TROPICAL LEGUMES III

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Bulletin of Tropical Legumes

About the bulletin

The Bulletin of Tropical Legumes is a quarterly publication of the Tropical Legumes III (TL III) project. The project is funded by the Bill & Melinda Gates Foundation and jointly implemented by the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA) in close collaboration with the national agricultural research systems (NARS) of target countries in sub-Saharan Africa and South Asia. In this quarter, we will be focusing on the progress made in groundnut breeding and seed systems during the two years of project implementation, 2015 and 2016. Groundnut breeding is under Objective 2: *Enhanced Groundnut productivity and Production in focus geographies of Sub-Saharan Africa*. Groundnut seed system is a component of Objective 6: *Sustainable and impact-oriented legume seed delivery systems for smallholders*.

Executive Summary

Groundnut Breeding _ICRISAT routinely develops breeding populations and recently NARS programs have initiated crossing programs to develop new populations. A total of 289 F1 populations were developed during 2015 crop season (ICRISAT-252, NARS-37) for various traits of interest including resistance to foliar diseases, rosette and aflatoxin, tolerance to drought, and early maturity. In 2016, the number of crosses made significantly increased to 396 F1 populations developed in total (ICRISAT-248, NARS-148). Fifty-six on-station and multi-location trials (ICRISAT-17, NARS-39) were conducted during the two years (i.e. 22 in 2015 and 34 in 2016) and 338 FPVS trials (ICRISAT-148, NARS-190) were conducted in the same period (i.e. 81 in 2015 and 257 in 2016). A total of five (Tanzania-3, Mali-2) farmer-preferred varieties of groundnut were released in 2016/17. A total of 15 varieties were identified for potential release in 2017/18 (Ghana: 6, Burkina Faso: 6, Uganda: 3). More than 76 metric tons of breeder seed of improved varieties released during Tropical Legumes II (TL II) and TL III were made available to support the groundnut seed system. Breeding improvement plans were developed and are being implemented to enhance genetic gains of ICRISAT hubs and NARS breeding programs. The number of crosses made (populations developed) and the size of multi-location trials (number of trials, entries and locations) are expected to increase during the 2017 crop season and subsequent years.

Seed system - In total, 19 multi-stakeholder platforms were established/strengthened at national and/or regional levels. To build the capacities of platform members in seed production techniques, good agronomic practices, post-harvest handling, seed marketing and group dynamics across legumes, 46 training and short course programs were organized benefiting 8,502 (4,271 male, 4231 female) platform members. More than 1300 demonstrations were conducted and 290 field days were organized to create awareness on improved groundnut varieties. More than 425 metric tons of basic (foundation) seed and 11,210 metric tons of certified/QDS seed of improved groundnut varieties were produced and injected into the groundnut seed system in the target countries. Twenty-four agri/seed fairs were organized across the target countries to link value chain actors. For 2017 and the following years, ICRISAT and partners will build on the achievements made so far and enhance efforts to achieve the project targets for a larger impact.

Quality Declared groundnuts seeds in small packs being marketed by seed marketers at the World Food Day (WFD) Celebration in Uganda_2

Project: Tropical Legumes III (TL III)

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

Investor: Bill & Melinda Gates Foundation

Partners: CIAT, ICRISAT, IITA

Introduction

Groundnut (*Arachis hypogaea L.*) is a major tropical legume cultivated across the world. Cultivated mainly by smallholder farmers, the crop plays an important role in sub-Saharan Africa. Countries like Nigeria, Senegal and Ghana, for instance, are among the top 10 global producers. It is grown for both household consumption and as a cash source. As a food crop, it is highly nutritious with 28% protein and contains many essential nutrients. As a cash crop, it accounts for up to 50% or more of the household cash income in many countries in West and Central Africa. Involvement of women and youth at various stages of groundnut value chain is very high in sub-Saharan Africa. For instance, 85% of groundnut fields in Mali are "owned" by women, and almost all small-scale groundnut processing (oil extraction) is done by women in Nigeria. The groundnut sector has benefited from several development projects over the years. The TL II project was implemented to improve the livelihoods of smallholder farmers in drought-prone areas of sub-Saharan Africa and South Asia through grain legumes production and productivity. The TL III project was designed to build on the achievements of TL II for making sustained larger impacts. Objective 2 and Objective 6 of the TL III project are complementary to increase productivity and production of groundnut through developing improved production technologies (Objective 2), and promoting and improving access to improved production technologies, particularly seed (Objective 6). Six countries are targeted for groundnut breeding and seed system (Figure 1): four countries - Burkina Faso, Ghana, Mali and Nigeria from West and Central Africa (WCA) and two countries - Tanzania and Uganda from East and Southern Africa (ESA).

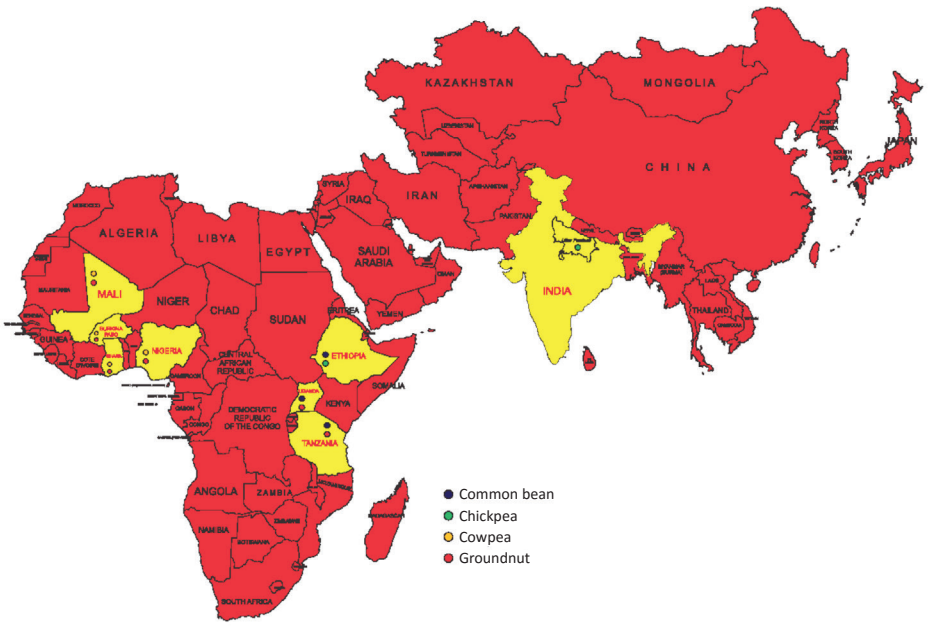

Figure 1. TL III Focus Geographies and Crops.

Objective 2 – Groundnut Breeding

Objective 2 aims to "Enhance the groundnut productivity and production in focus geographies of sub-Saharan Africa" by achieving realized productivity gains of 20% over local, and 10% over best improved varieties in groundnut production areas where seed of the improved varieties developed by the project have been extended in the six targeted countries. This objective is led by ICRISAT and the implementation of the planned activities in each country is led by NARS partners in ESA: Naliendele Agricultural Research Institute (NARI) - Tanzania and National Semi-Arid Resources Research Institute (NaSSARI) - Uganda; and in WCA: The Institute for Agricultural Research (IAR)/ Bayero University, Kano (BUK) - Nigeria, Institut d'Economie Rurale (IER) – Mali, Institut de l'Environnement et des Recherches Agricoles (INERA) - Burkina Faso and Savanna Agricultural Research Institute (SARI) - Ghana). The three breeding programs at ICRISAT regional offices (i.e. ICRISAT-SA, ICRISAT-ESA & ICRISAT-WCA) provide backstopping support. The center of excellence in genomics (CEG) in the Genetic Gain Research Program at Patancheru, Hyderabad, India, plays the lead role in developing genomic tools and providing pre-breeding support.

Objective 2 has five main activities, which are complementary covering sub-activities from discovery to final product delivery. The expected intermediate results of the main activities are: (i) **Trait discovery pipeline** - improving the understanding of genetic mechanisms governing key constraints and utilizing molecular technology to improve the efficiency of selection, (ii) **Breeding pipeline** - NARS partners using improved breeding lines for developing better varieties, (iii) **Testing for release** - NARS partners regularly releasing superior cultivars, (iv) **Best bet varieties -** farmers using improved cultivars, integrated crop management (ICM) practices and realizing higher yields, (v) **Genetic gain** - Enhanced genetic gain of CGIAR African hubs and partners that focus on breeding program improvement.

The five main activities contain several sub-activities that contribute towards enhancement of productivity and production in focus geographies of Sub-Saharan Africa. We highlight key progresses made towards trait discovery, trait introgression into breeding pipelines, testing of advanced lines towards release process, evaluation and promotion of best bet varieties as well as enhancement of genetic gains.

A training provided for 36 groundnut seed producers and distributers in Ghana.

Participants at a field day during harvest to compare technologies demonstrated to farmers' own practice in Ghana.

2.1 Trait Discovery

This activity has been focused on 1) developing genomic tools, 2) establishing/improving phenotyping platforms for drought and aflatoxin; and 3) improving data collection, analysis, storage and sharing capacity.

2.1.1 Trait Discovery Pipelines at ICRISAT Hubs

Developing genomic tools - This activity is led by ICRISAT whereby NARS partners are supported by ICRISAT's Global Genetic Gains Research Program. A high throughput genotyping platform, an Axiom_Arachis single nucleotide polymorphism (SNP) array with 58K genome-wide SNPs was developed and it is expected to accelerate the process of high resolution trait genetics and molecular breeding in cultivated groundnut. Thirty non-synonymous SNPs were identified for rust resistance affecting 25 candidate genes while 14 intronic and three synonymous SNPs were identified for LLS resistance affecting nine candidate genes. A panel of 10 SNPs for oil quality and foliar disease resistance (rust and LLS) have been verified through HTPG platform for further use in breeding material. SSR-based markers for rust resistance, late leaf spot resistance and high oleic acid have successfully been deployed in developing improved lines for foliar disease resistance and oil quality. Populations for drought QTL analysis have been developed at ICRISAT Mali and are being advanced to develop RIL population which will be genotyped for marker trait associations. A total of 110 advanced breeding (42 from ICRISAT Mali and 68 from ICRISAT Nigeria) lines were sent to ICRSAT-Nairobi for genotyping using validated markers for LLS, rust and oleic acid. The objective is to identify lines that have the validated markers so that they will be used as parents to develop populations.

Digitizing data management – All ICRISAT hubs have acquired handheld tablets for digitized data collection, transfer and storage for subsequent analysis. BMS is being used for generating breeding trials and analyzing and storing data. Most of the programs plan to finish migrating earlier year's data to BMS cloud by the end of 2017. ICRISAT biometrics unit led by Dr. Abhishek Rathore is backstopping the process. TL III project coordination office organized training on use of BMS for NARS breeders in Nairobi, Kenya in 2015. Dr. Rathore has been providing technical support to NARS programs. Training sessions for NARS breeding technicians from the project target countries were organized from 3 to 7 July 2017 at Nairobi, Kenya for ESA and from 24 to 28 July 2017 at Bamako, Mali for WCA. A total of 34 technicians (18 from ESA and 16 from WCA) working on beans, chickpea, cowpea and groundnut benefited from the sessions. Local training programs were also organized by ICRISAT hubs in each region, covering BMS as well. ICRISAT Mali trained four technicians (2 Mali, 2 Burkina Faso) on groundnut breeding techniques and data management including use of handheld devices and BMS. ICRISAT Nigeria trained one breeder and one technicians from IAR groundnut breeding program.

2.1.2 Trait Discovery Pipelines in focus countries

Deploying genomic tools - All the NARS programs have recently initiated crossing programs for various traits (short duration, resistance/tolerance to drought, foliar disease, aflatoxin, rust) and some are in the process of integrating/utilizing the SNP genotyping platform and validated markers (see 2.2 below). Drought and aflatoxin phenotyping platforms are being established through installation of irrigation facilities. The irrigation facilities are also being used for hybridization and seed (breeder and foundation) production during off-season. Simultaneously, the programs are evaluating/phenotyping advanced lines obtained from different sources - for further evaluation in multi-location trials to identify farmer preferred varieties for release (see 2.3. below).

Digitizing data management – All NARS programs are using digitized data collection, analysis and storage. The breeders received training on BMS, and all have adopted BMS where many programs have started migrating data to BMS Cloud. In Burkina Faso, INERA acquired three handheld devices and four technicians were trained

in the use of the devices for capturing data in the field in 2015. In Ghana, SARI acquired four Samsung Tablet devices and four technicians were trained in the use of the devices for capturing data in the field in 2015 and the program is using BMS to store such data. In Mali, IER purchased two handheld devices and two computers in 2015. BMS software (3.09) was installed on the computers and three technicians were provided on-job BMS training as well as at ICRISAT Mali. In Nigeria, four data capturing handheld devices were procured for the IAR groundnut improvement team. Two breeders and a technician attended the training session on BMS. In case of Tanzania, in 2015, 12 individuals [8 scientists and four technicians] were trained and are using BMS tool in day-to-day breeding pipeline activities. The program procured two Samsung Galaxy tablets in 2015 and are being used by scientists and technicians for e-data capturing. In Uganda, NaSARRI has digitized data management and the working germplasm and their pedigree have been sent to ICRISAT-India and uploaded on the BMS.

2.2 Breeding Pipelines

The breeding pipeline activities have been focused on developing new populations and evaluating segregating populations in observation nurseries for specific input and output traits. These include: 1. Short-duration (SD) breeding lines with moderate levels of resistance to rust, late leaf spot (LLS) and early leaf spot (ELS); 2. SD + drought tolerance, SD + high oil, SD + confectionery, SD and aflatoxin resistant; 3. Drought-tolerant breeding lines; and 4. Medium-duration (MD) breeding lines. In 2015, a total of 289 F1 populations were developed in the target countries from crossing programs (Ghana-4, Mali-217, Nigeria-55, Uganda-13) for traits of interest including 78 populations (ICRISAT Mali-50, ICRISAT Nigeria-24, Ghana-4) for SD with moderate leaf disease resistance, 53 populations (ICRISAT Mali-50, Nigeria-3) for SD with aflatoxin tolerance, 60 populations (ICRISAT Mali-50, ICRISAT Nigeria-10) for tolerance to drought at ICRISAT Mali, 79 populations (ICRISAT Mali-50, ICRISAT Nigeria-12, Mali-17) for medium-duration (MD), and 19 populations (ICRISAT Nigeria-6, Uganda-13) with short-duration and confectionery traits. The number of populations developed in 2016 significantly increased when compared to 2015, attributed mainly to the increase in the number of crosses made by NARS breeding programs. A total of 381 populations (Burkina Faso-60, Ghana-12, Mali-200, Nigeria-48, Tanzania-66 and Uganda-10) were developed. These included 112 populations (ICRISAT Mali-50, ICRISAT Nigeria-10, Burkina Faso-15, Ghana-12, Tanzania-15, Uganda-10) for short-duration + moderate leaf disease resistance, 65 populations (ICRISAT Mali-50, Burkina Faso-15) for short-duration + aflatoxin tolerance, 96 populations (ICRISAT Mali-50, ICRISAT Nigeria-10, Burkina Faso-15, Tanzania-21) for tolerance to drought, 105 populations (ICRISAT Mali-50, ICRISAT Nigeria-10, Burkina Faso-15, Tanzania-30) for MD, and 18 populations (ICRISAT Nigeria-18) for short-duration and confectionery traits. Other populations have been under evaluation for QTL analysis for drought at ICRISAT Mali, and for drought, rust and rosette at NARI, Tanzania. ICRISAT Mali evaluated more than 125 segregating populations (F3-F6) in 2016, which were developed before 2015. ICRISAT Nigeria evaluated 48 F3 populations in 2016.

2.3 Testing for Release

The testing activities focused on evaluation of advanced breeding lines in international/regional, in-country multi-location variety trials, farmer participatory variety selection (FPVS) trials, national performance trials (NPT) and distinctness, uniformity and stability (DUS) trials as well as nutrition profiling of candidate release varieties. A total of 56 on-station and multi-locations trials (ICRISAT-17, NARS-39) and 338 FPVS trials (ICRISAT-148, NARS-190) were conducted in the two years. In 2015, 22 on-station and multi-locations trials (ICRISAT-7, NARS-15) and 81 FPVS trials (ICRISAT-76, NARS-5) were conducted while number of trials increased to 34 (ICRISAT-10, NARS-24) and 257 (ICRISAT-72, NARS-185), respectively, in 2016. The increased number of trials is attributed mainly to increases from NARS programs; specific details about the trials are highlighted below for each breeding program. ICRISAT- India shared 32 advanced breeding lines and 20 high-oleic breeding lines with Niger,

42 kgs sack of groundnuts being sold by seed marketers at the World Food Day Celebration in Uganda

Nigeria and Uganda in 2016. ICRISAT-Mali conducted four on-station preliminary variety trials comprising 112 lines at Samanko during 2015 cropping season. The program also conducted 26 mother trials and 50 baby trials in partnership with NGOs (CAAD & GRAADECOM) in 2015. A total of 478 farmers (474 women, 4 men) participated in the FPVS trials. It shared 146 breeding lines to NARS (57 Ghana, 89 Mali) breeding programs. In 2016, a regional variety trial (RVT) with 16 entries was conducted at Samanko. The results indicate a highly significant difference in pod yield between the varieties tested. Pod yield ranged from 1010-2326 kg/ha (mean=1755 kg/ha). The same trial was conducted by NARS at five locations in Mali, two locations in Burkina Faso, six locations in Ghana and five locations in Nigeria. Four sets of preliminary variety trials, containing 122 breeding lines, were conducted at Samanko. Selected 34 lines will be evaluated in regional variety trials during 2017 in partnership with NARS. Ten mother and 50 baby trials were also conducted in partnership with NGOs, and farmers preferred two improved varieties based on pod yield, short duration, seed size, taste and forage yield. The program shared 129 advanced breeding lines with NARS (12 Mali, 57 Burkina Faso and 60 Nigeria). At ICRISAT-Nigeria, a total of 266 breeding lines (36 high-oil lines, 128 drought-tolerant lines, 102 rosette-resistant lines) were evaluated under observation nurseries and on-station replicated trials during 2015 and 2016 crop seasons. In 2016, RVT with 16 advanced lines obtained from ICRISAT Mali was conducted at three locations for adaptability. Also, 18 elite lines plus two check varieties were evaluated at three locations to identify NPT entries. A set of eight entries were evaluated in on-farm PVS trials at 12 sites. These material showed superiority in yield and other farmer-preferred traits over the check entries. A preference assessment of the entries in these trials was conducted with the support of The United States Agency for International Development (USAID) -supported Groundnut Upscaling Project at six selected sites with 212 farmers (61 women and 151 men) and three varieties were preferred by farmers.

Burkina Faso - INERA groundnut program conducted on-station trials in 2015: 1) Five lines with medium duration obtained from ICRISAT Mali were evaluated at Gampela and Kamboinsè stations for agronomic tests and multiplication, 2) 11 SD lines tolerant to aflatoxin received from ICRISAT Mali were evaluated and four lines were selected for aflatoxin tolerance and multiplied to increase the stock for further trials, 3) Another five lines tolerant to drought and 20 SD lines acquired from ICRISAT Mali were evaluated for agronomic performances and multiplied to increase the stock. In 2016, the program evaluated 60 advanced breeding lines for drought tolerance and 30 drought-tolerant lines were selected for further evaluation in advanced yield trials during the 2017 dry season. The program also

Foundation seed production, BUK 2015, Nigeria.`

evaluated 70 advanced breeding lines for tolerance to ELS, LLS, drought, and short duration from 120 breeding lines received from ICRISAT-Mali. RVT with 15 advanced lines obtained from ICRISAT Mali and a local check was conducted at two locations and the trial will be repeated in six locations during 2017. Three multi-location trials were conducted: 1) 7 best aflatoxin-tolerant varieties, 2) 9 best ELS and LLS resistant varieties, and 3) 10 best drought-tolerant + short-duration varieties. Based on the 2015 and 2016 on-station and multi-location trials, the program identified six superior breeding lines (ICGV 86015, ICGV 91317, ICGV 91328, ICGV 93305, ICIAR 19 BT and Fleur 11) for promotion to the variety release pipeline. Besides, the program conducted FPVS trials at Pagou (Eastern Centre region) and Pissila (Northern Centre region) with eight groundnut varieties where 100 farmers (70 men and 30 women) made a choice of four best varieties during 2015 crop season. Similarly, 12 FPVS trials were conducted during 2016 crop season where three varieties i.e. Fleur 11, Kiema, and QH 243C were preferred by farmers.

Ghana - SARI received breeding lines form ICRISAT Mali in 2015. These included 42 breeding lines (15 advanced breeding lines with SD and tolerance to foliar diseases, 10 SD lines with tolerance to aflatoxin, 15 lines showing tolerance to drought conditions and two lines showing high levels of resistance to foliar diseases), which were grown in an observation nursery under irrigation for seed increase. In 2016, 15 advanced breeding lines with SD and tolerance to foliar diseases were grown using a 4x4 partial lattice with three replications in 4-row plots of size 8 sq. m. RVT with 15 advanced lines obtained from ICRISAT Mali plus a check was conducted at six locations using a 4x4 partial lattice design with three replications. A total of 44 FPVS trials (4 mother and 40 baby trials) were conducted in 4 districts using 20 promising groundnut lines laid in 5m x 5m plots with three replications at each location. Based on multi-location and FPVS trials, six candidate varieties (ICGV-IS 08837, ICGV 13071, ICGV 13075, ICGV 91279, ICGV 13015 and ICGV 13110) were identified as preferred varieties on the basis of high pod yield, short duration, haulm yield and seed

color. The program plans to release these varieties (at least 2 -3 varieties) in 2017/18.

Mali – In 2015, IER identified 10 high-yielding breeding lines with tolerance to drought and ELS; 10 other early maturing lines for replicated trials. In 2016, a regional trial with 15 entries obtained from ICRISAT Mali plus local check was conducted in five locations using lattice design in three replications. Five promising lines (ICGV-IS 13834, ICGV-IS 13830, ICGV-IS 13806, ICGV-IS 13824, and ICGV-IS 13827) were identified and the trial will be repeated in 2017. A trial with nine early-maturing lines plus a check was conducted at three sites using RCBD with three replications. Three promising lines (ICGV-IS 13085, ICGV-IS 13054, and ICGV-IS 13079) were selected. Another trial with nine drought- and ELS-tolerant varieties plus a check was conducted at three sites using RCBD in three replications. ANOVA and multiple comparison of Tukey's indicate three promising lines (ICGV-IS 13871, ICGV-IS 13830, and ICGV-IS 13825) across the three locations. The six lines selected from the two trials will be evaluated in multi-location trials in 2017. Sixty FPVS trials with seven entries were also conducted in five regions. Three farmer-preferred varieties - ICIAR 19BT, ICGV 03181 and ICGV 00350 - have been identified on the basis of high pod yield, short duration, haulm yield and seed color. The program released two varieties (J11 and ICIAR 19BT) in 2016, which are now registered in the national and regional catalogue.

Nigeria - In 2015, IAR conducted two multi-location trials comprising of 45 short-duration and 15 medium-duration advanced groundnut breeding lines and standard checks at four locations (Minjibir-ICRISAT, IAR, BUK and FUD) to confirm their superiority and resistance/tolerance to biotic and abiotic stresses and to identify entries for NPT. FPVS trial/ National Performance Trial (NPT) comprising of 15 test entries and three ruling check varieties was conducted at two on-station (Minjibir and Zaria) and three on-farm (Gumel, Zango and Tambu) locations to document farmer preference and identify candidates for new groundnut varieties in Nigeria. In 2016, RVT with 15 advanced lines obtained from ICRISAT Mali and a local check conducted at two locations. The trial will be repeated in 2017. Twenty-eight early- and medium-maturing elite breeding lines selected from 2015 trials plus two checks were evaluated at four locations for yield and adaptability. As many as 124 advanced breeding lines together with four checks were evaluated in an observatory nursery for foliar disease resistance. A different set of 19 advanced breeding lines together with one local check were evaluated at an observatory nursery for foliar disease resistance. One trial with 34 entries was conducted for confectionery traits. A total of 15 FPVS were conducted in Gumel, Zango and Tambu, and four varieties have been submitted for release

Tanzania - In 2015, NARI evaluated a set of 20 genotypes to identify short-duration lines with moderate level of resistance to ELS, LLS and rust for further evaluation. Another 10 lines were evaluated under field conditions in low altitude and mid altitude moisture stress sites (Naliendele, Nachingwea, Tunduru, Makutupora and Tumbi) to determine their drought resistance. In 2016, the program conducted phenotyping for biotic and abiotic stresses, evaluated advanced breeding lines in replicated trails and FPVS trials, and more importantly released three new varieties. Three screenings/ phenotypings were conducted: 1) 50 lines for groundnut rust disease resistance, 2) 145 good x good lines for rosette resistance, and 3) 50 lines for drought tolerance during off-season. Three new groundnut improved varieties namely NACH 2013, NARINUT 2013 and KUCHELE 2013 were officially released at the National Release Committee meeting held on 16-17 March, 2016. A trial with 10 drought-tolerant lines was repeated at five locations (Naliendele, Nachingwea, Tunduru, Makutupora and Tumbi). The mean yield ranged from 969 kg/ha to 1,389 kg/ha (overall mean=1,168 kg/ha). ICGV-SM 08503 was the highest-yielding (1,389 kg/ha) followed by ICGV-SM 08584 (1,302 kg/ha). Also, 13 groundnut genotypes were tested in 35 FPVS across Tanzania. The results indicated a yield range of 795 kg/ha (for local) to 1,560 kg/ha (ICGV SM 08503), with a mean yield of 1,334 kg/ha at nine locations. Farmers preferred three varieties (ICGV-SM 08584, ICGV-SM 08503 and ICGV-SM 01514) from those evaluated in FPVS. Two of these have been proposed for release. Eight varieties (Mangaka 09, Mnanje 09, Naliendele 09, Nachingwea 09, Pendo 98, ICGV-SM 08584, ICGV-SM 08503 and ICGV-SM 01514) were profiled for nutritional properties at TFDA. Results showed a range of 40.1-51.5 % w/w fat, 29.5-34.5% w/w protein, 23.4-65.4 mg/kg Fe and 35.3-94.5 mg/kg Zn.

Uganda – In 2015, NaSARRI assembled drought and aflatoxin-tolerant genotypes in two sets of trials: ICRISAT regional trial set (20) and NaSARRI Serere sets (18) for drought and wide adaptability trials at five NPTs. ICRISAT regional trial set (20) lines were also screened in the laboratory for aflatoxin tolerance. Four previously evaluated NaSARRI lines and six more candidate materials were screened in the laboratory for aflatoxin tolerance. Eight medium-maturing lines (4 lines from 89751 x S.1 population and 4 lines from 91707 x S.1 population) were evaluated at NaSARRI. SD advanced lines, high oil lines, big seeded confectionary lines at NaSARRI undergone yield trials and final evaluation. They included lines from Gwerinut x S.2 red (4 test lines), Gwerinut x S.2 tan (4 test lines), S.3 x Erudu red (4 test lines); Acholi white x Igola/S6T populations. Eight superior lines have been identified from the two trials at NaSARRI for promotion to NPT, two lines each from 91707 x S1R; 89751 x S1R; S.3 x Erudu red; and

Quality Declared groundnuts seeds in small packs being marketed by seed marketers at the World Food Day (WFD) Celebration in Uganda_1.

Gwerinut x S.2 populations. Another set of 140 test lines were evaluated on-station fat NaSARRI or two seasons with best 10 lines selected for NPT. In 2016, the ICRISAT regional trial set (20) lines undergone a second season of evaluation and the second set (18), from NaSARRI undergone wide adaptability trials at National Performance Trial (NPT) level. Sixteen candidate lines were identified from national performance trials (NPT) and will enter the variety release pipeline. Samples of these candidate lines have been sent to JLA Lab in Georgia, USA for nutrient analysis. The 2016 FPVS materials were harvested and farmers have replanted them in 2017. A total of 19 FPVS trials were conducted hosted by 114 farmers (69 females; 45 males). Three best bet/ candidate lines (SGV-ER 10010, DOK 1T, and DOK 1R) passed the first DUS in 2016 B season and will undergo the final DUS test in 2017.

2.4 Best-Bet Varieties

This activity focused on producing and making available breeder seed for released best-bet varieties to support groundnut seed system (Objective 6). In addition, efforts have been made to develop a DNA fingerprint database for improved cultivars to complement adoption and impact surveys.

Breeder Seed Production - A total of 76.25 t of breeder seed was produced 40 released and pre-released farmer-preferred varieties across countries during the two years as summarized in the Table 1. There was a slight increase in breeder seed production volume in 2016.

DNA database - To accurately attribute impacts to products of research, TL III is supporting DNA fingerprinting-assisted adoption survey of improved groundnut varieties in Nigeria. DNA library is under development and progress so far includes:

- Seed samples for 74 popularly grown groundnut varieties were collected from Burkina Faso (10 varieties), Ghana (8), Mali (11), Nigeria (13), Tanzania (14), and Uganda (18).

Table 1. Summary of breeder seed production across target countries.

	Quantity (t)			Varieties (no)
Country	2015	2016	Total	
Burkina Faso	3	5.6	8.6	6
Ghana	2	5.75	7.75	8
Mali	9	2.1	11.1	4
Nigeria	7	14.8	21.8	6
Tanzania	5	9	14	6
Uganda	10	3	13	10
Total	36	40.25	76.25	40

- DNA isolation of the 74 varieties of groundnut was done at ICRISAT in Nairobi and the high-quality DNA sent to ICRISAT- India for the development of a reference library and genotyping with SNP array.
- SNP arrays with 58K SNPs developed recently by ICRISAT for groundnut will be used for generating genotyping data on all the 74 varieties of groundnut for constructing a reference library.
- These SNP arrays will provide dense genome coverage and very high-level of differentiation for each reference variety. This is very important in achieving precise results to assess varietal adoption.
- On receiving the complete information on survey samples collected from different countries for varietal adoption studies, reasonable samples capturing different geographies will be used for genotyping and adoption assessment using 58K SNP arrays of groundnut.

2.5 Enhancing Genetic Gain of CGIAR Hubs and Partners

ICRISAT regional offices (hubs) breeding programs went through external BPAT reviews in 2015 and 2016. Improvements were recommended by the review teams. Program improvement plans were developed by incorporating the review recommendations and significant progresses have been made to improve the programs. In February 2017, the NARS breeding programs went through BPAT self-assessment. Key current highlights of the ICRISAT hubs and NARS groundnut breeding programs are in Table 2. The detailed self-assessment report can be accessed here: Groundnut programs.

3. Objective 6 Seed System

Objective 6 aims to establish and strengthen sustainable and impact-oriented legume seed delivery systems for smallholders. This objective is led by CIAT with one seed system specialist appointed at ICRISAT ESA for ESA and another one at IITA for WCA to backstop NARS partners and seed value chain actors (private and public seed producers). The implementation of the planned

Table 2. Synthesis of BPAT self-assessments and program improvement plans.

Program	Status
ICRISAT-WCA	▪ After incorporating the recommendations from BPAT assessment, the number of crosses and/or lines in development and the scale of yield trial programs have more than tripled in order to enhance the level of genetic gains ▪ Currently, the program makes 100-200 crosses (populations) with 2 generations of segregating populations per year, which is adequate to routinely deliver >95% of crosses and >90% of seed (50-100 seeds) per cross required by breeders. ▪ The success rate of getting F_1 is relatively low (35-50%) compared to India (50-70%); hence, more emasculation and pollinations should be done to reach the required seed per cross. The program routinely delivers >95% of F_2 seed required by the breeder. ▪ The program has recently moved from pedigree method to SSD for advancing segregating populations. The program uses a staged trial system (ON-Observation nursery, PVT-Preliminary variety trial, and AVT-advanced/RVT-multi- location regional variety trial, FPVS-farmer participatory variety selection) to evaluate performance of advanced breeding lines in partnership with NARS breeding programs, with at least 6 locations representing important agro-ecological zones in target market(s) in each country. The success of the trials has been good with 80-95% of trials harvested, and ≤ 10% missing data in completed trials. ▪ The program evaluates 200 to 300 advanced lines per year under PVT and multi-location AVTs. Quality of trials is assessed using primarily CV & H; 10-20% of trials are rejected due to poor quality (H < 0.15). ▪ The program has started using BMS and plans to finish migrating all data since 2008 to BMS by the end of 2017. ▪ The program has acquired barcoding facilities for Nigeria and Mali, and NIRS machine for Nigeria. It is in the process of acquiring NIRS machine for Mali ▪ The program produces 10-20 metric tons of breeder and foundation seed of improved varieties in Mali and Nigeria using on-station main season and off-season facilities.
Burkina Faso	▪ The program made 60 new crosses (all elite x exotic) during 2016 main crop season. This was after two technicians were trained at ICRISAT-Mali on BMS, data collection and breeding techniques, including groundnut hybridization. This delivered 80-95% crosses, 80-90% of seeds per cross and 50-80% of F_2 required by the breeder. ▪ The program has installed an irrigation system bought with TL III funds which has minimized the breeding cycle time. ▪ The program has acquired 3 handheld digital data collection devices that are in use. ▪ The program is currently in the process of acquiring a barcode printer and scanners with the help from ICRISAT.
Ghana	▪ The program has started making around 12 crosses per season during the main cropping season. Before this, it used to rely on testing fixed breeding lines from ICRISAT and other sources. ▪ There is a plan to increase the number of crosses with a corresponding further training of technicians to be able to handle the large segregating population arising out of the crosses. ▪ The program has installed irrigation facility on 2.25ha of land with 20000litre water capacity water tank and drip irrigation system (photo 1), which is being used for off-season drought phenotyping of breeding lines (photo 2) and foundation seed production and (photo 3) as well as advancing segregating populations during off-season. ▪ BMS has been installed and put in use. Currently, the BMS database has 28 trials, 1 nursery, 1 F_1 list and 17 germplasm lists. The data has been shared with ICRISAT to be uploaded on the BMS. ▪ The program is currently in the process of acquiring a barcode printer and scanners through ICRISAT-Mali.

Mali	▪ The program has started making around 15 crosses per season and handling around 1,244 F_2 and F_3 using backcross and SSD. ▪ Irrigation facilities were developed in 2016 supported with additional resources from TL III enabling production of breeder and/or foundation seed of various varieties during the off-season. The irrigation facility is utilized to produce seed on an average area of 3.5 ha. ▪ Three people (two technicians and one field assistant) have been trained in BMS use and how to collect data using handheld devices. ▪ Pedigree data and breeding trials data have been shared with ICRISAT for uploading to the BMS database and phenotyping data is being managed with a handheld device. ▪ The program is currently in the process of acquiring a barcode printer and scanners through ICRISAT-Mali.
Nigeria	▪ The program has started making around 15 crosses per season during the main cropping season but fails to deliver >50% of crosses and/or 50% of F_1 seeds per cross required by the breeder. However, it delivers 80-95% of F_2 seed required by the breeder and 80-95% of trials are harvested with ≤ 10% missing data in the completed trials. ▪ In partnership with ICRISAT-Nigeria, the IAR breeding program is evaluating more than 300 advanced breeding lines in yield trials. ▪ Pedigree data at IAR has been uploaded on the BMS database. ▪ A senior groundnut breeder attended a short training course in Nairobi, Kenya on BMS. Another breeder, and technical support staff attended an Electronic Data Capture training session organized by ICRISAT- Nigeria. Four data capturing handheld devices were procured for the IAR groundnut improvement team. ▪ The program is currently in the process of acquiring a barcode printer and scanners through ICRISAT-Mali.
Tanzania	▪ The program has graduated from total dependence on ICRISAT for fixed breeding lines and evaluation for release. ▪ It is making around 42 crosses per season and managing >500 segregating populations (F_2-F_6). This is a significant jump from 10 crosses per season during TL II. The target is to reach 100 crosses. ▪ The program delivers 50-80% of crosses and of F_1 seeds per cross required by the breeder. It also delivers 50-80% of F_2 seed required. ▪ About 50-80% of selection nurseries and activities produce meaningful results (check entries express desired trait). This is attributed to poor agronomy as evidenced by establishment and/or weed/pest problems and minimal controlled-environment facilities. ▪ The program currently manages up to 3 generations per season with an irrigation facility on 6 ha of land that enables seed multiplication, drought phenotyping trials, and making crosses and advancing segregating populations during the off-season. ▪ It has also acquired two Samsung tablets from the TL III project and four from other sources, which have strengthened the data collection capacity of the groundnut breeding program. Plans are underway to migrate to a BMS cloud version.
Uganda	▪ The program design and operations maintain an entire pipeline (early generation to advanced breeding lines) annually that are bred through the hybridization. ▪ Around 50 crosses are made every year and the program routinely delivers >90% seeds per cross and >95% F_2 seed required by the breeder. ▪ The yield trial program involves a staged trial system, with multiple locations (at least 6) representing the important agro-ecological zones in target market(s); > 95% of trials harvested; < 10% missing data in completed trials. ▪ The current market share of program varieties released in the last 10 years indicates that the varieties are planted on >25% of groundnut area in Uganda. ▪ At least 5 ha of land is used for seed multiplication during off season with irrigation. The program produces around 4 metric tons of early generation seed of released varieties per year. ▪ The working germplasm and their pedigree have been sent to ICRISAT-India and uploaded on the BMS.

Popularizing Improved varieties in Nigeria.

Discussion and formation of multistakeholders platforms (MSPs) in Ghana_2.

activities in each country is led by the same NARS partners as Objective 2. It has five main complementary activities: 1) Establish Multi-Stakeholders Platforms; 2) Sustainable Production and Delivery of Various Seed Classes; 3) Innovative and Targeted Seed Marketing; 3) Popularize New Varieties and 5) Strengthen Multi-Legume Impact-Oriented Seed Systems. TL III project works in partnership with other projects in target countries to strengthen the groundnut seed system. In WCA, for example, TL III project closely works with the USAID-supported groundnut scaling project in Ghana, Mali and Nigeria to create awareness of improved technologies, enhance availability of seed and build capacity of value chain actors and stakeholders. Brief highlights of progresses made in groundnut seed system are given below.

Multi stakeholders' platforms – Activities conducted towards establishment of innovation platforms for groundnut are summarized in Table 3. Total of 19 platforms were established or functional ones were strengthened to link value chain actors; and platform members were trained in seed production and business management in each participating country. A total of 46 training and short course programs were organized in various areas including quality seed production, group dynamics and management, good agronomic practices, post-harvest handling and seed dressing benefiting 8,657 (4,497M, 4,160F) platform members (farmers, development technicians/experts, agro-dealers and extension officers).

Popularizing New Varieties – Various complementary awareness creation approaches were employed to popularize new improved varieties (Table 4). These included technology demonstrations, farmer field days, distributing technology factsheets (guides, flyers, leaflets, posters, brochures, and manuals), radio/TV programs and agri/seed fairs. More than 420 and 760 demonstrations were conducted in 2015 and 2016, respectively, while 90 and 190 field days were organized in the same period. More than 13,700 technology factsheets were distributed during the two years. A total of 180 radio/TV programs on improved technologies were broadcast. Twenty-six agri/seed fairs were organized across the target countries attracting more than 18,360 participants including 8104 (44%) females and 10,259 (56%) males.

Sustainable Production and Delivery of Various Seed Classes - In total 425.6 metric tons of basic (foundation) seed and more than 8400 metric tons of certified/QDS seed was produced and injected into the groundnut seed system in the target countries in the last two years (Table 5). The seed production volume increased significantly in 2016.

Innovative and Targeted Seed Marketing - Small packs approach was extensively used to enhance wider and

Table 3. Activities conducted towards establishment of innovation platforms for groundnut.

Country	Number of platforms established	Number of training programs organized	Number of platform members trained – Male	Number of platform members trained - Female
Burkina Faso	3	4	219	431
Ghana	5	4	442	110
Mali	2	3	126	12
Nigeria	7	1	4	30
Tanzania	1	21	2,190	2,088
Uganda	1	13	1,516	1,489
Total	19	46	4,497	4,160

Table 4. Summary of legume technology demand creation activities in 2015-17.

Country	No. of demonstrations		No. of field days		No. of technology guides/ leaflets distributed		No. of Radio/TV programs/print media		No. of Agri/seed fairs	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Burkina Faso	-	60	-	8	-	750	-	7	-	2
Ghana	107	65	80	125	1,000	1,000	-	24	-	0
Mali	100	60	-	30	-	400	2	4	2	2
Nigeria	58	345	-	2	-	1,854	3	32	-	0
Tanzania	100	100	5	10	1,500	1,000	34	11	1	1
Uganda	56	132	5	15	1,200	6,000	10	10	2	2
Total	421	762	90	190	3,700	11,004	49	88	5	7

Table 5. Summary of seed produced and marketed during 2015 and 2016, including proportions sold in small packs.

Country	Quantity of basic seed produced (t)			No. of varieties	Quantity of certified/QDS/TLS seed produced (t)			Quantity (t) of seed marketed in small packs
	2015	2016	Total		2015	2016	Total	
Burkina Faso	5	16.5	21.5	2	28	86	114	10.5
Ghana	2*	13.2	15.2	13	36.5	41.7	78.2	4
Mali	2.4*	43	45.4	6	109.35	1200	1309.35	40
Nigeria	4.8*	13.75	18.5	6	120	1017	1137	179
Tanzania	18	215	233	6	156	2133	2289	0.3435
Uganda	7	85	92	10	52	3500	3552	-
TOTAL	39.2	386.45	425.6	43	501.85	7977.7	8479.55	234

*Additional foundation seed quantities of 2 metric tons for Ghana, 2.6 metric tons for Mali and 3.7 metric tons for Nigeria were reported under USAID-supported Groundnut Up scaling Project

affordable access to seed of improved groundnut varieties. At least 234 metric tons of the seed produced was sold or given as seed loan (to pay twice amount loaned after harvesting) in small packs (1, 2, and 5 kgs) (Table 5). A total of 1,244 (115 in 2015 and 1,129 in 2016) organizations (seed companies, farmer organizations, public seed enterprises) and individual entrepreneurs were engaged in seed production/ marketing across groundnut in the target countries (Table 6). Individual entrepreneurs, primarily from Burkina Faso (263) and Nigeria (454) in 2016, accounted for more than 69% of the total followed by farmer organizations/groups (25.7%) attributed to large number (240) of farmer groups engaged in Tanzania in 2016.

Strengthen Multi-Legume Impact-Oriented Seed Systems – In 2016, skills and knowledge of 22,523 farmers and trainers (52.6% F=female, 47.4% M=male) from NARS, seed producers and development partners

Table 6. Number and type of organizations involved in seed production and marketing for groundnut.

Organizations	Burkina Faso		Ghana		Mali		Nigeria		Tanzania		Uganda		Total
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	
Seed companies	-	3	1	5	1	4	3	3	2	3	6	11	42
Public enterprises	-	6	1	1	1	1	3	3	2	1	1	-	20
Individual entrepreneurs	5	263	36	9	1	49	5	454	10	-	20	10	862
Farmer organizations/ groups	-	2	-	3	1	30	10	10	5	240	1	18	320
Total	5	274	38	18	4	84	21	470	19	244	28	39	1,244

NARO Council Chair Prof. Obua listens attentively as Kalule Okello David (In Country TLIII PI for Uganda) Explains Aflatoxin Management Poster. He also collected our groundnuts dissemination materials.

Participants at a training program observe different improved groundnut varieties available in Ghana

were enhanced through field days and training in areas of cross crop innovative, gender-specific seed production and marketing, improved groundnut production technologies, principles of seed production, postharvest seed management and marketing, setting up a functioning innovation platform and seed business management. This included 1,561 in Burkina Faso (M=401; F=1,160), 7,577 in Ghana (M=4,232; F=3,345), 4,551 in Mali (M=1,273; F=3,278), 1,551 in Nigeria (M=1,057; F=494), 4,278 in Tanzania (M=2,190; F=2,088) and 3,005 in Uganda (M=1,516; F=1,489). Useful seed systems lessons were documented and shared with partners and stakeholders, and were also presented in workshops/conferences including InterDrought-V and annual review meetings. Labour-saving technologies/mechanization tools were identified for target countries and are being tested for possible adoption by smallholder farmers to reduce drudgery, increase production/quality of post-harvest products. In Tanzania, four groundnut planters were bought and will be distributed to different project partners. Groundnut shellers 25 each are being demonstrated and distributed to farmer groups in Ghana, Mali and Nigeria through USAID-supported Groundnut Scaling Project.

For TL III updates follow:

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