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

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2007 – 2014

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Project:
Tropical Legumes-III
(TL III)

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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.

		Constraint level		
Country	Crop	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.