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

Ousmane Boukar, Steven Boahen, Bandyopadhyay R, Lava Kumar P, Christian Fatokun, Robert Abaidoo, Issa Drabo, Haruna Mohammed, Mamadou Touré, Moutari Adamou, Mohammad Ishiyaku, Olufajo Olusoji, Joseph Mligo, Meshack Makenge and Manuel Amane

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

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

Table 24. Cowpea varieties released in different countries.

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.