities, such as seed multiplication, advancing of segregating populations, and performing phenotyping for drought tolerance. Planting during the dry season increased the number of generations that could be obtained each year, thereby reducing the number of years needed for variety development and release. Equipment such as computers, tablets, and renovation of infrastructure for seed storage had provided an environment conducive for quality research.

Challenges

In the course of implementing both the phases of the project, challenges were identified, which are listed below:

- Some partners showed low commitment to the project activities while others had commitments to several other projects. Both cases resulted in poor achievements of milestones.

- There were considerable delays in financial and technical reporting on the part of some NARS colleagues, which had a huge implication on the coordination of the project.
- The breeder seed production plan needed to be strengthened to meet the targets of the project. Support for each participating country's seed producing companies and national research programs was required to achieve the goal in the plan.
- Activity 2 of phase II related to use of molecular markers was affected by the delay in validation of the developed markers of TL I project.
- Climate change had also affected the activities in some countries. In Nigeria, at Dugu Tsoho, the crop failed due to drought, and at Zuru water logging resulted in production of only 25 kg grain. Drought also destroyed breeding activities in Tanzania (2012) and Burkina Faso (2013).
- In 2012 and 2013, the security situation in Mali and north east Nigeria affected the implementation of planned activities.

Lessons learned

The following are some lessons learned during phases I and II:

- The combined involvement of farmers, farmers' groups, extension agents, and NGOs in FPVS and the testing of the improved lines in their own environment helped the farmers in good exposure to the performing lines. This accelerated the variety release from these lines and further facilitated for their adoption.
- The increased participation in field days and farmers' visits to others' fields also provided better exposure to the farmers about available technologies.
- The process of crop variety release could be cumbersome in many countries. The project helped in facilitating the process by supporting meetings of variety release committees in the different countries.
- There is a need to foster stronger collaborations with sub-regional seed initiatives, such as West-African Seed Alliance (WASA).
- Gender mainstreaming is critical in future project activities. This would facilitate female participation which has the potential to influence better adoption of improved technologies.
- Community seed production should be encouraged and promoted to facilitate easy access to improved seeds
- Policies should be designed to ensure that farmers have access to credit and agricultural inputs (fertilizers, insecticides, etc).
- Policies should be promoted to provide adequately trained and equipped extension workers for disseminating extension messages.
- Scientists from Francophone and Lusophone countries requested that their graduate students should be trained in English-speaking countries as the out of country trainings have cost implications.
- The MSc course work in cowpea breeding of two students, one each from Mali and Niger who were registered at the University of Ibadan, were sponsored by AGRA while TL II project supported their research.
- There is a need to encourage the NARS partners to plan for sustainability of the activities beyond the TL projects. Most of the partners depended on the funds received from different projects to conduct their breeding activities.

- There is a need to encourage the NARS partners to have succession plans to guarantee smooth implementation of project activities.
- Monitoring and evaluation tours revealed some of the important contributions made by the NARS colleagues to the project activities, which were usually not incorporated in their reporting.
- The same NARS breeders were involved in different legume projects (AGRA, PASS, TL I, McKnight, Kirkhouse Trust, etc). Coordination of these projects at each country level was required to be implemented in order to create complementarity and spirit of teamwork between projects.
- In Ghana, it was observed that land owners demanded compensation before giving out their lands for on-farm trials.

Conclusion

The objective of this project is to enhance cowpea productivity and production in the drought-prone areas of SSA. The main targets of phases I and II in most of the participating countries were accomplished despite some challenges, which also included the delay in delivery of molecular markers for activity 2 of phase II and security problems in northeast Mali and Nigeria. Advanced lines with enhanced drought tolerance and other desirable traits were identified and developed. FPVS were established in all the countries under which seeds of selected lines were multiplied and the demonstration plots were conducted across several communities in these countries. About 18 varieties were released in the participating countries and more are in the pipeline for release. Planned workshops and capacity building were completed in most of the countries. Farmers, seed growers, extension agents, technicians, and scientists participated in the implementation of the project and short term trainings. Degree training of scientists, improvement of facilities (irrigation and seed storage) and electronic equipment (computers and tablets) contributed in facilitating the institution of functional breeding programs in the target countries.

Enhancing common bean productivity and production in Sub-Saharan Africa

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Summary

When the TL II was initiated in 2007, breeding for drought tolerance in common bean had received only sporadic attention in East and Southern Africa. Under the TL I project, drought gained prominence and moved into the research agenda. Factors influencing the adoption of improved varieties of bean were found to be multiple and context-specific, but can be broadly categorized as technological attributes, household characteristics, and contextual factors. Across countries, adoption of bean varieties was higher in agro-ecological zones with moderate and high rainfall areas, but low in semi-arid areas. Improved varieties were preferred in regions with heavy and frequent rainfalls, probably, due to their disease resistance properties. This analysis was based on the adoption of varieties released between 2003 and 2008. The varieties released thereafter (2009-2013) though drought tolerant were not diffused to the communities then. Nurseries were distributed to the TL II participating countries, Malawi, Zimbabwe, Uganda, Kenya, and Tanzania. These nurseries consisted of materials segregating for drought tolerance and fixed lines by combining the drought tolerance with other traits, such as high mineral (iron and zinc) content, low soil fertility tolerance, pest resistance (bruchids and bean stem maggot; BSM), and disease resistance (common bacterial blight; CBB). Selections were made and materials were provided at different stages of the breeding pipeline. As many as 39 lines (2007-2014) were released for drought areas while others are in the last stages of the development pipeline. Most of the released lines had the yield advantage of nearly 10-40% over the commercial varieties in on-farm trials with additional traits of resistance to key pests and diseases and/or high grain Fe and Zn content. Effort was made to deliberately develop beans with drought tolerant germplasm with an added trait of high Fe and Zn content. The small-seeded Mesoamerican bush bean lines emerging from the breeding program in Colombia have 80% higher iron and drought resistance that was equal to or superior to the tolerant check. The improvement of mineral levels in climbing bean materials had been successful and had an added advantage of increased productivity per unit area.

High temperatures were shown to aggravate the stress imposed by drought, and combinations of stress tolerance would be necessary in the near future. While 20°C night temperature is normally considered to be a limitation for common bean, the breeding lines combining common bean with *P. coccineus* and *P. acutifolius* presented an excellent pollen formation and a good pod set at 22°C night temperatures. Some pod set is maintained at 25°C nights. Genetic diversity was fine-tuned and genetic analysis was applied to a number of national bean collections. In terms of genomic resources, the populations of recombinant inbred lines (RILs) were being developed for drought, yield, drought traits, and associated biotic constraints. High-quality maps were developed for several populations. Physiological studies, directed for understanding drought tolerance and yield processes *per se*, revealed the underlying mechanisms of drought resistance, and suggested how these could be applied within the breeding programs. While it was a challenge to find a consistent Quantitative Trait Loci (QTL) for yield under drought, focusing on the trait of Pod Harvest Index (PHI) was more promising, and some of the QTL candidates were being validated through additional phenotyping. Other factors limited the expression

of drought tolerance on farm. In particular, soil factors and poor soil fertility did not permit the adequate plant development for crops to sustain additional physiological stress imposed by drought. The establishment of SNP platform was the single most long-term result of the TL I project, since it would continue as the marker of choice for mainstream breeding programs with a modest budget in the foreseeable future. SNP markers for major disease resistance genes (BCMNV, CBB, bruchids, and ALS) were developed and markers of other classes (SCARS and SSRs) were converted to a SNP platform for ready to use purpose. Degree and technician training was undertaken with four PhD degrees and six MSc degrees granted. High priority was placed on the technicians given their role in the daily execution of field trials. Two seed delivery models were proved to be effective. One was small and low-cost seed packets within the easy reach of poor farmers (female) and the other was community exchange system of a kilo seed for a kilo harvested grain (barter system). Quality Declared Seed (QDS) was approved as a viable seed class for beans in Uganda, Tanzania, and Ethiopia which opened numerous opportunities for community-based seed systems.

Background

Phase II activities of the TL II project continued in five of the anchor countries, Kenya, Ethiopia, Tanzania, Malawi and Zimbabwe. Uganda was the newest entrant with activities initiated in August, 2012. In addition, efforts were extended to the Kagera and Kigoma regions of Tanzania and southern Tanzania. Activities were coordinated under the Pan-Africa Bean Research Alliance (PABRA) umbrella and results were presented in two steering committees Southern Africa Bean Research Network (SABRN) and East and Central Africa Bean Research Network (ECABREN) of PABRA. The main objective was to share results and products from TL II activities with other members of PABRA countries. TL II project activities were, hence, integrated into the PABRA framework to facilitate a wider dissemination and learning from the experiences. Among the anchor countries, country strategies were developed by laying out the seed road maps for each of the participating countries and defining the agroecologies for which the improved varieties were being developed and disseminated.

Description of TL II countries

Ethiopia: Ethiopia is the largest exporter of common bean in Africa, earning about $66 million in 2010. The export volume rose to about 77,000 tons in 2010, compared to 49,000 tons ($ 17 million) in 2006. Area under bean cultivation increased by 34.3% from 181,600 ha (2003) to 244,012 (2010), and 350,000 by 2012 ha. Production increased three-fold from 117,750 tons (2003) to 362,890 tons (2010), and the average yield more than the doubled from 0.615 tons/ha to 1.487 tons/ha. In terms of coverage, the common bean was widely grown across the country with highest concentrations in Oromia region, where more than 50% of the common bean grain products were produced for the export market. Central Rift Valley (CRV) that consists of parts of East Shewa, Arsi, West Arsi, and West and East Hararghe highlands belong to the Oromia region. The CRV areas were considered as the major “common bean belt” and were specialized in white pea beans, which was mainly produced for the export market. West and East Hararghe highlands produced beans that were intercropped with sorghum, maize, and chat. The Southern (SNNP) region included Sidama, Wolayta, and Gemu Gofa zones as the second production area though most of the production was for household consumption. Various administrative zones in the north and north-central, south-western, western, and north-western part of Ethiopia were also producing bean. Other regions, rather than CRV, mostly produced colored beans of various sizes that were used as food for local markets. They were also exported to the neighboring countries, like Kenya and Somalia, mostly through informal channels.

Kenya: Kenya is the seventh highest producer of dry beans in Africa. Dry bean contributed KES 13.18 billion to the national economy and are a source of dietary protein, especially for the rural and urban poor. They are the centerpiece for daily diet for many Kenyans. On an average, 401,880 tons of beans are consumed annually (Economic Review of Agriculture – 2009). In Kenya, beans are grown in a wide range of agro-ecological zones ranging from medium (800 m) to high altitude areas (2000 m above sea level; MASL) of Central, Rift Valley, Coast, Western, Nyanza, and Eastern provinces (Wortmann and Allen, 1994). They are mainly grown by smallholder farmers in high and medium rainfall areas. However in semi-arid lands, it is grown with additional rainwater harvesting. Beans are marginally grown in agro-ecological zone-5 due to the prevailing heat scenario. Bean research in Kenya is conducted by the Kenya Agricultural Research Institute (KARI), which works closely with CIAT in five of its centers Katumani, Thika (1500 MASL, Humic nitisols), Kabete (1800 MASL, Humic nitisols), Kakamega (1600 MASL, Dystric mollic nitisols), Embu, and Kitale. A substantial amount of the research on beans is also conducted by advanced universities, namely Kabete, Nairobi, Moi, and Egerton Universities.

Malawi: In 2012, common bean area was estimated at 243,700 ha and production at 127,464 tons. In the major bean growing areas, 74% to 90% of farmers grow beans as their main cash crop, and beans are second only to maize as a food crop (Scott and Maideni, 1998). About 35% of the production is marketed, contributing about 25% of total household income for over 68% of the households who sell their surplus (Kalyebara et al. 2005). Both production and demand for beans in Malawi are trending upwards, with an annual growth rate of 4% between 2002 and 2011 in production. Area under common bean increased tremendously in 2009 (51,844 ha) in response to the government mobilization of farmers to include legumes in their cropping system. This happened when some NGOs intervened with the provision of seeds as inputs to farmers and additional hectares under irrigation system. Projections for 2014-2020 suggest a continued growth in both national demand and production of beans. Common bean experiences high fluctuations in production associated with high variability in rainfall conditions, often resulting in excess demand. There is an indication of demand for improved high yielding common bean varieties to stabilize the yields. The bean improvement program in the Department of Agricultural Research Service (DARS) started developing bean varieties in 1996. This research is conducted in collaboration with CIAT, and through PABRA, and other NARS partners, such as the University of Malawi–Bunda College of Agriculture play key roles. So far, a total of 30 bean varieties have been released in Malawi, with 18 of them by DARS and 12 by the University of Malawi-Bunda College of Agriculture. The bean crop is grown across the country in three main agro-ecologies that are categorized according to altitude as high, medium, and low. Subhumid, > 1500 MASL, and >400 mm of unimodal rainfall and acidic soils covering the districts of Chitipa, Livingstonia, Viphya, and Dedza are categorized as high agroecology with an estimated area of 124,941 ha. Sub humid, 1000-1500 MASL, and >400 mm of unimodal rainfall covering the districts of Mzimba, Lilongwe, Dowa, Nmawera, and Shire are categorized as medium agroecology with an estimated area of 114, 198 ha. Low agroecology is categorized with <1000 MASL and unimodal rainfall covering 26,158 ha in the Lake basin and Phalombe. Beans are not well adapted to the lake shore areas and the Shire valley resulting in low cultivation.

Tanzania: Common bean is the leading leguminous crop accounting for 78% of land under legumes in Tanzania. It is estimated that over 75% of rural households in Tanzania depend on beans for daily subsistence (Xavery et al. 2006; Kalyebara and Buruchara 2008). The crop residues are used as livestock feed and source of organic matter to enhance the soil fertility. About 1.25 million hectares of bean are planted each year with the main production areas located in the Arusha region in the north, the great lakes region in the west and the Southern Highlands. Tanzania is the largest common bean producer in sub-Saharan Africa and the world's 7th largest common bean producer. The area occupied by common bean is second to maize accounting for nearly 11% of the total cultivated land. Total production is approximately 933,000 tons of production each year while national demand is estimated at 724,017 tons making Tanzania the net exporter of common bean. Both production and national demand for common bean have been trending upwards. The area under bean production has been increasing at an average rate of 11% per annum over the last decade. On the other hand, yield growth rates have been modest in absolute terms, increasing from 0.48 ton/ha in 1970 to 0.77 ton in 2001-2007 (Katungi et al. 2010). Greater improvements in productivity are expected between 2014 and 2020. The Agricultural Research System in Tanzania is divided into seven agro-ecological zones, Eastern, Northern, Western, Lake, Southern, Southern Highlands, and Central Zones. Each of the zones has a specific mandate crop depending on its zone priorities. However, during the colonial period, the main emphasis was on cash crops. Research on the main food crops, including beans, gained importance after independence. The Bean Research Program of Tanzania was formally initiated in 1977 though the research work on beans began as early as 1965. Bean research in Tanzania has been conducted in close collaboration with the International Center for Tropical Agriculture (CIAT), which started as early as 1973 (Hillock et al. 2006).

Uganda: Common bean is the number one legume grown and consumed throughout Uganda. It is a major source of food and income for the rural smallholder farmers. The crop is the most important source of protein for over 30 million people in Uganda and provides up to 25% of the total calories and 45% of the total human dietary protein (Pachico 1993; Mauyo et al. 2007). For those in need of immediate food remedies, like in war-ravaged areas like northern Uganda, parts of DRC, and southern Sudan, common bean is the first crop of choice as the early maturing varieties take a short time (60-80 days) to grow. Beans are produced in all the major agro-ecological regions of Uganda; however, the types of bean grown do vary from one region to another depending on the preferences of the farmers and consumers of that region. To a large extent, all the regions of Uganda grow the red mottled bean varieties, which are highly marketable within and outside the country borders. Thus, they have been given emphasis in the breeding program. Common bean production in Uganda has been trending upwards with the area expansion as the main source of growth. Between 2001 and 2010, area under common bean increased by 28.7% resulting in an increase of 7.7% in bean supply as the yield got stagnated due to a range of biophysical constraints (soil fertility, drought, pests and diseases) (Kimani et al. 2006). Area under common bean is projected to continue its growth at a high rate in the next few years in response to the growing population and increasing bean trade from the country. The national bean program is one of the programs of the National Crops Resources Research Institute (NaCRRI) of the National Agricultural Research Organization (NARO) that has several research and trial testing sites distributed in the major agro-ecological regions of the country. Collaborative research with CIAT has been conducted in the country for more than 20 years now.

Zimbabwe: Common bean is a well-known protein source which is consumed directly by the major populace in Zimbabwe. As bean is rich in micronutrients (Zn and Fe), it suits malnourished children, pregnant women, and young children. Common bean is among the top five crops that provide a high income to the farmers and traders. Bean trade is not limited within the country but is expanded to South Africa, Malawi, Zambia, Mozambique and Tanzania. The level of genetic diversity is also high with *P. coccineus* cultivated by some farmers for domestic consumption and to trade amongst the farmers within short distances. Landraces are also common among farming communities and at times limit the productivity of these farming areas. Both public and private breeding programs contribute to bean research in Zimbabwe. Universities through student projects also contribute to the research work in Zimbabwe. The national breeding program under the auspices of the Crop Breeding Institute is housed at DR&SS in Harare. The private seed companies are located in Harare while their research sites are spread all over the bean growing areas. Seed houses, like Seed Co., PANNAR Seeds, Agriseeds, Sandbrite, and Progene Seeds are actively involved in either breeding or marketing of the bean products. Zaka Seeds, a community-based company, has also joined hands in popularizing the improved new varieties since 2011.

Key achievements

Adoption and impacts

Early adoption and interventions in the seed market

After phase I, emphasis for social sciences research was put on anchor countries, Ethiopia, Tanzania, and Uganda and studies were conducted in these countries. Kenya, which was the focal country in phase I was replaced by Uganda. In phase II, objective 1 research activities were carried out to evaluate the early adoption and associated interventions in the seed markets. In Southern Tanzania, the study covered 750 households selected across 75 villages to represent the region. Market value chains for common bean were also included in the analysis for southern Tanzania, in order to provide lessons on the market-related challenges and opportunities for enhancing its new variety uptake and improvements. In Ethiopia, the data were derived from a survey of 600 households selected from 16 districts (Woredas) across three agro-ecological zones that were important for bean production. In Uganda, analysis was based on a national representative sample of 1800 households surveyed in 2012 under the 'Diffusion of Improved Varieties in Sub-Saharan Africa (DIVA)' project funded by Bill & Melinda Gates Foundation and coordinated by SPIA. Survey tools, used in Southern Tanzania and Ethiopia, were designed and discussed with NARS in respective participating countries through two-day workshops attended by NARS scientists and enumerators in each country. In both countries, studies were implemented with additional resources leveraged through the PABRA.

The baseline study also indicated that the few varieties released in 1970s-1980s were dominating the bean area while new varieties released five years after the commencement of the project occupied between 1-10% of the bean area (Katungi et al. 2010). Low adoption was attributed to the poor accessibility of new variety seeds (Xavery et al. 2005; Chirwa et al., unpublished; Assefa et al. 2006).

Learning from phase II

In phase II, research under objective 1 contributed to the learning about the adoption of varieties that were developed under the project and those that were released five years before the project, but were still on the shelf, and the potential seed channels that supported adoption. More varieties have moved to the farming communities. Compared to the adoption in 2008, when two bean varieties released during 2003-2005 in Ethiopia were grown in the communities, at present seven varieties that were released in the same period, are being grown due to the enhanced capacity in seed delivery. Overall, out of 48 varieties, released between 2003 and 2012 in Ethiopia, 16 varieties were taken up by farmers to diffuse them in the farming communities. Varieties released during 2008-2011 accounted for 4.4% of the bean area in the study regions. Varieties that dominated the bean area in 2008 were being replaced by the new ones. For example, baseline studies conducted in 2008 indicated that Red Wolaita, released in 1970s-1980s, was a dominant variety in the southern region of Ethiopia occupying 69.5% of bean area while Nasir another cooking bean variety occupied less than 2% of the bean area during the same period (Katungi et al. 2010). Follow up adoption study, conducted in 2012, showed that Nasir is planted on 89% of the bean area in the southern region, dethroning Red Wolaita which accounted for 14.8% of the area (unpublished reports). In Southern Highlands of Tanzania, about 23.4% of the households adopted the bean varieties that were released between 2002 and 2010. Of these, 15% replaced their traditional varieties while 8.4% have adopted partially (new varieties alongside traditional varieties grown before the project). In terms of area, varieties released since 2002 were grown on 18.3% of the bean area as the varieties between 1970 and 2000 dominated 46.58% of the area.

Despite impressive achievements, there are still some barriers that slow down the diffusion of new varieties that deserve considerable attention in the next breeding and seed delivery strategies. Attributes of the physical environment are major determinants of decision on whether or not to grow such improved varieties. There is a higher diffusion of improved varieties in agro-ecological zones with moderate to high rainfall, but low in semi-arid areas. This is probably due to the disease resistance properties of the improved bean varieties released (2003-2008), which dominated the study. Varieties, with enhanced drought tolerance ability released between 2009 and 2012, should be prioritized in the dissemination efforts to reach farmers of the semi-arid zones.

Poor accessibility to seed of the improved varieties remains an important constraint for the adoption of improved legume varieties. Larger private sector companies continue to under-invest in the legume seed systems, which shows a sign of market failure and points towards the need for stronger public support for legume seed production at least in the early stage until demand is high enough to attract private sector seed companies. Majority of the farmers access the new seed varieties at the time of adoption from informal sources that are built around the social networks or grain markets, which, in turn depend on adoption levels achieved.

Adoption studies also revealed that factors that influenced the learning about the existence of the improved varieties, their benefits, and the management practices were the significant determinants of the adoption of improved bean varieties. This was demonstrated by positive and significant relationship between adoption of new varieties with extension contact, education levels, membership in farmer associations, and context variable (ie, being in villages connected by better quality roads, better mobile phone coverage, and village population density) that reduced the cost of information acquisition. In Uganda, the poor bean-producing households were found to be less likely to adopt the new bean varieties, indicating potentially important poverty reductions that could occur if the poor producers can gain better access to the new bean technologies.

The competitiveness of new bean varieties on the market is important for their adoption at farm-level in most parts of the project area. Bean varieties, with highly demanded traits in the market, were favored by some producers over the new ones, which were not popular in the market even when the new varieties performed well in terms of the yields. New varieties being developed to replace the old ones (released in 1980-1990s), that are declining in productivity due to climate change should be able to outperform the existing ones in terms of market preferences. Social research was also necessary to generate new knowledge on the consumption patterns and market outlook in order to meet the targets of the breeding program.

Productivity of improved varieties

The preliminary estimates of productivity in Ethiopia and southern Tanzania also indicated about the positive and significant yields from the newly improved varieties. Improved common beans varieties, released in 2002-2010, gave an average yield of 437 kg ha^{-1} (higher than the landraces) in southern Tanzania and over 200 kg ha^{-1} in Ethiopia, where the varieties used as local checks were the improved varieties released in 1974-1990. However, the yield gained from the improved bean varieties are conditioned to crop management. Farmers using good management practices obtained higher yields compared to the non-practitioners. This means improving the agronomy and using inputs to manage the soil fertility in legume production could help in contributing significantly to the yield growth, thus, closing the yield gap. The challenge is that crop management practices, responsive to the climate variability, soils, and local socio-economic conditions, tend to be site-specific and require well-planned and targeted dissemination strategies.

Crop improvement

Genetics and Physiology of drought tolerance

Project work at CIAT headquarters, Colombia involved both breeding in support of the program in Africa, and physiology work as a complement to the breeding program. At the outset of the TL II project, substantial progress was made to improve the drought resistance of the small seeded Mesoamerican beans. This was carried out in part under a BMZ-Germany funded project in which Nicaragua, Rwanda, and Malawi participated. In 2009 and 2010, small red-seeded varieties with drought resistance capability were formally released from that effort in Rwanda and Nicaragua. The research works in TL II project were designed on the previous experiences, and it sought to extend its reach to the medium-to-large seeded beans of the Andean gene pool. Mechanisms being investigated, involve both root to access soil moisture, particularly from the deeper soil layers, and remobilization of photosynthate to grain (partitioning of biomass).

Studies on mechanisms of drought resistance: In phase I, a set of 36 elite lines were evaluated in the drought season of June to September in CIAT, Colombia. The variability in annual rainfall created different patterns of drought stress, which was experienced in the three-year period ie, light intermittent drought (2008), terminal drought (2009), and low rainfall extending to most of the vegetative period (2010). The crop response was different to each drought pattern and the ranking of genotypes changed under different drought patterns. Light intermittent drought in 2008 resulted in an acceptable yield from the drought-selected lines, although there were wide differences in relation to the commercial check. Under terminal drought (2009), early materials ranked relatively better, as expected. These included SER 125 (released in Nicaragua), SER 16 (released in Rwanda), and G40001 (*Phaseolus acutifolius*). SER 78 was the highest yielding variety in 2009 and was mediocre in other years. In 2010, occasional light rainfall during the vegetative phase of the crop resulted in more modest shoot development and the change in the ranking of some lines. The genotypes SXB 412 and SXB 405, developed for Brazil, ranked relatively better with adaptation to poor soil, whereas the early materials were mid-to-low in ranking. Such patterns of drought stress, due to low rainfall during the vegetative growth of the crop, might have stimulated the earlier root growth in some genotypes while the early materials could not benefit from this condition. On the other hand, genotypes SXB 412 in 2008 and SXB 405 in 2009 were mediocre under intermittent and terminal drought conditions. A few entries, particularly the black-seeded lines, were excellent under all drought patterns when provided with adequate soil moisture through irrigation. SEN 56 stood out among all these genotypes. In spite of being relatively early to mature, it was the best line in 2010 while other early materials slipped in ranking. NCB 226 genotype was especially noteworthy since it was also one of the best lines under combined stress of low phosphorus (P) and drought (Figure 3). Both lines had excellent remobilization of photosynthates to grain. This trait, shared with SER 118, was found to be good in 2010 and had performed well under low soil fertility conditions. These observations bode well for the potential of the developing varieties of the common bean with multiple stress resistance. However, these results also indicated about the complexity of the interactions of stress on the crops. Plant responses to different types of stress may well be independent traits, and if this is the case it appears that they can be recombined in lines, such as NCB 226. Correlations between yield and plant attributes under irrigated and rainfed conditions of the 36 lines varied from year to year probably reflecting the varied rainfall patterns of each year (Table 26). For example, days to flowering varied from -0.28 to -0.59 and leaf area index varied from -0.09 to 0.44 in rainfed trials. However, pod harvest index (PHI) or the percentage of pod biomass represented by seed weight was consistently positive, and this trait should be considered as a selection criterion for breeding.

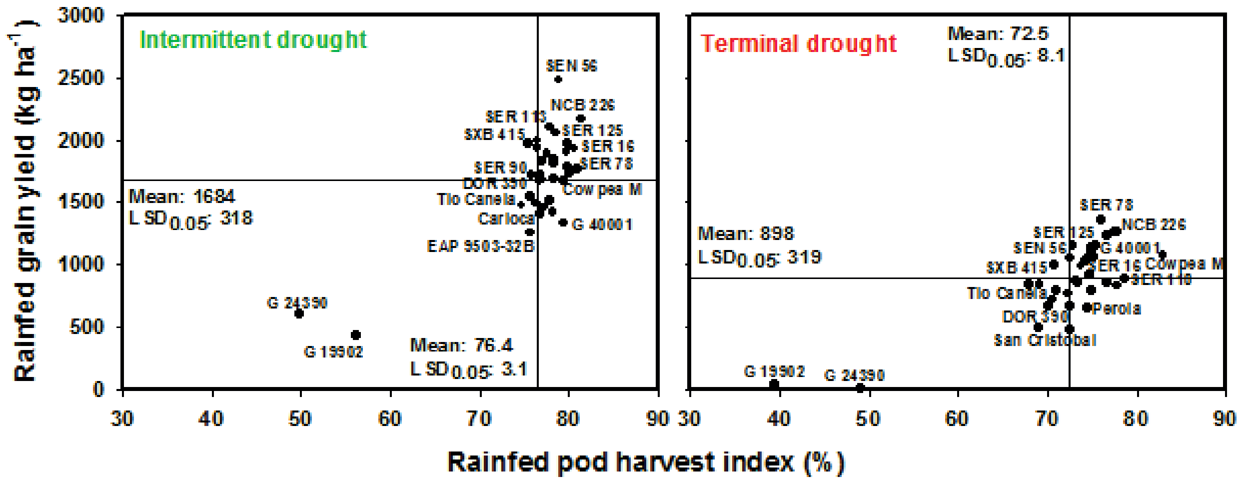

Figure 3. The relationship between pod harvest index and seed yields in lines planted under drought stress conditions.

Table 26. Correlation (r) between grain yield and plant traits.

Plant traits	Irrigated	Intermittent	Irrigated	Terminal
Leaf area index (m^2/m^2)	0.60***	0.34***	-0.25**	0.44***
Canopy temperature depression (°C)	0.29***	0.23***	0.12	0.24**
Canopy biomass (kg ha^{-1})	0.52***	0.21**	-0.01	0.59***
Pod partitioning index (%)	0.11	0.38***	0.21*	0.56***
Harvest index (%)	0.19**	0.46***	0.28**	0.61***
Pod harvest index (%)	0.64***	0.56***	0.64***	0.61***
Stem biomass reduction (%)	-0.22***	0.07	0.17	-0.03
Days to flowering	-0.12	-0.34***	-0.38***	-0.59***
Days to maturity	-0.13*	-0.20**	-0.46***	-0.60***
100 seed weight (g)	0.59***	0.60***	0.62***	0.52***
Seed CID (‰)			-0.14	0.45***

* significant at 0.05 probability level
** significant at 0.01 probability level
*** significant at 0.001 probability level

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In phase II, genetic diversity was fine-tuned and genetic analysis was applied to a number of national beans collections. In terms of genomic resources, populations of recombinant inbred lines (RILs) were developed for drought, yield, drought traits, and associated biotic constraints. High-quality maps have been developed for many of these populations, which will be available for the public to evaluate for traits for which the parents are contrasting to identify QTL. In addition, physiological studies directed at the understanding of drought tolerance and yield processes *per se* revealed the underlying mechanisms of drought resistance capability, and suggested how these could be applied within the breeding programs. Some of these mechanisms include remobilization of photosynthates from stems to pods and to seed enhancing the movement of photosynthate from pod walls to grain. Tolerant lines also displayed a pattern of traits that is consistent with transpiration efficiency. While it was a challenge to find a consistent QTL for yield under drought stress, the focus on the trait of Pod Harvest Index (PHI) was more promising, and some candidate QTL are being validated through additional phenotyping (Table 26). Research work supported by TL II confirmed the selection for PHI under drought conditions would have a beneficial effect on yield potential, ie, shoot biomass (g plant^{-1}) r =0.31, pod partitioning index (PPI) (%) r = 0.87, and PHI (%) r =0.58.

However, it soon became evident that other factors limited the expression of drought tolerance on farm. In particular, soil factors and especially poor soil fertility did not permit adequate plant development for the crop to sustain the additional physiological stress imposed by drought (Figure 4). A paper presented at the 4th InterDrought meeting in September 2013 at Perth, Australia highlighted this problem. The text of that paper was accepted for publication in 2014 in Crop and Pasture Science.

Applying physiological principles to breeding beans of the Andean gene pool

Historically, progress in improving the Andean beans tends to be slower than Mesoamerican beans. On one hand, Andean grains are larger with very specific criteria of size, shape, and color making the recovering of the commercial grain more difficult in segregating populations. This makes introgression of novel genes more laborious. On the other hand, most Andean-type varieties are of determinate growth habit, which limits the yield potential to some extent. In spite of the limitation, our first efforts in improving Andean beans for drought resistance were quite positive. Selected lines expressed excellent grain filling under stress, suggesting an enhanced remobilization to grain. Although they expressed an advantage of high yield over checks in optimal conditions of soil fertility, these lines were excessively early and resulted in poor yields under more realistic conditions of low to moderate fertility. Thus, Andean beans presented the same pattern as Mesoamerican bean types. We immediately adjusted the breeding program by including parents with a longer growth cycle and adaptation to poor soil, especially the cultivar CAL 143 from southern Africa. The results with selections under drought stress were excellent. Among the parental materials in the crosses represented in Table 27, CAL 143, KAT B1, and PAN 127 were the commercial varieties in Africa, and the last column represents their respective yields. Yields of the progenies are far superior to the yields of the parents.

Establishment of a SNP platform

This is the single most long term result of TL I project, and SNP will be probably used as the marker of choice for mainstream breeding programs of modest budget in the foreseeable future. With the support of TL I, communication was established with United States Department of Agriculture (USDA) to access the sequences of SNP identified these and under GCP they were converted to the KASPar system. SNP markers for major disease resistance genes (for BCMNV, CBB, bruchids, and ALS) were developed and markers of other classes (SCARS and SSRs) were converted to a SNP platform for ready-to-use purpose. To date, a number of students and NARS projects are utilizing this platform for key traits (CBB, root rot, bruchids, etc). Under TL I project markers for key resistance genes, for bean common mosaic virus

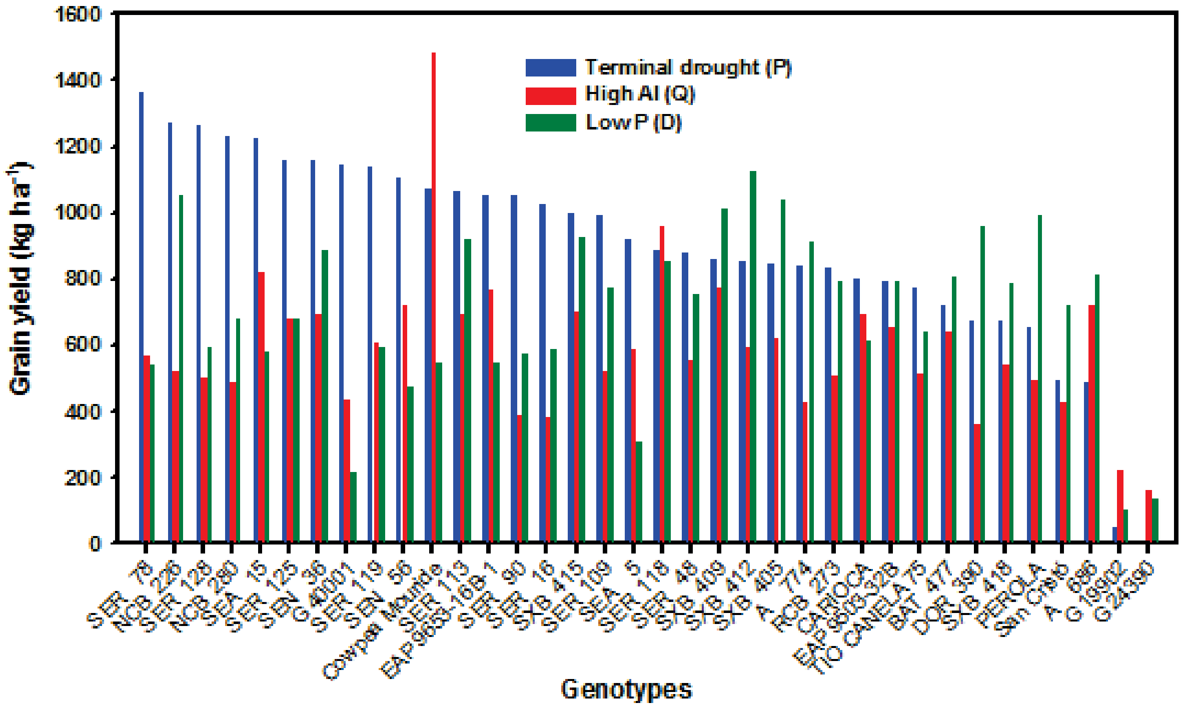

Figure 4. Grain yield of common bean under different abiotic stress conditions in the field.

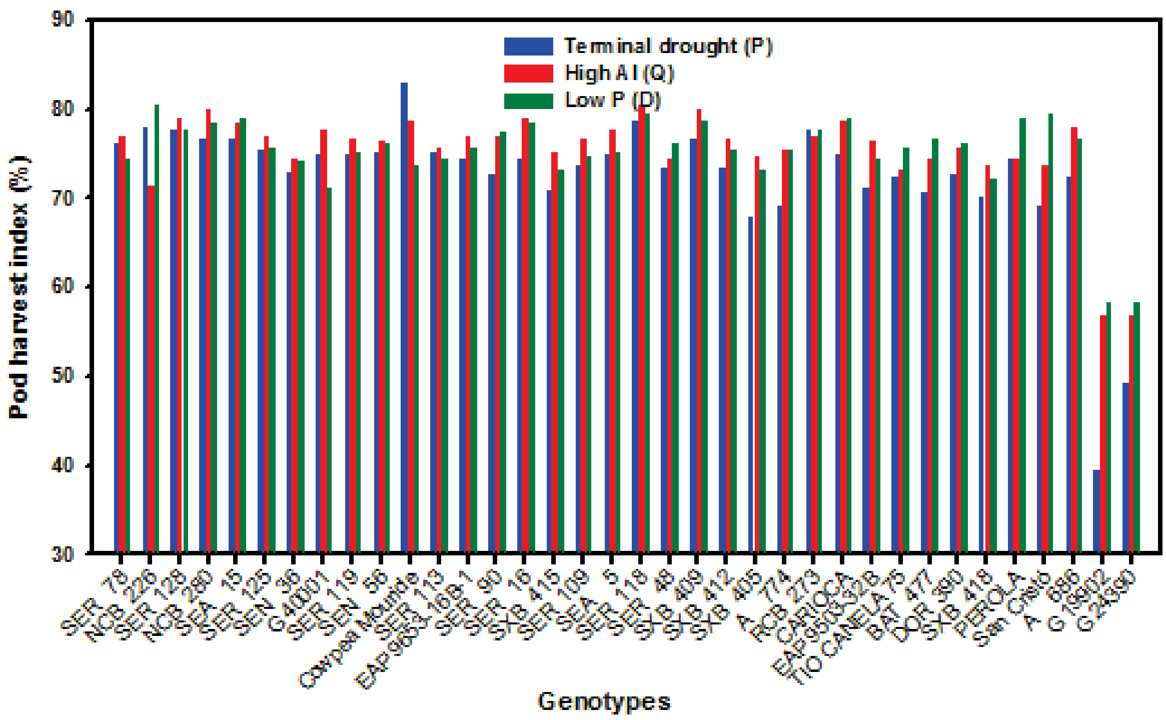

Figure 5. Pod harvest index under different abiotic stress conditions in the field.

Table 27. Yield (kg ha^{-1}) of elite lines of the Andean gene pool, evaluated under terminal drought in 2009.

Line	Yield (kg ha^{-1})	Commercial check (kg ha^{-1})
(CAL 143 x SAB 616) X SAB 629	1857	363
(CAL 143 x SAB 616) X SAB 629	1880	363
(CAL 143 x SAB 616) X SAB 629	1930	568
(KAT B1 x SAB 618) X (SAB 620 x SAB 631)	1962	1222
(KAT B1 x SAB 618) X (SAB 620 x SAB 631)	1882	1561
(SAB 630 x PAN 127) X SAB 676	1976	18

(BCMV), CBB, and bruchids were developed. Therefore, parental materials selected from these trait-based nurseries would permit the subsequent application of markers to their progenies.

Fast track evaluation of drought and heat tolerant *Phaseolus* species

At the outset of the TL II project, a nursery was compiled of more than 1700 entries, with contributions from PABRA (ECABREN in eastern Africa and SABRN in southern Africa), as well as from CIAT headquarters in Colombia. Some materials were selected under drought stress from CIAT-Colombia while some others were derived from regional nurseries like the Bean Improvement for Low soil Fertility in Africa (BILFA) nursery composed of selections made under various low fertility regimes. Others were elite lines from general breeding nurseries. Given limitations of seeds in their early stages, the first nursery was planted in KARI, Katumani, Kenya in two repetitions and short rows. The nursery developed vegetatively well in spite of suffering a moderate level of terminal drought stress with late rainfall conditions. It was, however, a useful nursery for the first evaluation of drought response of lines, many of which were not exposed to moisture stress previously. From this nursery, a sub-set of 500 entries were identified for subsequent distribution to other research sites in the ECABREN region. The nursery in Katumani served a training purpose as well. It was the first nursery planted under the TL-II project, and was the most significant effort in drought resistance till date. The nursery was also the first significant opportunity to expose regional scientists to physiological sampling techniques for the evaluation of drought resistance traits. Moreover, it was also the first opportunity to test the physiological parameters that were identified in CIAT-Colombia as potential indicators of drought resistance. A description of the training exercise *per se* is presented in the section on capacity building. With regards to the results of the physiological analysis, both PHI (seed biomass/pod biomass x 100) and PPI (pod biomass at harvest/total shoot biomass at mid-pod fill x 100) proved to be closely associated with the seed yield, validating the results from Colombia. A similar nursery of 1700 entries was planted in Kandiyani Research Station of DARS, Malawi under the SABRN network, but it suffered a severe attack by bean stem maggot (BSM; *Ophiomyia* sp.). Attack of BSM was a natural result of late planting that was practiced to simulate terminal drought stress, and thus delayed the progress in SABRN. Fortunately, materials selected under a parallel project on drought were advanced and these were employed in PVS trials.

In phase II, nurseries were distributed to the TL II participating countries Malawi, Zimbabwe, Uganda, Kenya and Tanzania. These nurseries consisted of materials segregating for drought tolerance and fixed lines combining drought tolerance with other traits, such as high mineral (Fe and Zn) content, low soil fertility tolerance, pest resistance (bruchids and bean stem maggot; BSM), and disease resistance (CBB). Selections were made for materials at different stages of the breeding pipeline. These nurseries for specific traits served to evaluate the breeding lines for their potential use as parents in additional crosses, and for the application of molecular markers to recover resistance with greater confidence. Currently, the application of marker assisted selection to populations developed in national programs is pending. Below is a brief report on the status of selections in different categories.

Improved drought tolerant germplasm with multiple traits

Evaluation of improved drought tolerant materials was conducted in Uganda, Zimbabwe, Kenya, and Malawi. In Kenya, three nurseries Andean drought tolerant populations (60 entries), 70 advanced lines with *bc*3 gene for BCMNV resistance, and 68 advanced lines from an interspecific cross between *P. vulgaris P. acutifolius* and drought tolerant Andean nursery (427 DAB lines), received from CIAT-Colombia, were evaluated for drought tolerance at two sites – Katumani and Kambi ya Mawe – under rain-fed conditions. High significant differences under both moisture stress treatments were observed in all three nurseries. The average yield of Katumani (2,463 kg ha^{-1}) and Kambi ya Mawe (1,123 kg ha^{-1}) were obtained among the lines with *bc*3 gene, most of which were of the small red market class (the third most-preferred seed types in Kenya). At Katumani, yield ranged between 1772 kg ha^{-1} (BCB 741) and 3,087 kg ha^{-1} (SCN 10). Only four lines had yields less than 2,000 kg ha^{-1} that included BCB 741 (1,772 kg ha^{-1}), GLPx 92 (1,818 kg ha^{-1}), SCR 7 (1,845 kg ha^{-1}), and SCR 2 (1,991 kg ha^{-1}) at Katumani. GLPx92 is a standard local cultivar considered to be drought tolerant, but with poor grain color. The obtained lines yielded far better than GLPx92 and with better color bodies would have a better future impact. The yields at Kambi ya Mawe ranged between 823 kg ha^{-1} (SCR 12) and 1,689 kg ha^{-1} (SCR 20). The average yield of 1,616 kg ha^{-1} across the two test sites was recorded among the inter-specific lines. The crop yield ranged between 709 kg ha^{-1} (INB 840) and 1,612 kg ha^{-1} (INB 812) with an average of 1,064 kg ha^{-1} at Kambi ya Mawe and 1,601 kg ha^{-1} (INB 822) to 2,631 kg ha^{-1} (INB 806) with an average yield of 2,168 kg ha^{-1} at Katumani. Among the 427 DAB lines, most adapted 191 lines were selected and evaluated further for adaptability during the April- July 2013 growing season at both KARI Katumani and Thika. Thirty-six out of the 191 lines were further evaluated at the farmers' fields at Nyeri, Kirinyaga, and Machakos.

In Ethiopia, selection results within the fast track nursery were less successful in the Melkassa program as not a single line convincingly out-yielded the local check, Nasir. This variety proved to be drought-tolerant likely due to its history of selection. It was originally selected in Honduras, a drought-prone region, which could have made it experience the drought pressure during its development. Moreover, accession of a Mexican race - Durango is present among its parental lines, which has been a source of drought tolerance. On the other hand, recombinant inbred lines introduced as part of a PhD thesis proved to be quite successful for the identification of high-yielding navy beans for Ethiopia's export market, both in managed drought trials that amply out-yielded the check (data not shown) and in regional trials although in 2010, rainfall was plentiful, and the yield data did not reflect any drought in

Table 28. Mean yield performance of 12 drought tolerant varieties in seven environments.

Environment	Mean yield (kg ha^{-1})	Min. yield (kg ha^{-1})	Max. yield (kg ha^{-1})	Standard deviation	Variance	%CV
Abi ZARDI	2389.6	1067	3583	657.8	432636	27.53
Ngetta ZARDI	928.4	115	1500	485	235202	52.24
Mbarara ZARDI	631.2	83	1225	363.7	132248	57.62
Nakasongola	582.3	106	1377	308.5	95178	52.98
Mobuku	227	0	592	203.4	41390	89.62
Nabuin	143.9	20	381	110	12107	76.44
NaSARRI	72.3	13	208	66.4	4404	91.77

ZARDI= Zonal Agricultural Research and Development Institute that particular year. Selections 23 with 11% and 80 with 12% yields were especially stable, which was more than the elite check Awash-Melka across environments, and 29% and 19% more in the lowest yielding environment, Pawe (Awash-Melka was distributed as an elite variety under objective 8). Data on disease were taken at all four test sites, but only data from Jimma are shown as, here, the disease pressure was especially intense. Several lines were superior to Awash-Melka in disease resistance, especially line 23 that was superior to others in reaction to four different diseases. In evaluations with traders, all lines were quite acceptable. However, line 80 was rated highest in canning quality in the tests carried out at Italy.

In Uganda, a nursery comprising of 34 elite lines, received from CIAT HQ (Table 29), was evaluated for drought tolerance during the off-season at NaCRRI-Namulonge under both rain-fed and irrigated conditions. The trials were set and subjected to the normal seasonal conditions of different localities. The north of Uganda is characterized by frequent droughts and high temperatures, thus, is considered as one of the few bean growing areas of Africa. Black beans are more preferred in this region. The black seeded introductions in this trial represented the first introductions of black seeded lines for drought tolerance. Results showed significant difference ($p<0.01$) between lines of the SCN bean lines series and the *bc*3 gene yielding slightly higher than the other series. The yields ranged from 875 to 2,447 kg ha^{-1} for the irrigated trials and from 638 to 2,030 kg ha^{-1} for the non-irrigated trials. Bean lines DOR 364, SCN 1, SCN 11, SCN 17, SCN 4, SCN 74, SCN 8, SCR 26, SEN 1, SEN 56, SEN 74, SEN 70, SEN 80. SEN 90, SEN 95 and SEN 98 were less affected by the drought as their yield losses due to drought were less than 20% of that achieved under irrigated conditions. The best performing lines were SCN 1, SEN 1, SCN 8, SEN 70, SEN 95 and SEN 98 with a yield loss of 15% and below. Significant differences ($p<0.05$) were also noted in the days to 50% flowering, where lines KAT X56, KAT B1, KAT B9, SCN 1, SCN 17 and SCR 118 flowered

Table 29. Number of drought tolerant lines evaluated and selected among the TL II countries.

Country	No. lines evaluated	No. of lines selected
Kenya	665	36
Uganda	34	16
Zimbabwe	377	168
S. Tanzania	92	4
Malawi	20	-

Table 30. Nurseries evaluated in the TL II countries.

Nursery	Trait	Codes	Recipient countries
Small reds	Drought and high minerals	SMR	Zimbabwe
Small reds	Drought	SER	Zimbabwe
Small reds	Drought and bc3	SCR	Uganda, Kenya
Small reds	Low soil fertility and drought	BFS	Kenya, Uganda, Zimbabwe
Blacks	Drought and high minerals	SMN	Zimbabwe
Blacks	*bc3*	NCB, BRB	Kenya, S. Tanzania
Blacks	Drought	SEN, SCN	Uganda, Kenya
Mixed colors	Bruchids	MAZ	Zimbabwe, Kenya, Uganda, Malawi
Mixed colors	Drought and high minerals	SMC, SMB	Zimbabwe
Mixed colors	*bc3*	BCB	Kenya
Mixed colors	BSM	BH, CIM	Zimbabwe, Uganda, Malawi
Mixed colors	CBB	CIM	Zimbabwe, S. Tanzania
Andean	Drought	DAB	Kenya, Zimbabwe
Andean	Drought	DAB	S. Tanzania, Zimbabwe

2-7 days earlier than the rest of the bean lines. Most lines were shown to be resistant to rust and BCMV, and moderately resistant to acetolactate synthase (ALS) and CBB. Twelve selected lines were further evaluated in six drought-prone areas of Uganda under on-station conditions (ABIZARDI, Mbarara ZARDI, NASARRI, NgetaZARDI, Mobuku, Nabuin and Nakasagola). They included DOR 364, SCN 1, SCN 11, SCN 8, SCR 26, SCR 35, SEN 46, SEN 56, SEN 70, SEN 80, SEN 95 and SEN 98 along with four Uganda market class varieties, K132, NABE 4, NABE 15 and NABE 16 as checks. AbiZADRI was the best environment for the genotypes with an average yield of 2389.6 kg ha^{-1} while NaSARRI with an average yield of 72.3 kg ha^{-1} was the worst performing environment (Table 28). The reason behind the good yield performance was the abundant rainfall in AbiZARDI (data not shown) than other environments during the growing season leading to higher yield potentials. It can also be noted, due to the intense drought experienced in these environments like Mobuku, total yield losses were obtained for some bean genotypes. Results showed that only AbiZARDi and NgettaZARDI environments had net positive effects on the genotypes, the rest of the environments contributed negatively to the performance of the genotypes. Yields of genotypes, SEN 70, SEN 80, SEN 56, SEN 46 and SCN 8 were not significantly ($p \geq 0.001$) different in the different environments whereas the yield of genotypes SEN 98, SCN 11, SEN 95, SCN 1, NABE 15 and SCR 35 significantly differed among the six environments.

In Zimbabwe, a total of 1007 lines were first evaluated for adaptation and photo-sensitive response under the irrigation scheme at Harare Research Station in August 2008. Some lines were adapted and those that excelled were planted again in two sets. One was planted under water stress and the other with irrigation at Gwebi Variety Testing Centre in February 2009. However, the crop in the irrigated field was partly grazed by antelopes during the trifoliate stage. Drought in the water stress treatment was not as severe as expected, since unexpected rains were received during the early podding stage. However, 200 lines were selected under drought conditions. During the 2009-10 summer season in Zimbabwe, the selected 200 lines were sent to farmers for participatory variety selection to expose genotypes to the natural drought conditions and farmer environment, improve efficiency of researcher's selections, meet standards of variety release, and increase chances of variety adoption once released. Many parts of the country received below-average rains and persistent dry spells were recorded that gave rise to two types of drought depending on the region/district. One type affected the beans at flowering stage (mid-season drought) and the other due to the late planting favored the terminal drought. There was also an extreme scenario where the rains did not even support the seed germination in the drought-prone areas, like Gutu and Mushagashe in Masvingo province. Of the 200 lines, farmers from different areas managed to select 30 lines. Farmers' selection criteria were mainly based on varieties resistant to drought since 2009-10 was a drought year. We managed to receive a few grams/line from the farmers since the majority of farmers retained some quantity of the seed. The varieties, which were selected by farmers under farmers' fields category, were reconstituted into one nursery and were bulked up at Harare Research Station to enable on-station trials under drought conditions of Lowveld during winter of 2011-12. The physiological parameters for drought tolerance will be precisely measured. The multilocation variety evaluation would have been followed then with a possible release of at least one drought tolerant variety in 2012/13 season. In phase II, 36 drought lines received from CIAT-Malawi were evaluated at Gwebi Variety Testing Center for tolerance to drought and fungal diseases. Fifteen lines were selected on the basis of high yield potential under terminal drought stress and tolerance to CBB and ALS. Another drought tolerant nursery (drought Andean bush; DAB with 130 entries) was evaluated at Harare Research Station, Gwebi Variety Testing Center, and Save Valley Experiment Station. Sixty-four lines were selected. The selected lines combined good stomatal control with high grain yield, which will be advanced into the Preliminary Yield Trials (PYT). Five other nurseries (drought physiology lines, drought Andean red & white nursery, BSM nursery, advanced backcross drought nursery, and Andean drought red mottled nursery were evaluated at Gwebi Variety Testing Center and Kadoma Research Station for their resistance/tolerance to different environmental constraints. Fifty lines were selected from 99 drought physiology lines, 20 lines were selected from 35 drought Andean red & white nurseries, eight were selected from 28 BSM nursery lines, and 11 lines were selected from 49 advanced backcross drought nursery. The selected lines were advanced into PYT. Nine BRB lines (*bc*3 gene) constituting the BCMV resistance nursery were evaluated in Zimbabwe, out of which four lines (BRB 267: 2,426 kg ha^{-1}, BRB 268: 2263 kg ha^{-1}, BRB 264: 1,510 kg ha^{-1}, and BRB214: 1,460 kg ha^{-1}) combined high grain yielding ability with high disease resistance (Angular Leafspot, Bean Common Mosaic Virus, Rust & Anthracnose). In addition, 36 genotypes (CBB nursery) were established at Harare Research Station for seed increase and identification of disease resistant sources. Six lines ie, BRB 265/VAX 3-5 (1,150 kg ha^{-1}), SEQ 1003/VAX 3-12 (1120 kg ha^{-1}), SEQ 1003/VAX 3-13 (1320 kg ha^{-1}), SEQ 1003/VAX 3-17 (1,440 kg ha^{-1}), SEQ 11/RMX 19-1 (1,460 kg ha^{-1}), SEQ 11/RMX 19-3 (1,410 kg ha^{-1}) were the best adapted ones with average yields ranging from 1,100 kg ha^{-1} to above 1,400 kg ha^{-1}. These lines also exhibited an exceptional performance with regard to their disease resistance (ALS, Rust and BCMV).

In South Tanzania, 36 drought bean lines were evaluated in a replicated trial at Ismani Research Station for adaptation and agronomic performance during the rainy season. Six genotypes, CAL 143, ALB 4, SER 80, SEN 39, SER 85, and NCB 280 were selected for drought tolerance testing. In addition, 56 bean lines were evaluated for tolerance to drought at ARI-Uyole and Ismani Research Station. Results are still under analysis.

A number of nurseries were evaluated for resistance or tolerance to multiple stresses in S. Tanzania. Eight lines from SARBYT (20 entries), 6 lines from Khaki nursery (29), 11 genotypes from Khaki lattice (36 entries), 11 genotypes from Sugar bean nursery lines (22), six from NUA (22 lines) were selected. Drought lines AS 16358 - 020, SAB 691 and MR 14125-3 gave higher yields under drought and low P (30 kg P/ha) environments at Ismani site and also showed resistance to anthracnose, bacterial blight, and rust. F4 Climber lines (56), Drought lines (36), BILFA lines nursery (18), Climbing bean nursery (Fe & Zn) (136), F3 Climbers pops (114), SARBYT Climbers (20), SABREN Climbers (49) were also evaluated.

In Malawi, evaluation of the fast track nursery in southern Africa was delayed due to attack of bean stem maggot or bean fly (*Ophiomyia* spp.), which was exacerbated by late planting of nurseries to increase the probability of drought stress. Lines are still being processed, but in the off-season nursery in Kasinthula 51 lines produced 30% more grain that the average of four checks, although almost none of them could beat the best check by this margin. We have noted that lines selected under the Malawian program have performed well in other environments, and the local soil materials might already have a degree of tolerance. While the fast track entries were recovered and cycled through the evaluation scheme, lines selected previously under a parallel project were advanced and were at the point of release. Across four sites including two on-farm sites in the north of Malawi (CHS and BOK), small red seeded lines out-yielded the local check CAL 143 by as much as 50%. Although not the most preferred type in Malawi, small red beans do appear in local mixtures. The national program is considering the release of SER 83 and SER 45. In Malawi, an experiment that evaluated 20 bean genotypes for multiple stress tolerance at Chitedze was conducted and ten lines were selected. Seeds were increased in these ten lines during the preparation for multi-location evaluation in the 2013/2014 season. In Ethiopia, 501 lines of different market classes were evaluated in different bean growing regions, out of which, 294 promising advanced lines were identified for further evaluation under advanced multi-location yield trials.

Drought and low soil fertility

In Kenya, 16 genotypes from Kabete, KARI-Kakamega, and KARI Katumani along with three commercial checks were planted to evaluate the effect of P on the grain yield at Muguga and Kabete university farm. There were varied responses to the applied P at medium P (30, 60) and high P (90) rates by all the genotypes. All the varieties showed a response to medium and high P rates, except for KK 20, VNB 81010, and KK 15 that did not show any response to the increase in P rates. KK 20 and VNB 81010

Table 31. Yield, under drought induced by low rainfall in the vegetative phase and post flowering water deficit, of SER 16 and its ALB progenies derived from a cross with runner bean (*Phaseolus coccineus*) evaluated during the drought season in 2010.

Line	Yield (kg ha^{-1})	Line	Yield (kg ha^{-1})
ALB 60	2155	ALB 147	1618
ALB 180	1908	ALB 77	1565
ALB 213	1830	SER 16	1558
ALB 209	1826	ALB 110	1312
ALB 214	1734	Tio Canela	1283
ALB 91	1713	LSD (0.05)	436
ALB 6	1631		

yielded more than all the other varieties under low P conditions (0 kg P/ha). The recently improved genotypes (KK15, NCB 226 and SEA 15) yielded relatively more than the older varieties. Drought susceptible varieties had a remarkable response to the P fertilizer applications. Lines NCB 226, SER 118, and SEA 14 selected for drought tolerance yielded relatively well under low P levels compared to older genotype, KAT B1, which was selected locally. In Malawi, experiments were conducted to identity low P and N tolerant bean germplasm at two sites of Bvumbwe and Chitedze. The results are still pending. In Zimbabwe, 23 BFS genotypes (low soil fertility and drought tolerance) received from CIAT-Colombia were evaluated for adaptation to low soil fertility and drought tolerance. NUA45 and Gloria were the control genotypes in this trial. A total of 14 genotypes (BFS 10, BFS 14, BFS 23, BFS 27, BFS 29, BFS 30, BFS 32, BFS 33, BFS 39, BFS 55, BFS 62, BFS 67, BFS 75 and SXB 412) were selected based on high yielding ability with earliness, good stomatal conductance, and resistance to common bacterial blight and angular leafspot. Four genotypes (BFS 32, BFS 55, BFS 67 and SXB 42) outperformed the two check varieties (NUA 45 and Gloria) in terms of high grain yield.

Screening for resistance to bean stem maggots

Screening for bean stem maggot resistance was done in Kenya, Uganda, and Zimbabwe though extensive studies, which were conducted under TL I in Ethiopia. In Kenya, KARI-Thika obtained eight bean lines with resistance to BSM from KARI Katumani. Ikisinoni, Mlama 127, Ikinimba, CCC 888, Mkombozi, Macho, CIM 9314-36, and Ex 290 lines were tested under the breeding protocol for their evaluation of BSM resistance that was validated at different sites as a standard protocol, which is yet to be adopted. In Kenya, the emergence of the adults from pupae, kept at room temperature ranged from 30-80% and from 30-60% in an incubator at 28 °C while the time of emergence ranged from 3-14 days.

In Uganda, pupae from NABE 4 were obtained from the field and reared in cylindrical jars (30 pupae/cylinder). Adult emergence was at an average rate of 53.42%. Thereafter, the adult flies were introduced into the cage at five DAE, and this was repeated every ten days. Thirty-two genotypes were assessed based on weekly plant mortality until flowering, ovipunctures (2WAE), number of pupae per plant (4WAE), stem damage on a scale of 1-9 (4WAE), and rated on a scale of 1-9 where 1 represents immune and 9 represents extremely susceptible. From this protocol, 14 lines were found to be resistant and 13 moderately resistant. One experiment evaluating 100 genotypes for BSM tolerance was implemented at Chitedze, but the data was being analyzed to identify superior genotypes. In Zimbabwe, 29 genotypes constituting the Bean Stem Maggot (BSM) nursery were included with the selections from CIM-x SUG- cross and CIM- x RM- cross, which were later evaluated at two sites. High infestations of BSM were observed at both the sites. A total of 8 genotypes (CIM-RM-03-42-20, CIM-RM-03-42-09, CIM-

RM-03-42-10, CIM-SUG-03-09-15, CIM-SUG-03-09-07, CIM-SUG-03-09-06, CIM-SUG-03-09-05, CIM-SUG-03-09-02) were tolerant to BSM across the tested sites. These genotypes also had average yields of above 1,500 kg ha^{-1}. This BSM nursery is currently being evaluated in southern Tanzania. In Ethiopia, the research work on BSM was conducted under TL I project.

Screening for resistance to bean bruchids

In Zimbabwe, 100 MAZ lines were evaluated both in the field for yield performance and in laboratory for bruchid resistance. The field trial consisted of the entire 100 genotypes while laboratory screening was done for 28 genotypes inclusive of three check varieties (NUA 45, Gloria and PAN 148). Laboratory experiments assessed tolerance to the Mexican bean weevil. Eleven lines, MAZ 190 (1,000 kg ha^{-1}), MAZ 2 (1,315 kg ha^{-1}), MAZ 173 (1,481 kg ha^{-1}) MAZ 42 (1,037 kg ha^{-1}, MAZ 211 (1,352 kg ha^{-1}), MAZ 116 (1,222 kg ha^{-1}), MAZ 207 (1,630 kg ha^{-1}), MAZ 145 (1,630 kg ha^{-1}), MAZ 204 (1,667 kg ha^{-1}), PAN 148 (930 kg ha^{-1}) and GLORIA (1,200 kg ha^{-1}) showed exceptional performances with regard to the bruchid resistance and potential yield. The varieties Gloria and PAN 148 were identified as improved varieties with high resistance to bruchid attack, however, it would require more confirmation. Results also showed that the shiny, small seeded MAZ lines and sugar types were more resistant to bruchid attack as compared to the large red MAZ lines. Evaluation of another sub-set of MAZ lines (25) is still in progress.

In Kenya, one hundred bruchid resistant lines (MAZ 4-217) received from CIA- Colombia were planted in the field at KARI Katumani to test for their adaptability during the short rainy season within November 2012-February 2013. Most of the lines consisted of the grain types preferred in the market. The grain yield during this season ranged from 22 g to 215 g per 1.5 m row. MAZ 3, 31, 150, 185, 207, 110, 112, 109, 205 and 150 were among the entries with highest seed yield. This trial was repeated during the long rainy season within April-July 2013, where the 100 MAZ lines were evaluated for adaptability at KARI Katumani. The 100 entries were then tested for resistance to bruchids under artificial infestation to identify the entries that could be used to cross with the susceptible commercial varieties. The same set of 100 MAZ lines was distributed to Uganda (AGRA, MSc study), Ethiopia (ACCI, PhD study), and Tanzania for evaluation. In Uganda, 28 accessions were screened for resistance to *O. spencerella* with an artificial infestation and ten resistant lines selected. These ten genotypes were screened to confirm the levels of resistance to bruchids for utilization in crosses, and the results are still pending.

Climbing beans responding to increasing bean production and productivity

Climbing beans have been shown to out-yield bush beans by doubling and tripling the yields (Niringiye et al. 2005; CIAT 2012), and utilizing the vertical space, and therefore, are becoming a very attractive enterprise among small-scale farmers for whom land is a major constraint. Moreover, the horizontal expansion of their agricultural land is also difficult. Climbing beans are a relatively new technology in Kenya and Ethiopia but have been found to exist in Uganda, Tanzania, Malawi and Zimbabwe even though they have been limited to specific agro-ecologies most specifically in the highland areas. With recent development of the Mid-Altitude Climbing (MAC) beans, the technology can be promoted in less traditional environments. Effort in phase II was to promote the climbing beans to new areas that were conducive for growth and the less traditional environments within the participating countries. In Central Kenya, for example, climbing beans is a relatively new technology with a different growth habit and crop management from the bush beans. Major constraints to their production included lack of information on the technology and availability of stakes, since the climbing beans have to be staked to produce optimally.

One of the areas identified to be potential for climbing beans is the Kagera and Kigoma region of Tanzania. Ten climbing bean varieties, Gasirida, Kenya Mavuno (MAC 64), Kenya Tamu (MAC 34), MAC 9, MAC 44, MAC 49, Mamesa, RWV 1129, RWV 5348 and Umubano, were introduced to this effect by CIAT and evaluated for adaptability and acceptability in Kagera region during the long rainy season of March-May 2013. A mother trial was designed in a split plot with and without P as the main plot and the variety as the sub plot, which was established on-station. The line RWV 5348 had a high overall mean yield of 1.26 t/ha, followed by varieties Kenya Tamu (1.13 t/ha), MAC-49 (1.11 t/ha), and Umubano (1.08 t/ha). RWV 5348 and Umubano also had high mean yield both in plots with and without P. Gasirida variety had the lowest overall mean yield of 0.319 t/ha, in with 0.39 t/ha in the plot with P and 0.25 t/ha in the plot without P. The overall mean yield for other varieties were 0.93 t/ha for MAC 44, 0.87 t/ha for MAC 9, 0.75 t/ha for Mamesa, 0.72 t/ha for Kenya mavuno, and 0.61 t/ha for RWV 1129. Gasirida and Mamesa were severely infected by viral disease both on-station and at Irango village. RWV 1129 was infected by angular leafspot and leaf rust diseases at low score levels.

Development and deployment of parental materials for various stresses

Development of new multiple stress resistance populations: Segregating populations were developed for selection in CIAT-Colombia, in CIAT research sites in Africa and in NARS programs. Based on the evaluations made in Colombia, elite parental lines were selected for another cycle of crossing with emphasis on beans from the Andean gene pool. Effort was made to deliberately develop bean germplasm that was drought tolerant with an added trait of high Fe and Zn content. Small seeded Mesoamerican bush bean lines, emerging from the breeding program in Colombia, presented as much as 80% higher iron and drought resistance equal or superior to the tolerant check variety. The improvement of mineral content in the climbing bean materials has been successful with an added advantage of increased productivity per unit area. High temperatures aggravate the stress imposed by drought, and combinations of stress tolerance would be necessary in the near future. While 20 °C night temperature is normally considered to be a limitation for common bean, the breeding lines combining common bean with *P. acutifolius* presented an excellent pollen formation and good pod set at 22 °C night temperatures. Some pod sets were maintained at 25 °C nights. Approximately, 60 populations were evaluated per year in CIAT-Colombia. Other populations were sent to the partners in four out of five participating countries while in Zimbabwe, the program focused only on giving follow up to the existing populations (Table 31-43). Additional crosses were made in the Ethiopian program (Table 31-43) and the parental materials were delivered to KARI-Kenya to initiate a crossing program over there.

Interspecific crosses with tepary bean

Phaseolus acutifolius or tepary bean is a desert species with multiple drought-resistance traits. It can be crossed with common bean only by using the embryo rescue, yet with great difficulty. However, several years of effort has resulted in the accumulation of a sizable number of interspecific progenies. The most drought resistant varieties were identified and intercrossed, and the selections from the second cycle were evaluated under terminal drought conditions of 2009. A very unusual breeding line- INB 841 was identified with the high level of resistance to wilting and rapid pod development, but root evaluations suggested that its root system is not superior. Thus, we suspect that it may possess possible mechanisms of stomatal regulation and/or osmotic adjustment to resist wilting. Its trait of rapid pod elongation may also be associated with hormonal regulation of pod growth and development. Lines, developed from this species, are being evaluated both by CIAT and other national partners, which show a lot of promise.

Inter-specific crosses with runner bean

As part of a BMZ project, combinations of drought resistance and aluminum (Al) tolerance were sought. Accessions of runner bean, or *Phaseolus coccineus*, proved to be highly resistant to Al, hence were crossed to drought resistant line SER 16. This cross was designed to combine the vigor and biomass of the runner bean with the remobilization capacity of the line. The resulting population was subjected to an intensive study of root attributes revealing large differences in the rooting patterns and morphology that are relevant for improvement of common bean for drought resistance. Runner bean has a coarse and rugged root system with thick basal roots that can penetrate acidic soil under drying conditions much better than common bean. Some lines from the runner bean source also display less wilting. Some progenies of runner bean also tend to produce large biomass and excellent yield potential reflecting in part their vigorous root system. We used these lines as parents for improved yields in combination with sources of enhanced photosynthate remobilization. This is still another source of traits that are being investigated as potentially relevant for drought resistance. Data presented in Table 31 represent yields under drought conditions induced by limited water supply during the vegetative phase, followed by soil drying through much of the reproductive phase. All ALB lines are derived from the cross of runner bean with SER16. The advantage of some ALB lines over the SER 16 parent is due to the introgression of genes and traits from the runner bean. Yield, under drought induced by low rainfall in the vegetative phase and post-flowering water deficit, of SER 16 and its ALB progenies derived from a cross with runner bean (*Phaseolus coccineus*) was evaluated during the drought season of 2010.

Population development by national partners

In phase II, Zimbabwe developed 85 single cross combinations involving 43 parents to develop new breeding lines combining bruchid and CBB resistance with BCMV resistance for good performance under drought pressure. The sources of resistance were selected from the MAZ line trials, DAB trials, BRB lines, and CBB trials. The aim of the hybridizations was to improve the yield of common beans by developing bean cultivars' tolerance to bruchids, CBB, BCMV, and drought. Fifty-three F1 populations were advanced to F2 under greenhouse conditions during December 2012. A total of 53 F2 populations were established at Save Valley Experiment Station in winter. These lines, resulted from bi-parental crosses, were initiated in 2012 with an aim of improving their tolerance to low N, low P, acid pH, and BCMV in commercially cultivated large-seeded beans. No selections were made due to the low heritability of the quantitative traits in common bean resulting in the delayed selection to F4/F5 stage. From the F5.6 nursery consisting of 47 progenies, a total of 15 families were selected based on their tolerance to CBB, ALS, and Rust.

In Uganda, NACRRI embarked on introgression of bruchid and bean stem maggot (BSM) resistant genes into the farmers' preferred varieties. Six exotic bruchid resistant genotypes sourced from Malawi, MALUWA/KK25/443, KK25/MALUWA/112-mw, KK25/MALUWA/19-mw, KK25/NAGAGA/184-mw, KK25/NAGAGA/184-mw, MALUWA/KK25/9-mw and one local (Tapara) were crossed with four susceptible local varieties (ie, NABE 4, NABE 15, NABE 17 and NABE 23). In addition, 16 different crosses were made to introgress with the BSM resistant genes into susceptible Ugandan market class varieties (NABE 4, NABE 15, NABE 16 and NABE 17) with known BSM resistant genotypes from CIAT. A field screening trial was set up to identify other bean genotypes that are resistant to BSM. Till the end of the project in Uganda, crosses were made with three local bean lines (K132, NABE 4, and NABE 15) and five drought elite lines (SCR 48, SCR 6, SCR 9 SEN 98 and SEN99) that resulted in 183 segregating populations that are still undergoing screening.

In Kenya, KARI-Thika conducted crosses targeted at introgressing observed BSM tolerance from eight lines into the popular bean varieties grown in central Kenya (ie, GLP 2, GLP 585, GLP 1127, GLP 24 and KAT B1). Successful crosses included Ikisinoni x GLP 24, GLP 24 x CCC888, GLP 585 x Mkombozi, GLP 24 x Ikinimba, GLP 2 X CCC 888, GLP 2 x macho, EX 290 x GLP 1127, CIM 9314 x GLP 2, GLP 1127 x Mrama 127, Mrama 127 x GLP 2, and Mrama 127 x GLP 2. The F1 seeds were planted in the screen house in May 2013 in Ethiopia. Crosses targeted the drought tolerance and seed market class. In Ethiopia, seven new single crosses were also made and successful pods were harvested in this pattern with genetic variability of several sources.

An ideotype for Mesoamerican beans

Beans are often planted in marginal soils. The Mesoamerican beans, in particular, often occupied the more difficult niches, even within a farm. Soil fertility is a critical issue for the improvement of bean yields, and poor fertility conditions often override the benefits of drought resistance. Beans are sensitive to poor fertility conditions compared to other legumes, due to their short growth cycle of less than 80 days. Our experience over the past many years has shown that rusticity and yield in poor soil fertility are greatly affected by the phenology. In one such experience, the trial of drought resistant lines were planted for evaluation in response to the low soil P availability that unexpectedly suffered severe mid-season drought. The better yielding lines tended to be late flowering while the grain filling period was not noticeably different (Table 32). We believed that the ability to withstand low fertility permits an overall plant vigor and root development, which contributes to drought resistance. A short season crop does not have sufficient time to explore the soil profile, whereas farmers prefer early varieties of bean. This presents a contradiction between the demand for a new ideotype that is rustic, yet not late-maturing. We suggested that such an ideotype would have an extended vegetative period to permit better root development, better plant nutrition, and greater biomass production followed by a reproductive phase characterized by aggressive remobilization and rapid dry down at maturity. Experience gained in characterization of remobilization in TL II project makes us hopeful that this is possible. In particular, one red-seeded line-SER 118 is consistently superior in PHI (a measure of remobilization) and tends to present the pattern of mid-late flowering and acceptable maturity. It often yields among the best lines.

Table 32. The four highest yielding entries and the four lowest yielding entries out of 36 drought resistant lines and checks subjected to combined stress of low available soil P and midseason drought. Darien, Colombia, 2009.

Line	Yield (kg ha^{-1})	Days to flowering	Days to grain filling
SXB 412	1257	41	38
NCB 226	1206	33	41
SXB 409	1187	40	42
SXB 405	1175	39	40
SEA 15	625	34	43
SEN 56	563	32	43
SEA 5	379	34	39
G 4001-P. acutifolius	190	37	39
LSD (0.05)	266	2.5	

Selections from segregating populations

Sixty-six segregating Andean drought populations were generated from two-, three-, four- and five-way crosses between Katumani drought tolerant varieties (KAT B1 and KAT B9) and CIAT drought tolerant lines (SAB 618, SAB 620 and SAB 659) in CIAT-Cali. They were evaluated in Kenya at two drought sites of Kambi ya Mawe and Katumani research fields. Yields at Katumani were relatively higher than those obtained in Kambi ya Mawe with an average yield of 2,191 kg ha^{-1} with a range of 1,305 kg ha^{-1} (AS 16468-006) to 2,730 kg ha^{-1} (AS 16372-013) in Katumani while at Kambi ya Mawe the yield ranged from 619 kg ha^{-1} (AS 16375-001) to 1,831 kg ha^{-1} (AS 16370-010) with an average yield of 1,028 kg ha^{-1}. Results were promising as all the lines yielded more than the national average yields of most commercially grown varieties (500 kg ha^{-1}). Twenty-five lines performed better than the best commercial check (GLP 1004, 1,638 kg ha^{-1}). Sixty-nine promising lines from the cross SCR 9 x INB 841 combining drought tolerant small red-seed type with the BCMV recessive resistance were selected on the basis of grain yield and grain filling trait. This population is a cross of *Phaseolius vulgaris* (SCR 9) with an interspecific cross derivative INB of *P. acutifolius.* Seventeen different populations consisting of 100 F_4 families with resistance to multiple constraints including BCMV, CBB and drought were received from CIAT-Colombia and evaluated for adaptability during the November 2012- February 2013 growing season at KARI Katumani. There were very minimal BCMV and CBB disease incidences noted in the field during the season and, therefore, were not scored. The grain yield ranged from 45-293 g per 1.5 m row. Progeny rows were planted at KARI Katumani and Thika during the long rainy season of April-July 2013, where further selection was done to produce the experimental lines. Selected lines were evaluated during the short rainy season of 2013. $F_{2.4}$ populations, developed for multiple stress tolerance, were advanced to the $F_{2.5}$ generation in Ethiopia. Most of the segregating populations are targeted drought tolerance.

Preliminary yield trials (PYT) and advanced yield trials (AYT)

In Northern Tanzania, Advanced Yield Trials (AYT) of 21 best lines and Preliminary Yield Trials (PYT) (2012) plus four checks were further evaluated at Selian Agricultural Research Institute (SARI), Arusha site in 2013 during the main rainy season. Twelve best lines of beans were selected from 21 lines (AYT in 2012) plus four checks were further evaluated at SARI and Machine Tools (Kilimanjaro) sites in 2013 during the main rainy season. All agronomic traits, yield components, and disease data were collected. All trials have been harvested and the seed processed. Data Analysis was also undertaken.

In Zimbabwe, PYT were conducted at two sites and AYT at five sites to supplement the data for variety selection and release. The five sites of AYT were a representative of the agro-ecological zones in Zimbabwe as required by the Variety Release Committee. A total of 25 entries were selected from SABYT and 20 lines of SARBEN were evaluated at PYT. PYT of SARBEN and four checks (NUA45, Gloria, Speckled Ice and PAN 148) were evaluated at Harare Research Station and Gwebi Variety Testing Center. Highly significant differences ($p<0.001$) were observed among the genotypes for grain yield after the combined analysis of the two sites. Eleven lines were selected from the PYT for further evaluation in intermediate variety trials (IVT) during the 2013-14 season. The best performing 25 lines selected from intermediate yield trial (IYT) (2012) were evaluated at Harare Research Station, Gwebi Variety Testing Center, Kadoma Research Station, and Save Valley Experiment Station during the 2012-13 season in the AYT. A total of 10 genotypes from the AYTs had more grain yields compared to the high yielding check varieties. A total of 24 on-farm trials were established to evaluate 15 promising bean genotypes including five check varieties in eight different locations. Genotypes showed highly significant differences for grain yield ($p<0.001$) under on-farm conditions. Five genotypes ie, SEQ 1001, ARA 4, DAB 51, DAB 52 and DAB 411 were selected for further evaluations. Two on-farm locations Chiota and Chivhu were characterized by dry spells, and this allowed for the identification of genotypes tolerant to drought. Seven varieties (SEQ 1001, ARA 4, MG 38, VTTT925/9/1/2, DAB 51, DAB 52 and DAB 411) performed well under the dry conditions giving an average yield of 0.7 t/ha.

In Malawi, PYTs with 30 entries and AYT with 20 entries were conducted at three sites (Chitedze, Bembeke, and Bvumbwe). The main objective of these trials were to test a selected number of promising bean varieties for better bean yield that were resistant to disease and adapted to different growing environments. At Chitedze, genotypes did not show any significant difference on seed yield ($p=0.09$) while at Bvumbwe and Bembeke, the genotypes showed significant differences ($p=0.004$) in relation to the grain yield. At both sites, several varieties produced higher yields as compared to the yield of the released check variety. These varieties were increased for further testing.

PVS trials and lines in the pipeline

The fast track activities were initiated in KARI, Katumani and were carried forward to dryland sites throughout eastern, central, and western Kenya. During the first season of 2009, five PVS were conducted, out of which three were in Central province and two in Rift Valley province. Both female and male farmers were invited to evaluate the test genotypes at physiological maturity stages using the ribbon method. During the exercise, 18 lines were selected. In the second season of 2009, 18 test genotypes and six checks (KAT B1, KAT B9, KAT X56, KAT x 69, GLP x 92, and GLP 1004) were evaluated in both on-farm and on-station trials. Eight on-farm trials were established, which was evaluated with farmers and the yield was estimated. On-station trials were grown under irrigation and under managed stress at KARI's Kiboko station in eastern Kenya. At the outset of the project, check varieties GLP x 92 and KAT B1 were identified as two better yielding varieties in farmers' hands. However in on-farm and managed stress at Kiboko, these varieties were found to be inferior to the new KARI varieties, being distributed in objective 8. Furthermore, lines being tested resulted in far better yield than the KARI varieties with an advantage of as much as 80% over the best check.

In phase II, KARI Thika conducted a PVS trial that included eight lines (ECAB 702, 703, 0019, 027, 241, K131, GLP 2 and GLPX92) at pod filling stage (R8) by a team of scientists from KARI Thika and Katumani. Twenty-six farmers (18 women and eight men) from Mla Jasho Yake self-help group and neighborhood participated in the selection process using the ribbon method. Some of the preferred traits, were many pods per plant, high yield in the midst of moisture stress, resistance to diseases, good seed and pod filling, good plant stand, and the seed color. The traits that were disliked included, few pods per plant, presence of insects and diseases, poor seed and pod filling, and seed size. Genotypes GLP X92, K 131, ECAB 702 and 703 were ranked as highest yield varieties amongst the farmers. GLP X92 was the most preferred genotype amongst the women, followed by ECAB 702 and ECAB 703. The most preferred genotype amongst men was ECAB 027, followed by GLP X92, K 131, and GLP 2. In general, women preferred the highest yielding lines in terms of the pod load and seed filling while the men preferred the large seeded types. Women did not mind the small-seeded types as long as the lines were high yielding, thereby, ensuring food security to their families. Men used the criteria of acceptability of the bean lines at the market place in their selection. The final yield data is still under analysis to compare the selection by the farmers and the actual yield performance of the lines.

Out of 427 DAB lines, 191 most adapted lines were selected and further evaluated during the April-July 2013 growing season at both KARI Katumani and Thika. Thirty-six out of the 191 lines were further evaluated at the farmers' fields at Nyeri, Kirinyaga, and Machakos. A PVS was conducted at Machakos, where 46 farmers selected the best performing lines. Data entry and analysis is still in progress. The best performing lines are currently being evaluated in multiple locations with PVS in the October 2013 - February 2014 season.

In phase II at Zimbabwe, the Agronomy Research Institute carried out PVS trials in two agro-ecological zones and the farmer/consumer preferences were captured. Ten dry bean varieties (PAN 148, MG 38, DAB 411, VTTT 925/9/1/2, Bounty, Speckled Ice, Gloria, SAN-1, Cardinal, and NUA 45) were tested on-farm and on-station in agro-ecological zones II, III and IV. The sugar bean types such as Gloria, VTTT 925/9/1/2, DAB 411, and Speckled Ice were the mostly preferred varieties. Farmers cited that these varieties were potentially easy to market as compared to the Calima types. Most female farmers preferred DAB 411 more because of its drought tolerance attributes, which is good for ensuring the food security of the region.

The SARI team in Arusha received lines of the fast track nursery from the University of Nairobi, and followed it up with several cycles of testing. Lines were divided into two groups ie, bush and indeterminate vining types, which were yield-tested on-farm in three regions. Lines were also subjected to PVS evaluation with farmers using colored ribbons to express favorable or unfavorable opinions on the materials. Lines including F9 Kidney selection (15), F8 Drought line (36), and Dwarf climber (6) expressed better yields and were also rated well by farmers.

Pre-released and released varieties

In Zimbabwe, three promising drought tolerant, high yielding, red speckled, and large seeded sugar bean varieties were submitted for distinct, uniform and stable (DUS) test in November 2013. These are as follows; DAB 51, DAB 52 and DAB 411. In Ethiopia, eight seed varieties were submitted to the release committee for release. They included five small white varieties (Ecabunci cross 4, Ecabunci cross 8, Ecabunci cross 11, Ecabunci cross 12 and Ecabunci cross 13) that out-yielded the standard check Awash-1 with a yield advantage of 10-15% and three small red *varieties* (SER 125, SER 128 and SER 194) that out-yielded the standard check (Dinknesh) with a yield advantage of 6-8%. Three varieties, KAT B1, KAT B9 and Navy-87 were approved for release. KAT B1 and KAT B9 were released in Kenya. KAT B1 was the best in seed color (yellow) and will be the first of the seed type. Considering all locations with similar maturity group as checks, KAT B9 gave more than 20% average grain yield advantage over Batu and 45% over Red Kidney. KAT B1 showed 8% yield advantage over the Batu and 32% over Red Kidney. Out of all these varieties, 22 were released (2009-2014) for drought areas whereas others were in the last stages of the development pipeline along with the six that were reported in phase I. This totals up to 28 varieties that were released directly with TL II project support in the period 2007-2014 (Tables 33 and 34). Most of the released lines had the yield advantage of 10-54% over the commercial varieties in on-farm trials with the additional trait of resistance to key pests and diseases and/or high grain Fe and Zn content. For example, the two varieties released in Zimbabwe were found to have an additional trait of high Fe content. It was probable that the other released varieties and lines in the pipeline had additional traits that needed to be identified and communicated for use in the seed delivery systems. In Zimbabwe, two bean varieties MG 38 (Cherry) & VTTT 925/9/1/2 (Sweet Violet) were released in Jun 2013 by the Crop Breeding Institute. MG 38 has an oval seed shape, drought tolerant, a red mottled seed coat pattern, and an acceptable seed size (44 g/100 seeds). The variety also recorded an attainable yield of 1,400 – 3,200 kg ha^{-1}. Sweet Violet was a very large seeded (55g/100 seeds) and red speckled sugar bean variety with an attainable yield of 1,400 – 3,300 kg ha^{-1}. Both MG38 and VTTT925/9/1/2 have high levels of tolerance to CBB and ALS. Seed-co also released one red speckled sugar bean variety, called SCBV07001, which performs well under irrigated conditions. In Kenya, two varieties were released by KARI, namely KAT-RM 001 and KAT-SR 01.

However in total, there are 73 newly released varieties in the six TL II participating countries ie, Ethiopia, Kenya, Malawi, Tanzania (N & S), Uganda and Zimbabwe in the period of 2007-2014 (Table 34). For the purpose of completeness, we have reported all the released varieties in this period realizing that a number of the released varieties were supported from other projects with or without leverage from TL-II with the same interest. Notably, the projects were Alliance for a Green Revolution in Africa (AGRA) and Pan African Bean Research Alliance (PABRA) that involved a number of donors but with an interest to the seed system's objective of the Tropical Legumes project. For instance, the varieties released in Uganda and South Tanzania were released before these countries were integrated into the TL II project while a number of varieties released in Kenya were supported by PABRA. In Kenya, from evaluation of 20 small red germplasms, five varieties were entered in NPT in the year 2014. Four varieties with root rot resistance from KARI Kakamega materials are at the DUS stage.

Table 33. Varieties released under TL II project (2007-2014).

No.	Variety Code	Year of release	Country	On-farm yield (t ha^{-1})	Yield advantage over check (%)
1	SUG 131 (Deme)	2008	Ethiopia	2200	116
2	A19 x OMNAZCr-02-11 (Batu)	2008	Ethiopia	2070	110
3	SNNRP-120 (Hawassa Deme)	2008	Ethiopia	2500	NA
4	GLP 2	2011	Ethiopia	2770	116
5	ECAB 0056	2011	Ethiopia	2617	110
6	02-04-11-4-1 (SARI-1)	2011	Ethiopia	2500	NA
7	ECAB 0060	2013	Ethiopia		
8	K132	2013	Ethiopia		
9	ECAB 0203	2013	Ethiopia		
10	ECAB 0247	2013	Ethiopia		
11	RXR 10	2013	Ethiopia		
12	ACC 4	2013	Ethiopia		
13	KAT B9	2014	Ethiopia		20-45
14	KAT B1	2014	Ethiopia		8-32
15	Navy 87	2014	Ethiopia		17-28%
16	KAT-SR 01	2012	Kenya		
17	KAT-RM-001	2013	Kenya		
18	VTTT 924/4-4	2012	Malawi	1.0	
19	SER 124	2013	Malawi		
20	VTTT 925/9-1-2	2013	Malawi		
21	SER 83	2013	Malawi		
22	BF 13607-9	2013	Malawi		
23	CIM 9314-17	2012	Zimbabwe		
24	SUG 131	2012	Zimbabwe		
25	Gloria (PC652-SS3)	2012	Zimbabwe	1.5 – 1.8	
26	NUA 45	2012	Zimbabwe	1.3 – 1.6	
27	MG 38	2013	Zimbabwe	0.8-1.1	
28	VTTT 925/9/1/2	2013	Zimbabwe	0.8-1.1	

Table 34. Varieties released in TL II project supported countries over a seven-year period (2007-2014).

S. No	Country	Varieties	Total number
1.	Kenya	KAT-SR 01, KAT-RM-001, §KK 15, §MN 14, §MN 17, §MN 19, *MAC 13, *MAC 34*, *MAC 64, §KK14, *Embean 118, *Embean 14, *Embean 7*, §Cardinal	14
2.	Ethiopia	ECAB 0060, K 132, ECAB 0203, ECAB 0247, RXR- 10, ACC4, KATB9, KATB1, Navy 87, ECAB 0056, GLP 2, DA-NAZCR-02-12, RXR 10, SARI 1	14
3.	Zimbabwe	CIM 9314-17, SUG 131, Gloria, NUA 45, MG38, VTTT 925/9/1/2, SCBV 07001	7
4.	Malawi	VTTT 924/4-4, SER 124, VTTT 925/9-1-2, SER 83, BF 13607-9, §KK03/KK25/68/S-F, §KK25/MAL/19/S-F, §MAL/KK25/9/S-F, §MAL/KK35/443/S-L, §K25/MAL/112/S-F, §NAG/KK25/168/S-F, §KK25/NAG/184/S-L, *NUA 45, *NUA 59	14
5.	§Tanzania	Njano-Uyole, Wanja Cross, NRI 06 E13, NRI 05 P200, Roba-1, Calima, Uyole, Pasi, Fibea, Rossela	10
6	§Uganda	NABE 15, NABE 16, NABE 17, NABE 18, NABE 19, NABE 20, NABE 21, NABE 22, NABE 23, NABE 26C, NABE 27C, NABE 28C, NABE 29C	13
	Total		73

*Partial funding from TL II (other support were from PABRA and AGRA)
§PABRA and/or AGRA support

Lessons learned

- Factors affecting the photosynthate remobilization to grain are key in determining drought resistance and probably yield potential as well. Pod Harvest Index (seed weight / total pod weight including seed) was found to be a viable selection criterion for drought resistance with positive effects on non-drought yield as well. While the conventional selection for stress tolerance or resistance was known to limit the yield potential, our work suggests that drought resistance traits can contribute to yield in favorable environments. Thus, drought resistance does not have a yield penalty.
- Even highly vulnerable farmers grow for the market. While one might expect that farmers living "on the edge" might be primarily concerned with food security, the baseline study showed that they are equally concerned with markets for income. Moreover, they maintain a "drought inferior" variety with the hope of selling some beans, and maintaining a preferred culinary type for home consumption. Thus, obtaining the drought resistance in types with best grain size and color in the market poses a major challenge to the breeders. Farmers are well aware of the genetic differences in drought resistance varieties and rank drought resistance as one of the highly considered traits for a preferred variety.
- Market opportunities have a dramatic influence on the usage of inputs and total yields. The case of Ethiopia is striking, where an assured market condition, combined with effective extension and seed systems, led the farmers to improve crop management and double national yields within eight years.
- On the down side, the benefits of degree training were limited because of staff instability. Only one scientist who had achieved higher degrees is currently working in the respective programs (although one may still reincorporate). Further, all but one studied in African universities. Therefore, this is not a cure for this enduring problem. Efforts for training technicians need to be intensified, as they are typically more stable in their posts than scientists.
- Farmers are willing to adopt new varieties once they are convinced that the variety will meet their requirements. In addition, their awareness about bean production and productivity systems as well as sensitization on the type and kinds of varieties enables the creation of market for seed companies especially for the new varieties. This has also triggered increased interest of individual farmers, private farms and farmers groups to venture in bean farming as a mode of business. However, they require remedial training after some years for enhancing their technical capacity and adopting multi-crop approach as both farmers and seed companies require several crops at a go. For instance, the seeds produced by the trained seed entrepreneurs are of good quality, and are highly demanded and such activities should be expanded.

Gaps in achieving intended outcomes

- Data recovery was inadequate both for GIS analysis and for gauging with statistical precision. It requires improvement in order to be more systematic in targeting the outputs and creating impact.
- The process of evaluating the potential of the sister species (*Phaseolus acutifolius* and *P. lunatus*) was not advanced enough for either determining their utility or identifying promising materials, which is still being addressed.
- Advances in combining drought tolerance trait with other traits in Andeans (nutrition) were slow, especially on the side of bio fortification and difficulties were encountered in obtaining adequate levels in bush types (Greatest progress is in climbing types of the Andeans).
- Consumer demand for energy efficiency was not considered during breeding both in rural and urban areas (eg, short cooking time).

- To increase bean productivity, the market should play a bigger role in breeding priorities. For example, yellow bean varieties are in high demand due to good palatability /short cooking time.
- Though several degree trainings were offered to the NARS scientists, the retention of newly graduated staff was limited.

Vision

From the phase I research, it became clear that target strategies along the value chain are required to address the problem of drought, declining soil fertility and in overcoming the constraints in seed and grain markets. Such investments are inter-related and are required to achieve a combined effect. In other words, issues related to germplasm improvement, management practices or extension and marketing need to be addressed in order to achieve maximum beneficial and equitable impacts.

In the course of phase I, drought research was firmly established as a research priority within PABRA at all levels. Field testing was practiced on a routine basis. Equipment was put in place for more detailed evaluation. In collaboration with TL I, the scientific capacity was enhanced through the post-graduate training. In phase II, the impact of TL II was expanded by involving other partner countries within PABRA with focus on enhancing the capacity by understanding G x E within drought trials, in conjunction with TL I. Breeding continued to address both terminal and intermittent types of drought while minimizing the trade-offs between large harvests and good culinary traits or marketability. The biodiversity of the *Phaseolus* genus through interspecific crosses and direct use, for both biotic and abiotic stress tolerance required more exploitation. Emphasis was laid on creating farmer-, market- and consumer-acceptable germplasm with multiple stress tolerance and enhanced nutritional value. Important culinary traits (eg, less cooking, low flatulence, keeping quality or taste) and market preferences (eg, seed shape and color) in Ethiopia were identified through the baseline studies. Currently, seed color and seed shape are the key attributes considered while grading beans available in the market for export in Ethiopia and are likely to become more important determinants of variety choice by farmers in the near future while the existing varieties with flat shape or less brilliant color could be disadopted.

Soil fertility is clearly a major confounding factor in the evaluation of drought lines and should be dealt with in a complementary fashion ie, by exploiting both genetic and crop management techniques to assure that drought tolerance is fully expressed. In phase II, there is a need to expand beyond the varietal introductions and focus on fertilizer associated with specialized seed production. In other words, improvement in soil fertility is key for all zones, especially stressed ones. Thus, N fixation, moderate use of P and manures (green and organic) might be among the themes to be pursued (in conjunction with the use of drought-tolerant varieties).

Pests and diseases like BSM, *Macrophomina,* CBB, BCMV and aphids (etc.) were of major importance in the drought-prone zones. Lessening their effects was recognized as a means to stabilize and increase the production. TL II in phase II linked up with the ongoing integrated pest and disease management research under PABRA to integrate good practices in managing these constraints. Lines developed for BSM, CBB, *Zabrotes* sp and “bc3” gene were deployed and evaluated in phase II. Further, with the development of new populations and wider evaluation techniques to identify resistance QTLs, this has turned to be an ongoing activity. With the development of SNP marker for a number of key diseases, the widespread application of markers for biotic stresses in both bush and climbing bean types required continuous promotion. Thus, the prospects of effective implementation of marker assisted selection (MAS) for drought per se continue to depend on obtaining relevant and reliable phenotypic data.

Seed systems

Common bean seed systems

Using innovative institutional arrangements to catalyze the sustainable production and supply of quality seed of improved bean seed varieties by small holders in SSA

Tropical Legumes II seed system activities were mainly implemented in Ethiopia, Kenya, Tanzania and Uganda where a pluralistic bean seed system, based on multiple but complementary seed producers (individual seed entrepreneur, companies, parastatals and farmer groups), was deployed with very limited support (training of seed producers). Seed system activities were also expanded to Malawi and Zimbabwe (TL II countries involved in breeding). The seed producers were also supported by a range of public–private partners (NGOs, farmer organizations and public extension) providing complementary services, eg, skills and knowledge enhancement/training, awareness creation, seed quality control, and financial and material support depending on the respective country/region specificities. Partners developed joint work plans for project research and implementation, and agreed upon its roles and responsibilities. Many of the partners also signed formal Memoranda of Understanding (MoU) and several incorporated TL II work plans in their own organizational yearly program plans. Bean Seed systems activities under TL II were, thus, implemented as part of country-led and nationally owned legume research for development plans (eg, seed road maps) and strategies. The engagement of the private sector by the TL II project (companies, individual seed entrepreneurs, NGOs and farmers' organizations) greatly enhanced the prospects for sustainability of the project outcomes. However, support from NARS and empowerment of development partners will remain essential in building an effective role of the private sector. Bean production and market opportunities are growing and attracting an increasing number of players, who are getting involved and establishing a strong and durable linkage in the bean innovation system across TL II countries.

Partnership in seed systems

More than 106 partners were involved in TL II bean seed systems in phase I, including NARS, private sector companies, specialized seed producers, governmental and non-governmental organizations, community- and faith-based organizations, and grain traders. In phase II, common bean seed systems in Ethiopia, Kenya, Uganda and Tanzania involved 67 farmer groups, 585 seed entrepreneurs, 15 seed companies, and 22 government organizations/institutions. Some of the successful bean seed system models practiced in phase I included three foundation seed production models (direct production through and by NARS seed unit with contractual farmers, private seed companies, and farmer cooperatives), four models of decentralized seed production (district/government officers supporting individual farmers, NGOs supporting individual farmers, farmer cooperatives/unions, and community-based seed production), and six seed delivery models (small pack sales at open markets, country stores, agro-dealers, and seed/grain traders, exchange system through seed loans and direct farmer-to-farmer diffusion).

Skills and knowledge enhancement

One of the pillars of expanding and sustaining the outcomes/outputs of the project is to build skills and knowledge of partners along the bean value chain. During phase I of the TL II project, training for trainers in the areas of bean seed production/post-harvest management and general bean agronomy were carriedout for 549 trainers (Ethiopia: 350 and Kenya: 189), who trained 35,943 farmers (women: 17,877 and men: 18,066). Further, a total of 54,733 farmers (women: 23,642 and men: 31,091) gained knowledge on bean production by attending a total of 193 demonstrations and seed fairs. Similarly, in phase II, a total of 135 trainings were conducted for 6,618 farmers/bean seed producers and 694 extension officers (4,596 in Tanzania, 1,302 in Kenya, 595 in Uganda, and 442 in Ethiopia). Improved variety awareness programs were implemented in Ethiopia, Uganda and Tanzania. For instance, 11,360 leaflets with information on bean seed production (6,000 in Uganda, 5010 in Tanzania and 350 in Ethiopia) were distributed. Through financial support from PABRA in Zimbabwe and Malawi, TL II bean team (from Kenya) extended the seed system's training and enhancement of skills and knowledge.

Awareness creation

A multi-media communication strategy and user-friendly tool for variety promotion and training manuals were adapted/developed/produced and shared with partners across the participating countries. Training modules, manuals, leaflets/flyers, and information bulletins were also produced. For instance, about 2,507 bean seed production/business manuals in four languages were produced and shared with partners in Ethiopia (Amharic), Kenya (Oromifa), Tanzania (Swahili), and Uganda (Luganda). Mass communication was also used to disseminate knowledge about new bean varieties and their seed source through several radio programs (12 in Ethiopia and 30 in Tanzania); TV programs (7 in Ethiopia, 15 in Tanzania, and 1 in Uganda); 3 articles in local newspapers on bean varieties in Ethiopia, and leaflets in Tanzania. Farmer field schools, field days, and seed fairs were carried out at selected learning centers annually. In Tanzania, field days (10 per season), open days and seed fairs (6), farmer field schools (8) had become regular tools for creating awareness about new varieties. Over 11,206 farmers/legume seed producers (1,990 in Tanzania, 5,535 in Uganda, 2,300 in Ethiopia and 1,381 in Kenya) participated in field days and farmers' fairs held on-farm locations. Strategies that create variety awareness were also implemented in private sector companies and farmer cooperatives. The partners included Dodoma Transport, Kilimo Markets, Beula Seed Co. Ltd, Tanseed International Co. Ltd, Stormy Hall Seed Growers, ARI-Uyole farm operation in Tanzania, several Farmers' Cooperative Unions (FCUs), Oromo and Southern Seed Enterprises, Alemayehu Farm and Haile Wako in Ethiopia, and several other companies (CEDO, Pearl, FICA and Victoria) and farmers' organizations in Uganda.

Seed production and supply

As a result of a strong partnership, supported by appropriate capacity building and availability of improved and user preferred varieties, seed production and supply significantly increased**.** Between 2007 and 2013, during phase I (2007-2010) and the first two years of phase II (2011-2013), 42,238 tons of assorted seed classes were produced across the implementing countries, as illustrated in Table 35. As a result of the lessons learned and the functional partnership established in the first phase (2007-2010), seed quantity increased drastically in the second phase (30,882.9 tons).

Table 35. Tons of bean seed produced across target countries (2008-2013).

	Assorted seed produced (tons) between 2008-2013							
Country	2007/8	2008/9	2009/10	2010/11	2011/12	2012/13	2013/14	Total
Ethiopia	386.2	2128.0	7557.0	2820.3	5133.2	5591.70	NT	23616.45
Kenya	377.4	452.8	453.6	574.0	710.0	2074.0	NT	4641.92
Malawi	NA	NA	NA	1044.5	863.7	1168.0	NT	3076.20
Tanzania	NA	NA	NA	538.9	678.9	735.8	NT	1953.6
Uganda	NA	NA	NA	1067.0	3559	4229.0	NT	7788
Zimbabwe	NA	NA	NA	350.0	353	458.9	NT	1161.9
Total	763.56	2580.93	8010.68	5327.70	11297.8	14257.4	NT	42238.0

NT: No data as yet
NA: Not applicable

Uganda and Tanzania joined TL II seed systems in 2010/11 as anchoring countries while Zimbabwe and Malawi only received limited technical support in the form of training. TL II experiences were shared by PABRA resource people from the anchoring country, particularly, Kenya (KARI) and CIAT.

Innovative approaches to target the poor and women farmers

Several innovative approaches were tested to avail seeds to poor farmers. The use of small seed packs is based on the field insights that farmers want to have access to new varieties, and some also were willing to pay for the certified seeds at affordable prices. This implies that seed simply has to be marketed at affordable size and price in places that can be easily accessible to farmers and by farmers' trusted vendors (or who may be held accountable to buyers). For instance, small seed packs (of 0.05, 0.1, 0.25, 0.5, 1, 2, 5, 10 and 25 kg sizes) were extensively used in bean seed dissemination in all the target countries (Table 36). The small pack approach gained popularity as the most efficient and cost-effective means of reaching more farmers with affordable quantities of seed and wide range of preferred varieties. For instance in Kenya, Dry-land Seed Company/FreshCo Seed Company, and KARI Seed Unit packed and sold 89 tons of seed of drought-tolerant bean varieties in 0.1 kg, 0.5 kg, 1 kg and 2 kg packs. This approach, which was initiated by NARS (public sector) bean seed system, has been extensively adopted by the private sector to enhance the extent of reach to the smallholder bean farmers who otherwise could not have access to the quality bean seeds. Moreover, PABRA is expanding the use of small packs to other countries (eg, Burundi, Cameroon, Madagascar and Rwanda) as well as crops other than beans. In Rwanda, more than 50 tons of bean seeds were sold to the smallholder farmers in small affordable packs.

Table 36. Amount of small bean seed packs distributed, by crop per country during 2007- 2013.

Country	Number of Small seed packs
Ethiopia	176,858
Uganda	20,129
Tanzania	3,045
Kenya	108,500
Total	308,522

In Kenya, seed loan (pay back) approach was implemented in partnership with 12 NGOs and ten district agricultural offices. More than 3 tons of drought tolerant bean seeds were supplied by TL II Project and 80 tons by Ministry of Agriculture, reaching over 1 million farmers.

Decentralized production of quality declared seed was also adopted to reduce the cost of accessing seed, especially in the areas not reached through the formal system. The premise is that, farmers are capable of producing high-quality seed when provided with technical support and sufficient start-up seeds. The neighboring farmers prefer purchasing seeds from known sources. Moreover, the farmers do not incur extra costs in accessing such seeds.

Variety use

The use of improved varieties is the key to increasing crop productivity in the context of smallholder farmers. Out of 132 bean varieties released before 2007, 67 are still in seed production phase while out of 87 varieties released after 2007, 56 are still in production, which indicates a retention rate of 50.76% for the varieties being used that were released before 2007 and 64.37% of varieties released after 2007 (Table 37). This demonstrated that a pluralistic and integrated seed system would be efficient in getting new varieties in the hands of farmers and replacing the older ones.

Table 37. Number of bean varieties released by period of release, varieties in production during 2007-2013.

Country	Total number of varieties released ***before 2007***	Number of varieties released ***before 2007*** which are in seed production	Total number of varieties released ***after 2007***	Number of varieties released ***after 2007*** which are in seed production
Ethiopia	37	5	16	8
Uganda	16	8	13	13
Tanzania	38	32	10	3
Kenya	16	14	30	17
Malawi	20	6	10	7
Zimbabwe	5	2	8	8
Total	132	67	87	56

Evolution of bean seed producers

Successful bean seed systems need to be sustainable and carried out by several partners/actors who respond to the farmers' seed demand. During phases I and II of the TL II project, there was a progressive evolution of four major categories of bean seed producers (private seed companies, public seed enterprises, individual seed entrepreneurs, and farmers' organization/ cooperatives) supported by government and NGOs. For instance, the number of individual seed entrepreneurs increased by 383% (from 186 to 899) while the number of farmers organizations increased by 341% (from 98 to 432) between 2007 and 2013 (Table 38).

Table 38. Evolution of the number of bean seed producers per partners/actors category per country (2007-2013).

	2007 (start of TL-2)				2013			
Country	PSC	PSE	Indiv	FO/C	PSC	PSE	Indiv	FO/C
Ethiopia	1	3	5	13	8	4	14	18
Uganda	20	1	0	54	27	1	0	92
Tanzania	7	1	0	4	7	1	2	8
Kenya	2	1	30	20	4	3	230	300
Malawi	3	1	150	3	5	1	650	7
Zimbabwe	6	1	1	4	8	2	3	7
Total	39	8	186	98	59	12	899	432

*PSC=Private seed companies, PSE= Private seed enterprises (University/Parastatals), Indiv= Individual seed enterprises, FO/C= Farmers organizations/ cooperatives supported by Government or NGOs, farmers crop

Lessons learned

Seed systems and delivery

- Introducing and popularizing new varieties require collaboration with partners and stakeholders. Therefore, the need to identify effective partners who share the same vision and interests is very important. For instance, strong partnerships are cemented through the formation of innovative platforms resulting in more effective and efficient bean seed system.
- The small pack seed dissemination approach has worked well in view of popularization and testing of new varieties while also targeting the farmers with all sizes of land (small to large). For instance, in Ethiopia, in the past, improved bean seed were only sourced from seed enterprises that had the capacity to meet less than 10% of the seed demand. Decentralized bean seed production and use of small seed packs have improved the seed supply capacity, which is currently estimated to meet more than 50% of seed demand. Whereas, in Kenya the seed loan and small seed packs approaches have proved popular for variety promotion and dissemination especially in case of poor farmers and women in particular. However, there is a need for a joint public-private initiative with a progressive vision of empowering the private sector to sustain and expand this approach.
- Integrated monitoring and evaluation systems helped to track the changes and scaled up good practices.
- Level of investment in seed systems and institutions is an important factor for determining the progress. Inadequate funds can slow down up-scaling of seed production activities and can even break the seed chain (considering that building up again would need substantial time and resources).
- Informal seed systems cannot be sustained without addressing the seed storage needs, both at the individual and community levels by farmer groups involved in seed production.
- Given the challenges of bulky nature and storage of groundnut seed, building the seed production supply chain between the seasons of two locations can be considered as a good option. This will also cut down the transportation charges thus bringing down the input cost.
- New organizational arrangements are needed for up-scaling the seed production, as partnerships with government agencies that are involved in seed production, certification and distribution are critical for success.
- More robust seed system models are needed for up-scaling the adoption of new varieties. The community seed bank system that relies on the use of quality declared seed can improve the technology reach of the project and needs further improvement. This is currently being investigated in Tanzania.
- Impact-oriented core team for a program is key for developing the seed systems in drought-prone regions, which should be geared to reach the poor. A program cannot be impactful unless the leader and the team devise strategies for solving the bottlenecks and reaching the end users. Otherwise, a program might end up with results like 'lots of seed produced' on the supply side.
- The professional and transparent engagement of partners is crucial for the widespread success of a program. This includes formal clarification of expectations and responsibilities and clear budget allocations. Productive partnerships require ongoing facilitation. Moreover, effective partners, private sector, NGO, unions and beyond, who shall continue production and deliver beyond the project need to be identified (after TL II exit). A better characterization of successful partner attributes could be useful.

- Unavailability and access to basic or certified seeds remains a bottleneck. Despite high demand and interest of the the drought-tolerant varieties, basic seed production is slowly being opened to the private producers for example, in Ethiopia, EIAR/ Melkassa has actively engaged two private seed farms who produce basic seed of two most popular varieties, Nasir and Awash Melka. These two producers make the basic seed available to the other producers of certified and quality declared seed in Ethiopia.
- Emergency seed distribution can clash with the project goals. Emergency supply orders directly compete with the project needs for foundation or certified seed. Further, free distribution of seeds clash with the project objectives of selling seed and creating demand among the small farmers. Emergency and Development efforts in the seed system development need to be better coordinated and designed to complement each other. Some major improvements have been made in Kenya wherein the Government of Kenya will be substituting seed loans for direct free distribution, at least in the eastern drought-prone areas.

Gaps in achieving intended outcomes: Seed systems and delivery

- Although much efforts have been employed to introduce new varieties in order to meet the seed road map requirement, the cultivation of obsolete varieties (low yield and susceptible to diseases) and non-availability of quality seed of improved varieties still remains a challenge in the quest for higher productivity.
- Though there is an increasing participation of seed companies, the limited commercial perspective of legume seed poses a hindrance for the involvement of private sector on very large scale.
- The majority of seed companies do not want to invest in the popularization of new varieties. Their interest in the legume seed increases mainly when the varieties are already popular.
- In some countries, seed policies and certification procedures have not changed substantially in favor of the informal seed sector. There is need to engage policy makers to recognize the role of the informal seed sector especially in the supply of legumes seed.
- With the increasing demand of seed varieties, the basic seed tends to be a limiting factor especially in some countries where its production is still centralized and remains under the control of NARS or other public institutions.
- In some areas, inadequate marketing and promotion strategies hinder the sustainability and viability of farmer seed entrepreneurs.
- Though good efforts have been deployed and encouraging results have been achieved, a mass legume production to enable the commercialization of grain legumes in many countries has not yet been achieved.
- There is need for continuous training and creation of awareness about the new varieties, quality seed production, safe storage and use of small seed packs.
- The price of certified seed (CS) marketed by the companies increase with the increasing distance to the rural localities thus making it unaffordable for the poorest farmers.
- Need for creation of assured irrigation facilities at the NARS level for producing the basic and breeder seeds in order to maintain the uninterrupted flow of seed production cycles
- The adoption of farmer-preferred varieties in the target locations is at different levels and restricted to the project pilot sites.
- The supply of seeds to the target locations is not sufficient to meet the target of achieving 20% replacement with the quality seed of improved varieties.

What worked

- Linking the breeding and seed systems accelerated the timely delivery and usage of improved varieties.
- Institutionalizing partnership in the production and delivery of bean quality seeds across the countries and increasing the efficiency in using resources effectively.
- Skills and knowledge enhancement along the value chain helped to expand and sustain the project results.
- Institutionalizing the seed delivery system through appropriate channels improved the production and delivery of quality seed.
- Though the alignment to seed road maps was a new concept, it remains as the seed systems guide.
- Involving the agri-development NGOs in up-scaling the technologies and seed delivery system worked well.
- Involving seed certifying agencies in monitoring the seed production areas held by the smallholder farmers that produce pure seeds of various seed classes, which would fetch higher price and help in entrepreneurship.
- Some community seed producers were transformed into seed cooperatives leading to increased seed delivery.

What did not work

- Generally, the situation of national seed systems in the target countries varies considerably and therefore a country-specific approach is needed. Success requires engaging policy makers, and institutional innovations in linking the farmers with the markets through collaborative research.
- In most target countries, the availability and access to basic seeds acts as a bottleneck. It remains solely in the hands of the NARS, limiting the speed of accessing the new varieties and initial seed by seed companies or other seed producers.
- Lack of resources and infrastructure of NARS is a major challenge to handle large scale breeder or basic seed production to feed other classes of seed.

Capacity building

Our goal was to establish a working group, within the PABRA network, with expertise in drought research. While formal degree training formed a part of this plan, an equally important part dealt with aquiring skills in field management and physiological analysis. All progress in abiotic stress resistance and drought resistance must be dependent on the reliable field evaluation. This also applies to prospects for marker assisted selection, which must be initiated with reliable phenotypic data. Trials for managed drought must incorporate calibration of drought stress, starting with quantification of the amount of moisture in the soil. While scientists must understand the principles, they should also appreciate the methods and logistics of field management to be able to supervise effective field research. Technicians should be fully capable of executing the field studies, assuring uniformity across the field, and mastering the logistics of the field work (eg, physiological sampling), so that the study could be carried out efficiently with minimum errors. Often the technicians are the most stable element within a research program, as scientists, should dedicate time to administrative duties. Thus, in addition to the formal degree training, we also made an effort to establish capacity among both the scientists and technicians of the region for practical field oriented drought research. Practical skills included quantification of soil moisture content, sampling of field grown plants, distribution of plant biomass in different plant parts, biomass drying, and data analysis.

Two field workshops were held in January 2008 at Katumani and in May 2008 at Malawi. Additionally, a physiology assistant from CIAT-Colombia visited each participating country to supervise the on-site work, and to give advice on phenotyping protocols and data analysis.

Degree and technician training was undertaken with four PhD degrees and six MSc degrees granted scholarships. Until now, three PhDs have been completed and one MSc degree has been awarded. Degree training proved to be an excellent bridge between the TL I and TL II projects as several theses were derived from the topics of TL I or were closely akin to the themes developed in the project.

Berhanu Amsalu of Ethiopian Institute of Agricultural Research (EIAR), Melkassa Research Center completed his PhD study at the University of Pretoria, Republic of South Africa. His study focused on the aspects of nitrogen fixation in common bean under drought conditions, focusing on the activity of protease inhibitors as indicators of nodule health. As known, when legumes come under stress, the nodules start degrading under the influence of proteases that break down the proteins including nitrogenase. Lower activity (or conversely, more activity) of protease inhibitors indicates the nodule health, especially under stress when fixation tends to decline. Berhanu initiated a greenhouse study of soybean (his thesis topic and its results), which could be relevant for biological nitrogen fixation (BNF) of soybean under stress as well. Subsequently, Berhanu continued the greenhouse studies on common bean with the high nitrogen fixing line BAT 477, the poor fixer DOR 364, and their progenies. He also carried out a field trial with the same genotypes. Finally, he executed a trial looking at the interaction of drought x P levels under the hypothesis that the protease degradation of nodules is a generalized mechanism in response to the stress, and BAT 477 will show low activity of proteases under both moisture and low P stress. He is currently assaying the protease activity to test this hypothesis.

Godwill Makunde of Zimbabwe also completed his PhD study at Free State University, RSA. His university expenses were financed under TL II project and his research was supported mostly by TL I. His research involved a physiological analysis of the TL I reference collection, which is a sub-set of 202 accessions from the CIAT core collection. The re-selection was based on detailed molecular analysis by employing a more focused attention onrace Durango from Mexico and Andean types. These two groups were emphasized with an ideology that race Durango might yield new sources of drought resistance and one could utilize the variability existing in the Andean types for more improvement. Godwill executed the physiological sampling and analyzed the reference collections in CIAT-Colombia under intense terminal stress. He also conducted root phenotyping studies at CIAT-Colombia on selected genotypes from the reference collection. With data from several sites and seasons, Godwill performed an analysis on the association mapping using the SNP data generated at UC-Davis in the group of Doug Cook. This will be the first such attempt in common bean varieties.

Felix Waweru graduated from the University of Nairobi, Kenya with an MSc degree in a study shared with TL I project. Felix carried out a field phenotyping of RILs of a cross of BAT 881 x G21212. BAT 881 is sensitive to abiotic stress and G21212 is relatively resistant. G21212 was first recognized to be tolerant to low soil P and subsequently it also proved to have a good response to drought and aluminum toxicity. It also presents an excellent remobilization of photosynthate to grain under stress, which appears to be its mechanism of multiple stress resistance. A genetic map exists for this population, and the data of Felix could help to elucidate further the inheritance of this trait. Felix also analyzed a regional collection of landraces and lines, compiled under TL I project.

Lizzie Kalolokesya of Malawi completed an MSc degree at the University of Zambia. Lizzie was brought on board when Isaac Fandika withdrew to study in New Zealand. Lizzie carried out MAS for disease resistance in collaboration with TL I project. Lizzie had the opportunity to carryout a part of her research in the installations of ARC-Potchefstroom in South Africa, which helped in broadening her perspectives and working in collaboration with an ongoing practical breeding program.

Mable Nabatregga: Mable is doing her Master's degree at Makerere University in Uganda. Her study is directed at determining the genetic basis of phenotypic traits associated with the drought tolerance ability in common bean using the SEQ1027 x BRB191 population and the identification of molecular markers linked to these traits. She will be setting up trials at Namulonge research station of NACRRI.

Others were Daniel Ambechew, Scholastica Wambua, Yetagesu Tebeka, Bikara innocent and Alemeyahu Fitsum (Table 39).

Table 39. Degree level training supported in TL I and TL II.

Name of student	Degree	Gender	Field	Country	Current status
Waweru Felix Muchiri	MSc	M	Plant breeding	Kenya	Finished
Susan Gachania	MSc	F	Plant breeding and Physiology	Kenya	Incomplete
Lizzie Kalolokesya	MSc	F	Plant Breeding	Malawi	Finished
Mable Nabatregga	MSc	F	Plant Breeding	Uganda	Ongoing
Daniel Ambechew	MSc	M	Plant Breeding	Ethiopia	Ongoing
Scholastica Wambua	MSc	F	Agri-business/Seed systems	Kenya	Finished
Yetagesu Tebeka	MSc	M	Agricultural Economics/Seed systems and objective 1	Ethiopia	Ongoing
Bikara innocent	MSc	M	Agricultural Economics/seed systems and objective 1	Uganda	Ongoing
Makunde Godwill	PhD	M	Plant Breeding/Physiology	Zimbabwe	Finished
Alemeyahu Fitsum	PhD	M	Plant Breeding/Physiology	Ethiopia	Ongoing
Teshale Assefa	PhD	M	Planting breeding	Ethiopia	Finished
Berahanu Amsalu	PhD	M	Planting breeding	Ethiopia	Finished

Degree training: operational support

Teshale Assefa, formerly of EIAR, Melkassa, Ethiopia, completed his PhD degree at the University of Padua in Italy. Teshale worked on the drought tolerance and canning quality of navy beans, analyzing the RIL of the cross SXB 405 x ICA Bunsi developed at CIAT. The former genotype is a rustic and low fertility tolerant line developed for drought tolerance. The latter is a small white canning type developed years ago in the national bean program of Colombia. Teshale selected 78 lines based on the grain type and planted them under managed drought and irrigated conditions in Melkassa Station. A physiological analysis showed that the parameters of both biomass accumulation and PHI contributed to the final yield, again validating the role of remobilization of photosynthate to grain as an important drought resistance mechanism. Teshale also involved farmers and traders in the evaluation process, bringing farmers on station for this activity. Finally, an evaluation of canning quality was carried out on eight elite lines. As a result, it was found that most of the lines were acceptable and one of the most drought resistant lines was also rated excellent for its canning quality. Lines were distributed throughout the region for evaluation by other partner countries. Teshale also received training in CIAT-Colombia on evaluation of bruchid resistance.

Susan Gachania received support towards her MSc degree research at the University of Nairobi. Susan worked on the physiological analysis of the fast track nursery. Unfortunately, Susan left her studies before finishing her degree.

Table 40. National program scientists trained under the TL II project in phase I.				
Country	Name	Gender	Position	Institute
Ethiopia	Amsalu Berhanu	Male	Agronomist	EIAR
	Gebeyehu Setegn	Male	Research Physiologist	EIAR
Kenya	Gachania Susan		Student	University of Nairobi
	Musyoki Robert	Male	Researcher biotechnologist	Kenya Seed Company
	Okwuosa Elizabeth	Female	Researcher Breeder	KARI
	Wachira Geofrey	Male	Research Assistant	University of Nairobi
	Macharia David	Male	Breeder	KARI
Malawi	Fandika Isaac	Male	Agronomist/Physiologist	DAR
	Kalolokesya Lizzie	Female	Research Assistant	CIAT – Chitedze
	Chisale Virginia	Female	Breeder	DAR
Tanzania	Msaky John	Male	Agronomist	SARI
	Slumpa Simon	Male	Entomologist	SARI
	Kweka S.O.	Male	Breeder	SARI
Zimbabwe	Makunde Godwill	Male	Breeder	Crop Breeding Institute

In addition to the graduate level training, high priority was placed on technicians for their role in the daily execution of the field trials. Thirteen technicians were trained in the first year in the basic techniques of crop physiology and monitoring the soil water content (Table 41). Plant sampling was also practiced to estimate the biomass level at mid-pod fill and the components of harvest index at harvest time. However, this is an activity that must continue and be reinforced, as the technicians are the backbone of every research program. Expanded effort should be given to this area in the near future.

Table 41. National program technicians trained under the TL II project.				
Country	Name	Gender	Position	Institute
Ethiopia	Lemlem Micheal	Male	Technician	EIAR/MARC
	Jemal Abdulshikur	Male	Technician	EIAR
	Dagne Belete	Male	Technician	EIAR
Kenya	Mutinda Duncan	Male	Technician	KARI
	Mwangi John	Male	Technician	University of Nairobi
Malawi	Banda Raphael	Male	Technician	DAR
	Ngwira Evelyn	Female	Technician	DAR
	Chibwana Willard	Male	Technician	DAR
Rwanda	Mukankubana Domitilla	Female	Technician	RAB
	Gasigwa Evariste	Male	Technician	RAB
Tanzania	Kisamo Alex	Male	Technician	SARI
	Mawalla Rogast S	Male	Technician	SARI
Zimbabwe	Mudzamiri Clemence	Male	Technician	DRSS
	Gachange N.	Male	Technician	University of Zimbabwe

Capacity building was also a priority under the TL I project, which supported students financed under TL II with research topics and research costs. Non-degree training was also carried out through several workshops in order to prepare breeders for the application of molecular markers (Table 40). Seven-day training was conducted for introducing the SNP genotyping and the IBP as a new tool for breeders at CIAT-Kawanda in May 2013. The training included various aspects, like field experimentation, data analysis, multi-environment trials to test for local adaptation, disease phenotyping under controlled conditions, planning crosses, reviewing the bean/PABRA breeding strategy, etc. Twenty-nine bean scientists (breeders, pathologists and agronomists) from 13 countries (DRC East and South, Kenya, Zimbabwe, Ethiopia, Ghana, Mozambique, Rwanda, Burundi, Uganda, Zambia, North and South Tanzania, Malawi, and Madagascar) attended the training (Table 42). The training was facilitated by trainers from CIAT (Colombia, Malawi, Tanzania and Uganda) and Makerere University.

Table 42. National program scientists trained under the TL II project in phase II.

Country	Name	Gender	Position	Institute
Burundi	Eric Nduwagira	M	Student (MSc)	ISABU
DRC East	Antoine Lubobo Kanyenga	M	Researcher/Breeder	INERA/HP+
DRC South	Illunga Meshac	M	Researcher/Breeder	INERA
Kenya	Arunga Esther	F	Researcher/Breeder	Moi University
	Kamau Eliezah	M	Researcher/Breeder	KARI
	David Macharia	M	Researcher/Breeder	KARI
Ethiopia	Daniel Ambachew	M	Researcher/Breeder	EIAR
	Kassaye Negash	M	Researcher/Breeder	EIAR
	Kidane Tumsa	M	Researcher/Pathologist	EIAR
	Tedla Tazene Yayis	M	Researcher/Breeder	EIAR
Ghana	David Appiah Kubi	M	Researcher/Breeder	
Madagascar	Waltram Second Ravelombo	M	Researcher/Breeder	FOFIFA
Malawi	Virginia Chisale	F	Researcher/Breeder	DAR
Mozambique	Divage Belarmino	M	Student (MSc)	IIAM
Rwanda	Emma Uwera	F	Student (MSc)	RAB
	Floride Mukamuhirwa	F	Student (MSc)	RAB
	Justin Tuyiringire	M	Research Assistant	RAB
Tanzania	Luseko Chilagane	M	Student (PhD)	SUA
	Micheal Kilango	M	Researcher/Breeder	UARI
	Tryphone Muhamba	M	Researcher/Breeder	SUA
	Papias H. Binagwa	M	Research assistant	SARI
Uganda	Gabriel Ddamulira	M	Student (PhD)	NACRRI
	Mable Nabaterrega	F	Student (MSc)	CIAT/MUK
	Moses Kiryowa	M	Student (PhD)	NACRRI
	Paparu Pamera	F	Researcher/Pathologist	NACRRI
Zambia	Lorraine N Chilipa	F	Research assistant	ZARI
Zimbabwe	Bruce Mutari	M	Researcher/Breeder	CBI/DRSS

At the initiation of the TL II project, a consultant was contracted to review the state of infrastructure and the suitability of the experiment stations for drought research. A characterization of nine research stations was carried out to identify the strengths and weaknesses of each site with regard to the soil and water quality and infrastructure needs in order to make recommendations on planting dates for obtaining the desired level of stress. The sites included were Melkassa, Ethiopia; Thika, Kenya; Kabete, Kenya; Katumani, Kenya; Kiboko, Kenya; Kandiyani, Malawi; Kasinthula, Malawi; Chiredzi, Zimbabwe; Selian, Tanzania; and Madiira, Tanzania. The sites were evaluated for water quality, soil water holding capacity, existence and/or state of irrigational facilities, weather patterns, and implications for planting dates. A report on this study is available.

Installation of irrigational facilities and acquisition of drought phenotyping equipment

While equipment was offered to all programs, in the second year the Bean Program, Selian elected to forego more equipment purchase in favor of obtaining a better irrigational system to facilitate the managed drought nurseries by using an existing bore hole as a source of water. Options were studied and a solar powered pumping system was purchased as a more economical mode than tapping the local energy network (which would have been the most costly part of the installation). The system was installed only to discover that the bore hole at the site was not properly drilled and was unable to reach the water table. An appeal was made to the central authorities for additional funds to remake the bore hole; the system should be functional soon. In addition, irrigational facilities were installed at KARI Katumani to facilitate drought evaluation trials for which a number of phenotyping equipment were purchased and delivered to Kenya, Zimbabwe and Tanzania (Table 43).

Table 43. Equipment purchased for national research programs under the TL-2 project.

Equipment	Countries
Davis Vantage Pro2 Weather Station	Ethiopia, Kenya, Malawi, Tanzania and Zimbabwe
Laptop computer	“
Watermark soil moisture system with meters	“
Sensor for Soil moisture system	“
Ohaus Explorer Pro Toploading Balance	“
Ohaus Explorer Pro Toploading Balance	“
Digital camera SONY DSC-H50/B	“
ET Gauge	“
SPAD 502DL Chlorophyll meter	“
Soil Corers	“
SC-1 Porometer	Ethiopia, Kenya and Malawi
Turf-Tec Infrared Turf Thermometer with probe	“
Hand-held FluorPen with firmware upgrade	“
WHINRIZO Prosoftware on CDROM	“
Calibrate Color Optical Scanner	“
Root positioning system for STD scanners	“

Rain-out shelter in CIAT-Colombia:

A rain-out shelter was established at the CIAT headquarters to facilitate more detailed and controlled physiological studies, and confirm results under field conditions where the control of moisture was less precise.

Enhancing the productivity and production of chickpea in Eastern and Southern Africa

Ganga Rao NVPR, Said N Silim, Chris Ojiewo, Emmanuel S Monyo, Moses Siambi, Joseph Joachim, Paul M Kimurto, Bernard Towett, Wilson Thagana and David Macharia

Summary

The chickpea research and development activities were conducted in three Eastern and Southern African (ESA) countries namely, Ethiopia, Kenya and Tanzania with due involvement of NARES, ICRISAT-ESA, progressive farmers, NGOs and all the major stakeholders.

The major success was achieved on the fast track release of seventeen chickpea varieties in the three target countries viz., Ethiopia (7), Tanzania (4) and Kenya (6).

Three hundred and twenty eight farmers' participatory varietal selection (PVS) trials were conducted in Ethiopia (136), Tanzania (107) and Kenya (85); with an involvement of 16,782 farmers (Ethiopia 10,461, Tanzania 4,102, and Kenya 2,219). In addition, 2,392 field demonstrations (Ethiopia–2209, Tanzania–11, and Kenya–172) were organized to disseminate the best bet varieties and promising production technologies. During the FPVS, 40 released or pre-released varieties (Ethiopia–15, Tanzania–12 and Kenya–13) were included along with a farmer's variety as a check and the feedback were collected from the farmers and other major stakeholders. During the farmer participatory varietal evaluations and the field days farmers were asked to select preferred varieties along with preference criteria that resulted in recording of a number of preferred traits, which facilitated the short-listing of varieties for fast track release. In Kenya, the utilization of chickpea products was demonstrated and this elicited the feedback on most preferred chickpea based products. The farmers rated *githeri* and stew as the most preferred food preparations.

During the past seven years, a total of 111.5 tons breeder, 1,036.5 tons basic and 15,328.5 tons certified seed of farmer–preferred improved varieties were produced by various stakeholders. In ESA, 2685.0 tons seed were produced under TL II involving 22 varieties.

Several training programs were organized to improve the knowledge of farmers on chickpea production, crop and seed health, and seed processing aspects. A total of 13,218 farmers and 570 Extension staff participated in these training programs. One hundred and twenty four field days were conducted in target locations of Kenya (37), Tanzania (34) and Ethiopia (53) with the participation of 16,782 farmers. An information bulletin was published on improved chickpea technologies and seed production in Ethiopia (in both English and Amharic). Twelve participants took part in a one-month training course on "Chickpea Breeding and Seed Production" organized at ICRISAT-Patancheru during January–February 2008 and 2009. One two-weeks training course on "Pre-breeding and legumes improvement" was organized at ICRISAT-Patancheru during 2013 in which five researchers from ESA (Ethiopia [1], Kenya [2], Tanzania [2]) participated. One training program on chickpea agronomic management and germplasm maintenance was organized during 10–12 September 2013 in Nairobi with 23 participants from seven ESA countries. Two MSc students from Kenya and one from Ethiopia finished the research work and one more student from Ethiopia also submitted master's degree thesis.

Background

Chickpea provides a unique opportunity of enhancing legume production in Africa as it does not compete for area with other major legumes. Groundnut, cowpea, soybean and common bean are the wet season (rainy season) legumes, whereas chickpea is a dry-season (post-rainy season) legume. There is not much choice of legumes for growing on the residual moisture in the post-rainy season, the conditions and season in which chickpea is grown.

Chickpea is grown in ESA countries namely Ethiopia, Tanzania, Malawi and Kenya and to a little extent in Eritrea and Uganda. During the last decade, chickpea production has increased by 153%, and this change was mostly caused by the productivity gains (85%) and followed by area increase (37%). The productivity in ESA surpassed by more than 1.2 t/ha (Table 44).

Table 44. Area, production and productivity trends in ESA.

Year	Area (1000 ha)	Production (1000 tons)	Productivity (kg ha^{-1})
ESA			
2001–2003	360.8	240.6	667.1
2004–2006	378.8	268.2	707.4
2007–2009	380.6	355.6	936.0
2010	384.8	420.3	1092.1
2011	453.9	558.6	1230.9
2012	493.0	609.4	1236.3
Ethiopia			
2001–2003	187.1	166.2	889.5
2004–2006	197.8	196.8	990.9
2007–2009	213.3	275.1	1289.6
2010	208.4	322.8	1549.2
2011	231.3	400.2	1730.0
2012	239.5	409.7	1710.7
Tanzania			
2001–2003	67.0	29.0	432.5
2004–2006	67.0	31.5	474.8
2007–2009	52.9	29.9	634.3
2010	45.0	38.3	850.5
2011	74.8	71.2	951.2
2012	120.0	120.0	999.9

Data source: FAO 2012

Ethiopia is the major chickpea producer and exporter among the ESA countries. It occupies the fifth position in terms of both production and exports at a global level. During the last one decade, the release of high yielding and market-preferred varieties and their adoption, export demand and technical and policy support coupled with involvement of several stakeholders along the value chain resulted in increased production (119% ie, 186,801 to 409,733 t), productivity (78%, 958 to 1707 kg ha^{-1}) and export earnings (139%, $14.7 to 35.1 million) in 2012 over the base year (2002). The bulk of the chickpea in Ethiopia (92%) is grown in Amhara and Oromia regions (Table 45). Chickpea yields are at around 1.7 t/ha at the national level and hold the potential to further increase. All these developments resulted in diversification of target locations and entering in to new areas like Sirinka, Axum, Areka and Mechara for varietal dissemination.

Table 45. Crop yields in Ethiopia.

		Yields (kg ha^{-1})	
AEZ	Area (ha)	Current	Achievable yields
Amhara	130,381	1,726	with best adoption condition is 3,500 kg ha^{-1}
Oromia	90,757	1,795	
Tigray	11,604	1,252	with medium adoption condition is 2,200 kg ha^{-1}
SNNPR	5,896	1,126	
National	239,512	1,711	

The above trends gave a filip to include chickpea in Ethiopian Commodity Exchange's trading, formation of multi-stakeholder (Agriculture Transformation Agency, PepsiCo, Inc., USAID, and WFP) and *EthioPEA* Alliance. This also included the receipt of golden cup award by DZARC-EIAR from the Ethiopian Prime Minister for best performance in promoting chickpea technologies in Ethiopia, and for organizing an 'International workshop on harnessing chickpea value chain for nutrition security and commercialization of small holder agriculture in Africa' to share Ethiopia's success story both regionally and internationally.

Tanzania and Kenya are the upcoming countries with new varietal releases (6–Kenya, 4–Tanzania) and increasing production. The major chickpea growing areas in Tanzania are Lake Victoria basin (76%), followed by Western Zone (15%) and Northern Zone (14%). In 2011 alone, chickpea worth $11.5 million was exported from Tanzania. Chickpea is indeed a bonus crop in Kenya and Tanzania. After harvest of maize and wheat in Kenya or maize and rice in Tanzania, the land is normally left fallow until the next cropping season (rainy season). Chickpea is planted immediately after the harvest of cereals and grows under the residual moisture thus giving farmers a second crop (where only one crop would traditionally be grown) and a source of income as well as nutrition. In Kenya, chickpea is mostly grown in the rift valley and parts of eastern Kenya, in about 81,620 ha with a huge potential for an increased area for wheat, maize and rice growing agro-ecologies as a rotation crop.

Further, the policy makers and people' representatives in Kenya are also in favor of drought tolerant chickpea, and have earmarked the constituency development fund to promote this crop. Further potential is envisaged with the enthusiasm and support from the newly established county governments. The bulk of chickpea produced in Eastern Africa is consumed locally, adding to the nutrition of people. Moreover, Ethiopia and Tanzania export a substantial amount of its chickpea produced (49,500 t–Ethiopia; 21,376 t–Tanzania). Chickpea has more diversified uses than any other food legume. The green leaves are used as leafy vegetable and are superior to spinach and cabbage in terms of mineral content. The green immature seed is used as a snack or vegetable. Selling green pods for green grains is highly profitable as these are sold for about $1–1.5 per kg and weigh 2–3 times higher than dry grains. The dry seed splits and flour are used in a variety of other preparations like Bhagia, *githeri*, stew, *mandazi*, cake, *samosa*, doughnuts, buns, *chapati* and grits.

Locations and partners

Three ESA countries were involved along with the target districts/locations as mentioned in Table 46.

Table 46. Project locations and partners for chickpea research in ESA.

Country	NARS partner	Region/Zone/ Province	Region/Zone/County	District/division
Ethiopia	DZARC-Debre Zeit, EIAR	Oromia	East Shewa zone	Gimbichu, Lume, Ejere, Alema Tena, Ada
			Oromia special zone	Sebeta, Holeta Genet
			Bale zone	Sinanna, Goro, Ginir, Agarfa, Gasera, Adaba
			West Harraghe zone	Mechara, Tulo, Oda Bulto, Habro
			South West Shewa zone	Sodo Dachi, Seden Sodo
			West Shewa zone	Ambo, Olonkomi, Ginchi, Dendi,
			Arsi zone	Huruta, Sire, Arsi Robe
		Amhara	North Shewa zone	Minjar-Shenkora, Moretna-Jirus, Basona Werena, Debre Birhan, Ensaro, Merhabete, kawat, Tarmaber, Deneba, Ankober, Bereh
			West Gojam zone	Awubel, Enemay
			North Gondar zone	Dembia, West Belesa, East Belesa, Delgi, Gonder Zuria
			North Wello zone	Dawunt, Weldia, Habru, Guba Lafto
			South Wello zone	Tehuledere, Kalu, Legambo
			Oromia Special zone	Dawa Chefa
		SNNPR	Wolaita zone	Damot Gale, Boloso Sore
			Gurage/Silte zone	Silte, Sodo
			Gamo Gofa zone	Kucha
		Tigray	Central zone	Tahitay Machew, Lailay Machew,
			North West zone	Tahitay koraro
Tanzania	LZARDI, Ukiriguru	Lake Zone	Mwanza region	Misungwi, Kwimba, Magu
			Shinyanga region	Shinyanga, Kishapu, Kahama
Kenya	Egerton University-Njoro and KARI	Formerly Rift Valley province	Bomet, Nakuru, Naivasha, koibatek, Kerio valley, Nakuru counties	Siongoroi, Longissa, Sigor, Eldama Ravine, Njoro, Lare, Mulot, Soy
		Eastern Kenya	Embu	Karaba

Key achievements

Crop improvement

Variety development

During the seven years of TL II, a number of advanced generation breeding materials generated at ICRISAT-Patancheru were received by ICRISAT-Nairobi and EIAR/Debre Zeit-Ethiopia in the form of international chickpea screening nurseries and other evaluation trials (Table 47). Suitable varieties were identified with a high yield potential combined with market-preferred grains and tolerance to biotic (Fusarium wilt, Ascochyta blight, pod borer) and abiotic stresses (drought and heat). After preliminary evaluation in Kenya, elite materials were shared with the NARS programs in Tanzania (LZARDI-Ukiriguru) and Kenya (KARI-Njoro and Egerton University).

Table 47. Details of nurseries evaluated and best genotypes identified.

Location	Nursery	No. of genotypes		Best lines identified	
		Desi	Kabuli	Desi	Kabuli
ICRISAT-Nairobi	Heat tolerant	61	62	ICCVs 07101, 07112, 07104, 07110, 07114	ICCVs 07304, 07308, 05312, 07306, and 05315
	Large seeded	84	60	D018, D047, D018, D064, D040, D065,D028,D021	K001, K014, K026, K022, K036, K004, K041, K010, K027, K016
	MABC lines	22		MABCs 2, 8,22, 17, 21, 19, 4, 10, 14,9, 1, 16, 15	
	ICSN-desi and kabuli	20	20	ICCVs 93954, 11103, 11114, 11112, 11107, 11104	ICCVs 92311, 11312, 11308, 11317, 11313
	Ascochyta	42		ICCVs 10516, 10514, 10510, 10505, 10512, 11505, 11520, 11503, 11507, 11506, 11519	
Ethiopia: EIAR-Debre Zeit	Large seeded	84	60	D047, D051, D058, D046,D056, D052	
	Breeding lines	225		41 high yielding and 12 large seeded with Fusarium wilt resistance identified and most promising ones are ICCVs 08111, 07104, 09118, 09108,10107, 10108, 10109,10103, 10102, 08105 and 08104	
	Drought tolerance	69		ICC 1397, ICC 11819, ICC 4872, ICC 1392,	
Egerton University - Kenya	Ascochyta tolerance	30		ICCVs 11505, 11519, 11515, 11510, 11512	
	Heat tolerance	35	35	ICCVs 07103, 07110, 07113, 07114, 07304	ICCVs 01303, 03404, 05315, 07313
	Pod-borer resistance	81	62	ICCV 07104, D064, D049, D036, D021, ICCV 08107	ICCV 08307, K031, K038, K007, K034
	MABC-drought	22		MABCs 2, 8,22, 17, 21, 19, 4, 10, 14,9, 1, 16, 15	
	Desi and Kabuli	97	117	28 promising lines identified	
LZARDI-Ukiriguru, Tanzania	Desi and Kabuli nurseries	97	117	ICCVs 97406, 07304, 97126, 97031, 97128, 97125	ICCVs 07112, 07110, 07114, 97306, 00302, 97406, 92311
	Large seeded	84	60	D 050,D 049, D 018	K 041, K 012, K 013, K 009, K 020, K 029

Based on the evaluation of 84–desi and 60–kabuli genotypes at ICRISAT-Nairobi, very good genetic diversity for larger seed size was observed among the kabuli genotypes, from which potential genotypes with significantly higher seed mass than the current high yielding varieties (like ICCV 92318) coupled with higher grain yield were selected (Table 48).

Table 48. Promising new generation large-seeded kabuli types evaluated in Kenya.

Name	Days to 50% flowering	Days to 75% maturity	100 seed mass (g)	Yield (kg ha^{-1})
K032	48	106	61.7	3,458
ICCV 08313	42	104	51.5	3,181
K034	44	113	49.7	3,595
ICCV 08308	42	110	48.7	3,748
K025	47	109	48.5	3,094
K021	50	107	47.5	3,863
K026	43	111	47.0	3,494

Over the years of on–station evaluation of advance breeding lines under TL II and TL I in Ethiopia, the best lines were identified based on yield, seed size and yield attributing traits (Tables 49 and 50).

Table 49. Performance of top 12 accessions selected from advanced breeding lines in Ethiopia.

Selected accessions	Yield (kg ha^{-1})	Days to 50% flowering	Days to 75% maturity	Plant height (cm)	100 seed weight (g)	Harvest index (%)
D 047	4,320	44	105	32.5	23.2	62.5
ICCV 08111	4,220	44	105	40.4	37.9	49.8
ICCV 08108	4,075	45	108	42.2	27.0	63.0
D 051	3,725	46	99	35.7	23.7	56.0
D 058	3,437	36	108	35.0	25.0	48.4
ICCV 08105	3,396	45	101	36.2	35.7	48.2
ICCV 08104	3,325	44	103	36.7	35.0	51.0
D 046	3,113	47	106	38.0	34.0	46.7
D 056	3,045	39	100	33.3	32.8	55.7
D 052	2,954	49	110	36.0	25.5	42.3
Desi local check	4,025	52	111	38.0	31.0	52.7
Kabuli local check	3,429	42	107	41.0	39.4	42.5

Table 50. Multi-locational performance of selected genotypes in Ethiopia.

Genotype	Akaki	Chefe Donsa	Debre Zeit	Mean
ICCV 10107	3,520	4,550	3,930	4,000
ICCV 09108	3,030	4,380	4,340	3,917
ICCX-060039-F3-P65-BP	3,500	4,130	4,070	3,900
ICCV 07104	3,050	4,630	3,820	3,833
ICCV 08111	3,480	4,360	3,440	3,760
ICCV 10108	3,290	4,210	3,240	3,580
ICCRIL-03-0208	3,330	3,690	3,450	3,490
ICCX-060039-F3-P38-BP	2,510	4,190	3,700	3,467
ICCV 10109	2,470	4,240	3,570	3,427
DO 51	2,950	3,920	3,340	3,403
ICCV 10103	2,990	3,930	3,280	3,400
ICCV 10102	2,550	3,620	3,790	3,320
ICCV 97105	2,990	3,780	2,840	3,203
ICCX-060039-F3-P44-BP	2,840	3,560	3,210	3,203
Natoli	3,130	4,070	3,880	3,693
Minjar	2,510	4,100	3,310	3,307
Local Check	2,850	3,340	3,530	3,240
Mean	2,889	3,934	3,514	3,446
LSD	539	366	368	244

Based on the on-station evaluation of advance breeding lines under TL II phase-II in Tanzania, best lines were identified based on the yield, seed size and yield attributing traits (Tables 51 and 52).

Table 51. Performance of selected desi genotypes in Tanzania.

Genotype	Yield (kg ha^{-1})	100 seed weight (g)	Days to 50% flowering	Days to 75% maturity
ICCV 06107	3,802	30.1	46	81
ICCV 08106	3,802	33.2	45	83
ICCV 07109	3,594	28.7	46	84
D 050	3,542	29.5	48	83
ICCV 07108	3,542	33.6	46	86
ICCV 07115	3,542	25.7	44	81
D 049	3,490	25.9	44	82
ICCV 00108	3,490	21.1	48	84
ICCV 08103	3,438	34.3	46	83
D 018	3,385	27.4	49	84
Mean	3,186	28.6	48	83
LSD	434	1.1	1	1

Table 52. Performance of selected kabuli genotypes in Tanzania.

Genotype	Yield (kg ha^{-1})	100 seed weight (g)	Days to 50% flowering	Days to 75% maturity
K041	3,125	49.9	45	79
ICCV 95423	3,073	38.5	49	84
ICCV 92318	2,917	36.5	43	74
K012	2,865	50.2	46	79
K013	2,604	47.9	45	79
K009	2,500	45.5	43	77
K026	2,500	42.8	45	77
K029	2,500	56.0	47	83
ICCV 00305	2,448	29.9	49	85
Mean	2,259	44.2	47	80
LSD	382	2.4	3	2

Variety release

In three target countries of ESA, 17 varieties were released during the project period as per the details below (Table 53).

Table 53. Chickpea varieties released in ESA.

Country	Popular/local name	Pedigree/code	Type	Release year
Ethiopia	Monino	Acos Dubie	Kabuli	2009
	Minjar	ICCV 03107	Desi	2010
	Akuri	ICCV 03402	Kabuli	2011
	Kasech	FLIP 95–31C	Kabuli	2011
	Kobo	ICCV–01308	Desi	2012
	Teketay	CJG-74 x ICCL-83105	Desi	2013
	Dalota	ICCX–940002	Desi	2013
Tanzania	Ukiriguru 1	ICCV 97105	Desi	2011
	Mwanza 1	ICCV 00108	Desi	2011
	Mwanza 2	ICCV 00305	Kabuli	2011
	Mwangaza	ICCV 92318	Kabuli	2011
Kenya	LTD 065	ICCV 00108	Desi	2010
	LTD 068	ICCV 00305	Kabuli	2010
	Chania desi 1	ICCV 97105	Desi	2012
	Saina K1	ICCV 95423	Kabuli	2012
	Chania desi 2	ICCV 92944	Desi	2013
	Chania desi 3	ICCV 97126	Desi	2013

Identification of farmer- and market-preferred chickpea varieties

Three hundred and twenty eight farmers PVS trials were conducted in Ethiopia (136), Tanzania (107) and Kenya (85) with the participation of 16,782 farmers (Ethiopia 10,461, Tanzania 4,102 and Kenya 2,219). In addition, 2,392 field demonstrations (Ethiopia–2209, Tanzania–11, and Kenya–172) were organized to disseminate the promising varieties and production technologies. During the FPVS, 40 released or pre-released varieties (Ethiopia–15, Tanzania–12, Kenya–13) were included along with a farmer's variety as a check (Table 54). Farmers came up with a number of preferred varieties like Fusarium wilt and

Ascochyta blight (in Ethiopia), based on the criteria such as early maturity to avoid end season drought and reach the market while the prices are still high; vegetable type for local niche markets; high yield potential; profuse podding; large seed size for domestic consumption/local and international markets; and resistance to terminal drought.

A few genderwise differences in preference were observed, with men going for market traits such as grain size, and women opting for consumption and green pods (Table 55).

Table 54. Varieties used in PVS trials over 7 years.

	Variety		
Country	Desi	Kabuli	Check
Ethiopia	Natoli, Minjar, Matsewal, Kutaye, Dalota, Teketay	Ejere, Teji, Shasho, Chefe, Arerti, Habru, Acos Dubie (Monino), Yelibe, Kasech, Akuri, Kobo	Farmer variety
Tanzania	ICCVs 97105, 00108, 07112, 97114, 97128	ICCVs 00305, 97306, 96329, 92318, 95423, 92311, 95311	Dengumawe
Kenya	ICCVs 97105, 00108, 92944, 97126, 97114, 95415	ICCVs 00305, 97306, 96329, 95423, 96318, 92311, 92318	Ngara Local

Table 55. Farmer-preferred varieties in the three countries.

Country	Desi	Kabuli
Ethiopia	Natoli, Minjar, Kutaye	Habru, Ejere, Teji, Arerti, Yelibe, Akuri, ACOS-Dubie
Tanzania	ICCVs 00108, 97105, 97114, 07112, 97128	ICCVs 92318, 00305, 95423
Kenya	ICCVs 97105, 00108, 92944	ICCVs 95423, 00305, 97306, 92318

Seed systems

During the past seven years, 111.5 tons breeder, 1,036.5 tons basic and 15,328.5 tons of certified seed of farmer-preferred improved varieties was produced by various stakeholders. In ESA, 2685.0 tons of seed were produced under TL II (Ethiopia–1,998.1 t, Kenya 372 t, and Tanzania 315 t) involving 22 varieties (Tables 56-59).

Table 56. Various classes of quality seed produced in ESA (tons).

Country	No. of varieties	Breeder	Basic	Certified/QDS	Total
Ethiopia	11	41.9	715.8	12,454.7	13212.4
Tanzania	4	42.0	303.8	1,412.9	1,758.7
Kenya	7	27.6	16.9	1,460.9	1,505.4
Total	22	111.5	1,036.5	15,328.5	16,476.5

Table 57. Certified seed production by variety in Ethiopia (tons).

Variety	Tolerance to/special trait(s)	Produced directly by TL II	Produced through partnerships	Total
Arerti	*Ascochyta*, *Fusarium* wilt	1,628.4	8,440.0	10,068.4
Shasho	*Fusarium* wilt	199.8	1,178.4	1,378.2
Habru	*Ascochyta*, drought	99.9	760.5	860.4
Ejere	*Ascochyta*, drought	19.9	14.7	34.6
Teji	High yield in potential areas	19.9	10.3	30.2
Chefe		12.0	3.0	15.0
ACOS Dubie	Bold seed size	7.8	11.9	19.7
Kutaye		4.8	15.6	20.4
Natoli	High yield in potential areas	2.7	9.5	12.2
Minjar	*Ascochyta*, *Fusarium* wilt	2.0	4.2	6.2
Marye	Moisture stress	0.9	8.6	9.5
Total		1,998.1	10,456.7	12,454.7

Table 58. Seed production by variety in Tanzania (tons).

Variety	Special trait(s)	Breeder	Basic	Certified/ QDS	Total	Produced by TL II	Produced through partnerships
Ukiriguru 1	Wilt resistant	7.6	55.1	286.0	348.7	125.0	223.7
Mwanza 1	Wilt resistant	6.6	47.0	133.4	187.0	90.0	97.0
Mwangaza	Early, wilt resistant	5.7	47.7	67.5	120.9	50.0	70.9
Mwanza 2	Wilt resistant	6.9	27.5	141.0	175.4	50.0	125.4
Total		26.7	177.3	627.9	831.9	315.0	516.9

Table 59. Seed production by variety in Kenya (tons)

Variety	Special trait(s)	Breeder	Basic	Certified/ QDS	Total	Produced directly by TL II	Produced through partnerships
Chania Desi 1	Wilt resistant	1.6	10.5	149.8	161.9	131.9	30.0
Saina K1	Wilt resistant	0.7	4.7	116.2	121.6	98.2	23.4
Chania Desi 2	Heat tolerant	2.3	1.4	65.8	69.5	41.8	27.7
LTD068	Wilt resistant	2.2	0.23	39.3	41.7	28	13.7
Chania Desi 3		0.23	0	25.5	25.7	15.7	10.0
LTD065		2.4	0.11	61.3	63.8	50.3	13.5
ICCV 97306		0.23	0	7.61	7.84	6.1	1.7
Total		9.64	16.9	465.5	491.96	372	120

Seed production and delivery strategies

Various seed production and delivery strategies have been employed for the various seed classes. The most effective ones are summarized in Table 60.

Table 60. Effective seed systems identified for chickpea production in Ethiopia and Tanzania.

Seed class	Ethiopia	Tanzania	Kenya
Breeder Seed	Research centers	Research centers	Research centers
Foundation Seed	Farmers' coops, private sector, NGOs, Seed enterprises	Farmer-Field-Schools, private sector, NGOs	Private seed companies
Certified Seed	Specialized smallholder farmers	Farm organizations	Farm organizations
Quality Declared Seed	Farmers, farm organizations	Farmers, farm organizations	-

A total of 6,445 small to large size seed packs (2–30 kg) were distributed to farmers in the three countries namely Ethiopia, Kenya and Tanzania. In Ethiopia, eight seed grower associations namely Megertu Denkaka, Ude, Chala, Biftu, Hawi Boru, Lemlem Chefe, Memihir and Ensaro were very active in seed production and delivery. In Tanzania, NGOs and one private seed company named Kilimo markets were involved in seed delivery. In Kenya, links were established with the seed companies (Leldet seeds, Agrosay seeds, Faida seeds), farmers' cooperatives (in Bomet, Koibatek), farmer training and field schools (Koibatek and Bomet FTCs), NGOs (KENPAP) and community organizations (Cheptebo Community centre).

Adoption and impacts

During the phase I, baseline data was collected in Ethiopia, which provided important information on several aspects of chickpea value-chain on production, seed systems and marketing as given below.

Cropping pattern: Bread wheat and white teff were the most common crops produced among the 700 sampled households in Gimbichu (149), Lume–Ejere (300) and Minjar–Shenkora (251). In terms of crop area allocated to improved varieties, kabuli chickpea takes the lead (42.5%) followed by bread wheat (36%). Desi chickpea is the third most popular crop produced by 53.6% of the sampled households.

Crop yields: The average yield for kabuli chickpea was relatively higher in Minjar–Shenkora district (3285 kg ha^{-1}) compared to the other two districts (Gimbichu–2374 kg ha^{-1} and Lume–Ejre–2389 kg ha^{-1}), whereas for desi chickpea there seems to be no yield difference across the three districts (Minja–Shenkora–1877 kg ha^{-1}, Gimbichu–1913 kg ha^{-1} and Lume–Ejre–1988 kg ha^{-1}). Shasho (20.6%) continues to be the most widely grown kabuli variety among the chickpea farmers, followed by Ejere (11.7%) and Arerti (10%), respectively. Local desi remains as the most widely grown variety among chickpea farmers while only 4.3% grow improved desi. Of the total chickpea area in the survey regions, about 54.5% is allocated to local desi followed by Shasho (21%) and Ejere (11.9%).

Fertilizer used in chickpea was relatively much less than its use in wheat and teff. For kabuli, the average amount of DAP and urea used per ha amounts to 16 and 11 kg, respectively, whereas the amount used for desi chickpea was by far less (3.4 kg each of DAP and Urea). Manure application is also popular especially in Lume-Ejere and Minjar-Shenkora districts.

Chickpea seed access: The first major source of seed for Arerti and Shasho varieties was the seed saved by the farmers followed by the producers' groups. About 47% of those who planted Arerti and 50% of those who planted Shasho used their own saved seed during the cropping season from 2006–2007 while about 33% and 26% planted the same variety sourced seed from producer marketing groups or cooperatives. Own saved seed again was a vital source of seed for Chefe (77%), Worku (71%) and local desi (84%) varieties while producer marketing groups also contributed for Ejere type (33%). The third and fourth important sources of seed during the planting season from 2006 to 2007 were the local seed producers and local traders and agro-dealers, respectively. The first and second major reason why some farmers never adopted the improved varieties was lack of access to seed and fear of theft during the green stage. The third and fourth major reasons are related to the shortage of land and lack of cash to buy seed and lack of credit. Only 48% of sampled households use at least some purchased seed, perhaps due to the use of recycled seeds. The share of seed purchased for kabuli was about 48.9%, which was significantly higher compared to desi (3.1%). The average total labor used in person days was about 97 per ha for kabuli and 83 per ha for desi.

Chickpea utilization: Over 70% of kabuli chickpea and 55% of desi chickpea produced are sold in the market, suggesting the relevance of chickpea as a cash crop in the study area. Kabuli chickpea is the first crop primarily produced for the market compared to all other crops grown in the study regions. Desi chickpea takes the third rank in terms of share of produce sold in the market.

Crop-livestock interactions: About 10.5% of the sample respondents use crop residue as source of animal feed whereas about 5.5% use it as green fodder or grazing land.

Preferred traits for chickpea: The highest score was given to the Chefe variety by both men and women farmers, which was followed by Ejere. Female chickpea farmers prefer Arerti variety for their taste and high price in the market whereas the male farmers prefer the same variety for high price and grain yield. Shasho variety is highly preferred owing to its high price in the market, grain size and grain color by both male and female farmers. Male farmers prefer the Chefe variety for their grain color and size while the female farmers prefer them for their high price in the market, grain size and low cost of production. The preferred traits for Ejere variety by both male and female farmers are high price in the market, grain size and grain color. Generally, kabuli varieties are highly preferred for their high economic return in addition to their grain color and size. The characteristics of Worku variety mostly favored by male farmers include good taste and uniformity in maturity while female farmers prefer them for good taste, grain color and high price in the market.

Net-return of chickpea: Generally, kabuli varieties perform superior in terms of yield, compared to the other desi types. Among all the chickpea varieties, Arerti and Shasho varieties have the highest gross margin in terms of returns to land and management. The average return for Arerti and Shasho is about ETB 10,283 and ETB 9,496 per ha, respectively, whereas the improved desi has a net–return of about ETB 2,481 per ha (1 $ = 21 ETB).

Post-harvest handling and consumption: About 86.4% of farmers thresh their produce with animals on dung cemented surface and grass while about 13% of them thresh their produce with animals on dirt surface. About 74% of Shasho and Ejere varieties produced are sold in the market, thus ranking first among chickpea varieties in terms of market share. Arerti and local desi take the second and third rank in terms of share of produce sold in the market. The proportion of improved and local desi sold in the market was about 20% and 55%, respectively. About 10% of all kabuli varieties produced are saved as seed for the next cropping seasons while the share is a bit higher for the desi types. Among the kabuli varieties, the share of produce used for home consumption is highest for Chefe (39%) followed by Arerti (25%). On the other hand, about 68% of improved desi and 32% of local desi produced by sampled households are used for home consumption.

Chickpea marketing: About 37% and 64% of kabuli and desi chickpea farmers are involved in marketing, indicating its role as a source of cash. Within the kabuli category, the proportion of chickpea farmers involved in marketing of Shasho variety is the highest, followed by the Ejere type. The marketed surplus for the kabuli chickpea is a bit higher than the desi types. About 74% of the chickpea are sold in the main market. Urban grain traders are the first major buyers of chickpea in all the three districts, followed by the rural traders and rural assemblers.

Both producer and retail price are higher for the kabuli chickpea over the desi types. The annual average rate of growth (ROG) of kabuli retail price (4.5%) is more than double the desi retail price (2.3%). On the contrary, the ROG of desi producer price (3.68%) is much higher than the kabuli producer price (0.37%).

About 75% of traders recognized kabuli chickpea as having two grades (Grade 1 and 2). For desi chickpea, the majority of the sample traders in the primary markets (70%) recognized only one quality grade for the commodity. The major quality traits used in markets to classify the grading for chickpea include grain color, grain size, presence of foreign matter and broken and shriveled seeds. The survey results indicate that at all the market levels (except for desi in primary markets), quality seems to attract a price premium. On average, there was a margin of about ETB 27 ($ 1.29) per 100 kg for the kabuli chickpea variety and ETB 15 ($ 0.714) per 100 kg for the desi chickpea variety.

Gender aspect of chickpea production and marketing: In the study areas, men and women appear to make decisions regarding the sale of chickpea. Women are less familiar with the modern markets and feel powerless to influence them. They are hampered by the cultural norms, and lack of access to information on new technology, prices, demand, etc. Unlike their husbands, they are rarely given training in modern small-business management. In addition, they are hampered by the factors common to all: lack of adequate transport and communications services, inadequate equipment and facilities in market places and the presence of exploitative middlemen. Compared to women, men have easier access to technology and training, mainly due to their strong position as the head of the household and greater access to off-farm mobility. Moreover, men have easier access to credit than women do.

Ex ante impact assessment

An assessment of the potential long term benefits was undertaken (Ibrahim et al. 2011) using the baseline and follow up (2008 and 2010) information for the critical parameter estimates like yield superiority and adoption rates as well as prices. In order to account for the possible fluctuations, sensitivity analysis was incorporated. The economic surplus model (based on DREAM model) was applied to estimate the total benefits. With an annual chickpea production of 175,734 ton, chickpea price of $164/ton, a production benefit of 31%, a supply and demand elasticity of 0.9 and 1.4 respectively, maximum adoption of 75% and an annual increase of consumption of 2.6%, the economic surplus produced was estimated to be $111 million for 30 years. It was further estimated that the consumers would receive 39% of the benefit while the producers were entitled to 61%.

With the project costs of $22 million, the benefit cost ratio was estimated at 5:1. Further, an IRR of 55% was obtained thus indicating that it was a profitable investment. Even with the worst-case scenario ie, lowest benefit (15%), highest discount rate (13%), lowest elasticity and price, the benefit-cost ratio of 2:1 was still able to justify the investment.

The generated benefit was expected to eliminate the poverty conditions for more than 0.7 million people (both producers and consumers). However, this benefit can be considered as a lower boundary, since the calculation was made using conservative parameters. Moreover, if as expected, the farmers continue to grow the improved varieties beyond 2030, the returns on investments to this project will become even more significant.

Additionally, the technology spillovers to geographic regions that are not intentionally targeted by the research investment (neighboring countries) could significantly help in increasing the benefit. Similarly, since chickpea like other legumes have the capability of fixing nitrogen, it may also generate significant environmental and sustainability benefits that can help improve the ecosystem health in case the crop area expands beyond what was grown under the traditional varieties. The government is also benefited from the increased tax revenues received from both producers and consumers. Further studies on social economic impact are recommended. Thus, further investments in the chickpea and other legume research in Ethiopia is justified as a means of poverty alleviation.

Upgrading data collection: Tablet based household surveys were piloted in Ethiopia. In order to facilitate the third round of a panel survey, which was meant for adoption tracking, tablets were deployed to ensure that the process of data collection was efficient. After holding a brief introductory training on the open source app ODK that was used for the survey, a small team consisting of the ICRISAT staff in Nairobi converted the TL II survey instrument to ODK and further trained the enumerators and partners in Debre Zeit research station in Ethiopia. While the questionnaire content had to be retained due to the panel setting of the survey, the implementation on the tablet had to be carefully planned with an aim of maximizing the benefits. Therefore, crosschecks and automatic skips were implemented according to the initial set up. Furthermore, the restrictions on variable ranges and limitations on skipping answers were set up to ensure the highest possible data quality.

The initial feedback received during the training and field deployment was very positive. Prior concerns about the enumerators' ability to adjust to the electronic questionnaire and touchscreen were wiped out after the enumerators' first hands of experience. The enumerators confidently handled the tablet and farmers were fascinated by the new technology. Therefore, the tablet based data collection not only helped in improving the data quality but also ensured quicker availability of data as data entry was no longer necessary and the need for data cleaning was reduced. Finally, the investment costs for the tablets are estimated to be recovered after approximately 1000 interviews.

Capacity building

Training of farmers and Extension staff

Training was provided to 13,218 farmers (Ethiopia-7,980, Tanzania-2,409, Kenya-2,829) and 570 Extension staff (Ethiopia-205, Tanzania-171, Kenya-194) on various aspects of good agronomic practices for improved crop and seed production, FPVS, large scale demonstrations, seed storage and utilization technologies.

Field days, farmers' fairs

One hundred and twenty-four field days were conducted in Kenya (37), Tanzania (34) and Ethiopia (53) with participation of 16,782 farmers (Kenya-2,219; Tanzania-4,102; Ethiopia-10,461). During the field days, the farmers were asked to select preferred varieties along with their preference criteria. The comprehensive analysis from this activity facilitated the release of the new varieties in each country and helped in planning the seed production strategy. Farmers' preference criteria also provided feedback to the researchers and development personnel involved in chickpea. In Kenya, researchers along with human nutritionists also demonstrated the utility aspect of chickpea in the form of various products such as chapati, *githeri*, stew, *mandazi*, cake, *samosa*, doughnuts, buns, grits, and beverage and elicited the feedback on preferred products (*githeri* and stew).

Awareness activities

Awareness activities were conducted through radio, television, newpaper, popular articles and telephone conversations. PVS village network, demonstrations, annual farmer field days, rural seed fairs and agricultural shows were also used in creating awareness. In Kenya, policymakers were engaged in creating awareness. Proceedings of all the field days were broadcast on the public media (Ethiopian Television, Ethiopian Radio, Ethiopian News Agency, and newspapers) in Amharic, Oromifa and English. Television and radio broadcasts with live interviews and newspaper articles about new varieties became a regular norm throughout the project sites in Tanzania. Information bulletin on 'Improved chickpea technologies and seed production in Ethiopia' were prepared and shared with all the stakeholders. Manuals in seed production were also produced in Swahili (Tanzania). Flyers describing chickpea were printed in Amharic and Swahili and distributed to the farmers in the project sites (more than 10,000 flyers).

Training of scientists, research technicians

A one-month training course on "Chickpea Breeding and Seed Production" was organized at ICRISAT-Patancheru during January to February 2008 and 2009, involving 12 participants from ESA, ie, four each from Ethiopia, Kenya and Tanzania. One two-weeks training course on "Pre-breeding and legumes improvement" was organized at ICRISAT-Patancheru during 2013 in which five researchers from ESA (Ethiopia 1; Kenya 2; Tanzania 2) participated. One training program on chickpea agronomic management and germplasm maintenance was organized during 10–12 September 2013 in Nairobi with 23 participants from seven ESA countries. In addition, three staff from ESA were trained on electronic field books and data management at Wageningen through the Generation Challenge Program (GCP).

Development of infrastructure facilities

Overall, the target countries' basic infrastructure facilities at the farm level were established/upgraded to ensure proper conduct of experiments and assured seed multiplication, as given below:

- KARI-Njoro: Existing irrigation facilities were renovated to produce seed under assured irrigation both during main and off-seasons.
- LZARDI-Ukiriguru: Land along with proper fencing was developed exclusively for chickpea yield trials/ nurseries and seed multiplication.
- EIAR-Debre Zeit: Irrigation facility for off-season variety evaluation and seed multiplication.

Degree students

Four MSc students (2-Kenya, 2 Ethiopia) and one PhD student from Ethiopia worked on various aspects of chickpea like heat tolerance, genetic diversity, nitrogen fixation, Helicoverpa and drought tolerance as given in Table 61.

Table 61. Degree students worked/working on chickpea research.

Name	Country	Program	University	Research area
Peter Kaloki	Kenya	MSc	University of Nairobi, Kenya	Identification of sources of heat tolerance in chickpea
Tadesse Sefera	Ethiopia	MSc	Haramaya University, Ethiopia	Genetic diversity analysis and DNA fingerprinting of chickpea varieties using simple sequence repeat (SSR) markers
Nigusie Girma	Ethiopia	MSc	Haramaya University, Ethiopia	Heterosis, Combining Ability and Heritability for Nitrogen Fixation in Chickpea (*Cicer arietinum* L.)
Nancy Njogu	Kenya	MSc	Egerton University	Genetic variability for resistance to *Helicoverpa armigera* in chickpea
Musa Jarso	Ethiopia	PhD	Haramaya University, Ethiopia	Development of molecular markers and use in Marker Assisted Back-Crossing for Development of drought tolerance in chickpea

Lessons learned

General (all countries)

- Mechanization is necessary for timely planting under the residual moisture conditions with very little planting window.
- Sensitization of policy makers is required for the quick dissemination of best bet varieties and other technologies.
- Farmers participation in varietal selection reduces the time required for varietal testing and possible high adoption of tested varieties before or after the formal release.
- In addition to yield, maturity duration and resistance to diseases, the seed traits most preferred by market (seed size, color and shape) were also given high weightage.
- The farmers' preferences for growing kabuli chickpea varieties largely depended on the price premium received over the desi type.
- Private seed industry is not very interested due to self-pollinated nature, no information on effective seed demand, low seed replacement rate and high transaction costs for transport, processing and storage.
- Off-season seed multiplication for faster spread and reducing the seed production cycle time.
- Individual farmers are often reluctant to become seed growers due to the lack of capabilities for seed processing and storage and difficulties in marketing. However, they were very keen to takeup seed production, provided suitable arrangements were made for assured procurement. Community Seed Producer Associations may be promoted and could have better access to seed processing, storage facilities and marketing.
- Sustainable seed production by smallholders will stand a better chance of success if complimented by functional seed and product markets. Project interventions should focus on smallholder-centered seed production and delivery systems that have a better chance of surviving beyond the lifespan of the project.
- Business-oriented smallholder farmers perform better in seed production, storage, and dissemination than the food security-oriented farmers; hence, these groups of farmers should be involved in seed systems.
- Limited number of researchers and technicians available in ESA also hamper the progress of varietal development and seed dissemination.

Country-specific

Ethiopia

- Active participation of Department of Agriculture staff was essential for the successful implementation of demonstrations both in number and in size.
- Farmers are still reluctant to follow best production practices and show low management syndrome to legumes.
- Poor product standardization and market unpredictability affects the growth of the seed sector.
- Shortage of initial seed of new varieties was a major bottleneck in promoting new varieties in Ethiopia.

- Off-season seed multiplication with supplemental irrigation facilitated faster varietal spread in Ethiopia. Thus, the infrastructure for irrigation needed to be strengthened.
- Still faces a weak level of private seed sector participation.
- Certification procedure for farmer-based seed does not exist.

Tanzania

- Generally, the farmers prefer desi types because traders are used to it and there is a high domestic demand for the desi types.
- There is a need for strengthening farmers' seed producer groups for seed production.

Kenya

- Identified to have higher drought tolerance compared to maize and beans, indicating high potential for area enhancement, particularly in the arid and semi-arid areas with vertisols.
- Sensitization of policy makers about the importance of chickpea in combating drought helped in getting their support and this has provided a boost to our efforts in enhancing the chickpea area.
- Better performance of chickpea under prevailing drought conditions created awareness among the farmers, policy makers, MoA staff and consequently a greater demand for seed.

Challenges/gaps and future directions

- Need for proper sowing machines for chickpea in a short window of soil moisture availability in Lake Zone of Tanzania after the harvest of maize/rice.
- Ascochyta blight is emerging as a major challenge in ESA especially in Ethiopia and Kenya.
- Demands for emerging technology for irrigation, double cropping, fertilization and relay cropping in Ethiopia to further increase the productivity.
- Lack of sick plots or artificial screening facilities in ESA for various diseases.
- Need for concerted efforts to enhance the adoption of integrated pest management (IPM) for pod borer control.
- Intensify the utilization of chickpea in the rural areas of Tanzania and Kenya.
- Expand cultivation of chickpea in traditional wheat growing areas of Kenya as a rotational crop.

Enhancing chickpea productivity and production in South Asia

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Summary

The chickpea activities in the phase I were conducted in Andhra Pradesh (Kurnool and Prakasam districts) and Karnataka (Dharwad and Gulbarga districts) states of India. In the phase II, the project activities were extended to Bangladesh and two additional states (Bihar and Odisha) of India. The project partners included ICRISAT-Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh; University of Agricultural Sciences, Dharwad (UAS-D), Karnataka; University of Agricultural Sciences, Raichur (UAS-R), Karnataka; Bihar Agricultural University, Sabour, Bihar; Orissa University of Agriculture & Technology, Bhubaneswar, Odisha; Bangladesh Agricultural Research Institute (BARI), Bangladesh; National Seed Corporation (NSC), India; State Farms Corporation of India Limited (SFCI), Andhra Pradesh State Seed Development Corporation (APSSDC); and Karnataka State Seed Corporation (KSSC).

The status of adoption of improved varieties and traits preferred by the farmers were assessed at the beginning of the project. Considering the requirements of target regions, the chickpea improvement program focused on developing breeding lines with high yield potential, early maturity, drought and heat tolerance, resistance to major diseases (Fusarium wilt, Ascochyta blight and Botrytis grey mold), resistance to pod borer, suitability to machine harvesting, and market-preferred seed traits. ICRISAT supplied over 300 improved breeding lines to NARS partners in India and ESA. The research team engaged in chickpea improvement activities in TL II much similar to TL I project and thus there was a good integration of research inputs and outputs between these two projects.

A "QTL-hotspot" containing QTLs for several root and drought tolerance traits were transferred from the drought tolerant line ICC 4958 to three leading cultivars, including JG 11, through three cycles of marker-assisted backcrossing (MABC) under TL I project. Introgression lines of JG 11 were evaluated at three to four locations each across India and ESA during 2011–12 and 2012–13. Several lines giving at least 10% higher yield than the recurrent parent JG 11 were identified at each location and each growing condition (rainfed/irrigated). Several breeding lines with higher levels of heat tolerance as compared to the heat tolerant cultivar JG 14 were developed. Breeding lines with enhanced resistance to botrytis grey mold were developed for Bangladesh and with enhanced resistance to Ascochyta blight for ESA. Early generation breeding materials were developed for resistance to *Helicoverpa* pod borer through interspecific hybridization and promising lines were identified. Breeding lines with greater plant height and semi-erect growth habit were developed for making them amenable to machine harvesting.

The earlier studies indicated that the adoption of improved chickpea cultivars continued to remain low in TL II target countries. Lack of awareness among the farmers about the improved cultivars and/or their useful traits and inadequate availability of seed of improved cultivars were among the major factors for poor adoption. Farmer-participatory varietal selection (FPVS) trials were conducted for exposing farmers to improved cultivars and allowing them to select cultivars according to their preference. The most preferred cultivars identified were JG 11, JAKI 9218, JG 130 and KAK 2 in Andhra Pradesh; JG 11, BGD

103, JAKI 9218 and MNK 1 in Karnataka; JG 14, KAK 2 and Subhra in Bihar; JG 14, Vihar and JAKI 9218 in Odisha. The traits for which these cultivars were preferred included, profuse podding, high productivity, early maturity, resistance to Fusarium wilt, and market-preferred seed traits (eg, medium-sized seed in desi type and large-sized seed in kabuli type). The results of FPVS trials strengthened release proposals of varieties. Two varieties, BGD 103 (large seeded desi) and MNK 1 (extra-large seeded kabuli) were released in Karnataka and one variety Nandyal Shenaga 1 (heat and drought tolerant desi) was released in Andhra Pradesh.

Seed availability at local level was enhanced by strengthening the formal as well as informal seed production chain. During phase I, 1,207 tons breeder seed and 886 tons certified and truthfully-labelled seed (TLS) of farmer-preferred improved chickpea varieties were produced by the research partners in India. In phase II (2011 and 2012), 7,560 tons chickpea were produced by the research partners in India and 6.1 tons by the research partners in Bangladesh.

Close to 17,000 seed samples (4,979 in phase I and 12,016 in phase II) of 2 kg to 20 kg were distributed to farmers in India and 90 samples (in phase II) to farmers in Bangladesh for enhancing their awareness about the improved cultivars. Various awareness activities created high demand of seed for farmer-preferred cultivars. The public seed corporations (NSC, SFCI, APSSDC and KSSC) joined hands with the research partners and produced 74,531 tons seed in phase I and 76,215 tons in phase II in India. In Bangladesh, 181 tons of quality seed was produced in phase II. In Karnataka state of India, 48 small seed companies started chickpea seed production through the policy support by the state government and produced 12,752 tons foundation seeds and 91,707 tons certified seeds during 2013.

Under capacity building in phase I, training on various aspects of improved crop and seed production technologies of chickpea was provided to 12,000 (10,842 men + 1,158 women) farmers and 1,411 extension personnel (1,229 men + 182 women) in India. In phase II, training was provided to 3,381 farmers (2,973 men + 408 women) and 1,075 (878 men +197 women) extension personnel in India; and 410 farmers (355 men + 55 women) and 90 (78 men + 12 women) extension personnel in Bangladesh.

A total of 48 field days and 10 farmers' fairs were organized, with the participation of 27,000 farmers (24,290 men + 2,697 women). In phase II, 52 field days were organized in which 5,255 farmers (4,282 men + 973 women) participated, 4,288 in India and 967 in Bangladesh. Efforts were made to reach large number of farmers through electronic and print media to disseminate information on the improved cultivars and crop production technologies.

Efforts were also made to enhance capacity of NARS in chickpea improvement and seed production. Two one-month training courses on "Chickpea Breeding and Seed Production" and one two-week course on "Pre-breeding and crop improvement of grain legumes" were organized at ICRISAT-Patancheru in which 17 researchers (13 men + 4 women) from the NARS of Ethiopia, Tanzania, Kenya and Bangladesh participated. The infrastructure facilities for seed production, processing and storage were strengthened at the research stations. Four PhD students (all men) and three MSc students (one man + 2 women) from India (5), Ethiopia (1) and Kenya (1) were provided accommodation for their thesis research on chickpea at ICRISAT-Patancheru.

Chickpea (*Cicer arietinum* L.) also called Bengal gram or Garbanzo is an important source of protein for millions of people in the developing countries, particularly in South Asia (SA), who are largely vegetarians either by choice or because of economic reasons. Chickpea is grown in more than 50 countries, but developing countries account for over 95% of its production. Over 80% of the chickpea production comes from South Asia, wherein India is the largest chickpea producing country accounting for about 70% of the global chickpea production. In India, chickpea contributes to over 40% of total pulse production and is denoted as the most important pulse crop of the country. Chickpea meets 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N ha^{-1} from air.

Because of its deep tap root system, chickpea can avoid drought conditions by extracting water from the deeper layers in the soil profile.

There has been a substantial increase in global area and production of chickpea during the past 10 years (2003–2012). Resultantly, chickpea has become the second largest grown and produced pulse crop of the world after dry beans. The global chickpea area, production and productivity have increased by 26% (9.6 million ha to 12.1 million ha), 26% (737 kg ha^{-1} to 931 kg ha^{-1}) and 59% (7.1 million tons to 11.3 million tons), respectively. Remarkable progress has been made in ESA, where the area increased by 35% (325,000 ha to 440,000 ha), productivity almost doubled (653 kg ha^{-1} to 1260 kg ha^{-1}) and production increased by 161% (212,000 tons to 554,000 tons). South Asia, which contributes to over 80% of the global chickpea production also showed good progress in chickpea production. The chickpea production increased by 59% (5.22 million tons to 8.32 million tons) due to an increase in its area by 32% (7.53 million ha to 9.96 million ha) and productivity by 21% (693 kg ha^{-1} to 836 kg ha^{-1}).

Drought and heat stresses at reproductive stage are the major abiotic stresses while Fusarium wilt, *Helicoverpa* pod borer, Ascochyta blight, Botrytis grey mold and Dry root rot are the major biotic stresses to chickpea production in SA. Though a wide range of improved chickpea cultivars are now available, many farmers continue to grow old varieties and landraces. The farmers are either not aware of the improved varieties or do not have access to seed of improved varieties. Thus, the achievements of chickpea improvement research have not been fully translated into increased productivity at the farm level. The productivity of chickpea can be substantially enhanced by the adoption of improved cultivars and associated improved production technologies. There is also scope for enhancing its area cover in the SA countries.

Intended targets to be achieved and major activities:

The project aims to increase the productivity and production of chickpea and the income of poor farmers in target regions by 15%, with improved varieties occupying 30% of the total area in the coming 10 years.

The major activities involved for achieving the different objectives are as follows:

Objective 1: To enhance the market opportunities, policies and partnerships along the legume value chain, to increase the income and nutritional security of smallholder farmers in the drought-prone areas of sub-Saharan Africa (SSA) and SA.

- Participatory monitoring and evaluation (M&E) of adoption and impact
- Targeting technologies and scaling-out innovations
- Assessment of market innovations, institutions and policy
- Capacity building

Objective 5: To enhance chickpea productivity and production in the drought-prone areas of SSA and SA.

- To identify and facilitate the adoption of farmer– and market–preferred chickpea varieties in the drought-prone areas.
- To develop improved chickpea germplasm to meet the requirement of farmers and consumers in the target environments.
- To enhance the capacity of NARS in chickpea improvement and empower the extension personnel and farmers with knowledge of chickpea production technology.

Objective 8.6: To develop sustainable seed production and delivery systems for the smallholder farmers in SA (India, Bangladesh)

- To provide support to the formal seed sector.
- To facilitate the promotion and economic analysis of alternate seed models.
- To enhance the local capacity to produce, deliver, store and market seeds
- To enhance the local–level awareness about the farmer-preferred varieties (Linked with Objectives 2, 5 and 6).
- To improve the availability of foundation seed by NARS and other public sector as well as private sector.
- To design and test the alternative seed production arrangements (tailored according to various clients needs)
- To design, test and implement diffusion, marketing and institutional arrangements to enhance the seed delivery (tailored according to various client needs).
- To enhance the local–level awareness about the released varieties (demand creation).

Locations and partners

In phase I, the target country was India, and the locations selected for chickpea activities included two districts (Kurnool and Prakasam) of Andhra Pradesh and two districts (Dharwad and Gulbarga) of Karnataka State in South India. During phase II, the project activities were extended to a new country Bangladesh and two other Indian states, Bihar and Odisha. The following were the key project partners:

- ICRISAT, Patancheru, Andhra Pradesh, India
- Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh, India
- University of Agricultural Sciences, Dharwad (UAS-D), Karnataka, India
- University of Agricultural Sciences, Raichur (UAS-R), Karnataka, India
- Bihar Agricultural University (BAU), Sabour, Bihar, India
- Orissa University of Agriculture & Technology, Bhubneswar, India
- National Seed Corporation (NSC), India
- State Farms Corporation of India Limited (SFCI), India
- Andhra Pradesh State Seed Development Corporation (APSSDC), India
- Karnataka State Seed Corporation (KSSC), India
- Pulses Research Center (PRC), Bangladesh Agricultural Research Institute (BARI), Ishurdi, Bangladesh

Situation and outlook

A number of biotic and abiotic factors limited the realization of yield potential, besides the lack of availability of improved seeds to farmers. The slow growth of chickpea yield in India can be attributed to: (i) the shift in crop area from favorable to marginal environments; (ii) the slow uptake of improved varieties and other production technologies; and (iii) its cultivation on poor soils under erratic rainfall conditions.

Trade in chickpea is relatively robust and has been growing over time. Close to 10% of the total chickpea produced during 2003–2005 entered the international market. The trade statistics indicated a demand-supply imbalance for pulses in Asia. While the quantum of chickpea exports from Asia doubled between 1981 and 2007, overall the region remains as a net importer. The increased import demand has induced countries such as Australia and Canada that traditionally did not grow chickpea to emerge as significant exporters now.

The scope of raising chickpea production in Asia through area expansion alone is extremely limited. Therefore, the main challenges for research and development are to bridge the gap between actual and attainable yield by: (a) enhancing the farmers' access to good quality inputs, improved technologies and information; (b) improving the competitiveness of pulse crops through domestic incentives related to production, marketing, processing prices in line with cereals and competing crops; and (c) achieving a technological breakthrough that not only overcomes yield barriers but also provides effective protection against insect pests and diseases, and tolerance to moisture stress.

Key achievements

Crop improvement

Development of cultivars

Considering the requirements of the target regions, the chickpea improvement program focused on developing breeding lines with high yield potential, early maturity, drought and heat tolerance, resistance to key diseases (Fusarium wilt, Ascochyta blight, Botrytis grey mold), resistance to pod borer, suitability to machine harvesting, and market-preferred seed traits.

Over 300 promising breeding lines were selected at ICRISAT–India and supplied to the project partners. Two international chickpea screening nurseries (ICSN–Desi and ICSN–Kabuli) were constituted each year and supplied to the project partners. Each ICSN consisted of 18 advanced breeding lines, one common check and one local check. The partners identified several promising breeding lines from these nurseries for further evaluation in station and multilocation trials. The promising lines identified included ICCV 09106, ICCV 09107, ICCV 09112, ICCV 09116, ICCV 09118, ICCV 07103, ICCV 07104 and ICCV 07110, ICCV 12101, ICCV 12110 and ICCV 12113 in desi type (>5–20% higher yield than the check JG 11/ICCC 37) and ICCV 06302, ICCV 12303, ICCV 12309 and ICCV 12313 in kabuli type (>5–10% higher yield than the check KAK 2). Considering the demand for extra-large seeded kabuli chickpeas, ICSN–Kabuli large seed was constituted and supplied to the project partners for evaluation during 2010 and 2012. Several lines (ICCV 10411, ICCV 10410, ICCV 10402 and ICCV 10404, ICCV 12402, ICCV 12403, ICCV 12405 and ICCV 12406) with larger seed and on par yields with check (KAK 2) were identified.

A "QTL–hotspot" containing QTLs for several root and drought tolerance traits was transferred from the drought tolerant line ICC 4958 to three cultivars (JG 11, KAK 2, Chefe) via three cycles of marker-assisted backcrossing (MABC) under the TL I project. A set of 20 BC_3F_4 introgression lines of JG 11 were evaluated at three locations in India (Patancheru, Nandyal, Gulbarga) and one each in Kenya (Koibatek) and Ethiopia (Debre Zeit) during 2011–2012. Another set of 20 BC_3F_4 introgression lines of JG 11 lines were evaluated at four locations in India (Patancheru, Nandyal, Gulbarga, Dharwad) during 2012–2013. Several lines giving at least 10% higher yield than the recurrent parent JG 11 were identified at each location and growing condition (rainfed or irrigated).

A set of 30 germplasm/breeding lines, including both desi and kabuli types, were evaluated during the normal-sown and late-sown conditions at three to four locations each during 2011–12 and 2012–13, with an aim to identify the stable heat tolerant genotypes. Based on the two years results, several promising heat tolerant genotypes (ICCV 07117, JG 11, JG 16, JG 130, JGK 2, JG 14, NBeG 3, ICC 8474, ICCV 07109, ICCV 06302, ICC 4958, ICCV 07102, and ICCV 07105) were identified. In addition, over 700 breeding lines were evaluated for heat tolerance at ICRISAT–Patancheru and several lines with higher levels of heat tolerance as compared to JG 14 were identified. Several tall and upright breeding lines suitable for machine harvesting were developed and evaluated at four locations (Patancheru, Nandyal, Dharwad, Gulbarga) in India. Promising lines identified included ICCV 13601, ICCV 13605, ICCV 13607, ICCV 05107, ICCL 85213, ICCV 04103 and ICCV 08108.

Breeding lines with enhanced resistance to botrytis grey mold were developed for Bangladesh and with enhanced resistance to Ascochyta blight for Ethiopia and Kenya. Pod borer (*Helicoverpa armigera*) is the most devastating insect-pest of chickpea. However, the levels of resistance available to Pod borer in the cultivated chickpea are very low. Interspecific crosses of *C. arietinum* (cultivated chickpea) x *C. reticulatum* (wild progenitor of chickpea) are being used to enhance the resistance to pod borer. Forty F_6 progenies derived from the cross between *Helicoverpa*-resistant *C. arietinum* accession ICC 506EB and the *C. reticulatum* accession IG 72953, along with parents and the susceptible checks (ICC 3137 and ICCC 37) were evaluated for resistance to pod borer using detached leaf assay in the laboratory and under no-choice cage conditions in the greenhouse. Some interspecific progenies with higher levels of resistance than either of the parents involved in the crosses were identified for further evaluation.

Identification of farmer- and market-preferred chickpea cultivars

The status of adoption of improved varieties and traits preferred by the farmers were assessed at the beginning of the project. Taking into account farmer- and market-preferred traits, in phase I, eight improved cultivars or breeding lines (4 desi + 4 kabuli) were selected for FPVS trials at each of the four project locations (Kurnool and Prakasam districts in Andhra Pradesh and Dharwad and Gulbarga districts in Karnataka). Twenty mother trials and 217 baby trials were conducted in 23 villages (5 to 8 villages in each district) during 2007–2008 to expose farmers to improved cultivars and allow them to select their preferred cultivars. The crop in Prakasam district of Andhra Pradesh was destroyed in the first year by heavy rains at maturity, so FPVS trials were repeated in the second year (2008–2009). About 1181 farmers (1052 men + 129 women) were involved in ranking of varieties in FPVS trials. The desi chickpea cultivars, JG 11 and JAKI 9218, were preferred in all four districts. In addition to these, desi chickpea cultivar JG 130 was preferred in both the districts of Andhra Pradesh while desi chickpea cultivar BGD 103 and kabuli variety MNK 1 were preferred in both the districts of Karnataka. Farmers in Prakasam district of Andhra Pradesh also preferred kabuli chickpea cultivar KAK 2. These cultivars were preferred due to traits like profuse podding, high productivity, early maturity, resistance to Fusarium wilt, and market–preferred seed traits (eg, medium seed size in desi type and large seed size in kabuli type).

During phase II (2011–12 and 2012–13), FPVS trials were conducted in new target regions of India (Bihar and Odisha states) and Bangladesh (Barind and Sylhet regions). Nineteen FPVS trials on six improved varieties were conducted in Bangladesh while 647 farmers participated in the selection process (608 men + 39 women), the most preferred cultivars identified were JG 14, BARI Chola 9 and BARI Chola 3. In India, 22 FPVS trials on six improved varieties were conducted in each of the new states (Bihar and Odisha). Hence, 1218 farmers (753 men + 465 women) ranked the varieties in Bihar and preferred one desi (JG 14) and two kabuli (KAK 2 and Subhra) varieties. Similarly in Odisha, 462 (386 men + 76 women) farmers participated in ranking of different chickpea varieties and the most preferred varieties identified were JG 14, Vihar and JAKI 9218. During Phase II, 17 demonstrations of BARI Chola 5 and BARI Chola 9 varieties were conducted in Bangladesh.

Release of cultivars

The results of FPVS trials strengthened the release proposals of varieties. A desi chickpea variety BGD 103 was released and notified for cultivation in Karnataka state of India in 2009. This was a high yielding, large–seeded variety with early maturity and resistance to Fusarium wilt. A kabuli chickpea variety MNK 1 was later released by the Central Variety Release Committee for South Zone of India. This variety had extra-large (52 g/100–seed) seed. One desi variety, Nandyala senaga 1 (NBeG 3), released in 2012 from the Regional Agricultural Research Station, Nandyal, Andhra Pradesh, India, was an early maturing, drought and heat tolerant, Fusarium wilt resistant and high yielding variety.

Seed systems

Seed systems and enhancing adoption of improved cultivars

The seed systems objective (Objective 8) was instrumental in catalyzing the scaling up of foundation and certified seeds (CS), seed delivery testing models, and raising farmer awareness about the improved cultivars. The economics of legumes seed production was not attractive enough for private seed sector, due to their large seed size resulting in high volume and consequently high costs incurred in transportation and storage. Thus, seed production was largely dependent on public seed sector and informal seed systems (seed production by individual farmers and farmers' groups/societies).

Breeder seed and other classes of seed produced by research partners

The project partners in the target locations of India and Bangladesh made excellent progress in chickpea seed production and distribution. Although the research partners were mainly engaged in production of breeder seed (BS) in phase I, they produced limited quantities of CS and TLS. They together produced 2,093 tons of seed, which included 1,207 tons BS, 205 tons CS and 681 tons TLS. The seed was produced both at the research stations and at the farmers' fields under direct supervision of scientists. The share of JG 11 was 84% in BS and 71% in CS and TLS. In phase II (2011 & 12), research partners in India (including new locations) and Bangladesh produced 7,560 tons and 6.1 tons quality seeds, respectively.

Foundation (FS) and certified seed (CS) produced by public seed corporations

A strong partnership between the research institutes and public seed corporations was established, where the research partners produced BS and the public seed corporations produced FS and CS. In phase I, the four seed corporations (NSC, SFCI, APSSDC and KSSC) together produced 74,531 tons of seed that included 3,924 tons FS and 70,607 tons CS. The JG 11 was the most popular variety with 85% share in CS. In phase II (2011 and 2012), the public seed sector partners in India (including new locations) and Bangladesh have produced 76,215 tons and 181 tons of quality seeds, respectively.

Foundation and certified seeds produced by private seed companies

During phase II, with the policy support from the state government of Karnataka, India, around 48 small private seed companies came forward to undertake the seed production of popular chickpea cultivars grown by the local farmers. These companies produced 12,752 tons FS and 91,707 tons CS during 2013.

Seed samples distributed to farmers

Seed sample packs of different sizes (2–20 kg) of farmer-preferred varieties were distributed to the farmers for enhancing their awareness about the improved varieties and ensuring the availability of initial quantity of high quality seed for further multiplication. In phase I4,979 seed samples were distributed in four target districts. The total quantity of seed distributed was 47.5 tons. In phase II (2011 and 2012), 76.2 tons of small chickpea seed samples (4–25 kg each) were distributed to 12,016 farmers in India and 90 farmers in Bangladesh.

Adoption and impacts

Key achievements and lessons learnt from Baseline survey and early adoption studies

Project progress during phase-I (2007-2010)

Under TL II, ICRISAT and its research partners tested promising chickpea varieties on farmers' fields at selected villages of Andhra Pradesh (AP) and Karnataka (KA) states during 2008–2009 through FPVS trials. Activities related to seed production and seed distribution of farmer–preferred varieties caused quick dissemination and improved the incomes of farmers within a short time period.

In Andhra Pradesh, which is a new area for chickpea, there has been a quick churning of varieties and cropping systems to hit on the optimum blend of soils, agronomy and varieties. Chickpea has taken deep roots as an alternative to tobacco, which is being discouraged by the governments and grown by farmers who grew other post-rainy season crops like sunflower, coriander etc. No varieties were entrenched as ruling varieties. The Regional Agricultural Research Stations (RARS), Lam and Nandyal of ANGRAU collaborated with ICRISAT and released few varieties like Sweta and Kranti in the early 1990s. Even Annigeri was tried as one of the alternatives in late 1990s. Farmers were quick in trying new varieties like KAK 2 and JG 11 which were released in 1999 by remaining in touch with the ICRISAT research stations and Krishi Vigyan Kendra's. The research stations were also in regular contact with the farmers in the selected villages to test their varieties and technologies. In case of Karnataka, chickpea is a traditional post-rainy crop but dominated by a single variety called Annigeri (A–1).

When TL II phase-I project was launched in 2007–08, some of these progressive villages were picked up as intervention and control villages. Due to this reason, farmers were already using the improved varieties in the baseline survey year of 2006–07. The same varieties were tried in the FPVS trials along with some other new varieties. JG 11 was preferred by the farmers in the FPVS trails conducted in both Kurnool and Prakasam districts of Andhra Pradesh. It showed better yields than the other desi and Kabuli varieties tested in the mother trials conducted in 2007–08 and 2008–09. The research system recommended the multiplication and supply of JG 11. Moreover, the public seed production units like the Andhra Pradesh State Seed Development Corporation (APSSDC), National Seed Corporation (NSC) and State Farms Corporation of India (SFCI) organized the seed production of JG 11 and put it in the seed supply chain. Farmers from both adopted and control villages of Kurnool district adopted it largely by 2009–2010, the years of early adoption survey. In the adopted and control villages of Prakasam district, the farmers used more of Kabuli varieties because of substantial difference in the market price over that of desi varieties. The marginal yield advantage in favour of desi varieties like JG 11 was swamped by the price difference of ₹500 ($7.57) to ₹600 ($9.09) per 100 kg in favour of the Kabuli varieties. KAK 2 remained as the most preferred variety in the adopted and control villages. The significant fact is that the farmers in the sample villages of both Kurnool and Prakasam district have completely adopted the improved varieties and other technologies. The impact of this technology adoption was seen in terms of improved yields and higher net returns (see Table 62 and 63).

Annigeri was a long entrenched variety in Karnataka region for nearly four decades. It evolved in Karnataka, earned quick popularity and remained as the most preferred variety of farmers even in 2006–07, when baseline survey was conducted. However, the FPVs trials conducted in 2007–08 in Dharwad and Gulbarga districts asserted the supremacy of new varieties like JG 11, BGD 103, JAKI 9218 among the desi varieties. KAK 2 and MNK 1 proved their superiority among the Kabuli varieties in Dharwad and Gulbarga districts, respectively. Farmers also selected JG 11 and BGD 103 as the top two varieties preferred for their agronomic and market characteristics. In TL II project, the researchers also supplied small quantities of the chickpea seeds of farmer-preferred varieties to the sample farmers in

Table 62. Performance of chickpea in the sample villages of Prakasam district of Andhra Pradesh.

	Varietal composition (%)		Yield (kg ha^{-1})	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	24.48	2.62	1,072	1,420
ICCV 2	9.87	0	1,200	-
KAK 2	26.37	78.5	1,317	1,912
JG 11*	39.28	18.88	1,241	1,877
JAKI 9218*	0	0	-	-
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-10

Table 63. Performance of chickpea in the sample villages of Kurnool district of Andhra Pradesh.

	Varietal composition (%)		Yield (kg ha^{-1})	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	45.35	10.13	1,015	1,235
ICCV 2	0	0	-	-
KAK 2	1.43	0	1,112	-
JG 11*	53.22	89.45	1,356	1,869
JAKI 9218*	0	0.42	-	1,766
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-10

adopted and control villages of Dharwad and Gulbarga districts. However, there was no large-scale effort to organize the seed production and distribution of preferred varieties by the State Seed Corporation in Karnataka. As a result, these varieties did not enter the seed supply chain in a big way (see Table 64 and 65).

Table 64. Performance of chickpea in the sample villages of Dharwad district of Karnataka.

	Varietal composition (%)		Yield (kg per ha)	
Varieties	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	91.5	41	1,023.8	1,030
Bhima	2.4	2	686.2	1,113
Kabuli (KAK 2)	4.9	2	992.9	1,019
Local or others	1.2	2	1,009.4	-
JG 11*	0	23	-	1,314
BGD 103*	0	18	-	1,374
JAKI 9218*	0	12	-	1,250
MNK 1*	0	0	-	889
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-2010

Table 65. Performance of chickpea in the sample villages of Gulbarga district of Karnataka.

Varieties	Varietal composition (%)		Yield (kg per ha)	
	BL–2007	EA–2009	BL–2007	EA–2009
Annigeri	94.2	42	1,148.4	1,097
Bhima	0	0	-	-
Kabuli (KAK 2)	1.6	5	1,007.8	1,175
Local or others	4.2	3	955.1	748
JG 11*	0	22	-	1,398
BGD 103*	0	18	-	1,405
JAKI 9218*	0	0	-	1,333
MNK 1*	0	10	-	1,227
Overall	100	100	-	-

* introduced through the TL II project; BL: Baseline in 2007; EA: Early Adoption survey in 2009-2010

Project progress during phase II (from 2011 to date)

During the phase II of the TL II Project, two new locations (Bihar in India and Barind region in Bangladesh) were identified for targeting and introduction of new technologies. The baseline surveys in Bihar were completed in Bhagalpur and Banka districts with reference to 2010–11. Subsequently, FPVS trials were carried out during 2012–13. The mother trials conducted in different locations have concluded that JG 14, Shubhra and KAK 2 are the most preferred cultivars in Bihar. Deshla Plain and Deshla Roon were the preferred dominant local cultivars noticed during the baseline survey. The baseline report is still being finalized. Similarly, the chickpea baseline surveys were also implemented in Rajshahi and Chapai Nawabganj districts of Bangladesh in 2010–11. BARI Chola 5 and BARI Chola 9 are the most common cultivars (occupied nearly 85%) observed in the baseline sample households. Among the different BARI Chola varieties, BARI Chola 9 gave the highest productivity in the study locations. Mustard is the most competing crop with chickpea during the post-rainy season. The early adoption surveys are planned during the end of the third year of the project.

Two massive real-time tracking surveys covering 500 households each were initiated in the phase I locations ie, in Andhra Pradesh and Karnataka states respectively for a better understanding about the adoption of TL II project introduced improved cultivars in the targeted sites as well as their further diffusion across the seed sample beneficiaries from the project. Primary data collection, data entry and data validation have been completed under these surveys and data analysis and report writing are in progress. Based on the preliminary field insights, the adoption of chickpea improved cultivars in Prakasam and Kurnool districts of Andhra Pradesh has reached its peak (nearly 99%). In case of Karnataka, remarkable diffusion of JG 11 (nearly 60–70%) was observed in both Dharward and Gulbarga districts. The chickpea farmers were significantly benefited through the enhanced yields, improved soil fertility, increased household nutrition and fodder availability.

Capacity building

Knowledge empowerment of farmers, extension personnel and seed traders

Training farmers in chickpea crop and seed production technologies

The farmers' training in improved chickpea production technology, seed production and storage was given high priority. Over 150 training programs were organized by the NARS partners in the phase I with the participation of 12,000 (10,842 men + 1,158 women) farmers. In phase II (2011 and 2012), 75 training programs were conducted with the participation of 3,381 farmers from India (2,973 men + 408 women) and 410 farmers from Bangladesh (355 men + 55 women). These training programs covered various topics like FPVS trials, improved chickpea varieties, improved chickpea production technologies, integrated pest management; seed production, processing and storage; and post-harvest value addition.

Field days and farmers fairs

In phase I, 58 field days or farmers' fairs (also called Kisan Mela or Krishi Mela) were organized with the participation of about 26,987 farmers (24,290 men + 2,697 women). These events exposed farmers to improved cultivars and production technologies and gave them opportunities of interacting with researchers, extension personnel and developmental agencies. In phase II (2011 and 2012), 52 field days (41 in India and 11 in Bangladesh) were organized in which 5,255 farmers (4,282 men + 973 women) participated totally – in India, and in Bangladesh, 796 (726 men + 70 women).

Awareness activities through electronic and print media

Efforts were made to reach a large number of farmers through the electronic and print media to disseminate information on improved cultivars and chickpea crop production technologies. During phase I, the project partners organized 55 activities through the crop growth period to enhance farmers' awareness on integrated chickpea production practices. Similarly in phase II (2011 and 2012), 34 awareness activities were organized in India which was followed by two activities in Bangladesh. A chickpea seed production manual was published in English, Telugu (for Andhra Pradesh) and Kannada (for Karnataka) languages. The English version is available online (http://tropicallegumes.icrisat.org/wp-content/uploads/2016/02/Chickpea-Seed-Production-_Manual_full.pdf).

Training of extension personnel

Training program on improved chickpea production technology was provided to the extension personnel from research organizations, Department of Agriculture (Agricultural Officers, Assistant Directors of Agriculture) and NGOs. In phase I, 1,411 (1,229 men + 182 women) extension personnel in India were given training at the district research stations. In phase II, 26 more training programs were organized with the participation of a total of 1,165 (956 men + 209 women) extension personnel 1075 from India, (878 men + 197 women) and 90 from Bangladesh (78 men + 12 women).

Training of seed traders

In addition to public seed sector, the local seed traders play an important role in making seed available to the farmers. This is particularly important when the private seed companies have little involvement in the legume seed production. Training programs were organized for improving the knowledge and skill of local seed traders in proper seed handling. In phase I, 130 seed traders were imparted training on seed processing and safe storage. Similarly, in phase II, 160 seed entrepreneurs from Andhra Pradesh and Karnataka states of India were given training on chickpea seed production technologies during 2011-12. There were no woman participants in these training programs because men dominate the local seed trading business.

Capacity building of NARS partners

Training of scientists and research technicians

In phase I, two one-month training courses on "Chickpea Breeding and Seed Production" were organized at ICRISAT-Patancheru. The first course was organized during January- February 2008 and the second course was organized during January-February 2009. Twelve researchers (9 men + 3 women) belonging to the NARS of Ethiopia, Tanzania and Kenya participated in these training courses. Various topics like conventional and biotechnological (genomic and transgenic) approaches of chickpea improvement and improved practices for chickpea cultivation and seed production were included. The participants also had an opportunity to visit other organizations in Hyderabad working on seed-related research, seed production and seed quality testing. In phase II, one two-weeks training program was organized on "Pre-breeding and crop improvement of grain legumes" in which four researchers from ESA (2 each from Tanzania and Kenya) and one researcher from Bangladesh participated. In 2012, one NARS scientist from Bihar Agricultural University received one-week training at ICRISAT, Patancheru on improved chickpea production technologies. Three scientists associated with TL II projects in India participated in multi-year training course on integrated breeding organized by GCP.

Development of infrastructure facilities

The research stations have responsibility of producing nucleus seed and breeder seed of the varieties developed by their institutes. Modest support was provided to strengthen the infrastructure facilities for seed production, processing and storage at the participating research stations. The following facilities were developed in phase I:

- RARS-Nandyal: Renovation of existing seed storage structures, motorbike, electronic weighing balance, digital seed counter, sump motor and multi-crop thresher.
- ARS-Darsi: Seed processing plant (capacity: 2 tons/hr), seed storage stands for the seed store and motorbike
- UAS-Dharwad: Mobile seed processing plant, seed storage bins, seed cabinets and motorbike
- ARS-Gulbarga: Sprayers, seed storage bins, motorbike, digital camera and computer.

Degree students

Seven students (5 men + 2 women), which included four PhD students (all men) and three MSc students (1 man + 2 women) were accommodated for their research work on chickpea at ICRISAT–Patancheru. Two PhD students (Tosh Garg and BS Patil from India) and one MSc student (Tadesse Safera from Ethiopia) completed their research work and were awarded degrees. Two PhD students (Pranab Paul and BP Mallikarjuna from India) are still conducting their experiments and two MSc students (Nancy Wathimu Njogu from Kenya and Prity Sundram from India) are writing their theses. Research work of four of these students has some components of the application of molecular markers (linked to TL I).

Lessons learned

The key lessons learned are as follows:

- Farmers' awareness about improved varieties and availability of the seeds of improved varieties are key factors in dissemination of improved chickpea cultivars.
- FPVS trials are very effective in enhancing the awareness of farmers about improved varieties and in dissemination of new varieties.

- In addition to yield, the maturity, resistance to diseases and seed traits preferred by market (seed size, color and shape) were given high weightage by the farmers in varietal selection.
- The farmers' preference for growing kabuli chickpea varieties largely depended on the price premium received over desi type.
- Lack of proper cleaning, grading and storage facilities hampers the seed production by individual farmers.
- The farmers were very keen to adopt the seed production of improved varieties, provided proper arrangement was made for seed procurement through national/state seed corporations or other agencies.
- Huge opportunities exist for the expansion of chickpea area in rice-fallows of Bangladesh, Bihar and Odisha.
- Dry root rot has emerged as a major disease of chickpea in southern India; however, tolerant varieties are not available.
- Varieties tolerant to herbicides and suitable for mechanical harvesting are needed in southern India.
- to be maintained among all the stakeholders for sustained pigeonpea productivity and trade.

Enhancing the productivity and production of pigeonpea in Eastern and Southern Africa

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Summary

In Eastern and Southern Africa (ESA), Tanzanian, Malawian and Uganda NARES implemented the pigeonpea research and development activities in close partnership with ICRISAT-Nairobi, farmers, NGOs, CBOs and all other major stakeholders. The project was implemented in Babati (Manyara Region), Karatu (Arusha Region) and Kilosa (Morogoro Region) districts of Tanzania. However, through linkages among other on-going projects, the proven technologies were moved to five spillover districts. In Malawi, on-farm research and promotion activities were carried out in 14 districts spanning from Southern (Balaka, Blantyre, Machinga, Mwanza, Zomba), Central (Kasungu, Mchinji, Ntcheu, Ntchisi, Salima), and Northern (Chitipa, Karonga, Mzimba, Rumphi) regions. In Uganda, the project was implemented in Lira, Albetong, Pader and Kitgum districts of northern region.

A major success was on the fast track release of 14 varieties in ESA countries namely Malawi–3, Kenya–3, Tanzania–4 and Mozambique–4. The new releases in Malawi was a major landmark, as no medium duration pigeonpea varieties were released in the past. With this, the number of pigeonpea varieties released in Malawi rose to seven (2 short, 3 medium and 2 long duration). In Tanzania, two medium (ICEAP 00554, and ICEAP 00557) and two long duration varieties (ICEAP 00053 and ICEAP 00932) were released in 2015. Four varieties namely ICEAPs 00850, 00557, 00554 and 00540 are being tested in National Performance Trials in Uganda.

Around 436 FPVS trials were conducted in Tanzania, Malawi and Uganda that included 28 pre–released and released varieties along with a farmer's variety as a check. In addition, 981 demonstrations were conducted involving best–bet farmer preferred varieties along with good agronomic package for quicker dissemination and adoption.

About 9498 farmers took part in the FPVS trials and demonstrations from Tanzania, Malawi and Uganda. During the FPVS, the farmers came up with a number of preferred traits, which facilitated in short-listing of varieties for fast track varietal release.

During the past seven years, 41.08 tons of breeder, 231.21 tons of basic, 2074.5 tons of certified and 685.5 tons of quality declared seeds of 16 farmer-preferred varieties was produced by various stakeholders.

Training programs on pigeonpea production, grain and seed storage, and utilization technologies and value chain were organized to improve the knowledge base of 21,964 farmers and 792 extension personnel. Fifteen articles highlighting the field days, training programs, visits of the ICRISAT scientists and exposure visit of farmers to ICRISAT and targeted villages were published in the local and English newspapers. A total 69 local awareness events on various topics have been conducted and published as well.

As many as 12,300 flyers and manuals (7000–Tanzania, 5300–Malawi) describing pigeonpea technologies in Chichewa and Swahili were distributed to farmers and all other stakeholders in the project sites. A documentary video on 'The pigeonpea revolution in Malawi: New opportunities along the pigeonpea value chain' was produced both in English and Chichewa, and broadcasted through Radio and MBC TV.

In Tanzania, a number of training of trainers (TOT) was conducted to improve the skills of master trainers on quality seed production, business skills and value chains and legumes marketing.

Five researchers from ESA participated in the training course on 'Pigeonpea improvement, including hybrids technology'. Five researchers from TL II NARS participated in one-week training program on 'Experimental designs and data analysis'. A training program on 'Hybrid pigeonpea technology, seed production and integrated crop management' was conducted with 18 participants (15 men + 3 women) from ESA. One PhD and one MSc student completed their research on pigeonpea. Two more MSc students are currently pursuing their research work.

Background

In ESA, pigeonpea is widely grown in Tanzania, Malawi, Kenya, Uganda and Mozambique, and to a little extent in Burundi, under maize–mixed (66% area) and root–crop–sorghum/millet mixed (29%). Area, production and productivity during the last decade increased by 68.3%, 98.8%, 18.2%, respectively (Table 66).

In Tanzania and Malawi, during the last 10 years, area (109%–Tanzania, 54%–Malawi), production (132.8%–Tanzania, 163.3%–Malawi) and productivity (11.4%–Tanzania, 71.1%–Malawi) increased with the release of high yielding, Fusarium wilt-resistant varieties suitable for cropping systems; improved seed systems; enhanced adoption, market stimulus and engagement of several stakeholders. In Uganda, there was an increase in area (23%) while production and productivity levels were still fluctuating.

In Babati district of Tanzania, which is famous for quality pigeonpea production, the adoption of improved pigeonpea varieties has reached 80%, and pigeonpea alone contributes to more than 50% of the cash income for the smallholder farmers. Pigeonpea production area expanded beyond the traditional Babati district to reach the neighboring districts of Karatu, Kondoa and Mbulu. The production has now expanded to the new districts of Arumeru, Hai, Moshi, Shia and Rombo in northern Tanzania.

The release of a new set of medium duration varieties in Malawi (ICEAP 00557 ICEAP 01514/15 and ICEAP 01485/3) that are suitable to grow in Southern, Central and Northern regions of this country have opened up avenues for area expansion.

Large traders are involved in buying grain for export to India and Europe. In 2011, about 80,000 tons and 50,000 tons of grains were exported from Tanzania and Malawi, respectively. Several dehulling factories are now operating in these two countries for value addition before export. The Government of Malawi considered pigeonpea as an important strategic crop and included its seeds in the Farm Inputs Subsidy Program starting from 2010. A scheme to provide short–term capital for production and export of pigeonpea has been mooted by the Reserve bank of Malawi.

Locations and Partners

The phase I project activities were implemented only in Tanzania and Malawi. Uganda was included in during phase II. A detailed account of it is presented in Table 67.

Table 66. Area, production and productivity trends.

Year	Area ('000 ha)	Production (000 tons)	Productivity (kg ha^{-1})
ESA[1]			
2001–2003	590.2	395.5	670
2004–2006	733.7	457.1	623
2007–2009	743.0	536.4	723
2010	856.1	648.3	757
2011	961.3	770.2	801
2012	988.6	737.8	746
2013	993.0	786.1	792
Tanzania			
2001–2003	138.7	90.2	650
2004–2006	155.6	111.1	713
2007–2009	130.1	121.7	943
2010	187.0	166.1	883
2011	288.2	272.6	946
2012	257.3	206.1	801
2013	287.2	247.4	861
Malawi			
2001–2003	141.0	109.4	776
2004–2006	148.2	96.0	651
2007–2009	168.3	164.5	976
2010	190.4	193.0	1014
2011	196.6	220.0	1119
2012	203.4	237.2	1166
2013	217.1	288.0	1327
Uganda			
2001–2003	82.0	82.0	1000
2004–2006	85.0	85.0	1000
2007–2009	88.3	89.3	1011
2010	98.2	92.5	942
2011	101.5	93.6	922
2012	101.0	84.2	834
2013	105.0	93.9	895

[1] = data source FAO and supplementary data from TIA. Mozambique

Table 67. Target locations and partners in ESA target countries.

Country	NARS Partner	Zone	Region	District
Tanzania	SARI- Arusha;	Northern Zone	Manyara Arusha	Babati Karatu
	IARI- Kilosa	Eastern Zone	Morogoro	Kilosa
Malawi	DARS-Lilongwe	- - -	Southern Central Northern	Mwanza Balaka, Blantyre, Zomba, Machinga Mchinji, Kasungu, Ntchisi, Salima, Ntcheu Mzimba, Karonga, Rumphi, Chitipa
Uganda	Ngetta ZARDI-Lira		Northern	Lira, Pader, Albetong, kitgum

Key achievements

Variety development

Varietal development and evaluation in the three target counties centered on target ecologies and, farmer- and market-preferred grain traits. Taking into account the existing biotic and abiotic constraints that affect productivity in the smallholder farming systems in the region, three preliminary test sites Kabete (high altitude cool environment), Kampi Ya Mawe (purely rain fed) and Kiboko (hot spot for Fusarium wilt) were considered as the integral parts of pigeonpea breeding program at ICRISAT in Kenya. ICRISAT-Nairobi with a large collection of regional germplasm and on-going breeding program on the three maturity groups (short, medium and long) evaluated 325 new genotypes (short–72, medium–71, long–182) at the three test locations mentioned above (Table 68–70). Simultaneously, best lines in each maturity group based on agro-ecologies in target countries were supplied and evaluated. In Tanzania, Selian and Ilonga, representing Northern Zone (more emphasis on long duration) and Eastern Zone (more emphasis on medium duration) respectively, evaluated 87 medium and 85 long duration genotypes. The Ilonga center also evaluated 36 short duration genotypes. Similarly, in Malawi, 80 medium and 69 long duration genotypes were evaluated at Central (more focus on medium) and southern regions. In Uganda, the focus was only laid on medium duration varieties and 73 medium duration genotypes were tested in Ngetta and Kitgum locations and the best bet varieties, identified (Table 71).

Table 68. Superior long duration genotypes selected in Kenya.

Genotype	Yield (kg ha^{-1})	100 seed mass (g)
ICEAP 01479	2112.6	17.2
ICEAP 01490	2041.4	16.8
ICEAP 01187	1983.6	16.9
ICEAP 01511	1962.8	17.8
ICEAP 01534	1917.4	18.0
ICEAP 01409	1836.9	16.9
ICEAP 01498	1799.7	17.0
ICEAP 01423	1730.1	16.9
ICEAP 00040	1203.8	21.5

Table 69. Superior medium duration pigeonpea varieties selected at Kiboko, Kenya.

Variety	Days to 50% flower	Days to 75% mature	100 seed mass (g)	Grain yield (kg ha^{-1})
ICEAP 00668	88	140	12.4	2106
ICEAP 01179	91	143	12.1	1863
ICEAP 01159	91	141	12.5	1825
ICEAP 01181	92	141	12.6	1809
ICEAP 00671/2	92	144	12.7	1803
ICEAP 01169	91	143	12.8	1760
ICEAP 01150/1	91	143	12.7	1715
ICEAP 00068 (check)	*91*	*144*	*12.6*	*1629*

Table 70. Superior medium duration varieties based multi-locational evaluation in Kenya and Tanzania.

	Total yield (kg ha^{-1})				100 seed mass (g)			
Variety	Ilonga	Kiboko	Kampi Ya Mawe	Mean	Ilonga	Kiboko	Kampi Ya Mawe	Mean
ICEAP 01170	2,389	1,063	1,236	1,563	16	12.6	14.0	14.2
ICEAP 01179	2,111	1,257	901	1,423	16	12.2	13.3	13.9
ICEAP 01147	2,322	990	939	1,417	16	12.7	13.3	14.0
ICEAP 00673	2,000	1,170	1,000	1,390	16	12.7	14.0	14.2
ICEAP 01181	2,333	927	861	1,374	17	13.3	14.0	14.7
ICEAP 01162	2,217	874	987	1,359	16	13.0	14.0	14.2
ICEAP 01161	2,022	991	1,029	1,347	16	12.6	13.3	13.9
ICEAP 01145	2,156	857	993	1,335	16	12.5	14.0	14.1
ICEAP 00677	2,400	748	823	1,324	15	12.2	14.0	13.9
ICEAP 01169	2,044	1,099	827	1,323	16	12.9	13.3	14.1
ICEAP 01175	2,078	982	908	1,323	14	15.0	12.0	13.8
ICEAP 00554	1,922	913	904	1,246	16	12.8	14.0	14.3

Table 71. Superior medium duration pigeonpea varieties selected at Lira, Uganda.

Variety	Days to 50% flower	Days to 75% maturity	Yield (kg ha^{-1})
ICEAP 01160	102	144	1,162
ICEAP 01179	105	145	1,081
ICEAP 01150/2	102	144	1,037

Through multi–locational and multi–year evaluations, high yielding genotypes possessing drought tolerance in medium (ICEAPs 01479, 01506, 01523, 01527) and long duration types (ICEAPs 01170, 01179, 01147, 01143/8, 01487/16, 01499/7, 01532, 01485/9) were identified. Fusarium wilt is one of the major diseases, constraining pigeonpea productivity in ESA.

The virulence pattern existing in ESA is entirely different from that of Asia. Further, it is believed that landraces in ESA co–evolved with virulent wilt races of ESA. Hence, the landraces collected from Tanzania, Mozambique, Kenya and Malawi were evaluated in wilt sick plots at Kiboko over the years. Wilt progression data indicated that Acc 128, 125, 130, 72, 74 and 135 (Tanzania), MZ 2/9 (Mozambique) and Mthwajuni (Malawi) showed less wilt incidence and high yield. Accordingly, they are more potential donors in wilt resistance breeding. All 54 elite lines screened at Kiboko, Bvumbwe and Ilonga identified eight promising wilt resistant lines namely ICEAPs 01203, 01408, 01197, 01532, 00673, 01392, 01499/7 with high yield and photoperiod insensitivity. This paved the way for dissemination of pigeonpea into non-traditional areas like central and northern regions of Malawi, lake zone of Tanzania, Kerio valley of Kenya and potential areas in southern Mozambique.

Pest incidence is a problem in most of the target areas and presently available varieties show little tolerance to insects like pod borers, pod fly and sucking bugs. Efforts are being made to incorporate purple and constricted pod traits into high yielding and adapted genetic background, thus retaining the farmer–preferred grain color (cream) as most of the purple–podded varieties have dark colored grains.

Eight CMS lines namely ICPA 2042, ICPA 2098, ICPA 2101-3, ICPA 2166, ICPA 2188, ICPA 2198, ICPA 2199-1 and ICPA 2193 were crossed with their counterpart B lines to maintain male sterility. Fifty–two testcrosses involving eight CMS lines and six elite lines of African origin namely ICEAPs 00540, 00554, 00557, 00902, 00040 and 00020 to test their ability as maintainers or fertility restorers were attempted. These 52 crosses were evaluated in 2013–14 crop season at Kiboko–Kenya. In addition to this, A, B and R lines of best hybrids in India were evaluated in ESA for their stability study.

Varietal release

In ESA countries, 14 varieties have been released during the project period as per the details below (Table 72).

Table 72. List of pigeonpea varieties released in ESA.

Country	Popular/local name	Pedigree/code	Maturity group	Release year
Malawi	Mwaiwathu Alimi	ICEAP 00557	Medium	2009
	Chitedze Pigeonpea 1	ICEAP 01514/15	Medium	2011
	Chitedze Pigeonpea 2	ICEAP 01485/3	Medium	2014
Kenya	Peacock	ICEAP 00850	Medium	2011
	Karai	ICEAP 00936	Long	2011
	Egerton Mbaazi M1	ICEAP 00902	Medium	2012
Mozambique	ICEAP 00040	ICEAP 00040	Long	2011
	ICEAP 00020	ICEAP 00020	Long	2011
	ICEAP 00554	ICEAP 00554	Medium	2011
	ICEAP 00557	ICEAP 00557	Medium	2011
Tanzania	Kiboko	ICEAP 00053	Long	2015
	Karatu 1	ICEAP 00932	Long	2015
	Ilonga 14-M1	ICEAP 00554	Medium	2015
	Ilonga 14-M2	ICEAP 00557	Medium	2015

Identification of farmer- and market-preferred varieties

A total of 436 FPVS trials including 28 pre–released/released varieties (12–Tanzania, 11–Malwi, 5–Uganda) along with a farmer's variety as a check were conducted in Tanzania (170), Malawi (138) and Uganda (128). In addition, 981 demonstrations involving best–bet farmer-preferred varieties along with good agronomic package were established (Tanzania–653, Malawi–168, Uganda–160) for quicker dissemination and adoption (Table 73).

Table 73. Pre-release or released varieties used in FPVS trials during 2008-13 crop seasons.

	Variety		
Country	Medium duration	Long duration	Check
Tanzania	ICEAPs 00554, 00557, 00850, 00068, 00911, 01514/15	ICEAPs 00040, 00053, 00576-1 00932, 00933, 00936	Local variety
Malawi	ICEAPs 01514/15, 00557, 01480/32, 01162/21, 1167/11, 00557, 01499/7, 01485/3, 01528, 01534, 01539, 00673/1	ICEAPs 00932, 00576-1	Mthwajuni
Uganda	ICEAPs 00540, 00554, 00557, 00850, Kat 60/8	-	

Table 74. Varieties preferred by farmers.

Country	Variety: Medium duration	Variety: Long duration	Farmer preferred traits
Tanzania	ICEAPs 00554, 00557, 00850	ICEAPs 00040 (Mali), 00053, 00932, 00936	High yield, early maturity, Large grains with good marketability, resistant to Fusarium wilt
Malawi	ICEAPs 01514/15, 00557, 01167/11, Mthwajuni	ICEAPs 00932, 00576-1	High yield, earliness, good taste, large seed size, tolerant to pests
Uganda	ICEAPs 00850, 00557, 00540, 00554	-	Early maturity, high yield, fast cooking, large seeds

Table 75. On-farm yield (kg ha^{-1}) of ICEAP 01514/15 across EPA locations.

Location	ICEAP 01514/15	Mthwajuni (local)	% increase over check
		Northern Region	
Mzimba	1,303	1,277	2.0
Karonga	1,639	904	81.3
Bolero	1,347	1,173	14.8
Euthini	1,769	910	94.4
		Central Region	
Manjawira	1,520	587	158.9
Mpingu	1,387	1,360	2.0
Mikundi	1,173	1,067	9.9
Kasungu	1,644	1,244	32.2
Chiwosya	956	964	-0.8
Chipoka	1,444	1,000	44.4

Table 76. On-farm preference for pigeonpea varieties in Tanzania.

			Number of farmers indicating their preference					
			1st Preference		2nd Preference		3rd Preference	
Variety	Yield (kg ha^{-1})	Yield rank	Men	Women	Men	Women	Men	Women
ICEAP 00557	1,931	1	20	15	10	12	3	4
ICEAP 00554	1,421	2	18	10	33	18	8	5
ICEAP 00053	1,371	4	5	8	11	8	30	12
ICEAP 00932	1,197	3	15	8	5	4	17	15
ICEAP 00040	1,125	2	25	15	11	7	7	5
ICEAP 00933	1,046	5	0	0	0	0	0	0
Local	330	6	0	0	0	0	0	0

Around 9,500 farmers took part in the FPVS trials and demonstrations from Tanzania (3,409), Malawi (2,881) and Uganda (3,208). During the FPVS, farmers came up with a number of preferred traits, which facilitated in short–listing varieties for fast track varietal release.

During FPVS, farmers–prefered early maturity, high yield potential, large cream colored seeds, resistance to Fusarium wilt, terminal drought tolerance, vegetable types with green pods for local niche markets. It was also noticed that while the male members were interested in market traits as a grain, the female members showed interest in consumption and green pods. The list of farmer–preferred varieties (Table 74–76) paved the way for fast tracking the release and notification (ICEAP 00557, ICEAP 01514/15 and ICEAP 01485/3 in Malawi, ICEAP 00053, ICEAP 00932, ICEAP 00554 and ICEAP 00557). Farmers were only aware of the long and short duration varieties released so far. However, after learning about medium duration varieties through the FPVS, farmers have started focusing on growing pigeonpea in areas such as southern (due to unreliable *chiperoni* rains), Central (early maturing varieties to meet livestock grazing demand after harvest of maize) and Northern regions (due to short growing season) of Malawi. Similar preferences for medium duration varieties were also noticed in a few places of Northern Zone, Tanzania, which experiences early cessation of rains.

Seed systems

Seed production and seed road maps

During the past seven years (2007–2013), 41.08 tons of breeder, 231.21 tons of basic, 2074.5 tons of certified and 685.5 tons of quality declared seed of 16 farmer-preferred varieties were produced at research stations and farmers' fields (Tables 77–79). In Tanzania, the farmers and farmer groups were engaged in seed production. About 21 tons of quality seeds of four varieties (12.2 tons Mali, 7.6 tons

Table 77. Various classes of quality seed produced in ESA (tons).

Country	No. of varieties	Breeder	Basic	Certified	QDS	Total
Tanzania	7	18.48	69.40	401.3	685.5	1174.70
Malawi	4	16.90	135.50	1672.2	-	1824.60
Uganda	5	5.70	26.31	1.0	-	33.01
Total	16	41.08	231.21	2074.5	685.5	3032.31

Table 78. Various classes of seed produced in Tanzania.

Variety	Breeder	Basic	Certified	QDS	Total	Produced directly by TL II	Produced through partnerships
Mali	6.1	53.9	318.5	518.0	896.5	354	542.5
Tumia	3.0	6.6	28.5	20.0	58.1	28	30.1
Komboa	4.5	4.5	18.3	0.0	27.3	25	2.3
ICEAP 00053	2.0	2.6	21.5	39.5	65.6	34.7	30.9
ICEAP 00554	1.0	0.9	7.5	33.0	42.4	28.4	14.0
ICEAP 00557	0.7	0.9	6.5	51.0	59.1	19.8	39.3
ICEAP 00932	1.2	0.0	0.5	24.0	25.7	14.3	11.4
Total	18.5	69.4	401.3	685.5	1174.7	504.2	670.5

Table 79. Various classes of seed produced in Malawi.

Variety	Breeder	Basic	Certified	Total	Produced directly by TL II	Produced through partnerships
Sauma	4.3	60.4	462.5	527.2	266.2	261
Kachangu	5.5	35.8	478.6	519.9	164.2	355.7
Mwaiwathu Alimi	4.6	28.9	617.2	650.7	241.7	409
Chitedze Pigeonpea 1	2.5	10.4	113.9	126.8	98.5	28.3
Total	16.9	135.5	1672.2	1824.6	770.6	1054

Table 80. Amounts (tons) of foundation Seed of four varieties distributed to farmers in Tanzania.

	Variety					
Year	Mali	ICEAP 00053	ICEAP 00932	ICEAP 00554	Total	Area covered (ha)
2008	5.0	3.6	-	-	8.6	995
2009	3.0	2.0	-	-	5.0	667
2010	4.2	2.0	0.4	0.8	7.4	991
Total	12.2	7.6	0.4	0.8	21.0	2653

Table 81. Seed distributed to farmers' groups for seed production in Tanzania (tons).

	Variety						
Year	Mali	ICEAP 00053	ICEAP 00932	ICEAP 00554	Total seed distributed	Seed Produced	No. farmer groups participated
2008	0.7	0.3	-	-	1.0	3.0	7
2009	0.38	0.28	0.02	0.02	0.7	5.0	8
Total	1.08	0.58	0.02	0.02	1.7	11.0	15

ICEAP 00053, 0.4 tons ICEAP 00932 and 0.8 tons ICEAP 00554) were distributed to the farmers during 2007–09. This covered 2,653 ha in farmers' fields in seed production and subsequent seed sharing among the farming community in the project areas. Similarly, 1.7 tons of quality seeds of the four varieties was distributed to 15 farmers' it groups and it facilitated the production of 11 tons of quality seeds (Tables 80–81). Organizations, Research, Community and Organizational Development Associates (RECODA) in Endabash Ward in Karatu District; World Vision through Gorowa Area Development Program(ADP) in Duru and Riroda wards in Babati District; and Catholic Relief Services (CRS) through Mbulu Catholic Diocese supported the smallholder farmers in North and Central Karatu by purchasing the pigeonpea seed from farmers and other sources and distributing them to the smallholder farmers.

Table 82. Effective seed systems identified for pigeonpea production in ESA.

Seed class	Malawi	Tanzania	Uganda
Breeder Seed	Research centres	Research centres	Research centres
Foundation Seed	Revolving seed scheme, private sector, NGOs	Farmer-Field-Schools, private sector, NGOs	Private sector, NGOs, ISSD
Certified Seed	Specialized smallholder farmers	Farm organizations	Farm organizations
Quality Declared Seed	Farmers, farm organizations	Farmers, farm organizations	Farmers, farm organizations

NGOs: Non–Governmental Organizations; ISSD: Integrated Seed Sector Development.

Seed production and delivery strategies

Various seed production and delivery strategies have been tested for various classes of seeds. The most effective ones are summarized in Table 82.

Two major NGOs have been identified in Tanzania (Dutch Connection and KIMAS) and three in Malawi (PLAN Malawi, CARE Malawi and MVP), which are actively involved in legume seed production and distribution. Two private seed companies in Malawi (Funwe Seeds and Seed Co) and seven in Tanzania (ASA, Zenobia, Krishna, Miombo Estate, Krishna Seed Company, Kibodya Tanseed International) ventured into commercial seed production. Three pilot marketing sites were established in Uganda in collaboration with ISSD with eight trained seed stockists and four commercial officers in target districts. Three pro–poor seed delivery systems such as seed revolving fund facility, community seed banks, and farmer field schools were tested. In all 5,325 small seed packs were distributed to farmers in Tanzania and Malawi.

Adoption and impacts

Baseline data collected during phase I in Malawi and Tanzania provided very valuable information on several aspects of pigeonpea value-chain on production, seed systems and marketing.

Pigeonpea producing areas and production systems: The bulk of pigeonpea production was concentrated in the southern region of Malawi. The Blantyre and Machinga Agricultural Development Divisions (ADDs) accounted for about 90% of the total pigeonpea area. Pigeonpea was widely grown as an intercrop with maize in southern Malawi, but it was mainly grown as a boundary marker in northern Malawi. In Tanzania, the major pigeonpea growing areas were Lindi and Mtwara regions in the southern zone; Kilimanjaro, Arusha, and Manyara regions in the northern zone; and Shinyanga region in the Lake zone. It is also grown along the coast, Dar es Salaam, Tanga and in Morogoro regions in the Eastern Zone, where it was mainly used as a vegetable.

Cropping patterns: In Malawi, over 90% of the households planted maize during 2006–2007. Groundnut was the second most frequently cultivated crop (55%) while pigeonpea was third and cultivated by 40% of the households in the sample. Taking into account the share of crop area, it was found that 54% of the cultivated land is allocated to maize while groundnuts and pigeonpea were allocated 17% and 15% of the total cultivated land, respectively. The average area cultivated for pigeonpea was 0.3 ha. In Tanzania, pigeonpea was the third most important legume, after common bean and groundnut. Pigeonpea was grown by 88% of the farmers in the target areas and its average planted area was about 1.36 ha, mainly achieved through intercropping with maize.

Available technologies: Although improved pigeonpea varieties were released as early as 1987, their dissemination and adoption by the smallholder farmers remained low. Simtowe et al. (2009) reported that, although 40% farmers could potentially adopt the improved varieties of pigeonpea if they were exposed to them and had access to seed, only 10% of the sampled farmers grew improved pigeonpea varieties in 2007. The main constraint to the adoption of improved pigeonpea varieties was the lack of accessibility to sufficient quantity of good quality seeds. The analysis on technology awareness indicated that about 74% of the households are aware of at least one pigeonpea variety. The awareness rate for improved pigeonpea varieties (ICP 9145 [released in 1987] and ICEAP 00040) is much lower. Of the two improved varieties, ICEAP 00040 is the most widely known by 20% of the farmers while ICP 9145 is only known to 8% of the farmers. Apart from the lack of awareness on some of the legume varieties, seed nonavailability is a major constraint to adoption. The findings further indicate that most highly-preferred varieties are liked for the three key traits they exhibit: high yield, early maturity and short cooking time. Interestingly, Mthawajuni, mostly considered as a local variety, is preferred for its high yield, as well as early maturity, and shorter cooking time. Three varieties were released in Tanzania, namely Mali (ICEAP 00040), Tumia (ICEAP 00068) and Komboa (ICPL 87091) in long, medium and short duration groups, respectively.

Productivity: In Malawi, the average grain yield of pigeonpea for the period 2001-06 was about 700 kg ha^{-1}. However, this was dramatically increased during TL II project period and reached up to 1327 kg ha^{-1} during 2013. This increase was mainly due to farmers adoption of the improved varieties and recommended management practices. Similarly, farmers in Tanzania also reaped the benefits of availability of high yielding varieties and they could attain grain yield up to 1061 kg ha^{-1} in 2009. However, there is huge gap exists between potential and realized yields .The low adoption of available new varieties is mainly attributed to the underdeveloped and inadequate seed systems, shortage of quality seed and lack of timely delivery, lack of awareness and insufficient accessibility of farmers to credit facilities, among others. In Tanzania, large number of Producer marketing groups (PMGs) was formed and working through PMGs resulted in better products for sale and received between 25-40% premiums. Farmers are getting a net profit of about 250 and 950 USD per ha, without and with adoption of high yielding varieties and improved agronomic practices, respectively. High market prices for pigeonpea about 0.8-1.0 USD per kg grain partially attributed for greater income. Usually pigeonpea price is 3-4 times higher that of maize price per kg.

Utilization: Available estimates indicate that 65% of the pigeonpea produced is consumed on-farm, 25% is exported while 10% is traded on the domestic markets. However, the consumption rate of 35% reported for Tanzania attributes the low on-farm consumption rates to the high integration of producers in the market channels.

Marketing systems: The actors in Malawi's pigeonpea market include small- and large-scale producers, intermediate buyers, farmers' associations, processors and consumers. The most prevalent grain legume marketing system involves individual farmers selling small quantities to the intermediate buyers. Other prevalent marketing systems involve (i) individual farmers selling pigeonpea to the local markets, (ii) farmers organizing themselves into groups, which pool together their products, identify buyers (often a company) and sell at negotiated prices, and (iii) farmers selling their grain legumes to NGOs. There are several categories of buyers, which include intermediate buyers, processing and packaging companies, and other consumers of grain legumes.

For example, Muli Brothers Ltd, a Malawian local company, is one of the companies involved in the marketing of pigeonpea. Malawi has the largest concentration of pigeonpea processing companies. About 40% of the pigeonpea exports to India are processed while 60% is exported in the form of raw pigeonpea grain. There are more than twelve pigeonpea millers in Malawi with a total milling capacity of 20,000 tons dal per annum. The companies processing pigeonpea include Transglobe Produce Exports, Rab Processors and Bharat Trading Company. Further, Export Trading Company Ltd installed a processing plant in Blantyre in April 2009.

Threats and opportunities: Demand for pigeonpea continues to rise. However, there is an increasing pressure on the African farmers to benefit from these markets due to intense competition for export markets (mainly India) from Myanmar and other emerging producers, as well as the surging demand for other substitutes (eg, yellow pea produced mainly in Canada and France). The findings suggest the need (a) for productivity enhancement, (b) strengthening seed delivery systems to reach farmers who continue to rely on low-yielding and disease-susceptible local varieties, and (c) development of existing value chains and alternative pigeonpea export markets. Lo Monaco further reports that seasonal pigeonpea price variations in India offer a window of hope for the African countries to export pigeonpea to India when prices are high. Lo Monaco further reports that pigeonpea prices in India are lowest in March-April, and begin to rise from July. The prices are reported to be at the peak around November-December. In Malawi, pigeonpea is harvested between July and August, which coincides with a period of high prices in India. Therefore, Malawi could, take advantage of this window to improve its pigeonpea competitiveness. The same is the case with Tanzania; the harvest season of long duration varieties in northern Tanzania coincides with lean pigeonpea availability in India.

Impact assessment – Tanzania:

The impact assessment was carried out using a subsample of the TL II baseline survey sample as well as additional households within the districts Kondoa, Karatu, Babati and Arumeru. Similar questions were used in order to create a partial panel data set and the progress was tracked from 2008-2012. The Table 83 captures the number of households covered in each round.

Table 83. Households covered across the survey years.

District	2008	2010	2012	Total
Kondoa	154	150	149	453
Karatu	150	150	210	510
Babati	156	152	222	530
Arumeru	153	153	150	456
Total	613	605	731	1949

Given the differences in targeted households, the total number of households in each round, which could be used in the panel analysis, was 276. In terms of adoption, clear increases could be seen over this relatively short period. The positive attributes of the improved varieties as stated by the farmers, go way beyond pure yield increase and include soil fertility improvements. Food security is also reflected in a highly significant expansion of the area under improved varieties in the survey districts. Figure 6 shows the expansion within the four-year period covered.

With respect to the increase in yield and income, the results showed superior performance in both 2008 and 2012 cropping seasons. However, in 2010 the local varieties did outperform the modern varieties. This fact has to be investigated further and it has to be highlighted that the revenues did vary tremendously indicating that closer investigation is required to establish the reliability of these outcomes. These results are confirmed by the nationwide estimates based on the related projects. The results are only marginally lower than in the intervention areas, which highlights that the seed systems efforts pay off way beyond the narrow intervention regions and are successfully creating nationwide linkages. For the overall ICRISAT efforts in Tanzania, which include several other projects, an IRR ranging between 13.5% and 25.5%, was estimated depending on the positive or negative assumptions taken.

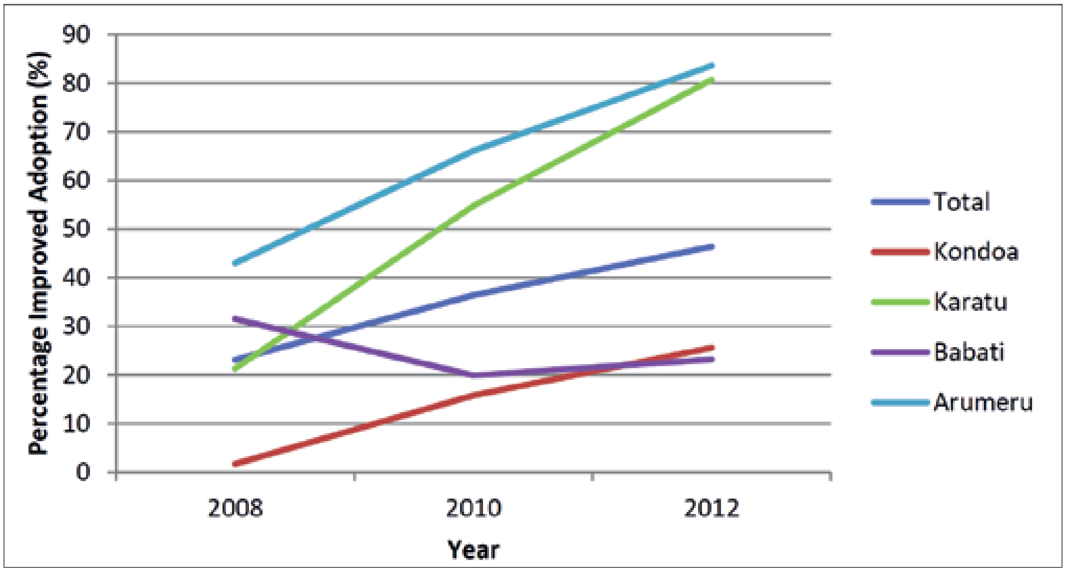


Figure 6. Adoption of modern varieties by plot.

Note: N: 2008 = 1,444; 2010 = 1,357; 2012 = 1,018
Source: Dalton et al. (2013).

Value chain analysis in Tanzania: For the Value chain assessment under EU-IFAD project, a set of interviews were conducted aiming at understanding the details of the chains present. The sample had to be kept rather small as the interactions were focused on all actors along the chain. Furthermore, the bigger picture was already established by several other reports. Therefore, 50 farmers, 6 cooperatives, 6 traders, 7 retailers and 45 consumers were included. The main findings were that the pigeonpea sector in Tanzania has grown massively in the recent years and by now constitutes the third biggest supplier in the world. However, the sector heavily depends on two dominant trading houses, which handle the bulk of the exports to India, which is by far the main market for Tanzanian pigeonpea. Besides being an important cash crop for Tanzanian farmers, it is also widely consumed and thus contributes to the local diet and food security. Additionally, the incorporation of improved varieties and management practices was reported to almost quadruple the revenues from pigeonpea production.

Capacity building

Training of farmers

In three ESA countries, 21,964 farmers (Tanzania-16302, Malawi-3812, Uganda-1850) were trained on various pigeonpea technologies including quality seed production and processing through field days and farmer or seed fairs. Such training generated greater interest about new varieties and promising integrated crop management (ICM) technologies among various farmer groups and individual farmers.

Awareness activities

Farmers' field days, bulletins, news media (both electronic/digital and print) coverage, farmers' assessments, processing and utilization were used to disseminate the technologies. Fifteen articles on the field days conducted, training programs, visits by ICRISAT scientists and exposure visit of farmers to ICRISAT and targeted villages were published in the local and English newspapers. A total 69 events (local newspaper-43, TV programs-12 and radio talks-14) of local awareness were conducted and published on various topics.

Table 84. Evaluation of pigeonpea cooked food items.

Score	Percent of responses					
	Soup	Bonko	Kande	Ng'ande	Kihembe	Bhagia
Very good	50.0	25.0	45.0	33.2	40.7	52.0
Good	38.6	41.9	45.0	46.2	41.2	35.7
Average	10.0	26.6	10.0	17.3	16.2	11.7
Bad	1.4	6.5	0.0	3.4	2.0	0.5

Information bulletin on various aspects of pigeonpea production, insect pest management, post-harvest processing and utilization in Kiswahili "*Kilimo Bora Cha Mbaazi*" were produced and distributed to the farmers and other stakeholders during their visits to the Institute, farmers' field days, farmers assessments, *nane nane* agricultural shows in Tanzania. The annual *nane nane* (meaning the eighth day of eighth month in *Swahili*) agricultural and livestock products and services show organized by the Tanzania Agricultural Society (TASO) coincides with farmers' day, a national holiday in Tanzania, on 8 August. A manual for pigeonpea production in Malawi was published in English and *Chichewa*. Manual on pigeonpea production technology in *Luo* language is under preparation in Uganda. A documentary video on 'The pigeonpea revolution in Malawi: New opportunities along the pigeonpea value chain' was prepared both in English and *chichewa*, and broadcasted through radio and MBC TV during the entire month of December 2012.

Training of extension personnel and other stakeholders

Across the 792 extension staff (Tanzania-279, Malawi-454, and Uganda-59) were trained on pigeonpea production technology including FPVS methodology, quality seed production, and safe seed storage. In Tanzania, a number of ToT trainings were conducted to improve the skills of master trainers on quality seed production (2,863), seed dehulling and storage methods (27), business skills and value chains (14) and legumes marketing (15).

Training of scientists and research technicians

Stephen Lyimo (SARI-Arusha), visited collaborating institutions and farmers in India to familiarize with pigeonpea seed production, processing and utilization, and marketing during December 2009. Similarly, Dr Geoffrey Kananji (CARS-Lilongwe) visited ICRISAT in January 2010 for imparting training on pigeonpea breeding and crop management. Five researchers from ESA participated in a two-week training course (26 November - 7 December 2012) on 'Pigeonpea improvement, including hybrids Technology' at ICRISAT-Patancheru. Five researchers from TL II NARS participated in a one-week training program (15-19 October 2012) on 'Experimental designs and data analysis' in Nairobi. Training Program on 'Hybrid pigeonpea technology, seed production and integrated crop management' was conducted from 9-12 December 2013 at Nairobi. Eighteen participants (15 men + 3 women) from NARS of Uganda, Malawi, Ethiopia, Tanzania and Kenya, ICRISAT-ESA research technicians and two representatives from private seed industry attended this training program. This was the first ever training conducted on hybrid pigeonpea technology in ESA, with an emphasis on hybrid parents' development, conversion of elite lines to male sterile lines, seed production of hybrid parental lines and hybrids in different agroecologies including seed production, integrated crop management and germplasm maintenance.

Degree students

One PhD (Maryanna Maryanga Mayomba, from Tanzania) and one MSc student (Samuel Kamau-Kenya) completed their research on pigeonpea. Two more MSc students (Moses Bayo-Uganda, Meshack Mekenge-Tanzania) are presently pursuing their research work.

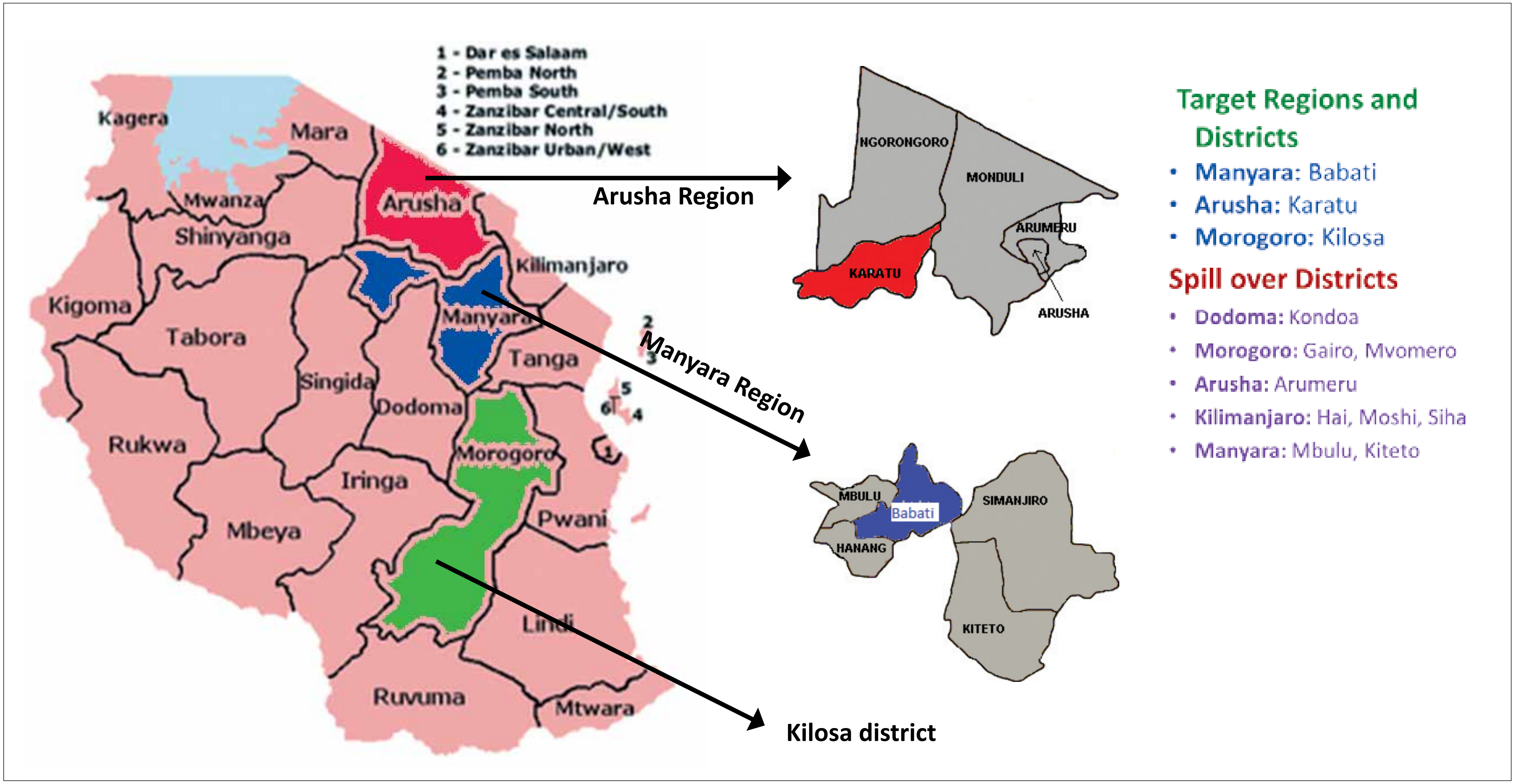
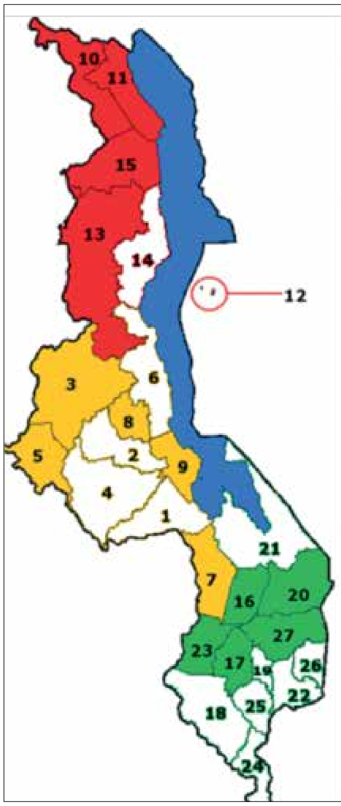


Figure 7. Target locations in Tanzania.



Region	District number in Map	District Name
Northern	10	Chitipa
	11	Karonga
	13	Mzimba
	15	Rumphi
Central	3	Kasungu
	5	Mchinji
	7	Ntcheu
	8	Ntchisi
	9	Salima
Southern	16	Balaka
	17	Blantyre
	20	Machinga
	23	Mwanza
	27	Zomba

Figure 8. Target locations in Malawi.

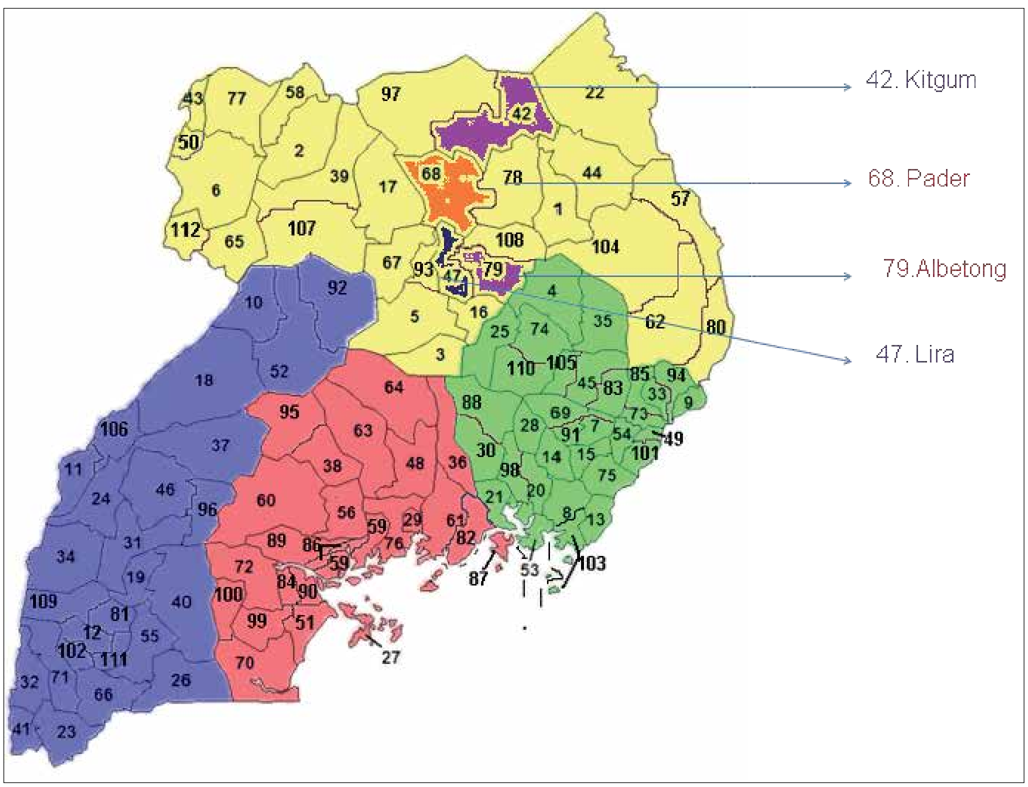


Figure 9. Target locations in Uganda.

Lessons learned

- Area and production of pigeonpea are fast increasing in ESA due to export demand, availability of promising varieties and technologies.
- Favourable policy interventions such as Presidential Initiative on Poverty and Hunger Reduction in Malawi and Kilimo Kwanza (Agriculture First) in Tanzania, etc., supported the increasing interest in pigeonpea, which further resulted in an increase in its area and production.
- Formation of farmer producer market groups (PMGs) has had positive impact on enhanced production and reliable markets with good market price.
- Development of climate resilient medium duration varieties resulted in the spread of pigeonpea into new niches like central and northern Malawi, Lake zone and Kilimanjaro region of Tanzania, Kerio valley in Kenya.
- There is increasing need for partnerships or networking within the legume value chain actors in order to disseminate the best-bet varieties and promising crop management technologies.
- The demand for pigeonpea in ESA continues to increase, both for domestic consumption and as well as for export market. The seasonal pigeonpea price variations in India offer a window of hope for the African countries to export pigeonpea to India when the prices are high at around November-December. This is also the time at which pigeonpea is harvested in Malawi, Tanzania and Uganda.
- Farmers' awareness on improved varieties and availability of improved seed varieties are the key factors in spreading improved pigeonpea cultivars and conducting FPVS, field days and seed fairs, which are very effective in creating awareness among farmers about new varieties and generate sustained seed demand.
- Business-oriented smallholder farmers show better performance in seed production, storage and dissemination than the food security-oriented farmers do. Hence, these groups of farmers should be involved in seed systems.
- Limited number of research and seed technicians available in ESA also hampers the progress of seed dissemination.
- Efficient linkages between formal and informal seed systems are critical success factors for seed production and delivery.
- Seed production should be under assured growing conditions like supplemental irrigation, transplanting technique in order to harvest assured seed.

Challenges/gaps and future directions

- Infrastructure and trained research personnel are major constraints to systematic crop improvement programme in NARES system.
- Frequent transfers of NARES scientists posing hindrance in focussed crop improvement.
- Integrated breeding approaches to hasten the process of variety and hybrid development by using genomic resources.
- Development of Cleisto lines to ensure complete self-pollination to avoid problems associated with quality seed production for SA and ESA.
- More emphasis on medium duration cultivars suitable for green peas in ESA.
- Linkages need

Enhancing pigeonpea productivity and production in South Asia

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Executive summary

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is an important food legume crop of rain-fed agriculture in the semi-arid tropics. It is grown in an area of 4.86 million ha worldwide with a global production of 4.1 million tons. India is the leading pigeonpea growing country in the world, accounting for 3.73 million ha area and 3.07 million tons of production. However, its productivity is lower than the world average. Non-availability of improved varieties, poor seed systems, and biotic stresses (Fusarium wilt, Sterility mosaic disease and *Helicoverpa*) are the major constraints to enhancing productivity. Although a wide range of improved pigeonpea cultivars are now available, many farmers still continue to grow the long duration old varieties and landraces. This may be because they are either not aware of the improved varieties or do not have access to the seeds of improved varieties. The productivity of the crop can be substantially improved by the adoption of improved cultivars and associated production technologies. Moreover, the pigeonpea production area can also be enhanced in the countries of SA.

In phase I, the pigeonpea activities were conducted in Andhra Pradesh (Mahabubnagar and Rangareddy districts) and Maharashtra (Akola and Washim districts) states of India. In phase II, the activities were conducted in Andhra Pradesh, Odisha, and Bihar states. The project partners include ICRISAT-Patancheru; Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad, Andhra Pradesh; National Seed Corporation (NSC); State Farms Corporation of India Limited (SFCI); Andhra Pradesh State Seed Development Corporation (APSSDC); Bihar Agricultural University (BAU), Sabour, Bihar; Odisha University of Agriculture and Technology (OUAT), Bhubaneswar; and Odisha State Seed and Organic Products Certification Agency (OSSOPCA), Bhubaneswar. Baseline and adoption survey studies were conducted in Andhra Pradesh and Maharashtra states during phase I and in the Bihar State during phase II.

TL II project has given scope for the fast-track release and breeding lines development in the target states. In Andhra Pradesh, the RGT 1 white seeded variety of pigeonpea with wilt resistance (first white seeded type for the state) was released during 2010 by the Agricultural Research Station Tandur, Rangareddy (district). This was estimated to help the farmers (120,000 households) in nearly 80,000 ha of the state where there is a peculiar preference for the white seeded types. Under the phase II of this project, the ICPH 2740 (first pigeonpea hybrid for the state) was released. The hybrid has a yield potential of 3 tons/ha under rainfed situation and fetches an additional income of $1,000 per ha for the rainfed smallholder farmer. Efforts are in progress with the State Agricultural University (ANGRAU), Department of Agriculture (Government of Andhra Pradesh), NGOs, progressive farmers and private seed companies for the large-scale seed production of pigeonea. It was expected to cover 100,000 ha by 2014. In Odisha, the hybrid ICPH 3762, which is the first variety/hybrid of pigeonpea released in the state, was released in the year 2014.

Hybrid breeding program has been initiated for ESA at ICRISAT Patancheru and maintainer lines have been identified from the African germplasm suitable for the region. This will accelerate hybrid development for the ESA region.

Breeding activities in varietal and hybrid research programs have been strengthened in NARS partners of Andhra Pradesh, Odisha, and Bihar states, and this will hasten the release of varieties and hybrids for different agroecologies of the respective states.

About 4,000 tons of various classes of seed have been generated till now for cultivation by farmers in the three target states. This has resulted in the substantial increase of the productivity and income of small and marginal pigeonpea-cultivating farmers. In Andhra Pradesh, the pigeonpea production increased from 450 kg ha^{-1} in 2007 to 600 kg ha^{-1} in 2012 due to the improving seed system and linkages with partners, which helped in the large-scale production of quality seeds.

Almost 19 tons of improved varieties and hybrid seeds were distributed in small packs during the seven years of the TL II in phases I and II. A total of 20,783 farmers (including 3,892 women) were trained on the aspects of improved crop management technology in the three states. Besides, 1,232 traders, extension personnel, and seed production officers were trained on aspects of seed production and crop management. A total of 28,500 booklets, leaflets, and pamphlets on crop management activities and packages, and practices of seed production, were distributed to the stakeholders during phase I and II. In addition, 12 students (including 5 women) were trained for their MSc and PhD degrees.

Major activities

The major activities under different objectives have been listed as follows:

Objective 1:

- Development of standardized baseline and market survey instruments and methods
- Data collection for baseline and market surveys
- Compilation and analysis of secondary data for regional situation and outlook reports
- Development of standardized survey form on end-users preferences, for breeders to use in PVS implementation in crop objectives
- Early adoption studies
- Coordination and capacity building for NARS partners, including the regional partners' workshops and training

Objective 6

- Expand adoption of farmer-preferred high-yielding pigeonpea varieties
- Develop genetically enhanced pigeonpea germplasm and hybrid parents that are resistant to major diseases and high-yielding cultivars and hybrids for target environments
- Enhance NARS capacity in modern pigeonpea research and development technologies through degree and non-degree training, meetings, and workshops

Objective 8.3

- Improve the availability of foundation and certified seeds by NARS/public sector as well as the private sector
- Design and test alternative seed production models that enhance seed delivery system (tailored to various client needs)
- Enhance local capacity to produce, deliver, store, and market seeds
- Enhance local-level awareness of released varieties (demand creation)

Key achievements

Crop improvement

During phase I, RGT 1, the first white seeded variety, was released in Andhra Pradesh and was estimated to transform the livelihoods of smallholder farmers in an area of 80,000 ha, where there is peculiar preference for white seeded types. Similarly, ICPH 2740, the first pigeonpea hybrid, was released for Andhra Pradesh in 2012. The hybrid has 1 ton/ha more yield potential than local types under rainfed situations. The State Agricultural University (ANGRAU) and the State Seed Development Corporation planned for large scale seed production of this hybrid during the 2013 crop season. It was expected to cover 100,000 ha in 2014 and up to 300,000 ha by 2017. This implementation will have an impact on the livelihoods of nearly 400,000 farmers in the state.

In Andhra Pradesh, PRG 176, TDRG-4 and TDRG-28 varieties are being promoted to second year minikit testing after the successful first year testing. Three new varieties (TDRG 33, TDRG 45, and LRG 105) and three hybrids (ICPH 3762, ICPH 2751, and ICPH 3933) have entered in state and national level multi-location evaluation trials. This provides an opportunity for releasing varieties and hybrids for different ecologies.

During phase II in India, the states of Bihar and Odisha used ICPH 2671, ICPH 2740, ICPH 3762, ICP 7035, Asha, and Maruti for FPVS and identified one variety (ICP 7035) and two hybrids (ICPH 2671, ICPH 2740) to be the most preferred varieties by farmers. Large-scale seed production of these varieties and hybrids is being undertaken for their widespread distribution.

In order to breed hybrid parents for high yield and disease resistance, new 25 CMS A- lines and their counterpart B- lines were tested out of which 7 were found to be resistant to both *Fusarium* wilt (FW) and sterility mosaic disease (SMD). A total of 92 hybrid combinations were also tested in sick plot nursery in which 44 lines were found to be resistant to FW and 26 were resistant to SMD. Wilt and SMD resistant hybrid parental lines and segregating generation material were supplied to NARS partners of Andhra Pradesh, Bihar, and Odisha.

In close collaboration with other on-going projects on the use of genomic resources, the project also developed kits for parental or hybrid purity testing, MAGIC populations for bringing alleles from land races, and shuffling of genes among elite genotypes through nested association mapping. Hybrid purity assessment kits are particularly useful in assessing the quality of hybrid seed produced since it is practically impossible to use the traditional GOT (Grow Out Test) in pigeonpea owing to photosensitivity and long- duration.

Maintainers were identified for new CGMS source from *Cajanus reticulatus* (A_8), and hybrid combinations were prepared to determine the restorers. This new cytoplasm source will be helpful in diversifying the cytoplasmic base as there is a risk of homogeneity due to the use of a single source of cytoplasm in hybrid development.

Efforts have been made to incorporate obcordate leaf marker to identify CGMS and fertile plants. Stabilized A- lines of obcordate leaf shape with potential hybrid combinations have been developed. This unique leaf marker serves as a phenotypic marker in the easy identification of off types from A- line in hybrid seed production fields and hence, aids in maintaining the purity of F_1 seed.

Forty-nine genotypes were screened for water logging tolerance at IIPR-Kanpur, IARI-New Delhi, PAU-Ludhiana, HAU-Hissar, JNKVV-Jabalpur and BHU-Varanasi. It was found that ICP 5028, ICPH 2740, MAL 15, ICPH 2431, ICPA 2037 Asha, and ICPL 332 are the most tolerant genotypes. ICP 7035, ICPH 2376, ICP 8863, ICPL 87051, and ICPL 149 were found to be susceptible to waterlogging stress. Crosses were made between ICP 5028 (tolerant) × ICP 7035 (susceptible) to develop mapping populations to tag genes for water-logging tolerance. Particularly, in the state of Bihar water-logging is a serious constraint and thus the material is under evaluation to determine the tolerant genotypes for the state.

Super early lines with 85 to 95 days maturity and a yield potentiality of 1 to 1.5 tons/ha have been developed. These genotypes are under multilocation testing and have the potential for being introduced in different agroecological niches and cropping systems. In Andhra Pradesh and Odisha, a large area is under rice-based cropping systems. Currently, cultivation of rice followed by maize and sorghum cropping system is predominant but not sustainable over a longer period. The cultivation of rice followed by a short duration of pigeonpea augurs well for soil sustenance and efforts are being carried out in this direction.

Cleisto, a selfing trait, has been introduced into elite lines, and stabilized advance generations material has been developed. The material will be further advanced to test their suitability and adaptability. The selfing trait will solve the problematic issues in seed production and maintenance of isolation distance. Owing to the cross pollination nature, the maintenance of quality of the seeds produced is a major challenge with the seed organizations.

During phases I and II, elite lines in varietal front and parents of hybrid breeding were shared with NARS partners of Andhra Pradesh and Maharashtra. This helped to strengthen their breeding program, and a number of varieties and hybrids are in pipeline for release. During phase II, the NARS partners of Odisha and Bihar were supplied with the breeding material, and they have initiated research programs to develop suitable varieties and hybrids for their respective states. In Odisha, the hybrid ICPH 3762, which is the first pigeonpea variety/hybrid released in the state, was released in the year 2014.

Seed systems

Seed system and enhancing adoption of improved cultivars

Improving the availability of breeder, foundation, certified and truthfully label seeds by NARS/ public sector as well as the private sector

During phase I, a total of 1,794.45 tons of different categories (breeder, foundation, certified, and truthfully labeled seeds) was produced by the NARS in Andhra Pradesh, Maharashtra, and ICRISAT. However, the certified and truthfully labeled seed production program of ‘farmer- preferred-varieties’ in Maharashtra and Andhra Pradesh was undertaken at the village level.

In phase II, a total of 1,201.07 tons of various seed classes was made available during the 2013 cropping season. ICRISAT, together with various partners (BAU, Bihar and ANGRAU, AP) and farmer seed growers, produced a total of 28.09 tons of breeder seeds. The foundation seeds were produced by the seed growers (farmers) in Odisha and the public seed sector in Andhra Pradesh for a total of 158.83 tons. The farmer seed growers of Odisha, Bihar and public seed sector in Andhra Pradesh produced a total of 1,006.05 tons of certified seeds. In addition, 8.1 tons of truthfully label (TL) seeds of hybrids and varieties were produced by ANGRAU-ARS, Andhra Pradesh and farmer seed growers of Odisha and Andhra Pradesh.

Seed packets (1-5 kg) of lines of pigeonpea, distributed annually to farmers for evaluation and further seed production to ensure seed sufficiency at the individual farmer level

In phase I, ARS-Tandur distributed a total of 1,000 samples of Asha seeds (3 kg/sample) and 1,200 samples of PRG-158 seeds (2 kg/sample) in Rangareddy and Mahabubnagar districts, respectively, during farmers’ field days so as to popularize high yielding varieties. In Maharashtra, PDKV-Akola distributed small seed packets (1 kg/sample) of various farmer-preferred varieties of pigeonpea to 1,866 farmers during the farmers’ field days.

During phase II, a total of 15.2 tons of various farmer preferred varieties and hybrids of various pack sizes were distributed during the 2012–13 cropping season for improving pigeonpea production in the three Indian states.

Promotion and economic analysis of alternate seed system models

Constraints and opportunities

During phase I, the pigeonpea seed delivery systems, storage and marketing in both target states (Andhra Pradesh and Maharashtra) differed in terms of constraints and opportunities. In Maharashtra, the information was collected from farmers during the group discussions, meetings, training sessions, and field days. The constraints to develop an efficient seed storage, marketing and delivery system for pigeonpea were identified; these were lack of storage facilities, vulnerability of pigeonpea seeds to storage grain pests, lack of drying facilities (more relevant when harvesting coincides with unexpected rains), lack of processing, packaging, and transport facilities, varying and inconsistent response of farmers to new varieties, and inconsistent market price by seed industries. In Andhra Pradesh, the farmers faced difficulty in registering and getting their fields certified. However, the farmers of this state considered selling seeds as TL seeds to co-farmers to be an opportunity in seed delivery systems.

By the time of Phase II implementation, the seed system was well established in Andhra Pradesh state in collaboration with SAU and the Department of Agriculture. There was no channelized pigeonpea seed system in Odisha and Bihar; however, efforts are in progress to establish proper seed channel in these states.

Formal and informal seed sector linkages

In phase I, PDKV-Akola established linkages with Maharashtra State Seeds Corporation Limited (MSSCL) and Krishi Vigyan Kendras (KVKs) at Karda and Durgapura to facilitate efficient seed production and marketing. While in Andhra Pradesh, ANGRAU-Hyderabad established similar linkages with Andhra Pradesh State Seeds Development Cooperation (APSSDC) and Adarsh Rythu for efficient production and seed diffusion. The involvement of APSSDC and Andhra Pradesh State Seed Certifying Agency (APSSCA) in roguing, inspection and selection, and certification of farmers' seed production fields ensured purity and quality of pigeonpea seeds. In addition, the seed village concept was introduced to grow one variety in target villages to guarantee isolation so as to avoid seed contamination. In Maharashtra, the MSSCL has linked farmer groups of selected villages, involved in seed production, for efficient marketing and diffusion of certified seeds in Akola and Washim. The MSSCL function is to monitor seed production plots, which will lead to the assurance of the procurement of seed produced by the farmers.

Transaction costs in seed marketing

In Maharashtra, it is difficult for individual farmers to market the seeds, but in Akola and Washim districts, the farmers have organized themselves into groups to carry out marketing of their seeds to other farmers. In both the districts, the government has also provided seed subsidies under various schemes and packages. In Andhra Pradesh, the seeds produced at the local level has authentic source of seeds, are much cheaper, are well perceived by local farmers since the varieties are adapted to the locality, and are high-yielding as compared to the seed procured from outside the districts or state.

Promotion and formal recognition of informal seed sector

In Maharashtra, Bihar and Odisha, there is a need to strengthen informal seed sector through the approach of 'seed village concept' where 'one variety-one village' strategy should be popularized because formal seed sector cannot lead to the supply of a huge quantity of quality seeds. The seed village concept will solve the problem of the lack of quality seeds required by the villagers. However, in Andhra Pradesh, the seeds produced in Mahabubnagar and Rangareddy districts were offered for certification by APSSCA, whereby the informal seed production was formalized.

Adoption and impacts

The top two pigeonpea growing districts, Rangareddy and Mahabubnagar, were chosen in Andhra Pradesh for the introduction of new varieties and crop technologies. Similarly, Akola district in Maharashtra was chosen for the implementation of the project. In each of the selected state, three villages were selected for intervention (called them as 'adopted' villages) and another three similar villages were picked up as control villages for the sake of comparison. Thirty pigeonpea growers were randomly chosen from each of the village while 15 pigeonpea growers were randomly chosen from each of the control village. Thus, 180 sample farmers were selected for conducting the baseline survey from the intervention villages from the two states while 90 farmers from the control villages were chosen for the same purpose. Data relating to marketing aspects were also collected from the traders, processors, retailers and consumers, apart from the sample farmers. The reference period for data collection was 2006-07 season as the data was collected in 2007-08. The relevant secondary data was also collected from the Directorates of Economics and Statistics of Andhra Pradesh and Maharashtra states and analyzed for better understanding of the performance of pigeonpea in these states over a period of time.

Farmers' Participatory Varietal Selection (FPVS) trials were conducted during the rainy season of 2008-09 in the adopted villages. Some new varieties were tested vis-à-vis the ruling varieties in the region to assess their comparative performance. Farmers were asked to rank the varieties based on the traits preferred by them. The varieties selected by the farmers were taken up for seed multiplication. The farmers were supplied with small quantities of seeds to increase their quantity and bulk the supply so that they can gradually switch over to the preferred varieties. In 2009-10, early adoption surveys were commissioned to assess the dent of the new varieties and whether this adoption has caused any improvement in the yields and incomes of the farmers.

During the baseline survey, the total cropped area under pigeonpea during rainy season was 331.7 ha in the three adopted villages of Andhra Pradesh. Around 61.5% of pigeonpea area was occupied by the Asha variety followed by Abhaya (11%), a local variety called Nallakandi (11.1%), Maruti (7.5%), Lakshmi (5%), Durga (2%), LRG-30 (1%), LRG-41 (0.5%), and white pigeon pea (0.4%). Asha was observed as the single dominant variety in the adopted village groups during 2007-08. Overall, nearly 90% of the cropped area during the baseline survey in adopted villages was under improved cultivars whereas the remaining 10% was occupied by a local variety Nallakandi.

In the case of control villages, the cropped area under pigeonpea crop was estimated to be 125.3 ha. Nearly 77% of the cropped area was covered by the Asha variety followed by local cultivars (7.11%), Lakshmi (6.14%), Abhaya (5.82%), Durga (2.26%), and white seeded variety (1.8%). The spread of improved varieties (Asha and Maruti) released in early 1990s' was dominant during baseline surveys in both the adopted and control villages. Relatively, the diffusion of Asha was much higher in the control villages than in the adopted villages. Other improved cultivars released in early 2000s' occupied less pigeonpea area both in adopted and control villages.

Similarly, Maruti was the first improved variety of pigeonpea introduced in Maharashtra state in the year 1999-2000 and it occupied a peak area within a short period of time. Based on the baseline survey conducted in 2007-08, the Maruti variety occupied 177 ha of pigeonpea area with a major share of 89% of the total in adopted villages, followed by Asha (8%) and Vipula (1.9%). Nearly 95% of the pigeonpea cropped area under control villages was dominated by Maruti variety followed by Asha (3.5%) and Vipula

(1.7%). The awareness and spread of these improved varieties was impressive in both the adopted and control villages during the baseline survey year. It was possible largely because of the prior contacts of the sample farmers with the research stations and scientists and subsequent efforts of Agricultural Universities and Department of Agriculture & Extension.

The early adoption surveys conducted during 2009-10 in both states indicate significant penetration of TL II introduced cultivars in the targeted locations. The extent of area under Asha came down from 61.5 to 43% in Andhra Pradesh. LRG-41 (20%) and PRG-158 (8%) gained significant area coverage by 2009-10. Around 26% of productivity enhancement was noticed in the new cultivars. In Maharashtra, the coverage of Maruti declined significantly from 89% to 47% in adopted villages while 95% to 55% in control villages. New cultivars like BSMR 736 (17%) and BSMR 853 (10%) diffused profusely. Asha also penetrated well from 3.5% to 15% between 2007-08 and 2009-10. Nearly 15% yield gains were perceived by farmers in the project sites.

During the phase II of the TL Project, two new locations (Bihar and Odisha) in India were identified for targeting and introduction of new technologies. But the baseline surveys were takenup only in Bhagalpur and Banka districts of Bihar with reference to 2010-11. Subsequently, FPVS trials were carried out during 2012-13. The mother trials conducted in different locations have concluded that Asha, ICP 7035, and ICPH 2740 were the most preferred varieties over the traditional variety 'Bahar'. There were no systematic efforts in the state of Bihar for crop improvement of pigeonpea by SAU. TL II has provided a way for the small holder farmers to have access to high yielding varieties suitable for their niches.

Capacity building

Farmers

In phase I, a total of 4,307 farmers (Andhra Pradesh – 2,474 and Maharashtra – 1,833) were trained in seed production, crop management, seed health, IPM, and post-harvest practices to enable them to produce quality seed. Aside from the training, Farmers' Day gatherings were also organized in Maharashtra with 351 farmers (including 21 women). This event showcased to farmers the isolation requirement in pigeonpea, identification of off-type plants in seed production blocks, off-type removal at appropriate time, irrigation scheduling, fertilizer application (including use of bio-fertilizers), harvesting, and seed storage.

In phase II, a total of 5,135 farmers (including 1,340 women) of Andhra Pradesh, Odisha, and Bihar were capacitated on various topics such as seed production and management including integrated and disease management, post-harvest and storage, and marketing.

Local seed traders and processor

During the three-year project period (phase I), a total of 533 traders/dal mill operators in Andhra Pradesh and Maharashtra were trained in seed storage, processing, and marketing. Around 10 dal mill operators (owners) and 76 local traders of Andhra Pradesh participated in the training course offered by ANGRAU at ARS, Tandur. In Maharashtra, training for local seed traders and dal mill owners at village level were implemented with 447 participants.

In phase II, 43 seed entrepreneurs of Andhra Pradesh and Odisha were capacitated on post-harvest storage and marketing.

Extension/NGO/Private Seed Company

During the phase I, 699 extension officers, NGO staff and private seed sector personnel were trained in seed production, scientific storage, stored grain pest management, and marketing network. In Andhra Pradesh, a training-cum-field day program was attended by 220 participants in Kosgi village of Mahabubnagar district and 346 participants in ARS, Tandur while in Maharashtra, 133 participants attended the training at KVK Karda, Washim.

In phase II, 939 (including 395 women) extension personnel in Andhra Pradesh and Odisha participated in various trainings and seminars on seed production and management including integrated disease management, post-harvest and storage, and marketing.

Farmers field day/farmer's fair

During the three-year period of the project (phase I), a total of 6,421 farmers attended the farmers' field days/fairs in Andhra Pradesh and Maharashtra. In Maharashtra, 1,791 farmers (including 3 women farmers) attended field days/fairs organized by KVK Akola and Washim. In Andhra Pradesh, ANGRAU organized farmers' field days with an attendance of 4,630 farmers (including 1,150 women farmers). In both states, the project staff involved in the program demonstrated how to conduct roguing of off-type plants, maintenance of isolation distance, control measures of pests and diseases, etc. Aside from these field days, 75 farmers were given the chance to visit demonstration fields at ICRISAT Headquarters. ICRISAT staff guided the farmers in different projects such as watershed and pigeonpea hybrid seed production technology.

During phase II, 2,292 including 417 women farmers attended the farmers' field day and trade fairs conducted in Andhra Pradesh, Odisha and Bihar.

Awareness activities through print and electronic media

Pigeonpea seed production manual in local language

In phase I, PDKV-Akola, in association with ICRISAT, prepared pigeonpea manuals on seed production (500 copies) and crop management (500 copies) in Marathi. Similarly, ANGRAU-Tandur published and distributed 3,500 copies of manuals on pigeonpea seed production and IPM technologies in Telugu. During phase II, 28,500 leaflets/ booklets were distributed on improved crop management practices in Andhra Pradesh, Odisha, and Bihar.

Radio, television and print media

During phase I in Maharashtra, 20 articles regarding the conduct of field days, training programs, visits of the ICRISAT scientists and exposure visit of farmers to ICRISAT, Hyderabad and targeted villages were published in local newspapers. These were also covered by three local radio stations and one local TV station for wider circulation of the project activities and gains among the farmers. In Andhra Pradesh, five local TV stations telecasted information on pigeonpea varieties and crop management technologies. During phase II, a total of 151 events (local newspaper: 118; TV programs: 20; and radio talks: 13) on local awareness were published and attended/conducted in various topics.

Degree students

Six students (2 women and 4 men) were trained for their MSc and PhD during phase I, and 6 students (3 women and 3 men) were under training for their MSc and PhD during phase II.

Infrastructure and equipment

Seed production facilities were upgraded at partner NARS research stations in Andhra Pradesh and Maharashtra. Installation of submersible pump, lay down of PVC pipelines (2800 ft), and fencing of field were upgraded in PDKV, Akola research station to strengthen and improve irrigation facilities and protect the crop from animals for better seed production. In Andhra Pradesh, the facilities for seed production were upgraded at the ANGRAU Research Station in Tandur.

List of equipment purchased by Andhra Pradesh during phase I

No.	Item	Qty.	Purpose	Cost (₹)
1	HDPENylonnet	205 kg	For isolation in Nucleus seed plots	67,035.00
2	Meteorological equipment	1	For recording daily weather parameters	41,490.00
3	Winnower	1	For winnowing of harvested produce	49,044.00
4	Water tanker	1	For providing life-saving irrigation tools	227,552.00
5	Cooling incubator cum shaker	1	For maintenance of *Fusarium udum* cultures	350,000.00
6	Horizontal and vertical electrophoresis systems.	1	For molecular variability work of the wilt pathogen	125,000.00
			Total	860,121.00

Seed storage facility (godown) with a capacity of 300 tons was constructed at ARS, Tandur, Andhra Pradesh. However, in Maharashtra, the farmers were not keen on having a seed storage facility due to the non-availability of land to construct the facility.

Lessons learned

- Farmers' awareness of the improved varieties and availability of the seed of improved varieties are the key factors in spreading high-yielding cultivars.
- FPVS trials were effective in enhancing awareness of farmers regarding improved varieties and in spreading new varieties.
- The farmers need some orientation and close follow-ups for their active participation in FPVS trials.
- Farmers participation in varietal selection reduces the time required for varietal testing and possible high adoption of tested varieties before or after formal release.
- Involvement of seed certifying agencies in Andhra Pradesh makes it easy to release good quality seeds of various seed classes.
- The farmers were keen to undertake seed production of improved varieties, provided arrangement was made for the procurement of seed through national/state seed corporations or other agencies.

Enhancing soybean productivity and production in sub-Saharan Africa

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Summary

This project was on "Enhancing soybean productivity and production in drought-prone areas in sub-Saharan Africa". The emphasis of the first and second phases were on improved soybean productivity through the development of improved germplasm, integrated crop management, marketing, commercialization, seed systems and other institutional issues that shape the adoption, use and retention of improved soybean varieties by smallholder farmers in the intervention areas. The main objective was to target crop breeding and seed delivery efforts so as to enhance the impact on the livelihoods of the poor in drought-prone regions of sub-Saharan Africa. The major objective was to quantify nodulation, biomass production, and grain yield characteristics of a set of best-bet, dual purpose and grain varieties, relative to a locally available variety in all five project sites. The dual purpose, promiscuous soybean that produce a substantial amount of grains and leafy biomass and do not require inoculation with specific *Rhizobium* spp. strains were developed by IITA and have increased resilience of farming while providing income to farmers. In some soils in Kenya, they have not been nodulating freely; and hence, there is a need for inoculation.

This project report covers the critical project objectives based on the activities included in the TL III proposal and justified as the challenges to be addressed in the TL III project. Addressing these challenges would help consolidate the positive achievements from the earlier two phases. The two phases have successfully led to the desired sustainable development and promotion of soybean in Kenya. The remaining issues include: (i) the need to influence supportive policy for soybean development and promotion in Kenya, (ii) integration of institutions at all levels in soybean value chain, (iii) building soybean-related skills and capacities of all stakeholders, (iv) fine-tuning of best agronomic practices with special attention given to overcoming the risk of growing soybean on degraded soils, (v) increased participation of the women networks in soybean enterprises, (vi) enhanced skills and capacity of the service providers, and (vii) ensuring that farmers obtain their soybean seeds from credible sources. These were followed by the key highlights of the project such as pilot cottage-level soybean processing sites, the concept of Soybean Resource Centers, Community Soybean Seed Payback System, the concept of commercial villages and soybean collection centres, other important developments following the project execution (the rising of interest-driven groups, several independent enquiries on how to get involved in soybean enterprises), overall impact of the project (impact on farm income, increase in number of soybean farmers and how the different associations, cooperatives, and other collective networks are contributing), challenges (branding, need for phosphorus (P), the problem of rust, poor soil fertility status, drought tolerance, limited access of farmers to farm and seasonal credit, etc.) as project innovations were scaled up. With the project, 11 soybean varieties were released officially in Kenya (DPSB19, DPSB8, Sc Squire, Sc Saga, Sc Salama, Nyala, Hill, Gazelle, Blackhawk, EAI3600 and 931/5/34).

Test existing soybean varieties and lines for their drought tolerance, promiscuity, disease resistance, low P tolerance, and processing/nutritional quality.

Milestone: At least 20 elite, early to medium maturity, soybean lines evaluated for drought tolerance, promiscuity, disease resistance, low P tolerance, and processing/nutritional quality, using farmer participatory approaches.

Mother Trial (March-August, 2008): Varieties used in the establishment of the mother trial in west Kenya were (i) varieties that had been tested and found best during earlier work in Kenya, led by CIAT and new materials from IITA; (ii) varieties and promising lines tested by the KARI; and (iii) widely available 'local' materials. The basis of selection of test genotypes from the IITA soybean breeding program was based on a prior superior performance in West Africa.

Key achievements

Select existing varieties

The Participatory Varietal Selection (PVS) was based on the mother trial established at the experimental farm of TSBF-CIAT at *Sidada* village in western Kenya. A total of 23 soybean varieties (comprising of 15 Tropical Glycine Crosses or the TGx series, 2 TGm varieties, 2 varieties that have earlier been recommended in Kenya, 1 local variety, and 3 other varieties that fell outside these four earlier categories) were planted and evaluated by 86 farmers (67% males and 33% females) drawn from eight districts (Bhukalarire, Busia, Butere, Ebuyangu, Migori, Mumias, Sidada, and Teso) in the recommendation domains in western Kenya.

The 15 TGx soybean varieties were: TGx 1440-1E, TGx 1448-2E, TGx 1485-1D, TGx 1740-2F, TGx 1835-10E, TGx 1908-8F, TGx 1910-14F, TGx 1844-4F, TGx 1951-4F, TGx 1895-33F, TGx 1895-49F, TGx 1889-12F, TGx 1893-10F, TGx 1871-12E and TGx 1903-1F. The two TGm varieties were TGm 1420 and TGm 1360. While Gazelle and Sable were the two varieties that have earlier been recommended in Kenya and included in the PVS, the local variety was *Nyala*. The three other varieties that fell outside these four earlier categories were named 931/5/34, 915/5/12, and 917/5/16.

Overall, the three most preferred soybean varieties were TGx 1440-1E (occupying first position across gender), TGx 1844-4F (occupying second position across gender), and TGx 1951-4F (occupying third position across gender). It is important to note that the two soybean varieties earlier recommended in Kenya (Gazelle and Sable) and the local check (Nyala) were out-performed.

Baby trials (March-September 2009)

In western Kenya, a total of 29 baby trials were implemented in Busia (5 farmers), Teso (6 farmers), Butere (5 farmers), Mumias (6 farmers), and Migori (7 farmers).

Participatory varietal selection

The PVS is based on baby trials established in Migori, Mumias, Butere, Busia, and Teso in western Kenya. A total of 17 soybean varieties (comprising of 8 TGx series (TGx 1835-10E, TGx 1871-12E, TGx 1895-33F, TGx1893-10F, TGx 1740-2F, TGx 1448-2E, Namsoy 4a, TGx 1903-1F, 3 local varieties (Nyala, EAI 3600, Gazelle), and six grain varieties (931/5/34, Sable, SCS1 from KARI, Njoro H1, H8, H11 from Moi University that fell outside these two earlier categories) were planted (Table 85). These varieties were then evaluated by 320 farmers (52% males and 48% females) from five districts (Busia, Butere, Migori, Mumias, and Teso) in West Kenya.

Overall, farmers in western Kenya used a total of 24 criteria (grain size, number of pods, filling of pods, size of pods, number of seeds per pod, disease free pods, grain yield, early maturity, biomass (number of leaves, size of leaves and number of branches), color of leaves, disease resistance, hardness of pods to shattering, plant height, uniformity in height, size of stem, ease of uprooting, ease of threshing, uniformity in maturity, pest resistance, drought resistance, growth in poor soils, vigor of plant (standability), wind resistance and resistance to heavy rain) to evaluate the 17 soybean varieties.

Table 85. Soybean varieties selected for baby trials in western Kenya.			
Variety type	TSBF-CIAT codes	Breeder codes	Source
Promiscuous varieties	SB3	TGx 1835-10E	IITA, NIGERIA
	SB4	TGx 1871-12E	IITA, NIGERIA
	SB8	TGx 1895-33F	IITA, NIGERIA
	SB17	TGx 1893-10F	IITA, NIGERIA
	SB18	TGx 1894-3F	IITA, NIGERIA
	SB19	TGx 1740-2F	IITA, NIGERIA
	SB20	TGx 1448-2E	IITA, NIGERIA
	SB25	Namsoy 4a	NAMULONGE, UGANDA
	SB37	TGx 1903-1F	IITA, NIGERIA
Grain varieties	SB69	931/5/34	KARI, NJORO
	SB73	Sable	KARI, NJORO
	SB96	SCS 1	KARI, NJORO
	SB92	H 11	MOIUNIVERSITY
	SB90	H 8	MOIUNIVERSITY
Local checks	SB23	Nyala	KARI, NJORO
	SB97	EAI 3600	KARI, NJORO
	SB72	Gazelle	KARI, NJORO

Farmers ranked the 17 varieties (on a scale of 1 to 10, where 1 was the best score or the most preferred on specific criterion basis while 10 was the least score or the least preferred, on each of the criteria that applied.

Comments given by farmers based on gender.

Women choose varieties that are early maturing, large-sized grain and with moderate yields for following reasons:

- They bring food on the table early at a time when hunger is biting hard - focus on food security.
- Large-sized varieties are most preferred in the local market.
- Give sufficient time for farm operations before the on-set of short rainy season (window period between rainy seasons is short).
- Tend to be short in height; hence, preferred for intercropping with the cereals.
- They mature early to escape drought conditions.

Men choose medium varieties because of the following reasons:

- They can improve soil fertility (high biomass accumulation and nitrogen fixation properties); hence, costs of farm inputs are cut down.
- Give higher yields; hence, better returns to the farmer.
- Good for environmental conservation (soil moisture and organic matter build-up).

Desired traits for grain varieties: - early maturity, large-sized grain, high pod load, and medium height.

Desired traits for promiscuous varieties: - early maturity, large-sized grain, higher height and longer viability, high biomass and good nodulation.

Farmers proposed a soybean growing strategy, to grow one grain variety and one promiscuous variety every season, in order to meet the household needs - food security and soil fertility improvement.

Milestones

1. At least 15 lines were evaluated for drought tolerance and biological nitrogen fixation (BNF);
2. At least 10 lines for rust resistance using FPVS trials; and
3. At least 35 lines (20 varieties, 15 lines) assessed for quality traits (protein, oil content) every year (Y1, Y2, Y3).

Evaluation of rust tolerant germplasm 1

Evaluation trial was established in Sidada, Siaya district (N 00˚00' 32.4"; E 034˚25' 25.8"; 1329 masl) and Kokare, Teso district (N 00˚ 36' 21.5"; E 034˚ 18' 48.4"; 1185 masl) with the following materials: NYALA (check), TGx 1740-2F, TGx 1835-10E, TGx 1987-10F, TGx 1987-11F, TGx 1987-17F, TGx 1987-18F, TGx 1987-20F, TGx 1987-23F, TGx 1987-25F, TGx 1987-28F, TGx 1987-31F, TGx 1987-32F, TGx 1987-34F, TGx 1987-62F, TGx 1987-64F, TGx 1987-65F, TGx 1987-6F, TGx 1987-8F and TGx 1987-9F.

All the varieties, except the first three varieties, were new breeding lines developed in the context of the TL II project. The varieties were screened with and without the application of P fertilizer in three replicates per site. Almost all the varieties responded to the P application at both sites. Yields were higher in Sidada than in Kokare and most of the new lines produced well in Sidada while in Kokare, about 3 lines outperformed the other materials (with P applied). Best yields were higher than 3 t/ha in Sidada and above 2 tons ha^{-1} in Kokare.

Total aboveground biomass at podding responded to P application for almost all varieties at both sites. Biomass was higher in Sidada than in Kokare and most of the new lines produced well in Sidada while in Kokare, the biomass production of new lines was not substantially higher than that of the earlier lines. Best yields were higher than 3 tons ha^{-1} in Sidada and above 2 tons ha^{-1} in Kokare.

Nodulation responded significantly to P application in Sidada for most lines with large variation in the total nodule numbers. Nodulation was very low to nil at Kokare. Most new lines noduled well at Sidada.

Rust scores at R6 were slightly lower for about 7 lines in Sidada compared to the earlier lines and some newer lines. At Kokare, over half of the new lines showed considerable improvements against rust damage compared with the earlier lines and with variety TGx 1835-10E, which has been released in Uganda as a rust-tolerant variety.

Evaluation of rust tolerant germplasm 2

Evaluation trials were established at Lolwe (N 00˚08' 22.6"; E 034˚24' 51.7"; 1331 masl) during short rain season 2012 and Mwadi (N 00˚ 08' 26.7"; E 034˚ 25' 42.6"; 1322 masl) during long rain season 2013 in Siaya County with the following materials: NYALA (check), TGx 1990-5F, TGx 1989-20F, TGx 1990-57F, TGx 1990-15F, TGx 1990-8F, TGx 1990-59F, TGx 1990-3F, TGx 1989-19F, TGx 1990-97F, TGx 1990-29F, TGx 1989-41F, TGx 1989-4F, TGx 1990-2F, TGx 1989-21F, TGx 1988-5F and TGx 1987-129F. All, except Nyala, were new breeding lines developed in the context of the TL II project. All varieties were screened with and without application of P fertilizer in 3 replicates per site.

Mother and baby trials were installed during short rains 2012 to evaluate soybean yield potential in different agroecological zones of western Kenya, response to inoculation with rhizobia, effect of inoculation on rust severity, tolerance of improved germplasm to rust and drought.

Milestone for phase I

There was an annual exchange of at least 20 lines between TL II and N2 Africa projects in five overlapping countries, including information about BNF and other agronomically important traits for at least 15 lines.

Presently, the exchange of soybean lines between TL II and N2AFRICA stands at 8. TGx 1740-2F, Namsoy 4M, Maksoy 1N, Sc Squire, Sc Sequel, Sc Samba, Sc Saga, and EAI 3600. Joint set up trials on BNF and agronomy were also set up in the region.

Milestone for phase II

At least 20 elite lines were distributed to partners in five countries each year (Y1, Y2, Y3).

Seventeen elite lines received by CIAT-TSBF from IITA in January 2011 continue to be evaluated at KARI Njoro. The lines are from TGx 1987 series namely 6F, 8F, 9F, 10F, 11F, 16F, 17F, 18F, 20F, 23F, 25F, 28F, 31F, 32F, 34F, 63F, 64F. On the other hand, CIAT-TSBF received 20 elite lines from IITA in February 2012. The new lines are from TGx 1987 (86F, 88F and 129F); from TGx 1988 series (3Fand 5F); from TGx 1989 series (4F, 8F, 19F, 20F, 21F and 41F); and from TGx 1990 series (2F, 3F, 5F, 8F, 15F, 29F, 57F, 59F, and 97F). The lines are being evaluated on station for adaptability to Kenyan conditions.

Milestone: At least 2 varieties submitted to the variety release authorities in the target countries. Ten grain type varieties (EA1300, Gazelle, Black Hawk, Hill, Nyala, Sc Squire,Sc Saga,Sc Salama, DPSB8 and DPSB19) and two dual purpose soybean varieties [DPSB19-TGx 1740-2F; DPSB8-TGx 1895-33F] have been released in Kenya.

Milestone: At least 20 *Rhizobium/ Bradyrhizobium* strains screened for efficient biological N fixation in farmer-preferred varieties This activity has been fully implemented through active linkages with the N2Africa project operating in Kenya. A formal implementation plan of N2Africa details relationships between TL II and N2Africa around the main principles: (i) N2Africa will use the best soybean varieties selected by TL II, and (ii) TL II will have access to the best *Rhizobium* strains, identified by N2Africa.

Within the TL II project, a study was conducted to assess the nodulation and nitrogen fixation of a set of nine indigenous *Bradyrhizobium* strains inoculated on three promiscuous soybean varieties grown under greenhouse conditions. Seedlings of three promiscuous soybean varieties (SB 8, SB 9 and SB 19) were inoculated with 3 ml each (10^8 cell mL^{-1}) of pure indigenous *Bradyrhizobium* strains (TSBF 404, TSBF 101, TSBF 131, TSBF 531, TSBF 534, TSBF 331, TSBF 442, TSBF 344, TSBF 3360). Negative and positive (98 kg ha^{-1} equivalent) controls were also included. The seedlings were grown in 2 kg sand filled polybags, kept at field capacity by alternate day watering with double distilled water and Broughton (Broughton and Dilworth, 1970) solution in a greenhouse at approximately 12/12 light and 25°C/32°C. Seedlings were harvested at R1 (Fehr et al. 1971) for each of the genotypes and nodule number and shoot biomass was recorded. All samples were dried to constant weight for 48 h at 70°C. Nodule dry weight and shoot dry weights were recorded. Dry shoot weights were used as proxy for nitrogen fixation (Abaidoo et al. 2000). The Effectiveness index (E) was calculated as described by Ferrera and Marques (1992):

$$E_J = (X_J - X_{TO}) / (X_{TN} - X_{TO})$$

where J is the shoot dry weight of the inoculated test strain, TO is the non-inoculated control while TN is the nitrogen control. Strains were arranged in ascending order and grouped into classes of effectiveness as described by Beck et al. (1994).

There was no interaction between strains and varieties on shoot dry weight (Figure 10). However, there was a highly significant (P<0.001) difference among strains on shoot dry weight. Shoot weight ranged from 0.1380 g per plant for negative control to 0.731 g per plant for TSBF 442. TSBF 442 had five times more shoot dry biomass than the negative control while it recorded 2.5 times more shoot biomass than the control strain (USDA 110). The control strain USDA 110 produced significantly less dry shoot biomass and nodules than all tested strains in all three varieties. All varieties fixed significantly higher amounts of nitrogen when inoculated with all indigenous strains but TSBF 131.

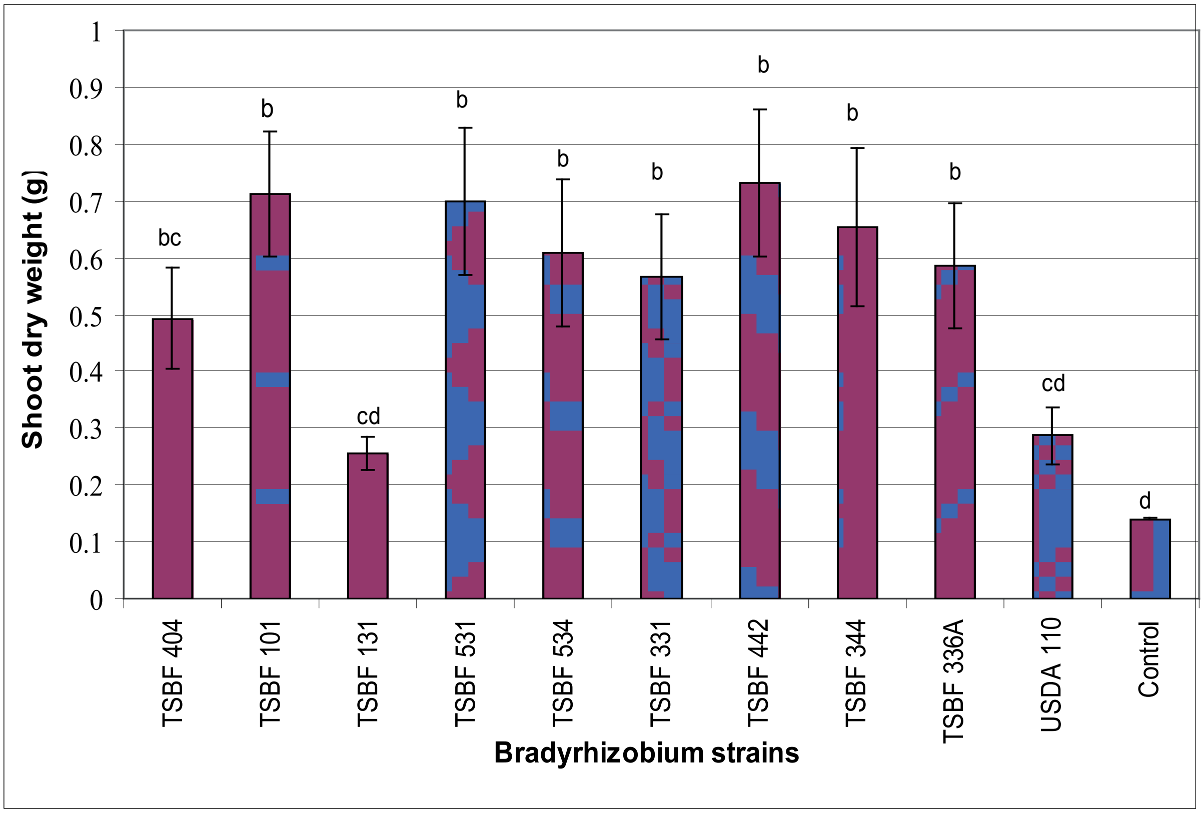

Figure 10. Dry weight of three promiscuous soyabean varieties grown in sand under greenhouse conditions.

There was a significant interaction between soybean varieties and indigenous *Rhizobium* strains for nodulation. SB8 nodulated best with strain TSBF 336A and least with TSBF 131, SB9 with strain TSBF 344 and least with TSBF 534, and SB19 nodulated best with TSBF 442 and least with TSBF 131. All tested indigenous strains nodulated significantly better than the introduced strain (USDA 110) on all promiscuous soybean varieties under greenhouse conditions. Nodulation did not necessarily result in high N_2 fixation. This study indicates that the indigenous rhizobia strains can be deployed to replace/ supplement introduced USDA 110 that is currently used in soybean inoculants in Kenya.

Create segregating populations for drought tolerance, promiscuity, disease resistance, and low P tolerance

Milestone: A total of 100-200 accessions screened for low P tolerance. The variation in P uptake among different species and genotypes was caused by a range of factors that are mostly related to specific root traits such as root architecture and root hair development (see Gahoonia and Nielsen 2004). However, the selection of P efficient varieties is a difficult process since direct screening requires large-scale field experiments including a large number of varieties. Hence, it would be desirable to develop screening techniques that would enable breeders to identify P efficient varieties in early stages of plant development. This research therefore, aims at developing such screening technique through the identification of 'early root traits' related to P efficiency. This will be accomplished by (i) qualitative and quantitative evaluation of root traits in early plant growth stages of a varied set of soybean varieties, through the use of innovative screening techniques and (ii) field testing of the same set of varieties to evaluate possible correlations between early root traits and efficiency under field conditions.
A multi-locational field trial was established during the short rains of 2009 in 10 locations of south-

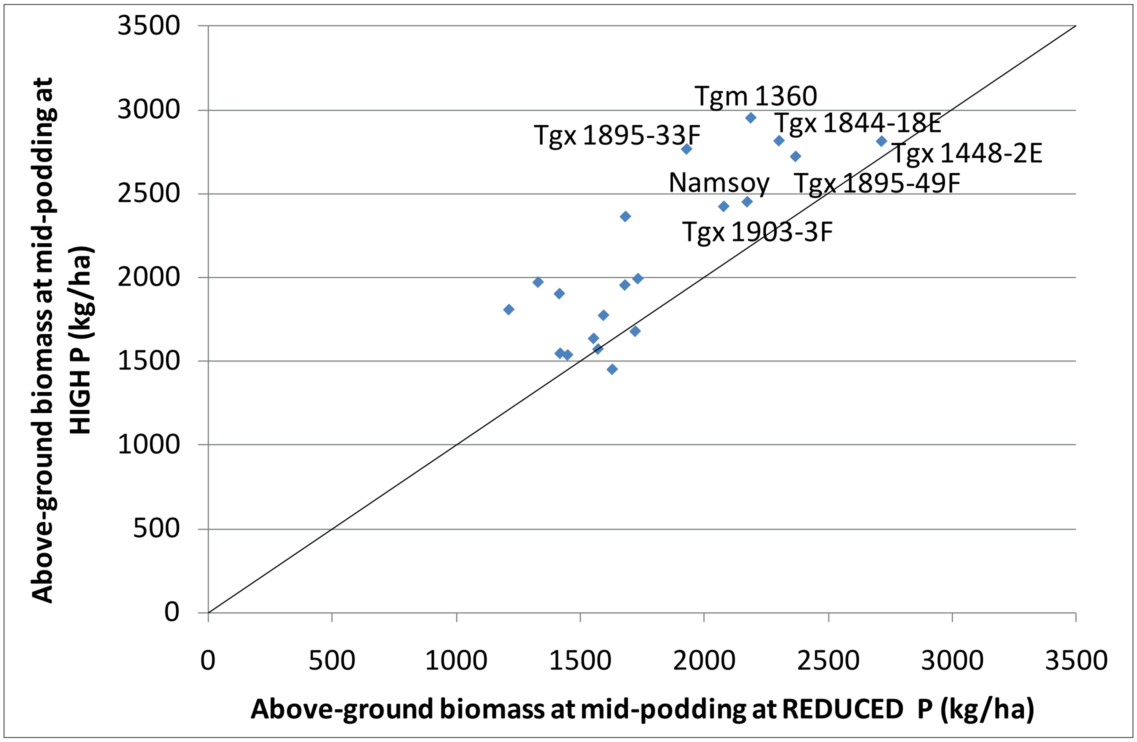

Figure 11. Relationship between above-ground biomass at mid-podding stage under reduced and high P application.

western Kenya (Migori district) and 10 locations of western Kenya (Siaya district). Twenty soybean varieties (10 dual-purpose varieties developed by IITA and 10 locally used varieties from different East African countries and China) were planted in combination with 50-60 kg P/ha (P at recommended rate, depending on area), a reduced P rate (40% of recommended rate), and a control treatment without P. All varieties were inoculated with Legumefix (Legume Technology Ltd).

The results of field screening showed substantial variability in P efficiency between varieties. In general, the dual-purpose varieties were superior in P efficiency compared to the locally used varieties (Figure 11). Varieties with good growth under low(er) P conditions showed larger root-shoot ratios, which indicates the importance of the root system for tolerance to low P conditions. Different groups of varieties could be distinguished based on their P efficiency in terms of biomass and/or harvest production under extremely low or reduced P rates. Only two varieties, TGx 1844-18E and TGx 1895-49F, produced well in terms biomass and harvest production under both, no and reduced P application, and can be considered superior in P efficiency.`

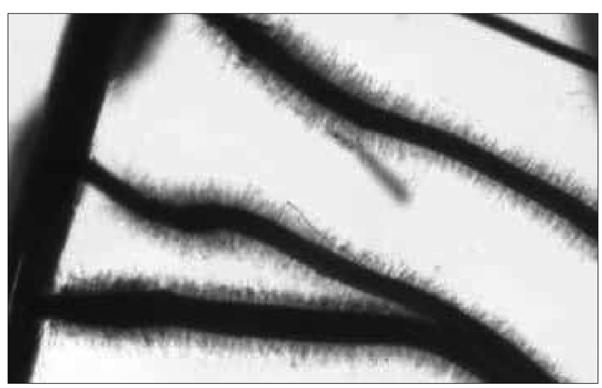

Figure 12. Evaluation of early root hair development in agar gel.

Early root traits of soybean varieties are currently being evaluated through the use of mini-rhizotrons filled with a mixture of sand and P adsorbed on aluminum oxides at different buffered P concentrations. Basal root angles, root length and diameter, and plasticity across P levels for these traits were assessed using WinRHIZO software. A method with agar gel containing aluminum-P as a growth medium was tested for evaluating root hair development. Figure 12 shows how early root architecture and root hair development under different buffered P concentrations can be closely followed-up in mini-rhizotrons and agar gel. These methods are currently being tested for different soybean varieties. It is hypothesized that certain 'early root traits' will appear to be indicative for P efficiency under field conditions. Two varieties contrasting in P efficiency under field conditions were screened in mini-rhizotrons filled with a mixture of sand and P adsorbed on aluminum oxides at low P availability (0.04 ppm) and moderate P availability (0.2 ppm) for 2 weeks. It was hypothesized that early root traits identified through the use of this screening technique would differ significantly between these varieties and would relate to their difference in P efficiency. In the early stages of growth, plant growth is strongly affected by the seed P reserve and to take this into account seeds of different sizes were selected for each variety.

Results showed that early root traits were influenced by the seed P reserve to such an extent that no useful conclusions could be drawn on the relation between early root traits and efficient P uptake in later stages (Figure 13). Young roots thus seemed to react strongly to the amount of P available in the seed which does not necessarily mean they will develop similar root traits after the seed P reserve has been used and that plants depend solely on the external P source. This finding interferes with our goal to identify differences in P efficiency in early plant growth stages. However, the mini-rhizotron technique was very promising for studying root architecture of a large number of varieties. The methods are currently being tested to compensate for the effect of seed P during early screening.

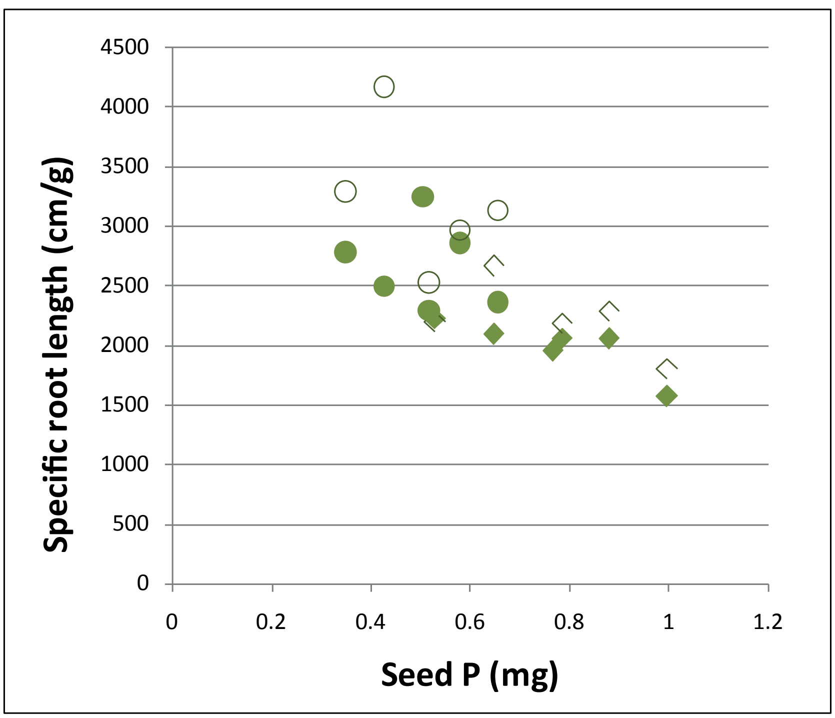

Figure 13. Specific root length of 2 soybean varieties grown in mini-rhizotrons filled with a sand-alumina-P medium (O: TGx 1895-49F;: TGx 1895-33F; filled marker points: 0.04ppm P; empty marker points: 0.2ppm P).*

Strengthen capacity of national agricultural research systems scientists, extension personnel, and farmers in the soybean value chain

Milestone: At least 3014 farmers trained in soybean participatory variety selection, processing, utilization, and/or agri-business following a training-of-trainers approach

Training of associations, women groups, youth groups, and other CBOs on pest and disease diagnosis and participatory variety selection.

Date	Venue	Duration	Topic	Participants	Attendance		
					Male	Female	Total
12-14/ 10/11	Maseno Club Hotel	3 days	• Integrated pest and disease management • Concept, methods and tools for participatory variety selection	Extensionists, farmer associations, women group, CBOs and youth groups	14	7	21
Mar- Aug, 2011	Butere Mumias Teso Busia Migori	1 day	• Methods and tools for participatory variety selectio	Extensionists, farmer associations, women group, CBOs and youth groups	160	110	270
Sep-Dec, 2010	Butere Mumias Teso Busia Migori	1 day	• Methods and tools for participatory variety selectio	Extensionists, farmer associations, women group, CBOs and youth groups	190	160	350
Mar-Aug, 2010	Butere Mumias Teso Busia Migori	1 day	• Methods and tools for participatory variety selectio	Extensionists, farmer associations, women group, CBOs and youth groups	170	130	300
Mar-Aug, 2009	Butere Mumias Teso Busia Migori	1 day	• Concept, methods and tools for participatory variety selectio	Extensionists, farmer associations, women group, CBOs and youth groups	167	153	320
Mar-Aug, 2008	Sidada	1 day	• Concept, methods and tools for participatory variety selection	Extensionists, farmer associations, women group, CBOs and youth groups	58	28	86
				Total:	759	588	1347

Integrated seed systems delivering on the promise: Experiences from Tropical Legumes II

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Summary

Due to limited commercialization of legume varieties by the private sector, the legume seed system has remained rather underdeveloped and weak in many countries of sub-Saharan Africa. The TL II project developed and successfully implemented innovative seed delivery models that significantly impacted the seed systems in 13 countries of SSA and two in SA. First, the pluralistic and integrated seed system was developed, which strengthened linkages amongst various legume seed value chain actors. Second, the participation of several seed producers in a decentralized system increased production of certified and quality declared seed of legumes, which ensured seed access to farmers in remote areas. Third, there was a rapid adoption and use of newly released varieties by farmers as a result of increased awareness on improved varieties through multi-media and user-friendly communication strategies and tools. In addition, the increase in the number of channels and outlets that conveniently made available seeds to farmers, combined with affordable small seed packs, enhanced access to quality seed of improved legume varieties, especially by previously disadvantaged women farmers. Fourth, as a result of enhanced skills and knowledge of seed value chain actors, seed production significantly increased by 221% (from 139,048 tons to 446,232 tons) while seed access increased by 70% (from 5,033,913 to 8,512,050 beneficiaries) between phases I (2007-2010) and II (2011-2014).

The problem

Grain legumes play a paramount role in human nutrition and market economies of SSA and SA. Smallholder farming households with limited access to inputs, including quality seed of improved legume varieties, dominate legume production in these regions. New varieties with attainable yield of more than two tons ha^{-1} have been developed and released. However, most farmers still continue to get yields below 500 kg ha^{-1} due to the use of landraces or obsolete varieties combined with poor agronomic practices. Therefore, the continued deployment of obsolete varieties has dampened the prospects for increased legume productivity for food and income security. Thus, there is a requirement for revamping legume seed systems to meet smallholder farmers' production and agroecological intensification needs, which was a major activity under TL II.

Solution

Seed systems approach and processes

In each country and for each crop, TL II adopted an inclusive pluralistic and integrated seed systems approach that recognizes the roles of seed producers such as individuals, seed companies, government organizations and farmer groups (Figure 14). The production of breeder and basic seed was exclusively in the hands of publicly funded NARS, whose productivity inefficiencies inadvertently caused delays in the scale and scope of adoption of new varieties. Under TL II, due recognition was given to other seed producers to augment the efforts of NARS. Strategic strengthening of the capacity of NARS for seed production was also considerably improved. These seed producers were supported by a range of public-private partners, such as NGOs, farmer organizations and public extension teams, providing complementary services, including skills and knowledge enhancement/ training, variety demand creation, seed quality control and financial and material support, depending on the country, region and crop specificities.

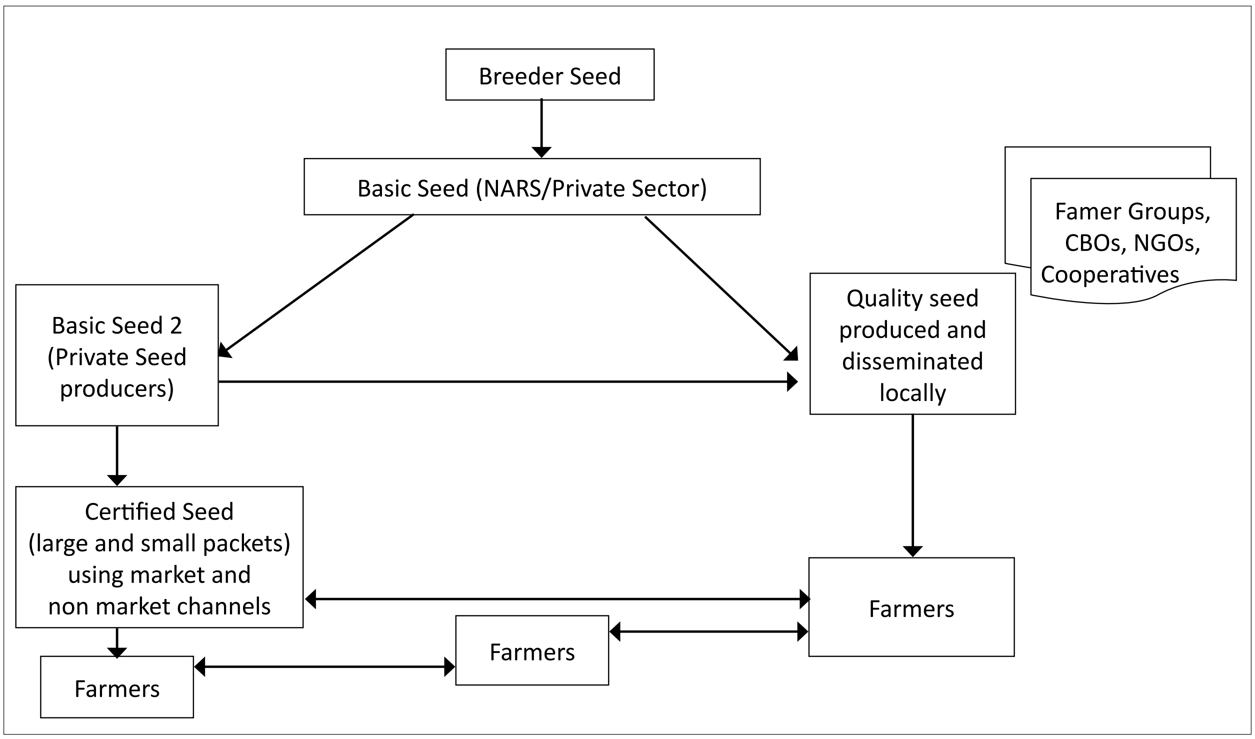

Figure 14. Integrated seed systems approach.

Partners developed joint work plans for project research and implementation and agreed on roles and responsibilities. Many of the partners also signed formal Memoranda of Understanding and incorporated TL II work plans in their yearly program plans. Thus, seed systems activities under TL-II were implemented as part of the country-led and nationally-owned legume research for development plans and strategies. The engagement of private seed companies, individual seed entrepreneurs, NGOs, grain traders, CBOs, and farmers' organizations greatly enhanced the prospects for the sustainability of project outcomes. The NARS supported and empowered the partners in two main ways. First, NARS ensured the availability and accessibility of breeders' and basic seed to feed into production plans of private producers. Second, it provided technical support to private seed companies through training on seed business management, especially marketing of seed in small packs. This resulted in improved collaboration and enhanced effectiveness of the private sector. The net impact was a drastic growth in production and market opportunities of legumes, attracting an increasing number of players in establishing strong and durable linkages in the legume innovation system across TL II countries.

Results

Seed delivery systems models

The need for synergy informed engagement of a wide range of partners in seed production and dissemination. Between 2007 and 2010 (phase I), nearly 500 seed producers were involved in TL II seed systems across several legumes. By the end of phase II, the number of seed producers across TL II countries had increased by 72% to more than 1,700.

Various successes were obtained with different models in specific regions. The use of small affordable seed packs was extensively used across several TL II member countries (see Box 1). In some countries, the approach was an opportunity for private companies to expand seed business to remote areas and

Farmers want access to new varieties and some are willing to pay for certified seed at affordable prices. To meet this demand, seed simply has to be marketed in affordable sizes and in places where farmers can easily access, and from vendors that farmers trust (or who may be held accountable to buyers). Small seed packs (sizes 0.05, 0.1, 0.25, 0.5, 1, 2, 5, 10, and 25 kg) were extensively used in seed dissemination across all crops in all the target countries (see Table 86). More than two million farmers were reached with seed through this approach, 72.5% of them women.

Table 86. Amount of small seed packs distributed, by crop, per country, from 2007- 2014.

	Number of small seed packs per crop						
Country	Chickpea	Groundnut	Common bean	Soybean	Pigeonpea	Cowpea	Total
India	16,622	11,460	NT	NT	8,140	NT	36,222
Bangladesh	90	290	NT	NT	NT	NT	380
Ethiopia	424	NT	176,858	NT	NT	NT	177,282
Uganda	NT	NT	-	NT	40	NT	40
Tanzania	45	NT	3,045	NT	4,825	NT	7,915
Kenya	3,568	NT	108,500	35,566	NT	NT	147,634
Mozambique	NT	NT	NT	457,099	NT	9,345	466,444
Nigeria	NT	11,500	NT	308,000	NT	75,885	395,385
Niger	NT	NT	NT	NT	NT	64,399	64,399
Malawi	NT	839,500	NT	NT	500	NT	840,000
Mali	NT	6,740	NT	NT	NT	17,300	24,040
Total	20,749	869,490	288,403	800,665	13505	166,929	2,159,741

NT: Country not targeted

The small packs approach is increasingly gaining popularity as the most efficient and cost effective means of reaching more farmers with affordable quantities of seed and a wide range of preferred varieties. In Kenya, Dry-land Seed Company Ltd and Kenya Agricultural Research Institute (KARI Seed Unit) packed and sold 89 tons of seed of drought tolerant bean varieties in 0.1 kg, 0.5 kg, 1 kg and 2 kg packs. In India, a total of 115,232 tons of assorted legume crops were distributed in different pack sizes, ranging from 2 kg to 20 kg.

Box 1. Effectiveness of innovative seed delivery strategies: evidence from small seed pack approach in TL II countries.

reach the poor, hard-to-reach women farmers. For instance, seed companies in Uganda and Kenya reached more smallscale farmers through the use of small bean seed packs at various outlets, and at times with the support of NARS staff. Another successful seed system model was the 'one village-one variety' concept with pigeonpea open pollinated varieties and hybrids in Andhra Pradesh and Odisha in India. In this model, smallscale farmers with limited access to land consolidated small units of land to produce seed collectively and avoid contamination of the varieties; all members of the village had to adopt one variety. In India (Karnataka and Tamil Nadu), ICRISAT and partners developed and promoted an integrated groundnut seed system (see Box 2). Due to policy support from state government in Karnataka, 48 small private seed companies ventured into seed production of popular chickpea varieties grown by local farmers. This led to the production of more than 91,000 tons of certified seed in 2013–14.

In Malawi, seed loans were successful in disseminating new groundnut varieties. Under the scheme, smallscale farmers produced new varieties and passed it on to members of the community as loan. Moreover, with groundnut, successful dissemination of varieties at community level was achieved in women's groups in Mali. Similarly, commercially oriented mixed gender farmers groups and farmer cooperative unions have become the backbone of common bean and chickpea seed production in

Two alternate groundnut seed system models were developed and promoted in partner states of India (Karnataka and Tamil Nadu) during Phase I.

The first model is the Panjabrao Deshmuch Krishi Vidyapeeth (PDKV) model that engages farmers in informal seed multiplication. Improved varieties in 2 kg packs are distributed to farmers who then multiply the seed over two seasons, producing 20 kg in the first season and subsequently 200 kg in the second season, which is enough for planting in 1 ha by the third season. In the third season, farmers save 2 kg from selected plants and repeat the cycle. This model enables farmers to attain seed self-sufficiency, sustaining high adoption rates among farmers.

The second seed system model is semi-formal and was implemented successfully in Karnataka state. In this model, the University supplies basic seeds to farmers, who either offered land, for certified seed production under the formal seed chain or Truthfully Labeled Seed (TLS), which was produced without certification but monitored by the University, NGOs and farmer associations. A similar model was also used in Tamil Nadu. Semi-formal seed systems were found to be successful in meeting local groundnut seed demand. In Tamil Nadu, the transport cost of 100 kg of pods alone is about 700 Indian rupees (INR), which is 20% of the cost of seed. Thus, the alternate seed systems reduced the costs of seed transportation by more than 10%.

Through the semi-formal model, which was implemented in the five districts of Erode and Thiiruvannamalai in Tamil Nadu and Bagalkot, Hiriyur and Raichur in Karnataka, linkages were established between formal and informal seed sectors through supply of basic seed by the University. In Karnataka state, additional linkages were also facilitated through certification of seed production plots by the state seed certifying agencies leading to certified seed production. This seed was procured by the state seed corporations or the State Department of Agriculture. About 100 kg of basic seed of the variety ICGV 87846 was supplied to ICRISAT's Agri-Business Incubation (ABI) Program, Krishi Vignan Kendra-Sandhiyur, and Regional Research Station-Vridhachalam for further multiplication and distribution to farmers through this system. Similarly, 100 kg seed of ICGV 00351 was also supplied to ICRISAT's ABI program during 2010 rainy season.

Source: Tropical Legumes II project (2012). – Four Seasons of Learning and Engaging Smallholder Farmers: Progress of Phase I

Box 2. Efficiency of integrating formal and informal seed system models: Case of Karnataka and Tamil Nadu states of India.

In Central Rift Valley of Ethiopia, beans are important cash crop and are predominantly a man's enterprise. Inadequate presence of women farmers and gender inequitable access to bean seed as well as the use of poor quality seed of older and degenerated varieties had stalled bean productivity and marketing prospects in Ethiopia. An impact driven seed systems approach was designed to accelerate the supply of quality seed of market-demanded varieties to both women and men farmers. In addition to accessing seed of improved bean varieties, farmers also accessed good crop management techniques, a combination which increased production and unlocked market opportunities. Between 2008 and 2012, with support from TL II, the Catholic Relief Service (CRS), Diocese received 13.7 tons of basic seed of two canning bean varieties (Awash 1 and Awash Melka) from the Ethiopian Institute of Agricultural Research (EIAR), Melkassa and the seed was availed to 186 (102 male and 84 female) seed entrepreneur farmers, who produced 133.5 tons of quality declared seed. In addition, TL II and EIAR, Melkassa provided complementary support such as training of trainers on improved bean, pre and post-harvest management practices as well as business management skills. Furthermore, TL II facilitated the engagement of various stakeholders through public-private partnerships in which EIAR and other bean value chain actors in Ethiopia, including seed producers, bean exporters and local traders, development partners like CRS, Meki Diocese came together with a common goal of improving the bean value chain to improve livelihoods of Ethiopians.

Mrs Milko Bati, a 38 year old widow of Tuka Kabele (Lungano village), is an example of smallholder farmers whose livelihood improved by engaging in seed production. The mother of six, received 150 kg of seed of the variety Awash Melka and used this to produce seed that she sold to meet her farm family livelihood. The bean seed enterprise and additional income from production and marketing of bean seed radically improved Milko's livelihood - economically, nutritionally, and socially. Having been economically empowered through the sale of beans, Milko constructed a new house for her family, moving from her initial grass-thatched-mud-walled house (see Photo 1) to a spacious permanent house, worth Birr 16,500 ($ 921.8) (Photo 2). Moreover, feeding her family has become more affordable than before. With the high yields achieved from improved bean varieties, her household income has drastically increased and most expenses greatly offset by the proceeds from sale of beans. Apart from meeting her family's cash needs, additional income is invested in other diversified enterprises to support bean production and the family welfare. For instance, she increased her herd from one cow in 2008 to four in 2012 (see photo 3); the family is more nutritionally secure through inclusion of milk in their food basket. The family has also bought three pairs of oxen, three donkeys, four sheep, ten goats, and ten chickens from bean sales. The income from bean seed sales and associated investments in livestock has also reduced pressure on the family for tuition of her six children The significant impact on the turn-around in her household livelihood has prompted Milko to increase her bean crop progressively from 5.25 ha in 2008 to 8.25 ha in 2012. Her ambition does not stop there. Using the proceeds from bean sales in 2012, she bought a plot to build a commercial building at Meki trading center.

Milko's social status has also risen in the neighborhood, especially among fellow women to whom she sells or donates bean seed as a kind gesture. About 58 female farmers and 5 male farmers have benefited from her generosity.

To thousands of bean farmers in Ethiopia including Milko and her neighbors, white pea beans are *white gold*.

Photo 2

Photo 1

Photo 3

Box 3. Women thriving in men's world as a result of enhanced access to quality seed: Evidence from Central Rift Valley, Ethiopia.

Ethiopia. In West Africa, the project promoted and strengthened community seed production for cowpea and soybean seed production. This ensured availability of cowpea seeds in target communities in Mali, Nigeria and Niger Republic and soybean seeds in Nigeria. Community based seed production involving NGOs, CBOs and farmers associations, improved access to cowpea and soybean seeds in target communities in Mozambique.

Equity and gender was the cornerstone of TL II seed systems. For instance, among Ethiopia women, seed entrepreneurs are increasingly playing a major role in male dominated seed production (see Box 3). This effort has contributed to improved livelihoods and role of women farmers in household and rural economies of beneficiary communities.

Due to the concerted efforts invested in developing and implementing the seed delivery models, impressive results were achieved in terms of access to high quality legumes seed of user-preferred varieties. In phase I, more than 5 million farmers received high quality seed of one or more improved legume varieties. In phase II, collaborative efforts were stepped up enabling more than 8.5 million beneficiaries to access seed (see Figure 15), indicating a 70% increase in the number of beneficiaries from phase I. In total, more than 13.5 million smallholder farmers (including 61.2% women) accessed seed of improved legume varieties in TL II countries between 2007 and 2014.

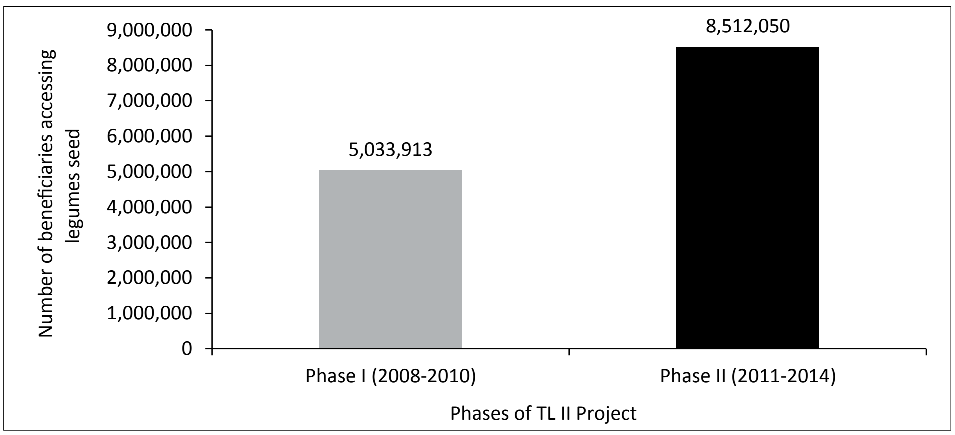

Figure 15. Seed access across TL II countries in phases I and II, for all crops (2008-2014).

Enhanced capacities

To expand and sustain the project outcomes/outputs, TL II engaged in building the skills and knowledge of partners/actors along the seed value chain of various grain legumes. More than 130,000 legume seed system actors were trained between 2007 and 2014 across target countries (pigeonpea: 87,160; chickpea: 47,075; soybean: 26,677; common bean: 23,633; groundnut: 18,384 and cowpea: 8,548). Ninety percent of the trainees were legume seed farmers while public extension staff, private sector extension staff, representatives of NGOs/FBOs and legume traders constituted 10%. Notably, 54% of the individuals trained were females.

Enhanced awareness on improved legumes varieties

Multi-media communication strategies and user-friendly tools for variety promotion were adopted/developed and shared with partners across crops, countries, and regions. These included training modules, manuals, leaflets/flyers, and information bulletins. During Phase I and Phase II of TL II (2007–2014), a total of 8,000 leaflets with information on groundnut seed production (6,000 in Uganda, 2,000 in Malawi) were distributed. Additional 15,000 flyers describing groundnut varieties were printed in Chichewa and Swahili and distributed to farmers in project sites. More than 2,000 bean seed production/ business manuals were produced in four languages (Amharic, Oromifa, Swahili and Luganda) and shared with partners in Ethiopia, Kenya, Tanzania and Uganda, respectively. A total of 2,200 cowpea production guides were distributed to stakeholders in Nigeria. The guide was translated into French and 2,500 copies were distributed in Niger and Mali. Two thousand production guides of soybean were produced and distributed in Nigeria. Mass communication was also used to disseminate knowledge about the new varieties and their seed source through several radio programs (12 in Ethiopia, 30 in Tanzania, 6 in Malawi, 16 in Mozambique. 42 in Nigeria for cowpea and soybean and 14 each in Mali and Niger Republic for cowpea), and TV programs (7 in Ethiopia, 15 in Tanzania, 2 in Malawi, 1 in Uganda, 8 in Mozambique, 21 in Nigeria for cowpea and soybean, 7 each in Mali and Niger Republic for cowpea). In India, more than 28,000 booklets and pamphlets with information on pigeonpea were distributed to 22,250 farmers and extension personnel.

Certified and quality declared seed production

The strong partnership supported by appropriate capacity building and availability of improved and user-preferred varieties resulted in increased seed production and supply**.** Between 2007 and 2014, more than 580,000 tons of assorted seed classes of the six legumes were produced as indicated in Table 87; of which, more than 430,000 tons were certified and quality declared seed. The total seeds produced per crop per seed grade in each implementing region/country are indicated in Tables 87 to 98.

In phase II, impressive seed production/supply levels were recorded. Most of the crops surpassed the targeted milestones (based on already executed two year period of the project). For instance, quantities of chickpea seed produced (294,308 tons) surpassed the milestone (11,645 tons) by more than 2,000% (see Table 88).

Table 87. Quantity of seed produced (tons) across target countries, by crop and project phase (2008-2014).

Crop	Phase I (2008-2010)	Phase II (2011-2014)	Total
Chickpea	99,877	294,308	394,185
Common bean	11,355	49,401	60,756
Cowpea	2,495	9,665	12,160
Groundnut	21,927	70,235	92,162
Pigeonpea	1,086	6,612	7,698
Soybean	2,308	16,011	18,319
Total	139,048	446,232	585,280

* The data do not include Groundnut seed from one West African country; pigeonpea and chickpea from South Asia; cowpea from one ESA country

Table 88. Milestones and actual seed production across target countries by crop (2011-2014).

Crop	Phase II milestones	Phase II actual achieved	% achievement
Chickpea	11,645	294,308	2,427
Common bean	6,920	49,401	7,076
Cowpea	120	9,665	8,054
Groundnut	24,085	70,235	292
Pigeonpea	770	6,612	859
Soybean	210	16,011	7,624

Groundnut seed systems in Western and Central Africa

Tables 89 to 98 indicate the quantities of seed produced across TL II project countries during phases I and II.

Table 89. Quantity of groundnut seed produced (tons) in WCA, by country, by seed class (2008-2014).

	Seed classes and amount (tons) produced														
	2008		2009		2010		2011		2012		2013		2014		
Country	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	Total
Mali	13.67	48.00	15.88	60	19.30	68.00	22.50	272.00	29.40	313.00	34.15	520.0	9.8	98.8	1,524.50
Niger	7.72	11.78	10.63	27	14.69	75.68	13.28	152.55	26.34	367.55	25.00	540.0	0	245.0	1,517.20
Nigeria	1.27	20.25	10.76	41	2.78	88.50	0.75	111.63	6.11	945.90	6.55	1,061.8	21.6	292.8	2,611.70
Burkina Faso	6.70	80.00	8.80	78	7.70	71.00	8.20	75.00	8.80	77.00	11.00	85.0	28.4	147.0	692.60
Ghana	1.20	9.50	1.10	12	0.90	14.50	1.80	11.80	1.60	12.70	1.40	10.3	2.7	346.1	427.60
Senegal	0	0	0	0	0.3	0.85	0.42	0.64	0.35	0.83	0.23	1.0	0	0	4.62
Total	30.56	169.53	47.17	218	45.67	318.53	46.95	623.62	72.6	1,716.98	78.33	2,218.1	62.5	1,129.7	6,778.22

EG=Early generation seed (Breeder/Basic seed)
CS=Certified seed

Chickpea, groundnut and pigeonpea in eastern and southern Africa

Table 90. Quantity of chickpea seed produced (tons) in ESA, by country, by seed class (2008-2014).

	Class and quantity (tons) of seed produced			
Country	Breeder	Basic	Certified/QDS	Total
Ethiopia	41.9	715.8	12,454.7	13,212.4
Tanzania	42.00	303.80	1,412.9	1,758.70
Kenya	27.59	16.90	1,460.9	1,505.39
Total	111.49	1,036.5	15,328.5	16,476.49

Table 91. Quantity of groundnut seed produced (tons) in ESA, by country (2008-2014).

Country	Certified/QDS produced (tons)
Tanzania	25,575.0
Uganda	577.7
Malawi	18,502.9
Mozambique	132.7
Total	44,788.3

Table 92. Quantity of pigeonpea seed produced (tons) in ESA, by country, by seed class (2008-2014).

Country	Breeder	Basic	Certified/QDS	Total
Tanzania	23.38	84.00	1,488.40	1,595.78
Malawi	23.90	170.39	1,787.20	1,981.49
Uganda	7.70	42.81	39.30	89.81
Total	54.98	297.20	3,314.90	3,667.08

Common bean seed systems in ESA

The lessons learned and functional partnership established in the first phase (2007–10) resulted in an increased quantity of bean seeds produced in the second phase (40,980.19 tons), as indicated in Table 93.

Table 93. Quantity of bean seed produced (tons) in ESA, by country (2008-2014).

	Assorted seed produced (tons)							
Country	2008	2009	2010	2011	2012	2013	2014	Total
Ethiopia	386.20	2,128.00	7,557.00	2,820.3	5,133.2	5,591.7	7,090.98	30,707.38
Kenya	377.40	452.80	453.60	587.8	721.9	2,088.3	1,636.30	6,318.1
Malawi	NA	NA	NA	1,064.8	887.2	1,200.3	1,074	4,226.3
Tanzania	NA	NA	NA	544.6	687.7	745.3	493.54	2,471.14
Uganda	NA	NA	NA	1,069.7	3,559.0	4,229.0	6,459.14	15,316.84
Zimbabwe	NA	NA	NA	426.5	439.6	570.0	280.20	1,716.3
Total	763.6	2,580.80	8,010.60	6,513.70	11,428.60	14,424.60	17,034.16	60,756.06

NA: Not applicable : Uganda and Tanzania joined TL II seed systems activities started in 2010/11 as anchoring countries while Zimbabwe and Malawi only received limited technical support (training and TL II experiences sharing by PABRA resources people from anchoring country particularly from Kenya (KARI) and CIAT.

Cowpea seed systems in SSA

Table 94. Quantity of cowpea seed produced (tons) in SSA, by country, by seed class (2008-2014).

	Class and quantity (tons) of seed produced				
	2008-2010		2011-2014		
Country	FS	CS	FS	CS	Total
Nigeria	108.55	991.60	205.15	2,719.91	4,025.21
Mali	22.87	133.8	64.61	716.08	937.36
Niger Republic	15.02	963.01	31.11	5,182.58	6,191.72
Mozambique	21.15	228.30	78.75	666.45	994.65
Tanzania	8.40	2.30	0	0	10.7
Total	175.99	2,319.01	379.62	9,285.02	12,159.64

FS=Foundation Seed, CS= Certified Seed

Soybean seed systems in SSA

Table 95. Tons of soybean seed produced in SSA, by country, by seed class (2008-2014).

	Class and quantity (tons) of seed produced				
	2008-2010		2011-2014		
Country	EG	CS/QDS	EG	CS/QDS	Total
Nigeria	33.8	1,248.30	3,661.83	7,612.08	12,556.01
Mozambique	32.9	762.00	314.60	4,060.87	5,170.37
Kenya	38.3	80.24	64.00	260.31	442.85
Malawi	27.6	122.00	0	0	149.60
Total	132.6	2,212.54	4,040.43	11,933.26	18,318.83

EG=Early Generation seed, CS/QDS= Certified Seed/Quality Declared Seed

Chickpea, groundnut and pigeonpea seed systems in SA

Seed production and supply

Table 96. Tons of chickpea seed produced in SA across target countries (2008-2014).

	Seed classes and amount (tons) produced												
	2008		2009		2010		2011		2012		2013/14		
Country	EG	CS/ QDS	EG	CS/ QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/ QDS	EG	CS/ QDS	Total
India	903.4	13,413	1,407.1	17,857	1,683.3	17,428.9	2,637.8	22,793.5	31,840.0	3,234	18,702.43	136,685	268,585.43
Bangladesh	0	0	0	0	0	0	0	0	21.2	65	28.90	72	187.10
Total	903.4	13,413	1,407.1	17,857	1,683.3	17,428.9	2,637.8	22,793.5	31,861.2	3,299	18,731.33	136,757	268,772.53

EG=Early generation seed (Breeder seed/ Basic seed); CS/QDS=Certified seed/ Quality declared seed
NT: Not yet

Table 97. Tons of groundnut seed produced in SA across target countries (2008-2014).

	Seed classes and amount (tons) produced												
	2008		2009		2010		2011		2012		2013/14		
Country	EG	CS/ DS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/ QDS	Total
India	158.65	618.7	497.87	1,251.68	381.09	2,710.48	1,874.18	4,237.50	2,503.1	3,613.5	2,733.32	7,659.69	28,239.76
Bangladesh	0	0	0	0	0	0	0.63	1.62	6.0	6.0	59.95	158.4	232.6
Total	158.65	618.7	497.87	1,251.68	381.09	2,710.48	1,874.81	4,239.12	2,509.1	3,619.5	2,793.27	7,818.09	28,472.36

EG=Early generation seed (Nucleus/Breeder/Foundation seed); CS/QDS=Certified seed/ Quality declared seed

Table 98. Tons of pigeonpea seed produced in SA across target countries (2008-2013).

	Seed classes and amount (tons) produced												
	2008		2009		2010		2011		2012		2013/14		
Country	EG	CS/ QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	EG	CS/QDS	Total
India	0	0	13.45	6.5	29.88	68.76	300.34	161.52	186.92	1,014.15	620.19	1,120.43	3,522.14
Bangladesh	-	-	-	-	-	-	-	-	-	-	-	-	
Total	0	0	13.45	6.5	29.88	68.76	300.34	161.52	186.92	1,014.15	620.19	1,120.43	3,522.14

EG=Early generation seed (Breeder /Foundation seed); CS/QDS=Certified seed/ Quality declared seed

Adoption and use of newly released varieties

Impressive results were also achieved in improved varieties release process, adoption and retention. During phases I and II, a total of 163 varieties were released through farmer participatory variety selection; of which, 106 varieties are still in production (Figure 16), representing 65% retention. This resulted from rigorous and well-coordinated research for development that clearly focused on end-user preference. The process was also enhanced by sound collaboration between the TL II Project, NARS, civil society, farmer organizations, seed companies as well as local seed and grain dealers.

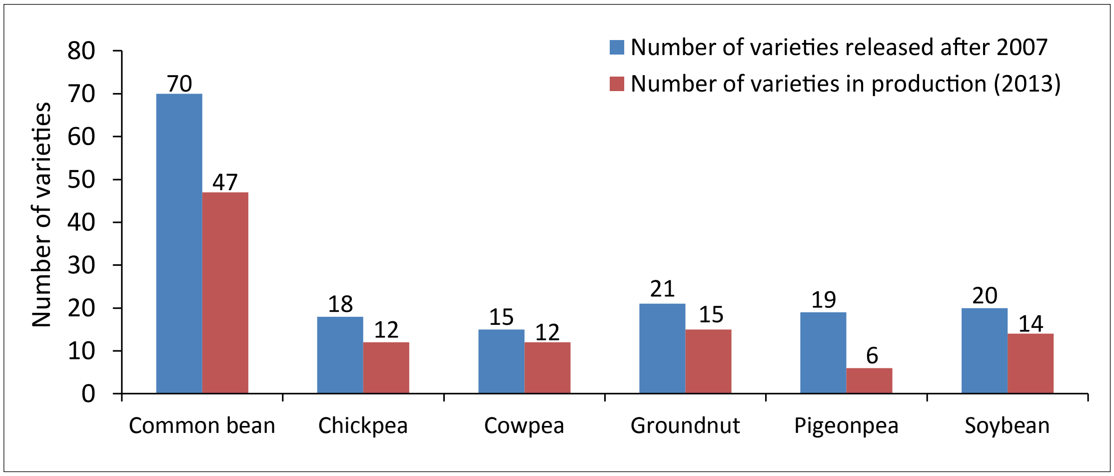

Figure 16. Number of varieties released in TL II countries after 2007 and those in production, by crop.

Conclusion

While resource-poor farmers are ready to adopt new improved varieties of legumes, it is also worth noting that the variety, complementary technologies and seed delivery can together achieve the desired impact. Moreover, an efficient seed system for delivering varieties has to be linked to the commodity value chain; developed grain markets are an obvious driver of seed demand through which the need for productivity is justified. The seed delivery systems may intrinsically be region-and-crop-specific; therefore, a pluralistic approach offers an opportunity to identify the best bets, especially when enabled by policies that recognize seed outside the certification scheme. The recognition of quality declared seeds, contributed significantly to the access of improved legume varieties and shortening the lag time in variety release and adoption by farmers. It is also critical that investment should be made towards creating awareness of new varieties.

Gross Economic Benefits from Tropical Legumes II modern varieties in Project Countries

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The Tropical Legumes II (TL II) project aims to increase the productivity (yield per unit area) and production (total availability) of six major grain legumes – chickpea, common bean, cowpea, groundnut, pigeonpea and soybean in rural areas of SA an SSA. The project worked in a total of fourteen countries: twelve in SSA (Burkina Faso, Ghana, Mali, Niger, Nigeria, Ethiopia, Kenya, Malawi, Mozambique, Senegal, Tanzania, Uganda and Zimbabwe) and two in SA (India and Bangladesh) during the Phase II. Burkina Faso, Ghana, Uganda are new anchor countries during phase II.

The project focused on developing improved legume varieties and ensuring that smallholder farmers have access to seed of these varieties, in the context of ongoing environmental constraints such as drought, pests and diseases. In particular, efforts were targeted on the informal and formal seed sector and the supply of quality seed, which is a major constraint in the adoption of legumes. The expected increase in added value of productivity gains in the rural areas of these regions will amount to about $1.3 billion over the ten year period 2007 to 2017. It is expected that at least 50 new varieties, with yield advantages of at least 20% over the adapted checks, across the six crops will be released to farmers, with the seed sector (public and private) producing more than 96,000 tons of quality seed, enough to plant 1.6 million ha through the formal seed sector and considerably more when informal distribution systems are added.

During the first two phases (2007 to 2014), more than 100 varieties have been released, yielding more than 20% over the local checks. More than 112,000 tons of seed of modern legume varieties were produced directly with project funds and more than 354,000 tons with project and partners' investment. In addition, the total amount of seed produced during the 2 phases covered almost 2 million ha with the funds provided under TL and almost 6 million ha with project and partners' investment. The average adoption rate of modern legume varieties in TL countries is estimated to 23.82% of area cropped with legumes. So far, the project has attained some of its major targets only after 7 years of implementation. The total gross benefits from project intervention was computed using two approaches: (1) the total seed produced during the years of project implementation and (2) the adoption rate data from adoption surveys and/or expert opinions conducted between 2010 and 2012.

It is estimated that, since 2007, modern legume varieties (MVs) developed/disseminated under the TL project implemented by ICRISAT, CIAT, and IITA with NARS partners have been adopted on at least **2 million ha** and have generated more than $448 million from project funding and $976 million from project and partners' investment. Even when using the adoption rates data from adoption and expert opinion surveys, the aggregate gross benefits from TL related modern legume varieties is estimated at about $978 million, which is still far above the total TL investment grossly compounded at $48 million[1] (phases 1 and 2). The returns on investment are high. In effect, for each TL dollar invested, the project generates $9 with direct project investment, $20 with partnership's investment and again $20 when using adoption rate based estimation.

1. Uncompounded investment is $42 million. Compound rate is about 5% as in many projects in SSA with annual investment roughly estimated to $7 per year

Methods and data

In order to compute the gross benefits resulting from TL intervention, two approaches were used. One approach was based on the quantity of seed produced during the 7 years of project implementation, and the second approach was based on adoption rates estimated from adoption surveys or expert opinions.

a. Seed based estimation of total gross benefits

The concept of cumulative adoption implied by the logistic function was applied. The area planted to MVs (or the number of adopters) in a given year includes the new area planted to MVs (or the new adopters) in that year as well as the areas planted to MVs in all previous years. The area planted was estimated based on the quantity of seed produced each year. It was assumed that the seed produced is recycled every 5-6 years and improved seed generates a stream of benefits with the yield gains accruing beyond the year of planting of fresh seed. Thus, the annual benefits were aggregated across the years to derive the total benefits for the whole 2008-2013 period. The gross benefit calculation per year was based on the cumulative quantity of seed produced over the years, the seeding rate, the yield with the local varieties, the yield gains over the local check, and the producer price of the crop from FAO. The yield gains were obtained from survey data using econometric methods where available or adjusted on-farm trials where not available. The parameters used in the calculation of gross benefits from TL investment since 2007 include:

1. The quantity of seed produced in year *t* (QS*t*)(tons)
2. The seeding rate [SR] (kg ha^{-1})
3. The percent yield gain over the local check [PYGOL] (%)
4. The yields with local varieties [YLO] (tons/ha)
5. The FAO producer price of the crop [PPCROP] ($/ton)

The gross economic benefits using the seed based approach (*GEBSEED*) were estimated as the value of additional crop production per year (*t*) and country as follows:

$$GEBSEED_{2013} = \frac{(1000 \times \sum_{t=2008}^{2013} QSt)}{SR} \times YLO \times PYGOL \times PPCROP$$

The total value of additional production was aggregated over crop, country and year.

b. Adoption rates based estimation

Adoption is an outcome resulting from increased productivity. Farmers convinced with increased productivity from modern varieties are likely to use more and more of the varieties. Adoption rate expressed in terms of percentage of area adopted along with productivity gains provide gross measures of additional gross benefits from using modern varieties. The gross benefit calculation was based on the adoption rates obtained from formal adoption surveys that are nationally representative or expert opinion surveys. The following parameters were used to compute the total gross economic benefits from TL intervention. These include the adoption rate (% area), the area under the crop (ha), the yield of the local varieties/local check (tons/ha), the yield gains over the local check (%), and FAO producer price of the crop from FAO statistics.

The parameters are measured as follows:

6. The adoption rate (% area) [ADOPAREA]
7. The area cultivated under the crop (ha) [AREACROP]
8. The yields of the local varieties/local check (tons/ha) [YLO]
9. The yield gains over the local check [YLDGAINS] (%)
10. The FAO producer price of the crop [PPCROP] ($/ton)

The total gross economic benefits using the adoption rate approach (*GEBADOPT*) were calculated as follows:

$$GEBADOPT_{2013} = \frac{ADOPAREA \times AREACROP}{100} \times \frac{YLO \times YLDGAINS}{100} \times PPCROP$$

The adoption rate used was derived from adoption surveys that are representative of the major growing areas of the respective legumes. However, because adoption studies were not conducted for all crops and countries, expert opinions collected in other Bill & Melinda Gates Foundation projects such as DIVA and TRIPSA were used. These rates were adjusted depending on actual information one has about the period.

Results

Appendix 6 through 26 provide the individual calculations of gross benefits by crop, country and scenarios. Tables 99-101 presents a summary of gross economic benefits derived from TL related modern legume varieties from 2007 to 2013 under 2 scenarios on (1) seed production and on (2) adoption rate by crop and region scenario. Using seed production, the total gross benefits were calculated with seed produced using project funds and seed produced using both project and partners' investment. The latter provided measures on the effect of partnering in seed production. Using the total seed produced with project funds, the total gross benefits were estimated at $448.884.845 compared with $1.566.362.854 using both project and partners' funds, indicating the significant impact of partnering in seed production. In effect, the total gross benefits have more than tripled. Using the adoption rates, the gross benefits from project intervention were estimated at about $976.730.258.

Most of the direct gross benefits were derived from chickpea in South Asia accounting for about 59% of the total gross benefits of the project followed by common beans in ESA (20%) and pigeonpea in ESA (5%). Without accounting for chickpea in South Asia, most of the gross benefits are accounted for by the adoption of common beans in ESA (48%), pigeonpea in ESA (11%), cowpea in WCA (10%), etc (Table 100). Though West and Central Africa has the largest area cultivated to groundnut and cowpea, it is noted that the quantity of seed produced is still very low. The search for alternative institutional arrangements to increase seed production in countries and crops remain essential in increasing the gross benefits from TL II investments and thus impacts of TL II investments in WCA.

When including partners' investments, it is noted that more than 65% of the gross benefits is realized through chickpea in SA, followed by groundnut in ESA (9%), common bean in ESA (6%), and soybean WCA (4%). Total gross benefits are 3.5 times higher due to strong partnership.

The significant drop in the share of common beans in ESA in total gross benefits may be explained by the weak partnership in seed production when compared to groundnut or chickpea in ESA.

When using the adoption rate estimates, the share of the gross benefits significantly changes. In fact, chickpea accounts for about 25% of total gross benefits followed by groundnut in ESA (23%), cowpea in

Table 99. Total gross benefits derived from TL II related modern legume varieties from 2007-2013 from direct funding from TL II; including partners' funding and with adoption data.

		Additional production					
		Direct TL II funding (Seed)		Including partners' funding (Seed)		With adoption data	
Crop	Region	Value ($)	Percent of total	Value ($)	Percent of total	Value ($)	Percent of total
Common bean	ESA	87,729,042	19.54%	93,218,739	5.95%	97,118,775	9.94%
Cowpea	WCA	18,106,550	4.03%	52,530,800	3.35%	171,848,588	17.59%
	ESA	2,013,900	0.45%	3,208,275	0.20%	8,775	0.00%
Groundnut	ESA	249,624	0.06%	140,938,849	9.00%	220,393,530	22.56%
	WCA	11,780,249	2.62%	15,667,599	1.00%	59,911,053	6.13%
	SA	2,826,623	0.63%	32,531,282	2.08%	10,871	0.00%
Pigeon pea	ESA	20,894,784	4.65%	49,634,696	3.17%	37,467,104	3.84%
	SA	6,210,978	1.38%	30,085,440	1.92%	65,097,080	6.66%
Chickpea	ESA	7,875,685	1.75%	44,479,455	2.84%	43,516,886	4.46%
	SA	266,330,610	59.33%	1,019,913,136	65.11%	248,146,829	25.41%
Soybean	WCA	10,605,000	2.36%	59,841,250	3.82%	33,173,095	3.40%
	ESA	14,261,800	3.18%	24,313,333	1.55%	37,672	0.00%
Total gross-benefits ($)		**448,884,845**	**100.00%**	**1,566,362,854**	**100.00%**	**976,730,258**	**100.00%**

Table 100. Total gross benefits derived from TL II related modern varieties from 2007-2013 from direct funding from TL II; including partners' funding and with adoption data (excluding chickpea in SA).

		Additional production					
		Direct TL II funding (Seed)		Including partners' funding (Seed)		With adoption data	
Crop	Region	Value ($)	Percent of total	Value ($)	Percent of total	Value ($)	Percent of total
Common bean	ESA	87,729,042	48.06%	93,218,739	17.06%	97,118,775	13.33%
Cowpea	WCA	18,106,550	9.92%	52,530,800	9.61%	171,848,588	23.59%
	ESA	2,013,900	1.10%	3,208,275	0.59%	8,775	0.00%
Groundnut	ESA	249,624	0.14%	140,938,849	25.79%	220,393,530	30.25%
	WCA	11,780,249	6.45%	15,667,599	2.87%	59,911,053	8.22%
	SA	2,826,623	1.55%	32,531,282	5.95%	10,871	0.00%
Pigeon pea	ESA	20,894,784	11.45%	49,634,696	9.08%	37,467,104	5.14%
	SA	6,210,978	3.40%	30,085,440	5.51%	65,097,080	8.93%
Chickpea	ESA	7,875,685	4.31%	44,479,455	8.14%	43,516,886	5.97%
Soybean	WCA	10,605,000	5.81%	59,841,250	10.95%	33,173,095	4.55%
	ESA	14,261,800	7.81%	24,313,333	4.45%	37,672	0.01%
Total gross-benefits ($)		**182,554,235**	**100.00%**	**546,449,718**	**100.00%**	**728,583,429**	**100.00%**

Table 101. Total gross benefits derived from TL II related modern varieties from 2007-2013 from direct funding from TL II and direct and indirect funding from TL II by region and country.

		Additional production			
		Direct funding (seed)		Including partners' funding (seed)	
Region	Country	Value ($)	Percent of total	Value ($)	Percent of total
ESA	Kenya	8,844,033	2.01%	22,272,886	1.42%
	Tanzania	12,890,619	2.94%	103,122,340	6.59%
	Malawi	18,265,442	4.16%	98,439,364	6.29%
	Uganda	32,874,159	7.49%	33,811,252	2.16%
	Zimbabwe	257,775	0.06%	3,858,316	0.25%
	Ethiopia	36,337,778	8.28%	72,537,956	4.63%
	Mozambique	13,592,324	3.10%	21,751,232	1.39%
WCA	Mali	4,830,688	1.10%	10,201,088	0.65%
	Niger	4,038,504	0.92%	9,349,404	0.60%
	Nigeria	31,098,426	7.09%	107,963,705	6.89%
	Burkina Faso	267,294	0.06%	267,294	0.02%
	Ghana	254,768	0.06%	254,768	0.02%
	Senegal	2,119	0.00%	3,391	0.00%
SA	India	275,210,205	62.70%	1,081,977,988	69.10%
	Bangladesh	158,007	0.04%	55,187	0.00%
Total gross-benefits ($)		438,922,141	100.00%	1,565,866,171	100.00%

WCA (18%), and 10% for common beans. If one excludes chickpea in SA, groundnut accounts for 30% of the total gross benefits followed by cowpea in WCA (24%), common bean in ESA (13%), pigeonpea in SA (9%), groundnut in WCA (8%), etc.

Country-wise, with direct project funding, the total gross benefits from TL II related modern varieties is dominated by India accounting for 62%, followed by Ethiopia (8%), Uganda (7%), Nigeria (7%), etc. Similar trends are observed with project and partners' investments with India accounting for 69% now followed by Tanzania and Nigeria (7% each). The lowest shares are recorded in West Africa countries except for Nigeria. With direct project investments, when examining the gross benefits per hectare of legume cropped area, it is noted that Ethiopia has the largest benefit $211.74 /ha of legume cropped area, followed Mozambique ($27 /ha), Uganda ($23 /ha), Malawi ($19 /ha), Kenya (15%), India (14%). As for the case of total gross benefits, the lowest values of gross benefits per cropped area are recorded in West African countries. Region-wise, SA accounts for 54%, followed by ESA (38%) and lastly WCA with 8% of the total gross economic benefits.

Conclusions and caveats

The results showed that the gross benefits from TL II intervention are very high under different scenarios. Using direct project funding, the total gross benefits are estimated at a little more than $448 million. With partnership investment, the gross benefits increase by more than threefold. These results follow the same trend when using adoption data. The returns on investment are high. In effect, for each TL II dollar invested, the project generates $9 with direct project investment, $20 with partnership's investment and again $20 when using adoption rate based estimation.

There are however severe disparities between regions where SA and ESA accounts for about 90% of the total gross benefits. This calls for more research investments in appropriate institutional arrangements to enhance seed production and uptake in WCA. Investments in irrigation facilities for off-season cropping and breeder seed production may be highly necessary.

This analysis relies heavily on the total quantity of seed produced and does not account for farmers' recycling of seed and improved seed generates a stream of benefits with the yield gains accruing beyond the year of planting of fresh seed. Thus, the annual benefits were aggregated across the years to derive the total benefits for the whole 2008-2013 period. This analysis may suffer from attribution issues when using both the total quantity of seed production or adoption rates. This is likely to be refined as more adoption studies with nationally representative samples are undertaken.

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Appendix 6. Total direct gross economic benefits derived from modern common bean varieties disseminated/developed under the TL II project in ESA (2007-2013).

Country	Certified/QDS seed 2009-2013 (tons)	Seeding rate (kg ha^{-1})	Yield gains over local checks (%)	Yield with local varieties (tons/ha)	Yield gain over local check* (tons/ha)	Area under bean in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of bean at farm gate ($/ton)	Value of additional bean production 2009-2013 ($)
Kenya	4,573.90	70	42	0.79	0.3318	1,078,685	65,341	6.06	21,680	760	16,477,017
Tanzania	1,279.84	70	49.5	0.883	0.437085	817,303	18,283	2.24	7,991	320.5	2,561,248
Malawi	227.00	70	42	0.527	0.22134	306,509	3,243	12.71	8,573	550	4,715,543
Uganda*	8,817.70	70	56.4	0.964	0.543696	1,005,091	125,967	12.53	68,488	480	32,874,159
Zimbabwe	62.00	70	41.2	0.883	0.363796	37,000	886	2.39	322	800	257,775
Ethiopia	20,908.56	70	35.5	0.895	0.317725	331,708	298,694	90.05	94,902	325	30,843,300
											87,729,042

Appendix 7. Total gross economic benefits from modern common bean varieties from direct TL II Project and partnership seed production interventions from 2007 – 2013.

Country	Certified/ QDS seed 2009-2013 (tons)	Seeding rate (kg ha^{-1})	Yield gains over local checks (%)	Yield with local varieties (tons/ha)	Yield gain over local check* (tons/ha)	Area under bean in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of bean at farm gate ($/ton)	Value of additional bean production 2009-2013 ($)
Kenya	4,573.90	70	42	0.79	0.3318	1,078,685	65,341	6.06	21,680	760	16,477,017
Tanzania*	2,223.84	70	49.5	0.883	0.437085	817,303	31,769	2.24	13,886	320.5	4,450,404
Malawi	2,728.00	70	42	0.527	0.22134	306,509	38,971	12.71	8,574	550	4,715,543
Uganda	8,817.70	70	56.4	0.964	0.543696	1,005,091	125,967	12.53	68,488	480	32,874,159
Zimbabwe	928.00	70	41.2	0.883	0.363796	37,000	13,257	2.39	4,823	800	3,858,316
Ethiopia	20,908.56	70	35.5	0.895	0.317725	331,708	298,694	90.05	94,903	325	30,843,300
											93,218,740

Appendix 8. Total gross economic benefits derived from modern common beans varieties and from TL II intervention from 2007 to 2013 using adoption rate data from several sources.

Country/ Variety	Year released	Adoption under variety 2013 (% area)	Average Yield of local varieties (tons)	Yield gain of new varieties over local checks (%)	Average yield gains over local (t/ha)	Area under beans 2012** (ha)	Area under variety 2012/2013 (ha)	Additional production (tons)	Bean price/ton* ($/ton)	Value of additional output in 2012 ($)	Total gross benefits ($)
ETHIOPIA											
Meher season	2003-2011	38.7	0.905	35.5	0.321	331,708	128,370	41,207	325	13,378,641	
Belg season	2003-2011	25.5	0.895	66.1	0.591	112,461	28,678	16,948	325	5,508,241	
	Total										**18,886,883**
UGANDA	1998-2011	13.2	0.964	56.4	0.544	1,060,000	139,920	76,116	480		**36,535,910**
KENYA											
Western region	1998-2011	24	0.85	10	0.085	110,026	26,406	2,245	837.5	1,879,792	
Eastern province	1998-2011	30	0.675	9	0.061	275,065	82,519	5,013	837.5	4,198,433	
Rift valley	1998-2011	16	0.9	10	0.090	275,065	44,010	3,961	837.5	3,317,280	
Central province	1998-2011	21	0.75	10	0.075	137,640	28,904	2,168	837.5	1,815,560	
	Total										**11,211,065**
ZIMBABWE											
Highveld	2007 – 2013	34.2	0.92	29.4	0.8	15,000	5,130	4,104	800	3,283,200	
Midleveld	2007 – 2013	24.4	0.75	36.7	0.6	10,000	2,440	1,464	800	1,171,200	
Lowveld	2007 – 2013	16.1	0.98	58.9	0.8	12,000	1,932	1,546	800	1,236,480	
	Total										**5,690,880**
MALAWI											
High altitude	(2002-2011)	30	0.5	50	0.25	124,971	37,491	9,373	550	5,155,054	
Mid-altitude	(2002-2011)	25	0.5	42	0.21	114,198	28,550	5,995	550	3,297,467	
Low altitude	(2002-2011)	0									
	Total										**8,452,521**

Continued.

Appendix 8. *Continued*

Country/ Variety	Year released	Adoption under variety 2013 (% area)	Average Yield of local varieties (tons)	Yield gain of new varieties over local checks (%)	Average yield gains over local (t/ha)	Area under beans 2012** (ha)	Area under variety 2012/2013 (ha)	Additional production (tons)	Bean price/ton* ($/ton)	Value of additional output in 2012 ($)	Total gross benefits ($)
TANZANIA											
Southern Tanzania	(2002-2011)	18.3	0.883	49.5	0.437	365,661	66,916	29,242	320	9,357,528	
Northern Tanzania	jesca 1997, Selian 98, selian 94	18.6	0.883	35.9	0.317	370,153	68,849	21,825	320	6,983,988	
	Total						690,116	221,207			16,341,516
TOTAL											**97,118,775**

Appendix 9. Total direct gross economic benefits derived from modern cowpea and soybean varieties disseminated/developed under the TL II project in WCA and ESA (2007 to 2013).

Country	Certified/ QDS seed 2008-2013 (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under cowpea in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of cowpea ($/ ton)	Value of additional cowpea production 2013 ($)	Value of additional cowpea production 2008-2013 ($)
Cowpea												
Mali	174	25	80	0.5	0.40	250,000	6,960	2.8	2,784	350	974,400	3,410,400
Mozambique	548	25	100	0.3	0.30	300,000	5,480	5.5	1,644	350	575,400	2,013,900
Niger	339	25	100	0.3	0.30	4,700,000	3,390	0.07	1,017	150	152,550	533,925
Nigeria	1051	25	60	0.7	0.42	3,200,000	17,517	0.5	7,357	550	4,046,350	14,162,225
											5,748,700	**20,120,450**
Soybean												
Malawi	150	60	38	0.8	0.30	75,000	2,500	3.3	760	600	456,000	1,596,000
Mozambique	1734	60	28	0.8	0.22	13,000	28,900	222.3	6,474	500	3,236,800	11,328,800
Nigeria	1212	50	25	1.0	0.25	600,000	24,240	4.0	6,060	500	3,030,000	10,605,000
Kenya	382	60	10	1.0	0.10	2,000	6,367	318.3	637	600	382,000	1,337,000
											7,104,800	**24,866,800**

Appendix 10. Total gross economic benefits from modern cowpea and soybean varieties from direct TL II Project and partnership seed production interventions from 2007 – 2013

Country	Certified/ QDS seed 2008-2013 (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under cowpea in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of cowpea ($/ton)	Value of additional cowpea production 2013 ($)	Value of additional cowpea production 2008-2013 ($)
Cowpea												
Mali	448	25	80	0.5	0.40	250,000	17,920	7.2	7,168	350	2,508,800	8,780,800
Mozambique	873	25	100	0.3	0.30	300,000	8,730	8.7	2,619	350	916,650	3,208,275
Niger	3711	25	100	0.3	0.30	4,700,000	37,110	0.79	11,133	150	1,669,950	5,844,825
Nigeria	2813	25	60	0.7	0.42	3,200,000	46,883	1.5	19,691	550	10,830,050	37,905,175
											15,925,450	**55,739,075**
Soybean												
Malawi	150	60	38	0.8	0.30	75,000	2,500	3.3	760	600	456,000	1,596,000
Mozambique	2800	60	28	0.8	0.22	13,000	46,667	359.0	10,453	500	5,226,667	18,293,333
Nigeria	6839	50	25	1.0	0.25	600,000	136,780	22.8	34,195	500	17,097,500	59,841,250
Kenya	1264	60	10	1.0	0.10	2,000	21,067	1053.3	2,107	600	1,264,000	4,424,000
											24,044,167	**84,154,583**

Appendix 11. Total direct gross economic benefits derived from modern cowpea and soybean varieties from 2007 to 2013 using the adoption rate from several sources.

Country	Adoption of MVs* (% area)	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under cowpea in 2009 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of cowpea ($/ton)	Value of additional cowpea production per year ($)
Cowpea										
Mali	30	80	0.5	0.40	283,665	85,100	30.0	34,040	325	11,062,935
Mozambique	3	100	0.3	0.30	300,000	9,000	3.0	2,700	325	877,500
Niger	9	100	0.3	0.30	4,156,263	374,064	9.0	112,219	130	14,588,483
Nigeria	30	60	0.7	0.42	2,320,590	696,177	30.0	292,394	500	146,197,170
										172,726,088
Soybean										
Malawi	25	38	0.8	0.30	86,796	21,699	25.0	6,596	575	3,792,985
Mozambique	35	28	0.8	0.22	10,000	3,500	35.0	784	480	376,320
Nigeria	36	25	1.0	0.25	592,000	213,120	36.0	53,280	550	29,304,000
Kenya	43	10	1.0	0.10	2,950	1,269	43.0	127	600	76,110
										33,549,415

Appendix 12. Total direct gross economic benefits derived from modern groundnut varieties disseminated/developed under the TL II project in WCA (2007-2013).

Country	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under groundnut in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of groundnut ($/ton)	Value of additional groundnut production ($)
Burkina Faso	466	80	15	0.683	0.10	388704	5,825	1.5	597	447.9	267,294
Ghana	71	80	15	1.304	0.20	356780	888	0.2	174	1467.6	254,768
Mali	1412	80	21	0.765	0.16	340,000	17,650	5.2	2,835	501	1,420,288
Niger	1175	80	35	0.334	0.12	690,853	33,571	4.86	3,925	893	3,504,579
Nigeria	1406	80	20	0.749	0.15	2,342,810	70,300	3.0	10,531	601	6,331,201
Senegal	5	80	15	0.609	0.09	865,770	63	0.0	6	371	2,119
											11,780,249

Appendix 13. Total gross economic benefits from modern groundnut varieties from direct TL II Project and partnership seed production interventions from 2007 – 2013 in WCA.

Country	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under groundnut in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price of groundnut ($/ton)	Value of additional groundnut production ($)
Burkina Faso	466	80	15	0.683	0.10	388704	5,825	1.5	597	447.9	267,294
Ghana	71	80	15	1.304	0.20	356780	888	0.2	174	1467.6	254,768
Mali	1412	80	21	0.765	0.16	340,000	17,650	5.2	2,835	501	1,420,288
Niger	1175	80	35	0.334	0.12	690,853	33,571	4.86	3,925	893	3,504,579
Nigeria	2269	80	20	0.749	0.15	2,342,810	113,450	4.8	16,995	601	10,217,280
Senegal	8	80	15	0.609	0.09	865,770	100	0.0	9	371	3,391
											15,667,599

Appendix 14. Total gross economic benefits derived from modern groundnut varieties from 2007 to 2013 using the adoption rate from several sources.

Variety	Groundnut adoption (2007-2013) (% area)	Average Yield of local varieties (tons)	Yield gain of new varieties over local checks (%)	Average yield gains over local (ton/ha)	Area under groundnut 2012** (ha)	Area under variety 2012/2013 (ha)	Additional production (ton)	Groundnut price/ton* ($/ton)	Total gross benefits (2007-2013) ($)
Burkina Faso	0.5	0.683	15	0.10245	388704	1943.52	199	447.9	89,183
Ghana	0.5	1.303	15	0.19545	356780	1783.9	349	1467.6	511,698
Mali	17.64	0.765	21	0.16065	340000	59976	9,635	501	4,826,244
Niger	10.98	0.334	35	0.1169	690853	75855.66	8,868	893	7,918,701
Nigeria	22	0.749	20	0.1498	2342810	515418.2	77,210	601	46,418,439
Senegal	0.5	0.609	15	0.09135	865770	4328.85	395	371	146,787
						659306.1			**59,911,053.14**

Appendix 15. Total direct gross economic benefits derived from modern groundnut varieties disseminated/developed under the TL II project in ESA (2007-2013).

Country	Varieties released / supported	Certified/ QDS seed* (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Groundnut in 2011 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price of Groundnut ($/ton)	Value of additional Groundnut production per year ($)
Malawi	ALL / average	0			0.50	0.00	353,138	0	0	422	0
	CG 7	0	80	150	0.50	0.75	353,138	0	0	422	0
	Nsinjiro	0	80	150	0.50	0.75	353,138	0	0	422	0
	Baka	0	60	120	0.50	0.60	353,138	0	0	422	0
	Chitala	0	80	100	0.50	0.50	353,138	0	0	422	0
	JL24	0	80	100	0.50	0.50	353,138	0	0	422	0
	Chalimbana 2005	0	80	100	0.50	0.50	353,138	0	0	422	0
	SC Mwenje	0	80	100	0.50	0.50	353,138	0	0	422	0
Tanzania	ALL / average				0.55	0.00	839,631	0	0	422	0
	Mnanje	0	80	150	0.55	0.83	839,631	0	0	422	0
	Pendo	0	80	150	0.55	0.83	839,631	0	0	422	0
	Nachingwea	0	80	130	0.55	0.72	839,631	0	0	422	0
	Mangaka	0	80	150	0.55	0.83	839,631	0	0	422	0
Uganda	ALL / average	0			0.90	0.00	421,000	0	0	422	0
	Serenut 1-14	0	80	70	0.90	0.63	421,000	0	0	422	0
	Serenut 2	0	80	57	0.90	0.51	421,000	0	0	422	0
Yield	Serenut 3R	0	80	57	0.90	0.51	421,000	0	0	422	0
advantage	Serenut 4T	0	80	57	0.90	0.51	421,000	0	0	422	0
averages	Serenut 5R	0	80	57	0.90	0.51	421,000	0	0	422	0
	Serenut 6T	0	80	57	0.90	0.51	421,000	0	0	422	0
	Acholi White	0	80	60	0.90	0.54	421,000	0	0	422	0
	Igola	0	80	40	0.90	0.36	421,000	0	0	422	0
	Red beauty	0	80	0	0.90	0.00	421,000	0	0	422	0
Mozambique	ALL/ average	66.5			0.50	0.00		831	0	429	249,624
	Mamane	30	80	140	0.50	0.70	389,266	375	263	429	112,613
	Nametil	36.5	80	140	0.50	0.70	389,266	456	319	429	137,012
								831			**249,624**

Appendix 16. Total gross economic benefits from modern groundnut varieties from direct TL II Project and partnership seed production interventions from 2007 – 2013 in ESA.

Country	Varieties released / supported	Certified/ QDS seed* (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Groundnut in 2011 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price of Groundnut ($/ton)	Value of additional Groundnut production per year ($)
Malawi	ALL / average	16253.25						203,192		422	63,520,917
	CG 7	13243.4	80	150	0.50	0.75	353,138	165,543	124,157	422	52,394,201
	Nsinjiro	2410.12	80	150	0.50	0.75	353,138	30,127	22,595	422	9,535,037
	Baka	6.25	60	120	0.50	0.60	353,138	104	63	422	26,375
	Chitala	473.44	80	100	0.50	0.50	353,138	5,918	2,959	422	1,248,698
	JL24	46.12	80	100	0.50	0.50	353,138	577	288	422	121,642
	Chalimbana 2005	49.92	80	100	0.50	0.50	353,138	624	312	422	131,664
	SC Mwenje	24	80	100	0.50	0.50	353,138	300	150	422	63,300
Tanzania	ALL / average	17542.2						219,278		422	76,231,214
	Mnanje	4850	80	150	0.55	0.83	839,631	60,625	50,016	422	21,106,594
	Pendo	11562.2	80	150	0.55	0.83	839,631	144,528	119,235	422	50,317,249
	Nachingwea	190	80	130	0.55	0.72	839,631	2,375	1,698	422	716,609
	Mangaka	940	80	150	0.55	0.83	839,631	11,750	9,694	422	4,090,763
Uganda	ALL / average	330.9						4,136		422	937,093
	Serenut 1-14	183.2	80	70	0.90	0.63	421,000	2,290	1,443	422	608,819
Yield	Serenut 2	40.33	80	57	0.90	0.51	421,000	504	257	422	108,498
advantage	Serenut 3R	29.344	80	57	0.90	0.51	421,000	367	187	422	78,943
averages	Serenut 4T	37.326	80	57	0.90	0.51	421,000	467	238	422	100,416
	Serenut 5R	3.11	80	57	0.90	0.51	421,000	39	20	422	8,367
	Serenut 6T	3.09	80	57	0.90	0.51	421,000	39	20	422	8,313
	Acholi White	5	80	60	0.90	0.54	421,000	63	34	422	14,243
	Igola	5	80	40	0.90	0.36	421,000	63	23	422	9,495
	Red beauty	24.5	80	0	0.90	0.00	421,000	306	0	422	0
Mozambique	ALL / average	66.5						831		429	249,624
	Mamane	30	80	140	0.50	0.70	389,266	375	263	429	112,613
	Nametil	36.5	80	140	0.50	0.70	389,266	456	319	429	137,012
								427,437			**140,938,849**

Appendix 17. Total gross economic benefits derived from groundnut varieties disseminated/developed under the TL II project in ESA (2007-2013) using adoption rates from several sources (2007-2013).

Country	Varieties released/ supported	Adoption rate	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under in 2012 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Malawi	ALL / average	0.81		117.1429	0.50	0.59	353,138	286,042	167,539	422	79,295,796
	CG 7	0.367	80	150	0.50	0.75	353,138	129,602	97,201	422	41,018,921
	Nsinjiro	0.141	80	150	0.50	0.75	353,138	49,792	37,344	422	15,759,313
	Baka	0.001	60	120	0.50	0.60	353,138	353	212	422	89,415
	Chitala	0.013	80	100	0.50	0.50	353,138	4,591	2,295	422	968,658
	JL24	0.025	80	100	0.50	0.50	353,138	8,828	4,414	422	1,862,803
	Chalimbana 2005	0.263	80	100	0.50	0.50	353,138	92,875	46,438	422	19,596,687
	SC Mwenje	0	80	100	0.50	0.50	353,138	0	0	422	0
Tanzania	ALL / average	0.32		145	0.55	0.80	839,631	268,682	214,274	422	90,423,557
	Mnanje	0.001	80	150	0.55	0.83	839,631	840	693	422	292,318
	Pendo	0.184	80	150	0.55	0.83	839,631	154,492	127,456	422	53,786,426
	Nachingwea	0.001	80	130	0.55	0.72	839,631	840	600	422	253,342
	Mangaka	n/a	80	150	0.55	0.83	839,631	n/a	n/a	422	n/a
Uganda	ALL / average	0.556		57	0.90	0.51	421,000	234,076	120,081	422	50,674,177
	Serenut 1-14	n/a	80	70	0.90	0.63	421,000	n/a	n/a	422	n/a
	Serenut 2	n/a	80	57	0.90	0.51	421,000	n/a	n/a	422	n/a
	Serenut 3R	0.142	80	57	0.90	0.51	421,000	59,782	30,668	422	n/a
	Serenut 4T	0.119	80	57	0.90	0.51	421,000	50,099	25,701	422	n/a
	Serenut 5R	n/a	80	57	0.90	0.51	421,000	n/a	n/a	422	n/a
	Serenut 6T	n/a	80	57	0.90	0.51	421,000	n/a	n/a	422	n/a
	Acholi White	n/a	80	60	0.90	0.54	421,000	n/a	n/a	422	n/a
	Igola	n/a	80	40	0.90	0.36	421,000	n/a	n/a	422	n/a
	Red beauty	n/a	80	0	0.90	0.00	421,000	n/a	n/a	422	n/a
Mozambique	ALL / average	n/a			0.50	0.00		n/a	n/a	429	n/a
	Mamane	n/a	80	140	0.50	0.70	389,266	n/a	n/a	429	n/a
	Nametil	n/a	80	140	0.50	0.70	389,266	n/a	n/a	429	n/a
								788,800			**$220,393,530**

Appendix 18. Total direct gross economic benefits derived from modern pigeonpea varieties disseminated/developed under the TL II project in ESA (2007-2013).

Country	Varieties released / supported	Certified/ QDS seed* (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Pigeonpea in 2012 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Malawi	ALL / average	770.6						77,060			11,953,899
	Sauma (ICP 9145)	266.2	10	23	0.99	0.23	203,400	26,620	6,061	526	3,188,283
	Kachangu (ICEAP 00040)	164.2	10	30	0.99	0.30	203,400	16,420	4,877	526	2,565,165
	Mwaiwathu Alimi (ICEAP 00557)	241.7	10	35	0.99	0.35	203,400	24,170	8,375	526	4,405,200
	Chitedze Pigeonpea 1 (ICEAP 01514/15)	98.5	10	35	0.99	0.35	203,400	9,850	3,413	526	1,795,251
Tanzania	ALL / average	504.2						50,420			8,940,885
	Mali (ICEAP 00040)	354	10	40	0.945	0.38	290,000	35,400	13,381	486	6,503,263
	Tumia (ICEAP 00068)	28	10	35	0.945	0.33	290,000	2,800	926	486	450,085
	Komboa (ICPL 87091)	25	10	30	0.945	0.28	290,000	2,500	709	486	344,453
	ICEAP 00053	34.7	10	38	0.945	0.36	290,000	3,470	1,246	486	605,593
	ICEAP 00554	28.4	10	35	0.945	0.33	290,000	2,840	939	486	456,514
	ICEAP 00557	19.8	10	35	0.945	0.33	290,000	1,980	655	486	318,274
	ICEAP 00932	14.3	10	40	0.945	0.38	290,000	1,430	541	486	262,702
								127,480			**$20,894,784**

Appendix 19. Total gross economic benefits from modern pigeonpea varieties disseminated/developed from direct TL II project and partnership seed production interventions in ESA (2007-2013).

Country / variety	Certified/ QDS seed *	Seeding rate (tons)	Yield gains over local check (kg ha^{-1})	Yield with local varieties (%)	Yield gain over local check (tons/ha)	Area under Pigeonpea in 2011 (tons/ha)	Area under TL II varieties (ha)	Additional production (ha)	Producer Price (tons)	Value of additional production per year ($/ton)
Malawi [ALL / average]	**1824.6**						**182,460**			**28,606,904**
Sauma(ICP 9145)	527.2	10	23	0.99	0.23	203,400	52,720	12,004	526	6,314,285
Kachangu(ICEAP 00040)	519.9	10	30	0.99	0.30	203,400	51,990	15,441	526	8,121,982
Mwaiwathu Alimi(ICEAP 00557)	650.7	10	35	0.99	0.35	203,400	65,070	22,547	526	11,859,593
Chitedze Pigeonpea 1(ICEAP 01514/15)	126.8	10	35	0.99	0.35	203,400	12,680	4,394	526	2,311,044
Tanzania [ALL / average]	**498.5**						**117,468**			**21,027,792**
Mali(ICEAP 00040)	896.5	10	40	0.945	0.38	290,000	89,650	33,888	486	16,469,422
Tumia(ICEAP 00068)	58.1	10	35	0.945	0.33	290,000	5,810	1,922	486	933,926
Komboa(ICPL 87091)	27.3	10	30	0.945	0.28	290,000	2,730	774	486	376,142
ICEAP 00053	65.6	10	38	0.945	0.36	290,000	6,560	2,356	486	1,144,868
ICEAP 00554	42.4	10	35	0.945	0.33	290,000	4,240	1,402	486	681,557
ICEAP 00557	59.05	10	35	0.945	0.33	290,000	5,905	1,953	486	949,196
ICEAP 00932	25.73	10	40	0.945	0.38	290,000	2,573	973	486	472,681
							299,928			**$49,634,696**

Appendix 20. Total gross economic benefits derived from modern pigeonpea varieties disseminated/developed under the TL II project in ESA using adoption rates from several sources (2007-2013).

Country	Varieties released / supported	Adoption rate	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Pigeonpea in 2011 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Malawi	ALL / average	0.5	29.3	0.99	0.29	203,400	101,700	29,534	526	**14,299,000**
	Sauma (ICP 9145)	0.25	23	0.99	0.23	203,400	50,850	11,579	526	6,090,315
	Kachangu (ICEAP 00040)	0.2	30	0.99	0.30	203,400	40,680	12,082	526	6,355,111
	Mwaiwathu Alimi (ICEAP 00557)	0.05	35	0.99	0.35	203,400	10,170	3,524	526	1,853,574
Tanzania	ALL / average	0.497	35	0.945	0.33	290,000	144,130	47,671	486	**23,168,105**
	Mali (ICEAP 00040)	0.306	40	0.945	0.38	290,000	88,740	33,544	486	16,302,248
	Tumia (ICEAP 00068)	0.003	35	0.945	0.33	290,000	870	288	486	139,848
	Komboa (ICPL 87091)	0.016	30	0.945	0.28	290,000	4,640	1,315	486	639,304
Uganda	ALL / average	n/a		0.8	0.00	101,000	n/a	n/a	422	n/a
							245,830			**$37,467,104**

Appendix 21. Total direct gross economic benefits derived from modern chickpea varieties disseminated/developed under the TL II project in ESA (2007-2013).

Country	Varieties released / supported	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Chickpea in 2012 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Ethiopia	ALL / average	1605.4					239,512					5,630,772
	Arerti	1328.4	140	110	1.19	1.31	239,512	9,489	4.0	12,421	407	5,055,160
	Shasho	151.1	140	68	1.19	0.81	239,512	1,079	0.5	873	407	355,457
	Marye	0.9	120	51	1.19	0.61	239,512	8	0.0	5	407	1,853
	Habru	69.9	140	51	1.19	0.61	239,512	499	0.2	303	407	123,328
	Ejere	16.4	140	26	1.19	0.31	239,512	117	0.0	36	407	14,751
	Natoli	1.2	120	68	1.19	0.81	239,512	10	0.0	8	407	3,293
	Kutaye	3.8	120	68	1.19	0.81	239,512	32	0.0	26	407	10,429
	Teji	16.4	140	51	1.19	0.61	239,512	117	0.0	71	407	28,935
	Bifru	0	132	54,5	1.19	0.65	239,512	0	0.0	0	407	0
	Chefe	12	140	68	1.19	0.81	239,512	86	0.0	69	407	28,230
	Acos Dube	4.8	140	51	1.19	0.61	239,512	34	0.0	21	407	8,469
	Minjar	0.5	120	43	1.19	0.51	239,512	4	0.0	2	407	868
	Arerti, Natoli, Teji, Habru, Sasho*	0	132	54,5	1.19	0.65	239,512	0	0.0	0	407	0
Tanzania	ALL / average	315.2					120,000					1,413,076
	Ukiriguru 1 (ICCV 97105)	150.4	90	46	1.12	0.52	120,000	1,671	1.4	861	822	707,706
	Mwanza 1 (ICCV 00108)	108.8	90	43	1.12	0.48	120,000	1,209	1.0	582	822	478,569
	Mwangaza (ICCV 92318)	28.9	120	54	1.12	0.60	120,000	241	0.2	146	823	119,875

Continued

Appendix 21. *Continued*

Country	Varieties released / supported	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Chickpea in 2012 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
	Mwanza 2 (ICCV 00305)	27.1	105	45	1.12	0.50	120,000	258	0.2	130	822	106,926
Kenya	ALL / average	293..4										831,837
	Chania Desi1 (ICCV 97105)	75.97	90	50	1.00	0.50	190	844	444.3	422	615	259,564
	Saina K1 (ICCV 95423)	82.8	105	35	1.00	0.35	190	789	415.0	276	615	169,740
	ICCV 92944	43.45	90	50	1.00	0.50	190	483	254.1	241	615	148,454
	LTD068 (ICCV 00305)	44.38	105	38	1.00	0.38	190	423	222.5	161	615	98,777
	ICCV 97126	14.9	90	50	1.00	0.50	190	166	87.1	83	615	50,908
	ICCV 97306	3.15	110	35	1.00	0.35	190	29	15.1	10	615	6,164
	LTD065 (ICCV 00108)	28.75	90	50	1.00	0.50	190	319	168.1	160	615	98,229
												$7,875,685

Appendix 22. Total gross economic benefits from modern chickpea varieties disseminated/developed from direct TL II project and partnership seed production interventions in ESA (2007-2013).

Country	Varieties released / supported	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Chickpea in 2012 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Ethiopia	ALL / average	12062.04					239,512					42,234,542
	Arerti	9768.4	140	110	1.19	1.31	239,512	69,774	29.1	91,335	407	37,173,158
	Shasho	1329.5	140	68	1.19	0.81	239,512	9,496	4.0	7,685	407	3,127,596
	Marye	761.4	120	51	1.19	0.61	239,512	6,345	2.6	3,851	407	1,567,268
	Habru	84.56	140	51	1.19	0.61	239,512	604	0.3	367	407	149,193
	Ejere	26.73	140	26	1.19	0.31	239,512	191	0.1	59	407	24,043
	Natoli	4.2	120	68	1.19	0.81	239,512	35	0.0	28	407	11,527
	Kutaye	15.73	120	68	1.19	0.81	239,512	131	0.1	106	407	43,172
	Teji	31.96	140	51	1.19	0.61	239,512	228	0.1	139	407	56,388
	Bifru	0	132	54.5	1.19	0.65	239,512	0	0.0	0	407	0
	Chefe	21.53	140	68	1.19	0.81	239,512	154	0.1	124	407	50,648
	Acos Dube	8.95	140	51	1.19	0.61	239,512	64	0.0	39	407	15,791
	Minjar	9.08	120	43	1.19	0.51	239,512	76	0.0	39	407	15,758
	Arerti, Natoli, Teji, Habru, Sasho*		132	54.5	1.19	0.65	239,512	0	0.0	0	407	0
Tanzania	ALL / average	315.2					120,000					1,413,076
	Ukiriguru 1 (ICCV 97105)	150.4	90	46	1.12	0.52	120,000	1,671	1.4	861	822	707,706
	Mwanza 1 (ICCV 00108)	108.8	90	43	1.12	0.48	120,000	1,209	1.0	582	822	478,569
	Mwangaza (ICCV 92318)	28.9	120	54	1.12	0.60	120,000	241	0.2	146	823	119,875

Continued

Appendix 22. *Continued*

Country	Varieties released / supported	Certified/ QDS seed (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Chickpea in 2012 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
	Mwanza 2 (ICCV 00305)	27.1	105	45	1.12	0.50	120,000	258	0.2	130	822	106,926
Kenya	ALL / average	293.4										831,837
	Chania Desi1 (ICCV 97105)	75.97	90	50	1.00	0.50	190	844	444.3	422	615	259,564
	Saina K1 (ICCV 95423)	82.8	105	35	1.00	0.35	190	789	415.0	276	615	169,740
	ICCV 92944	43.45	90	50	1.00	0.50	190	483	254.1	241	615	148,454
	LTD068 (ICCV 00305)	44.38	105	38	1.00	0.38	190	423	222.5	161	615	98,777
	ICCV 97126	14.9	90	50	1.00	0.50	190	166	87.1	83	615	50,908
	ICCV 97306	3.15	110	35	1.00	0.35	190	29	15.1	10	615	6,164
	LTD065 (ICCV 00108)	28.75	90	50	1.00	0.50	190	319	168.1	160	615	98,229
												$4,479,455

Appendix 23. Total gross economic benefits derived from modern chickpea varieties disseminated/developed under the TL II project in ESA using adoption rates from several sources (2007-2013).

Country	Varieties released / supported	Adoption rate (% area)	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area under Chickpea in 2012 (ha)	Area under TL II varieties (ha)	Additional production (tons)	Producer Price ($/ton)	Value of additional production per year ($)
Ethiopia	ALL / average	0.63	59.55	1.19	0.71	239,512	150,893	106,921	407	43,516,886
	Arerti	n/a	110	1.19	1.31	239,512	n/a	n/a	407	n/a
	Shasho	n/a	68	1.19	0.81	239,512	n/a	n/a	407	n/a
	Marye	n/a	51	1.19	0.61	239,512	n/a	n/a	407	n/a
	Habru	n/a	51	1.19	0.61	239,512	n/a	n/a	407	n/a
	Ejere	n/a	26	1.19	0.31	239,512	n/a	n/a	407	n/a
	Natoli	n/a	68	1.19	0.81	239,512	n/a	n/a	407	n/a
	Kutaye	n/a	68	1.19	0.81	239,512	n/a	n/a	407	n/a
	Teji	n/a	51	1.19	0.61	239,512	n/a	n/a	407	n/a
	Chefe	n/a	68	1.19	0.81	239,512	n/a	n/a	407	n/a
	Acos Dube	n/a	51	1.19	0.61	239,512	n/a	n/a	407	n/a
	Minjar	n/a	43	1.19	0.51	239,512	n/a	n/a	407	n/a
Tanzania	ALL / average	n/a	47	1.12	0.53	120,000	n/a	n/a	822	n/a
	Ukiriguru 1(ICCV 97105)	n/a	46	1.12	0.52	120,000	n/a	n/a	822	n/a
	Mwanza 1(ICCV 00108)	n/a	43	1.12	0.48	120,000	n/a	n/a	822	n/a
	Mwangaza(ICCV 92318)	n/a	54	1.12	0.60	120,000	n/a	n/a	823	n/a
	Mwanza 2(ICCV 00305)	n/a	45	1.12	0.50	120,000	n/a	n/a	822	n/a
Kenya	ALL / average	n/a	44	1.00	0.44	190	n/a	n/a	615	n/a
	Chania Desi1 (ICCV 97105)	n/a	50	1.00	0.50	190	n/a	n/a	615	n/a
	Saina K1(ICCV 95423)	n/a	35	1.00	0.35	190	n/a	n/a	615	n/a
	ICCV 92944	n/a	50	1.00	0.50	190	n/a	n/a	615	n/a
	LTD068(ICCV 00305)	n/a	38	1.00	0.38	190	n/a	n/a	615	n/a
	ICCV 97126	n/a	50	1.00	0.50	190	n/a	n/a	615	n/a
	ICCV 97306	n/a	35	1.00	0.35	190	n/a	n/a	615	n/a
	LTD065(ICCV 00108)	n/a	50	1.00	0.50	190	n/a	n/a	615	n/a
							150,893			**$43,516,886**

Appendix 24. Total direct gross economic benefits from TL II related modern groundnut, chickpea and pigeonpea varieties disseminated/ developed under the TL II project in South Asia (SA) (2007-2013).

Country	Certified/ QDS seed* (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production ($)
Groundnut											
India (2008-2013)	1821	125	40	1	0.40	5,856,145	14,568	0.2	5,827	483	2,814,538
Bangladesh (2011-13)	9	125	30	0.8	0.24	31,755	72	0.2	17	699	12,086
											2,826,623
Chickpea											
India (2008-2013)	56833	62	45	1.35	0.61	9,190,000	916,661	10.0	556,872	478	266,184,689
Bangladesh (2012-2013)	53	62	30	1	0.30	8,229	855	10.4	256	569	145,921
											266,330,610
Pigeonpea											
India (2008-2012)	307	5	22	0.95	0.21	4,420,000	61,400	1.4	12,833	484	**6,210,978**

Appendix 25. Total gross economic benefits from modern groundnut, chickpea and pigeonpea varieties disseminated/developed from direct TL II project and partnership seed production interventions in SA (2007-2013).

Country	Certified/ QDS seed* (tons)	Seeding rate (kg ha^{-1})	Yield gains over local check (%)	Yield with local varieties (tons/ha)	Yield gain over local check (tons/ha)	Area in 2011 (ha)	Area under TL II varieties (ha)	Adoption rate of TL II varieties (%)	Additional production (tons)	Producer Price ($/ton)	Value of additional production ($)
Groundnut											
India (2008-2013)	20,940	125	40	1	0.40	5,856,145	167,520	2.9	67,008	483	32,364,864
Bangladesh (2011-13)	124	125	30	0.8	0.24	31,755	992	3.1	238	699	166,418
											32,531,282
Chickpea											
India (2008-2013)	217,679	62	45	1.35	0.61	9,190,000	3510,952	38.2	2,132,903	478	1,019,527,684
Bangladesh (2012-2013)	140	62	30	1	0.30	8,229	2,258	27.4	677	569	385,452
											1,019,913,136
Pigeonpea											
India (2008-2012)	1480	5.0	22	1.0	0.20	4,420,000	296,000	6.7	62,160	484	**30,085,440**

Appendix 26. Total gross economic benefits derived from modern pigeonpea, chickpea and groundnut varieties disseminated/developed under the TL II project in SA using adoption rates from several sources (2007-2013).

	Year	Adoption rate (% area)	Avg. yield of local varieties (tons/ha)	Yield gain of new cultivars than check (%)	Average yield gain over local (tons/ha)	Area under crop in 2012 (ha)	Area under TL II varieties (ha)	Additional Production (tons)	Price/ton ($/ton)	Value of additional production ($)	Total benefits ($)
Groundnut											
Tamil Nadu	2013	8	1.8	35	0.63	386,000	309	195	483	93,965	
Karnataka	2011	1	1.2	30	0.36	848,000	85	31	483	14,745	
											108,710
Chickpea											
Andhra Pradesh	2013	85	1.35	45	0.6075	615,000	522,750	317,571	478	151,798,759	
Karnataka	2013	65	1	35	0.35	886,000	575,900	201,565	478	96,348,070	
											248,146,829
Pigeonpea											
Andhra Pradesh	2011	31	1.1	25	0.275	498,000	154,380	42,455	484	20,547,978	
Maharashtra	2011	40	0.95	22	0.209	1,101,000	440,400	92,044	484	44,549,102	
											65,097,080

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369-2015

ISBN 978-92-9066-568-7