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CGIAR

Innovating **for impact**

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Innovating for impact
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International mailing address
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Cover photo: Yemisrach Aseffa, Adenew Ayele's niece, happily showing the growing *Sesbania sesban*, which they use as fodder, during a field visit to Debre Berhan and Hadiya by the AfricaRISING team (Photo: ILRI/Simret Yasabu).

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Improving crops

Molecular breeding comes of age in cassava improvement

Ismail Y. Rabbi

In December 2020, the IITA Cassava Breeding Program and the National Root Crops Research Institute (NRCRI) released four NextGen cassava varieties in Nigeria under the Next Generation Cassava Breeding Project (www.nextgencassava.org). This achievement is the culmination of an ambitious modernization program and demonstrates the first products of molecular breeding and genomic selection breeding in cassava globally.

Genomic resources developed

Until recently, cassava was classified as an orphan crop with inadequate access to modern breeding technologies, particularly genomic resources for genetic studies and predictive breeding, despite the crop's significant role in ensuring food security for more than half a billion people in the tropics. Breeders traditionally rely on recurrent phenotypic selection, and it takes several years to complete a breeding cycle. This lengthy population cycling time is due to the crop's long maturity period of at least 12 months, low clonal multiplication rate, and limited seed set per cross.

As a result of the low multiplication rate, several propagation cycles are needed to obtain sufficient material for replicated and multilocational evaluation. Consequently, it typically takes five to six years from seedling germination to multilocation yield trials. In addition, cassava genotypes show wide variation in flowering time, rate, and fertility, limiting

the number of successful crosses a breeder can make between selected parental clones.

To address these challenges, scientists at IITA, collaborating with national and international partners, embarked on a journey to modernize cassava breeding. The first achievement was developing sufficient genomic resources for the crop, including chromosome-scale reference genome and a detailed haplotype map from re-sequencing important landraces, elite breeding lines, and wild cassava diverse accessions (Ramu et al. 2017).

A catalog of genes controlling important traits in cassava

Concurrent with the generation of genomic resources, the team at IITA led global efforts to pinpoint the genomic regions that control the variation of key traits in African cassava germplasm. A detailed catalog of more than 40 chromosomal regions or SNP markers associated with 14 desirable traits related to biotic stress, root quality, and agro-morphology was published (Rabbi et al. 2020). This output resulted from a large genome-wide association study involving more than 5,130 clones developed in Nigeria at the IITA Cassava Breeding Program that were genotyped at high density and phenotyped at several locations over four years.

It is well known that trait-linked marker discovery does not automatically translate to deployment in breeding programs. One of the reasons for the slow uptake is a failure to translate genomic knowledge into assays/tools that breeders can easily use to support selection decisions. To overcome this bottleneck, the discovery team converted the markers anchoring the genes of several traits into a set of robust assays that are

available marker-assisted selection (MAS) to any cassava breeder worldwide through independent genotyping service providers. The initial traits include resistance to cassava mosaic disease—a major biotic constraint to the crop's productivity, increased provitamin A content for biofortification, and increased dry matter content.

For the first time, these assays have been deployed to overcome new outbreaks of cassava mosaic disease in Southeast Asia, particularly Vietnam, Thailand, and China (Ige et al. 2021). IITA shipped varieties with inbuilt resistance to the disease and the markers linked to the resistance genes to breeders in Asia. This has permitted rapid mobilization of the resistance genes into locally adapted cassava varieties in Asia.

The benefits of overcoming cassava mosaic disease are immense. In Africa, the disease causes yield losses of up to 80% depending on infection type and cassava variety. These translate into an annual reduction of more than 30 million tons of fresh root yield. The thriving Asian cassava industry is also at risk of severe disease that would result in huge losses if not addressed in time.

Another significant milestone in molecular breeding progress at IITA is the addition of a new set of markers associated with low cyanogenic potential into the breeders' toolbox. Together with scientists from the Brazilian Agricultural Research Corporation (EMBRAPA) and Boyce Thompson Institute in Cornell University, scientists from IITA discovered major genes associated with the accumulation of the toxic compounds in cassava roots (Ogbonna et al. 2020). Cyanide glucosides are toxic metabolic products found in varying concentrations in different cassava genotypes. Varieties with high concentrations of these compounds must be processed thoroughly

before consumption. Breeding for low cyanogenic potential is rather cumbersome due to the technical complexity associated with the measurement of the compound. Availability of markers linked to low cyanide content genes is now helping to make selections easier and cheaper, allowing breeders to screen thousands of lines at early breeding stages.

Genomic selection: From proof-of-concept to products

Another innovation in cassava breeding is genomic selection to predict breeding values and clone performance at the seedling stage before field testing. This approach, initially pioneered in animal breeding, is useful for complex traits such as yield and yield components that are controlled by a large number of genes with small effects. Genomic selection works through statistical modeling of marker and phenotype data in a training population and then using the developed models to predict phenotypes in new lines that have only been genotyped.

The IITA breeding program has shortened the breeding cycle from at least five years to two years using genomic selection. The program has been able to carry out five cycles of population improvement since 2012, culminating in the release of the four varieties in 2020. These include IITA-TMS-IBA000070 (Baba 70), IITA-TMS13F1343P0022 (Obasanjo 2), IITA-TMS13F1160P0004 (Game Changer), and NR130124 (Hope, developed by NRCRI). They are characterized by high yield, high dry matter content, resistance to cassava mosaic disease, and wide adaptation.

To facilitate the mainstreaming of molecular breeding, the NextGen Cassava Project has developed CassavaBase, an open-access breeding database (https://cassavabase.org). The user-friendly database is critical for the efficient management of large amounts of genotype and phenotype data. Breeders from around the world currently use the database to (1) track breeding accessions; (2) design field trials; (3) store field trial data; (4) capture phenotype data using standardized ontologies; (5) store genotypic data, including from Next Generation Sequencing platforms; and (6) implement standard algorithms for breeding trial analysis and selection decisions.

Certainly, cassava has come a long way from being an orphan crop following the significant advances in the modernization of breeding approaches as outlined above. Still, much remains to be done, particularly for mainstreaming molecular breeding approaches in national breeding programs across Africa.

Funding

The Bill & Melinda Gates Foundation (Grant INV—007637 http://www.gatesfoundation.org); the UK Foreign, Commonwealth and Development Office (FCDO); and the Roots, Tubers and Bananas Program of CGIAR.

Partners

- International Institute of Tropical Agriculture (Nigeria)
- National Root Crops Research Institute (Nigeria)
- National Crops Resources Research Institute (Uganda)
- Tanzania Agricultural Research Institute
- Brazilian Agricultural Research Corporation (Brazil)
- International Center for Tropical Agriculture (Colombia)
- Cornell University (New York)
- Boyce Thompson Institute (New York)
- USDA-ARS (Ithaca, New York; Hilo, Hawaii)

Introducing operational innovations in breeding

IITA's breeding programs have experienced massive organizational and operational change in the past one year alone. This has resulted in a reorientation to achieve customer-centricity by employing customer-facing breeding strategies and augmenting successful industry processes for product design and development.

The manifestation of this change includes increasing the numbers of staff supporting breeding, engaging ancillary disciplines in the modernization drive, and centralizing facilities, farms, breeding operations, and services at the institutional level for cross-crop support and across the hubs.

Another innovation emphasizes collaboration with market-facing breeders in national breeding programs to build or enhance sustainable chains, from releasing market-preferred varieties through viable formal seed systems to farmers' fields. There are strengthened partnerships with complementary projects on seed value chains. This will take the breeding gains in productivity and quality attributes from the breeding plots to the farmers and end-users. There are also numerous motivations for change, such as preparation for the transition to One CGIAR.

The digitization of data collection, deployment of the Enterprise Breeding Systems (EBS) database, mechanizing field operations, improving irrigation design, and introducing world-class systems to manage farms will transform breeding

operations. The modernization drive will usher significant gains in efficiency, effectiveness, cost savings, a culture of continuous improvement, and teamwork among the breeding staff across crops and the hubs.

The modernization efforts followed assessments of the breeding programs by the University of Queensland using the Breeding Programme Assessment Tool (BPAT). This strengthened capacity to deliver farmer- and market-preferred, nutritious, and climate-resilient crop varieties. There is a re-focus of products to align with customer and consumer requirements, institutionalizing operational excellence, strengthening partnerships with National Research and Extension Systems (NARES), training, retraining, and staff development. Thus, the central pillars or the tenets of modernization consist of customer focus, operational excellence, and organizational leadership.

New staff with industry experience were recruited to drive the modernization of breeding operations across all crops and move seed from breeders' plots to the farmers. The Head of Breeding works closely with the Head of Farm Management and Operations to spearhead a shift towards centralized field and breeding operations. This will enable more efficient field trialing and increased genetic gain for all crops.

Product managers work with the breeders across clonal and grain crops and partners from national programs and the private sector to drive product development, anchor seed systems, and implement a clear pathway to market. A plant breeding informatics and analytics cluster comprising a biometrician, bioinformatics, and data management team enables data-driven decision-making for selection and product advancement teams in collaboration with partners.

Another notable change is the integration of other disciplines to support breeding activities across crops and the hubs. These functional teams are vital in consolidating breeding and seed projects as IITA transitions towards One CGIAR. Social scientists, such as market economists, gender scientists, and seed specialists, provide essential information for product profiles and market intelligence. This will increase the adoption of new products and enhance the journey from innovation to impact and growth potential for the customer and end-users.

Numerous change management activities have been undertaken to accelerate breeding for better products and enhance the continuous delivery of products to the farmers and markets. For example, a change management pilot was initiated with the cassava breeding program with support from the CGIAR Excellence in Breeding (EiB) platform. The lessons learned were then used to change five other crop programs: banana, cowpea, maize, soybean, and yam.

The IITA teams are increasingly active in capacity-building meetings, including workshops and webinars supported by partners, such as Bayer Crop Science and EiB in the Modern Breeding Project (MBP) and facilitated by the Crops to End Hunger (CtEH) project. The earlier partnership with Bayer on cowpea breeding was successfully

expanded to benefit all breeding programs. As a result, institutional and crop-specific improvement plans were developed to enable mechanization, leading to an increased breeding speed, seed delivery, and contribution to One CGIAR initiatives.

Current breeding projects and programs are used as vehicles for modernization and transition to One CGIAR. These are CGIAR Research Programs (CRPs) and bilateral breeding projects, such as Accelerated Genetic Gain (AGG) for maize, NextGen Cassava for cassava, Accelerated Varietal Improvement and Seed Delivery of Legumes and Cereals in Africa (AVISA) for cowpeas, and Accelerated Breeding Better Banana (ABBB) for banana (*matooke* and *mchare*). Similarly, current seed system platforms, such as Building Economically Sustainable Seed Systems for Cassava (BASICS II), Yam Improvement for Incomes and Food Security in West Africa (YIIFSWA II), and AVISA are vehicles for delivering genetic gains to the farmers. These platforms focus intensely on smart partnerships with the private seed sector and strengthening national regulatory agencies.

Overall, all innovations benefit the farmers and markets, aligning with the strategic plan for modernizing breeding programs to develop farmer- and market-preferred varieties. The strategic plan is a response to the funders for Crops to End Hunger requests of CGIAR centers.

Making crops healthy

Aflasafe revives the groundnut value chain in The Gambia

Matieyedou Konlambigue, Njeri Okono, Amadou Lamine Senghor, Alejandro Ortega-Beltran, and Ranajit Bandyopadhyay

The Gambia faces severe difficulties in meeting export-quality requirements for food-grade groundnuts. For many years, The Gambia's groundnuts have been banned in Europe—its primary export market.

Groundnut exports with aflatoxin levels exceeding European Union (EU) limits—4 parts per billion (ppb) for confectionery and 20 ppb for feed raw materials—were rejected and summarily returned or destroyed, with the exporter bearing the costs, further compounding losses. The total aflatoxin-related overall loss in monetary terms is estimated at US$7.9–29.9 million.

Aflatoxin infection greatly handicaps The Gambia's food and economic security and undermines poverty eradication efforts.

Between 2014 and 2015, IITA and Senegal's Plant Protection Department (Direction de la Protection des Végétaux [DPV]) collaborated with the National Agricultural Research Institute, The Gambia Groundnut Corporation (GGC, now the National Food Processing, Security and Marketing Corporation [NFSPMC[), and the US Department of Agriculture to conduct effectiveness trials of Aflasafe SN01—the aflatoxin biocontrol product developed for Senegal and The Gambia. The results showed that Aflasafe SN01 reduced aflatoxin contamination by more than 90%, with 86% of the samples from Aflasafe-treated fields having less than 4 ppb compared to 61% in the untreated fields. These results paved the way for registering the product with the country's regulatory

authorities (CSP/CILSS1) in 2016 and subsequent commercialization.

Following the registration, IITA's Aflasafe Technology Transfer and Commercialization (ATTC) project facilitated the dissemination of the technology. ATTC vigorously engaged with private-sector actors, leading to the selection of BAMTAARE Services as the licensed partner to undertake production, marketing, and distribution of Aflasafe SN01 on a commercial basis. IITA granted a five-year exclusive license to BAMTAARE to manufacture and distribute Aflasafe SN01 in both Senegal and The Gambia.

With support from the International Islamic Trade Finance Corporation, NFSPMC introduced Aflasafe SN01 in the input package and extension system as part of a program to improve the quality of grain supplied by farmers2. Between 2016 and 2020, 236 tons of Aflasafe SN01 were procured and applied on 23,600 ha of groundnut in the country.

ATTC, working with the African Union's Partnership for Aflatoxin Control in Africa (PACA), BAMTAARE, NFSPMC, and the Ministry of Agriculture, enhanced project knowledge through sensitization campaigns and training on aflatoxin and its management and how to use Aflasafe SN01. ATTC supported the production of communication tools for these events. NFSPMC also introduced an incentive system, which rewards farmer groups that meet the EU standard with a 15% bonus of the regular price.

Results in 2018 and 2019 after consecutive Aflasafe SN01 applications showed total aflatoxin at 4 ppb and less, well below the EU standard for human consumption. These results have enabled NFSPMC to regain export sectors in foreign markets that it had lost due to unsafe aflatoxin levels. For instance, independent external testing at the entry point to export markets in 2019/2020 showed aflatoxin at 1.8–2 ppb for Aflasafe-protected groundnuts. After more than 20 years of being locked out by aflatoxin, The Gambia is back in the highly lucrative United Kingdom market for groundnut.

With these successful results, NFSPMC plans to scale up nationally by expanding Aflasafe SN01 to all groundnut fields. The dual objective is to increase exports to Europe and assure public health for Gambians.

To sustain and extend these gains, IITA is working with the government to complement and expand NFSPMC's effort in using Aflasafe SN01 and good agricultural practices, among other important solutions for taming aflatoxin. Other concrete steps with the government include continued public awareness of aflatoxin and developing and enforcing a national aflatoxin safety standard.

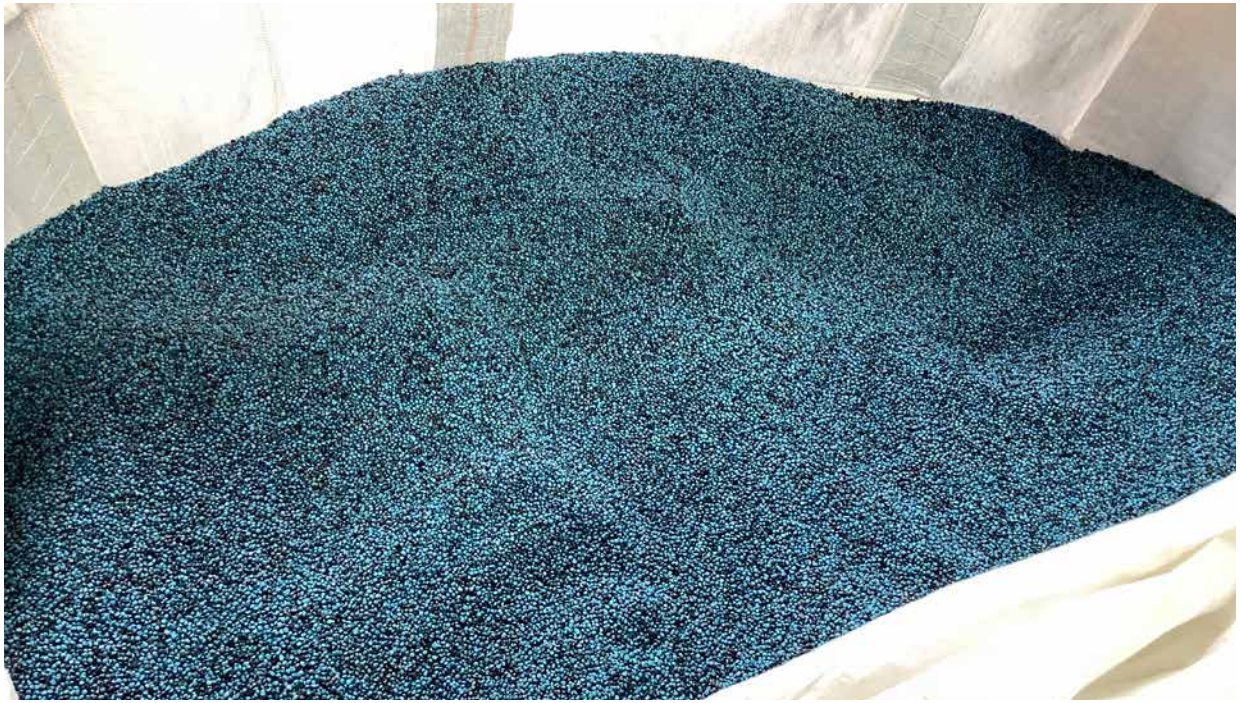
1 Comité Sahélien des Pesticides (CSP) of the Comité Permanent Inter-Etats de Lutte Contre la Sécheresse dans le Sahel (CILSS)

2 Ramsay, D. 2019. Private sector development and international trade in The Gambia. Rural 21, International Journal for Rural Development. https://trade4devnews.enhancedif.org/en/impact-story/private-sector-development-and-international-trade-gambia

Simplifying the manufacture of aflatoxin biocontrol products using dry spores

A. Ortega-Beltran[1], L. Kaptoge[1], A.L. Senghor[2], M.O.S. Aikore[1], P. Jarju[3], H. Momanyi[4], M. Konlambigue[5], T.D.O. Falade[1], J. Atehnkeng[6], G. Mahuku[7,8], and R. Bandyopadhyay[1]

[1]IITA-Nigeria; [2]IITA-Senegal; [3]National Food Security, Processing and Marketing Corporation, Banjul, The Gambia; [4] IITA-Kenya; [5] IITA-Ghana; [6] IITA-DR Congo, [7] IITA-Tanzania, [8] IITA-Uganda.



Various biocontrol products under the Aflasafe trade name have been developed to address aflatoxin contamination in maize, groundnut, and sorghum in several African countries. The Aflasafe products contain four native atoxigenic *Aspergillus flavus* strains as the active ingredient.

The products are normally manufactured by coating sterile sorghum grains with a suspension of freshly produced spores of active ingredients mixed with a polymer and a dye. However, producing the active ingredient is somehow difficult and is the main limitation to manufacturing high-quality products.

BAMTAARE, the Aflasafe licensee in Senegal, had difficulties producing the spores during its first year of operation because the laboratory to produce spores was not finished on time. BAMTAARE had a large order from a major groundnut processor that planned to work with a farmer cooperative to produce aflatoxin-safe groundnut. There was the risk of failing to deliver the order. A process was developed in the lab in Ibadan for producing high-quality dry spores to overcome this.

In 2019, BAMTAARE manufactured Aflasafe SN01 using dry spores produced in Ibadan and sent via courier. BAMTAARE received **4 kg** of dry spores to manufacture **200 tons** of Aflasafe to treat and protect **20,000 ha** of commercially grown groundnut and maize in Senegal and The Gambia and for effectiveness trials in Mali (300 fields).

This much-needed innovation was rapidly conceptualized, developed, tested, and validated in the laboratory and used industrially to produce a reliable aflatoxin mitigation tool in the field. Thousands of commercial farmers in Senegal and The Gambia had access to the technology as a part of an integrated aflatoxin management program that included pre- and postharvest interventions. Most farmers were able to produce aflatoxin-safe crops: **less than 4 ppb** (the tolerance threshold in the EU) compared to up to **380 ppb** in untreated crops.

In December 2020, during the COVID-19 pandemic, the production of Aflasafe products with dry spores continued. Farmers in Tanzania, Mozambique, and Malawi needed Aflasafe products. The dry spores of the active ingredients for the three countries were shipped from Ibadan to the Aflasafe manufacturer in Tanzania (A to Z Textiles Ltd), who produced the products in record time. A to Z shipped the Mozambique and Malawi products to one company each in the two countries for distribution. Farmers received the Aflasafe products in time to treat their fields and are producing aflatoxin-safe groundnut. In addition, dry spores of atoxigenic strains to constitute the biocontrol products specific for Burundi and Uganda were sent to IITA Dar es Salam for manufacturing and to both countries for field effectiveness testing.

The dry spore innovation makes biocontrol manufacturing more versatile, cost-efficient, and accessible to smallholder farmers in several African countries without compromising its effectiveness. Efforts to develop the innovation are part of ongoing actions to improve the archetype of the technology. The laboratory-scale process to dry the spores, however, needs improvement to make it more cost efficient. Currently, an industrial-scale version of the dry spore technology is being developed for scale-up.

More information on the process to produce the dry spore process and the effectiveness of Aflasafe manufactured with dry spores in commercially grown crops:

Ortega-Beltran A, Kaptoge L, Senghor AL, Aikore MOS, Jarju P, Momanyi H, Konlambigue M, Falade TDO, Bandyopadhyay R. 2021. Can it be all more simple? Manufacturing aflatoxin biocontrol products using dry spores of atoxigenic isolates of Aspergillus flavus as active ingredients. Microbial Biotechnology (IF = 5.328) doi: 10.1111/1751-7915.13802

Captions of attached pictures: Fig. 1. A brief description of the process to dry spores of atoxigenic isolates of Aspergillus flavus. Harvesting fungal spores from colonized sorghum grains using sterile funnels with the stem covered with a sterile 1.7-mm2 sieve (A). Harvested fungal spores in suspension in a 250-ml glass bottle (B). Vacuum-dried fungal spores on Tyvek® membrane (lining the sieve in a Büchner funnel) being collected using a sterile spatula (C). Spore powder transferred to a sterile glass vial and ready for drying in the oven; note minimum humidity at the bottom of the vial (D).

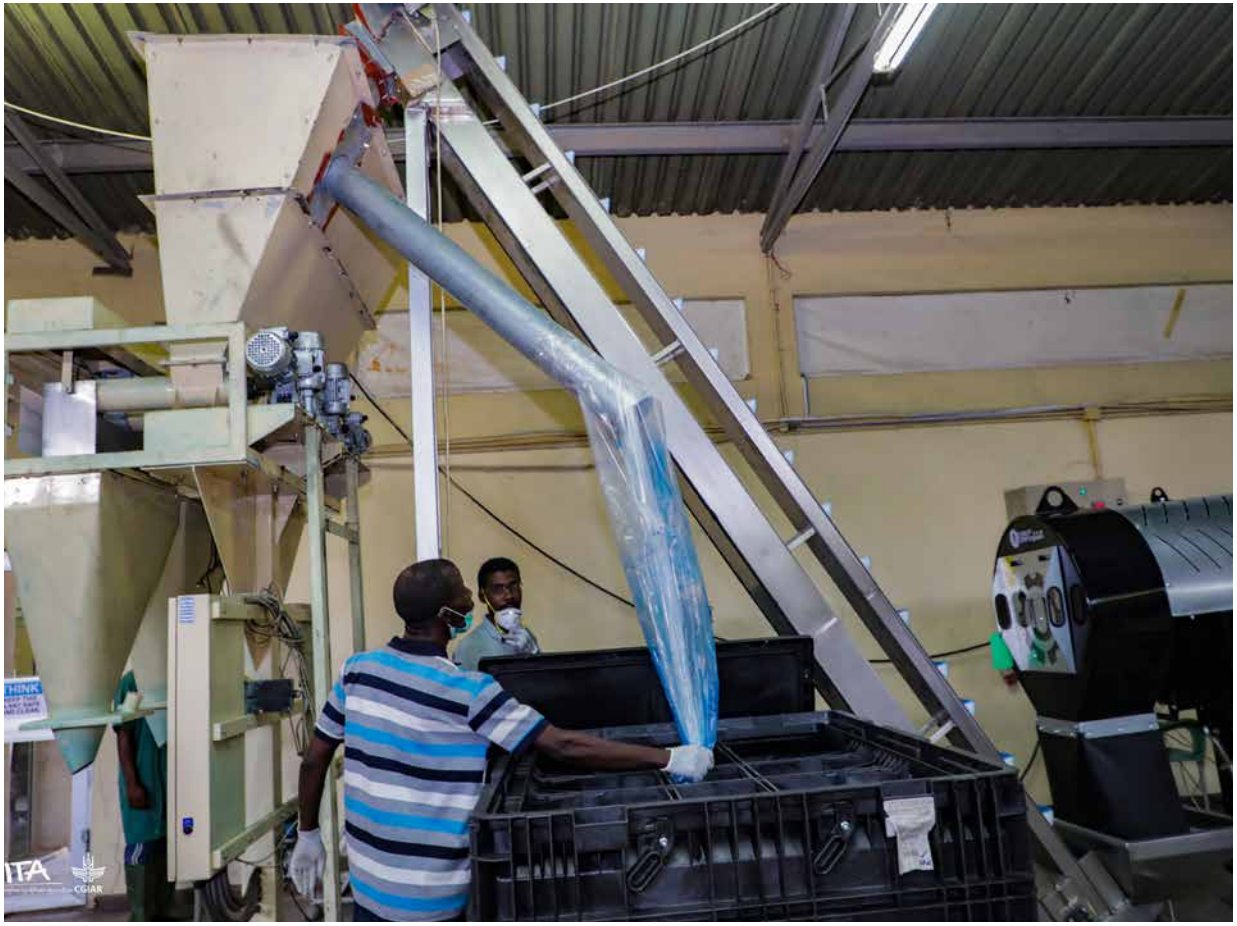


Fig. 2. Manufacturing facility in Kahone, Senegal, where a seed treater (T) is used to coat roasted sorghum grains with a mixture of spore suspension, blue food colorant, and a polymer (A). Biocontrol product temporarily stored in a 1-ton bag and ready to be packaged in 5-kg plastic bags (B).

Fig. 3. Trials conducted in six regions in Senegal with conventional formulation in 2018 (A) and dry spore formulation in 2019 (B). The percentage of groundnut and maize crops in each of four total aflatoxin concentration categories is indicated by different colors. The outer circle shows Aflasafe SN01-treated crops, while the inner circle shows untreated crops. For groundnut, there were 150 and 120 farmer field trials in 2018 and 2019, respectively. For maize, there were 90 and 70 farmer field trials in 2018 and 2019, respectively. In all cases, half of the trials were treated and the rest untreated.

The neem “tea bag”: Bane for cowpea insects, blessing for Niger’s rural women

The seeds of the neem tree provide natural protection against insect pests, including the legume pod borer—a pest that attacks cowpea fields and can account for up to 80% crop loss. Cowpea is the most important grain legume crop in the Sahel region, including Niger.

The USAID-funded Feed the Future Innovation Lab for Legume Systems Research, managed by Michigan State University, has established a regional project to develop innovative cowpea pest management solutions that incorporate non-synthetic pesticide options. The project includes Burkina Faso, Niger, and Nigeria.

Prof. Ibrahim Baoua from the University of Maradi and Dr Amadou Laouali from INRAN, Maradi, lead this project in Niger. In collaboration with Dr Manuele Tamò from IITA in Benin, the Principal Investigator of this project, they have worked together to design and deploy natural solutions to fight pests in the field using sustainable approaches over the last decade. These include releasing adapted biological control agents (parasitic wasps) targeting the legume pod borer and an innovative way of using neem products, which we call the neem "tea bag". It was developed and tested with success by our Niger collaborators by establishing women-led Community Based Neem Production Units (CBNPs) where participating members have learned how to harvest the seeds of the neem and manufacture them into natural pesticide packets (picture). The packets are sold to local farmers, cooperatives, and traders.

What are the innovative aspects of the neem tea bag? This approach uses neem seeds, the kernels inside the soft-fleshed neem fruit, widely available in many rural settings in Niger. The first step is to remove the pulp from the fruit, which is usually done by soaking them overnight and crushing them by hand the next day.

Now, free from the pulp, the kernels are sun-dried and sorted to ensure a

good and consistent quality product. The kernels are subsequently de-husked and ground to powder, either using the traditional mortar or processed with a small, easily transportable motorized mill purchased during the project's initial phase. This motorized mill is now proving to be a real game-changer by allowing women participating in the CBNPs to save time and enormously reduce the drudgery of pounding the kernels in the mortar (picture).

The powder of the neem kernels is sieved and packaged at the rate of 5 (tomato paste) cups (about 250 g) into tissue bags which are machine-sewed in the community (picture). This is the neem tea bag, which borrows its name because it is soaked overnight in 5 L of water, providing a watery extract that can be sprayed on cowpea crops the next day. The neem tea bags are sealed inside small plastic bags (using a heat sealer) to keep their freshness and are properly labeled to make the product more appealing for sale. One tea bag sells between 500 and 1000 CFA (equivalent to 1 to 2 USD) and can be used to spray a surface of up to 400 m^2 of cowpea, depending on the crop's growth stage.

Currently, 29 women are participating in three CBNPs, and have produced 3988 neem tea bags and sold most of them to farmer cooperatives and NGOs. However, the cowpea farmers in their community still purchased only a small percentage.

So, why all this hassle and not just spray chemical pesticides, which are also widely available in Niger? Farmers indeed know the efficiency of chemical pesticides. But they are also becoming aware of some of the unintended side effects, such as itchy skin and eye irritations, particularly because they do not have access to personal protective equipment, either unavailable in rural settings or unaffordable. They have experienced that spraying neem products does not result in any health problems while giving similar yield outputs.

Here are some testimonies from members of the three communities "My knowledge in the ecological management of pests has grown, and so has the cohesion between our unit members and the producers," says Indo Maman, a widow from the village of Danja in the Madarounfa Department who became involved in the program through the women farmer cooperative. She has used some of her earnings to pay for her grandson's breakfast at school, along with their extra fees and school supplies.

Her main job is threshing neem grains, but Indo has big dreams. "I would like to organize advertising campaigns and market the neem tea bags on a larger scale. I dream of seeing the unit becoming a big company."

Aicha Mahaman, 55, is from Mai Ganga village in the Mayahi Department. "My role is processing neem kernels into flour," Aicha explains as she tends to her small herd of sheep recently expanded through her profits from neem tea bag sales.

She also shares Indo's dream of one day building a neem processing company. "I believe cowpea producers will be ready to pay for the neem tea bag if it's affordable, and they are well sensitized about the safety and effectiveness in reducing the population of cowpea pests."

As president of the Farmer's Cooperative in Serkin Hatsi village, Guidan Roumdji Department, 43-year-old Sa'a Moussa was the initiator of the women's organization. She participates in the neem processing through packaging the product.

"The activity is profitable not only because it generates income, but I have been able to weave relationships with other villages," says Sa'a. The fertilizer bought from her profits has increased the production of her farm. The additional income has also allowed her to purchase clothes for her grandchildren.

"I would like to see this industry grow."

Neem tea bag production is being expanded into new communities. We are seeing a potential to create a whole biopesticide value chain, creating job opportunities for women and youth.

Training maize stakeholders' trainers on Fall Armyworm scouting and IPM in northern Nigeria

A. Togola[1], A. Kamara[1], and P. Chinwada[2]
[1]International Institute of Tropical Agriculture, IITA, Kano Station, Nigeria [2]International Institute of Tropical Agriculture, IITA, Zambia

The innovation

The innovation is about the ToT (training of trainers) on Fall Armyworm (FAW) scouting and Integrated Pest Management (IPM) package with the following components: weekly field scouting, spraying of neem-based products (neem oil solution[3], neem cake solution[4], neem leaves solution[5]), intercropping of maize with soybean, handpicking of caterpillars and use of chemical insecticide (Emamectin benzoate) as last option and only when the action threshold is reached.

This ToT in northern Nigeria is under a GIZ-IITA funded project on Maize, Cassava and Yam value chain. Two hundred and fifty trainers, including 200 extension agents (EAs), 40 youth (agri providers), and 10 seed companies, participated in the capacity-building exercise. Two Nigerian states benefited from this training: Kaduna State with 120 participants and Kano State with 120 participants. Each of the 200 EAs was assigned to train at least 20 farmers through a step-down training to transfer the FAW IPM knowledge to 4,000 maize farmers in northern Nigeria. Our activities

included the retraining of an additional 100 EAs that GIZ trained some years back.

The training included theoretical and practical sessions. Participants were divided into batches of 40 to 45 people per session because of the COVID-19 guidelines in Nigeria. Participants learned how to identify FAW from other maize pests (stem borers, African indigenous *Spodoptera* species, leaf rollers, etc.). They were also taught the biology and ecology of the pest, the scouting techniques and the decision for the action threshold, the components of IPM, the treatment windows for chemical application and recommendations for avoiding insecticide resistance in the pest, the calibration of sprayers, etc.

An IPM demonstration plot was established in Kura Local Government Area, a FAW hotspot, to allow participants to implement what they had learned during the theoretical session. Both sessions were participatory, and we noted considerable interest and motivation among the beneficiaries. We created two WhatsApp groups to monitor the training properly, one for each state. The forum became very active. Through the WhatsApp groups, questions from stakeholders (EAs, youth, seed companies, farmers) are addressed, and IITA trainers provide timely responses.

The State Agri commissioners, the zonal supervisors, and trainees (EA, youth, and seed companies) highlighted the success of the training and recognized the value of the innovation. We expect this activity will substantially impact increasing maize production in Kano and Kaduna states this season. We are going to collect necessary indicators to compare the before and after training situations.

Some EAs have started the step-down training already. Mr Abdulahi, registered as EA_37 in the Kano State WhatsApp group, trained 20 farmers three days after completing the training module and has shared photos of the farmer group he trained.

Research challenges: No single option can sustainably control the FAW. Farmers rely on chemical insecticides only, which leads to the increase of pesticide resistance in the pest. Poor knowledge of both farmers and extension agents exists on FAW biology, ecology, and management. Consequently, in Nigeria, the average economic loss of maize production reaches 15% due to FAW.

Title and description of project or program that generated the innovation: GIZ-IITA Maize Cassava and Yam Value Chain Project

Location: Northern Nigeria (Kano and Kaduna states)

Beneficiaries involved: 300 extension agents, 40 youth (agri providers), and 10 seed companies.

Evidence of benefit and impact of innovation: Seven days of theoretical training engaging 45 participants each, with two days of practicals. A total of 350 trainers trained; 4,000 farmers will be reached through the step-down training. Two WhatsApp groups created as forums for proper monitoring and evaluation.

Implications to future research or development: Decrease of FAW incidence and an increase of farmers' productivity, contribution to food security in northern Nigeria

Partners and collaborators: IITA, GIZ, KNARDA, KADA, Seed companies

[3]**Neem oil solution:** Add 1 liter of neem oil + 2 liters of water + 10 g of soap powder (Omo, Kleen, Viva Plus, or any detergent). Stir very well to get a homogenous solution. This obtained product is a concentrate and should not be applied directly in the field. For field application, take 1 liter of the concentrate and add 9 liters of water + 10 g soap powder to be sprayed in the field using a Knapsack or any hand sprayer.

[4]**Neem cake solution**: Neem grain cake is the powder obtained from the kernel of the rap fruits initially dried under shade and pounded in a mortar or a mixer. The cake can be applied directly in the field, or we can infuse 1 kg of it by putting it in a muslin cloth and soaking it in 10 liters of water for one night. The liquid can be sprayed in the field.

[5]**Neem leaves solution**: Cut fresh neem leaves (2 kg). Grind it in a mortar or a mixer. Put the extract in a muslin cloth and tie it. Put the bag in 10 liters of water and let it soak overnight for a good infusion. Collect the liquid and add 20 g of soap powder. Mix them to get a homogenous liquid applied in the field using a Knapsack or any hand sprayer.

Managing natural resources

AKILIMO: Placing revolutions in digital agriculture into the hands of extension workers and smallholder farmers

Pieter Pypers, David Ngome, Theresa Ampadu-Boakye, Christine Kreye, Meklit Chernet, Guillaume Ezui, Stefan Hauser, Friday Ekeleme, Freddy Baijukya, Thompson Ogunsanmi, Mwantumu Omari, Sammy Barasa, Turry Ouma, Ademola Adebiyi, Saburi Adekunbi, Godwin Atser, Abubakari Mzanda, Ally Ngádoa, Evelyne Omotolani, Esther Kimatu, Toyo Oluwafisayomi, and Hadi Rashidi

African smallholder farmers face low productivity because they lack reliable agronomic recommendations tailored to their local conditions. For example, judging the correct quantity of fertilizer requires knowing the fertilizer cost and crop produce prices, expected weather, cropping history, and soil conditions.

Crop responses to fertilizer may differ between the fields of two neighbors, as much as they can vary between regions or countries because of differences in past soil fertility management. Prices of crop produce vary between areas depending on the proximity and type of market. As a result, farmers are often unable to judge if an investment is worthwhile before trying it.

Smallholder cassava growers now have real prospects through AKILIMO, an advisory service developed by the African Cassava Agronomy Initiative (ACAI) and scaled through a Roots, Tubers and Bananas (RTB) research program-funded scaling grant. AKILIMO offers tailored recommendations on different agronomic operations, maximizing

returns on investment within a user-defined budget. **These cover:** Fertilizer recommendations for cassava growers tailored to local soil conditions and crop calendars for sustainable cassava intensification

Advice on appropriate fertilizer blends for cassava-producing geographical areas based on soil types and nutrient deficiencies, cost, and potential demand for the fertilizer industry

Advice on best planting practices with a focus on tillage and weed control to guide farmers to choose the most cost- and labor-effective practices

Intensification options for cassava intercropping systems, including recommendations on planting density and arrangement and best-suited fertilizer rates for common intercrops

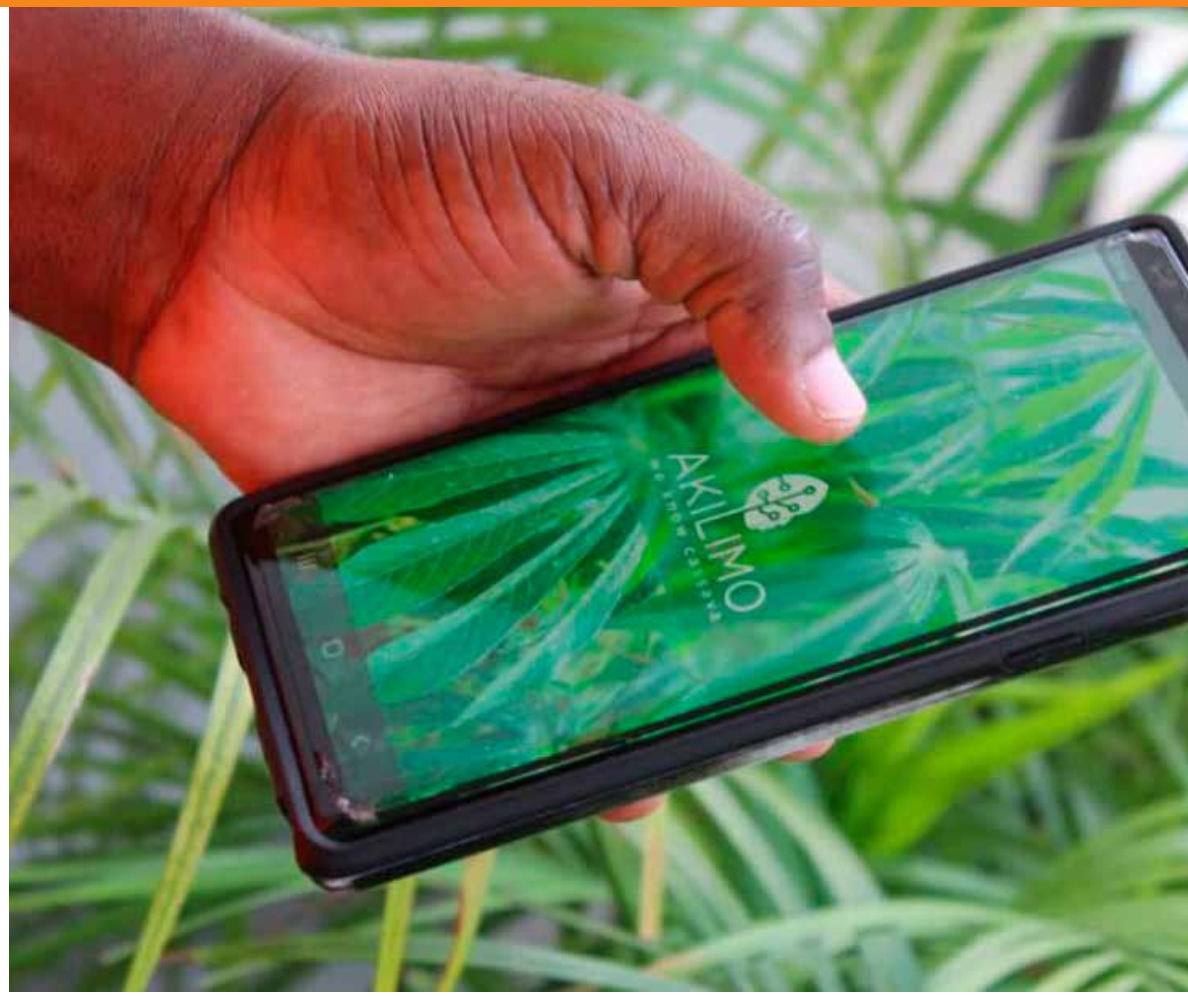
Planting and harvest schedules considering local weather to optimize the year-round supply of cassava for the processing industry

Agronomic practices to maximize root starch content for cassava growers supplying roots to the processing industry

AKILIMO was co-created by a partnership led by IITA, including national and international research institutes and universities, and development partners from the public and private sectors. Scaling partners defined upfront use cases and specified their particular needs for agronomy products. They were fully involved in an inclusive stepwise process to develop tools, hosting on-farm experiments, evaluating early prototypes, and coordinating field exercises to validate the recommendations. Partners also co-designed all training and promotion materials. All AKILIMO products are owned by the partnership. Today, over 30 partners in Nigeria and Tanzania have fully integrated AKILIMO in their dissemination strategies and operations.

AKILIMO usage

In February 2021, AKILIMO recorded over 170,000 registered users in Nigeria and Tanzania. Users mostly requested advice on best planting practices, including tillage and weed control and customized fertilizer recommendations. We recorded high retention, with 69% of users continuing to use the tools and requesting recommendations again after the initial exposure. Over 75% of users applied recommendations at least partially on their farms. Based on observed yield responses and price records, we calculated that users increased their income by US$120 per household per year on average. Increased profits are most often obtained through investments resulting in increased root yields, smarter decision making, reduced investment costs, market trend-monitoring, and harvesting at opportune times to obtain higher prices for the root produce.



AKILIMO leverages over 50,000 yield measurements from experiments carried out in the fields of over 20,000 farmers combined with satellite-based weather information and digital soil maps and user-provided input on crop history to calculate recommendations. AKILIMO's modeling framework combines machine learning with state-of-the-art crop models,

geospatial statistics, and economic optimization algorithms to provide advice that maximizes net returns on investments.

Accessing AKILIMO

AKILIMO is available in various formats. An app for android is freely available on the Google Play Store. Further, cassava growers can access the recommendations for free through IVR on VIAMO's 321 short code service and by interactive SMS on Arifu's chatbot. Finally, on the AKILIMO website (www.akilimo.org), simplified printable decision guides are available, where farmers can look up recommendations in maps and tables and do the calculations in simple worksheets.

All interfaces went through a development process with the help of partners and extension workers to ensure a positive user experience. Modifications and simplifications were made for each interface to balance precision with end users' capabilities and preferences. Learning journeys were implemented and tested with farmers to ensure the advice is provided in an intuitive way that aligns with farmers' needs.

Participatory validation and legacy

Validation exercises were carried out in 2019 and 2020. Over 5,000 farmer volunteers compared the AKILIMO recommendations against their current practice in small side-by-side plots on their farm. Participants were supported by trained extension workers within partners' dissemination network, without the direct involvement of researchers. Between 60% and 95% recorded profitable increases in root yield, while less than 10% recorded a loss in revenue. Data collected enabled further improvements to the recommendation framework and provided insights into enhancing the tool interfaces.

Many of the lessons learned in AKILIMO's development process are relevant to other agronomy-at-scale projects. Already the approaches used to develop fertilizer recommendations are being adapted to potato for the Rwandan highlands by the International Potato Center (CIP). Critical for success was a digital data collection system that enables all data to be available for analysis within 24 hours after collection.

Including scaling partners through an inclusive co-creation process is critical to generate trust and ownership, fast-track integration into partners' operation, and engender learning along the way. In the future, the Excellence in Agronomy 2030 Initiative will be an important platform to advance the tools and approaches used by AKILIMO and make these available to the wider digital agronomy community.

Taking integrated crop management to scale in highland banana systems in East Africa

[1]Taulya Godfrey, [1,2]Ochola Dennis, [1]Najjuma Zahara, [1]Jabungu Allan, [1]Nakamanya Florence, [3]Senyondo Brian, [4]Kubiriba Jerome

[1]International Institute of Tropical Agriculture, PO Box 7878, Kampala, Uganda
[2]Wageningen University and Research Center, Plant Production Systems, The Netherlands
[3]Grainpulse Limited, PO Box 6217, Kampala, Uganda
[4] *National Agricultural Research Laboratories, Kawanda, PO Box 7065, Kampala, Uganda*

East African highland bananas are the major food crop for 20 million people in the Great Lakes region of Africa, encompassing Burundi, DR Congo, Kenya, Rwanda, Tanzania, and Uganda. They are widely traded in local markets, contributing to the monetization of rural economies and sustaining the livelihoods of resource-poor farmers.

Poor soil fertility exacerbated by low input production practices has contributed significantly to low and declining productivity of East African highland bananas. Manure is the soil fertility input used by relatively rich farmers, compared to no fertility input by the poor farmers who are the majority. However, manure application is labor intensive and is scarce in most banana-growing areas of Uganda.

This project sought to develop an alternative nutrient management practice that is less laborious yet cost-effective in a farmer

participatory manner with relevant stakeholders to ensure rapid scaling up and scaling out. IITA partnered with Wageningen University and GrainPulse to demonstrate integrated mineral and organic input practice in farmers' banana fields in Uganda's major banana growing areas. The National Agricultural Research Organization (NARO) leads the project with funding from the Bill & Melinda Gates Foundation.

Farmer choice experiments led by Wageningen University and IITA were used to allay farmers' reluctance to using mineral fertilizers in East African highland bananas in Uganda. It was observed from the farmers' choices that they tended to combine cattle manure with mineral fertilizers as fertility inputs in banana cropping systems. A follow-up on-farm experiment was designed with various combinations of cattle manure and potassium chloride fertilizer in southwestern and western Uganda.

These trials showed that banana response was strongest when mineral fertilizer was combined with cattle manure (Fig. 1). Fresh bunch weight increased the most (18%) with a 50%:50% combination of cattle manure to mineral fertilizer as potassium chloride in southwestern Uganda. Sole mineral fertilizer posted an equally strong response in southwestern Uganda, where the trial fields had a history of manure use. In contrast, almost all the trial farms in western Uganda had no previous history of manure application, and crop response to sole mineral fertilizer was less than expected (Fig. 1). In western Uganda, the most significant increase in fresh bunch weight (36%) was observed with a 75%:25% combination of cattle manure to potassium chloride (Fig. 1).

*Insert **Figure 1**: Effect of soil fertility management inputs on East African highland banana fresh bunch weights in on-farm demonstration plots in southwestern and central Uganda.*

Farmers observed that the application of soil fertility inputs shortened the time taken for a banana plant to bear a bunch to maturity. This amplifies the increase in yield due to improved fresh bunch weight. Based on the findings from the on-farm trials in Figure 1, on-farm demonstrations were set up with cattle manure at half the rate farmers use, supplemented with half the recommended dose of potassium from mineral fertilizer. This was compared against the use of sole manure at the farmers' full dose, with no soil fertility input or control on established farmers' fields. Combining a half dose of manure with a half dose of mineral fertilizer increased fresh bunch yield by 53% in southwestern and 8% in central Uganda over the control (Fig. 1).

The combination of manure with mineral fertilizer halved the labor input cost for fertilizing bananas compared to using only a full dose of manure. The net cost (excluding investments in other agronomic practices like weeding) associated with combining a half dose of manure and a half dose of mineral fertilizer was 25% lower than the cost of applying only a

full dose of manure. The women farmers, who are both cash- and labor-constrained, particularly appreciated this, according to feedback from farmers during the field days held on the demonstration plots.

*Insert **Figure 2**: Effect of soil fertility management inputs on East African highland banana fresh bunch yields in on-farm demonstration plots in southwestern and central Uganda.*

Combining a half dose of manure with a half dose of mineral fertilizer increased the return on investment of the soil fertility inputs to US$500 per hectare per year over that for the full rate of manure only at the responsive site in southwestern Uganda. The crops in central Uganda were less responsive to the soil fertility inputs partly due to intercropping with beans and coffee. The return on investment in soil fertility inputs was higher (US$281 per hectare per year) for half the manure dose combined with half the mineral fertilizer dose than for the full dose of manure alone (US$387 per hectare per year) relative to the control.

However, soil fertility input use had the same benefit, whether the full dose of manure alone or a combination of manure and mineral fertilizer at half dose each: the cost ratio was above 1. This outcome implies that both technologies demonstrated to the farmers on both sites do not pose a financial risk either way.

The observed positive effect of the mineral fertilizer supplement to half dose of manure led some farmers in central Uganda to apply the mineral fertilizer to the control plots, thus masking the treatment effects (Fig. 2). Doing this also partly accounted for the poor estimates of returns to investment in soil fertility inputs in the region.

Two farmer field days around the demonstration plots strengthened information flow between farmers, researchers, and input providers. This increased the demand for the mineral fertilizers at the local dealerships, which started partnering with GrainPulse to secure mineral fertilizers at the factory price, thus reducing the cost incurred by the farmers. The orders for mineral fertilizers from the farmers following the farmer field days amount to application rates more than double the national average application rate. This trend indicates a potential for uptake rates that will outlive the project life span.

GrainPulse operates a fertilizer blending facility that customizes the compound mineral fertilizers to the specific requirements of the crops commonly grown in the farming systems, including bananas. It is receiving information directly from the research team from IITA, NARO, and Wageningen University concerning the specific requirements of East African highland bananas to fine-tune their blends further to the crop requirements.

Farmers still question the long-term effects of using mineral fertilizers on the soil quality and productivity of East African highland bananas. That question needs to be addressed with data from long-term soil fertility trials.

Leading a consortium of international and national research and development institutes to improve agricultural livelihoods in the Great Lakes Region: a practical perspective on One CGIAR

With the aim to develop and implement a more coherent and efficient research strategy, CGIAR centers are being reorganized into "One CGIAR". The success of this new working model requires proven experiences to avoid institutions focusing on internal organizations at the expense of strategy implementation.

Over the past 15 years, IITA has co-led the Consortium for Improving Agricultural Livelihood in Central Africa (CIALCA, www.cialca.org). CIALCA is the longest-standing consortium consisting of National Agricultural Research Systems (NARS), extension services, European universities, and CGIAR centers (three from 2005 to 2016; two from 2017 to present) working in the Great Lakes Region of sub-Saharan Africa.

From 2005 to 2008, CIALCA and NARS partners developed science-based products and technologies for improved banana and legume germplasms, integrated cassava-legume cropping systems, and integrated pest and disease management. From 2009 to 2012,

CIALCA and national, regional, and international extension services disseminated technologies and innovations, lifting more than half a million people out of poverty (https://www.iita.org/countries/drc/).

The importance of CIALCA is reinforced by the recognition that CIALCA-based research has informed and changed national policy. For instance, the Rwandan government's Crop Intensification Program moved away from monocropping of the major food and cash crops to intercropped systems due to the high income that households generate from the latter (Fig. 1).

During these phases, CIALCA, in collaboration with regional and European universities, has trained more than 150 PhD, MSc, and BSc students in Burundi, DR Congo, and Rwanda. CIALCA alumni are now in senior governmental positions across the focus countries.

Figure 1. Examples of intercropping systems for more income generation and multiple benefits

From 2013 to 2016, CIALCA continued developing and disseminating science-based technologies and innovations and building capacity within the NARS. In addition, CIALCA used the Innovation Platform approach to facilitate multi-stakeholder networks (from input suppliers to consumers, including private sector operators) in the value chains such as cassava, banana, legumes, and cereals. With the long history of conflicts in the Great Lakes Region, these networks were a unique framework where the private sector, organizations, and research-for-development systems across countries discussed mutual development strategies and exchanged experiences.

Since 2017, CIALCA applied a partner co-investment model *("we do not pay you, and you do not pay us")* to ensure it worked on stakeholder

demands. For instance, CIALCA co-invested in Rwanda with One Acre Fund (OAF), one of the regions' largest farmer extension networks (serving 500,000 farmers), to better understand farming household heterogeneity and develop tailored tools and innovations for a specific group of farmers.

In Burundi, CIALCA co-invested with the International Fertilizer Development Center (IFDC), which is leading the country's fertilizer subsidy program, to develop ICT-based tools to enhance soil responsiveness to fertilizers and improve farmers' returns on fertilizer investment (Fig. 2). During the 2019 mid-term review (CIALCA phase 4) in Kigali, the representative of CIALCA's donor (Directorate-General for Development Cooperation and Humanitarian Aid of Belgium [DGD]) provided a positive testimony on CIALCA as an exemplar for capacity development and impact generation. Representatives of development and co-investing partners (OAF and IFDC) also expressed the appropriateness for farmer needs of the tools being developed by CIALCA.

Under CIALCA's phase 4, demand mapping revealed a need to provide insights for increasing water use efficiency to counteract drought effects on cassava production. To address this demand, CIALCA contacted the Soil and Water Management & Crop Nutrition Laboratory (SWMCNL) of the Joint FAO/IAEA Division, who became a member of the consortium. Furthermore, CIALCA attracted funds, representing about four times the original investment, by leveraging 'spin-off' projects.

We anticipate that the above lessons learned by CIALCA can be of interest to One CGIAR.

Ensuring impact and delivery

Expanding the footprint of IYA through STEP

Adetola Adenmosun, IYA, IITA, Ibadan, Nigeria

The IITA Youth in Agribusiness continued to expand its footprint in 2020, extending the gains of youth engagement in agriculture with a focus on younger youth through the Start Them Early Program (STEP) initiative.

Although the outbreak of the COVID-19 pandemic posed some challenges, the youth remained undeterred as they engaged in proposal development and negotiations for resource mobilization, policy dialogue, partnerships, and scaling of innovations for various activities and expansion.

IITA Director General Dr Nteranya Sanginga had initiated STEP in 2018 after IITA received the Africa Food Prize. The strategy behind STEP was to "catch them young," ensuring that secondary school students develop an interest in agriculture and later embrace it as a business at a young age. The initiative aims to encourage young people to view agriculture as a viable career and not as a last option if they cannot find jobs in other sectors of the economy. The International Development Research Centre (IDRC) and CTA funded the inception stages of the program.

The birth of STEP-Oyo

After gaining recognition from the impact recorded in 2019 across the countries of implementation—DR Congo, Kenya, and Nigeria, 2020 paved the way for STEP to expand its strategies and operations, especially in Nigeria with buy-in from government at various levels and project portfolios within the Youth in Agribusiness Unit. The year gave birth to one subgroup known as STEP-Oyo.

STEP-Oyo originated with the inauguration of Fasola Grammar School, one of the secondary schools in Nigeria where STEP piloted its strategy.

Fasola Grammar School, which is in a rural area in Oyo state, was in a deplorable state, with abandoned and dilapidated classrooms, learning facilities, furniture, toilets, libraries, school halls, etc. STEP interventions elevated the school's infrastructure to a level that is rare to find even in urban centers in

Nigeria and enhanced the skills of the school's students in agribusiness.

STEP re-introduced the innovative but long-forgotten agricultural club into secondary schools by establishing school farms, ICT in agribusiness, value addition, use of modern farm machinery, marketing, branding, etc.

Thrilled by this model, the Oyo State government, under the leadership of Governor Seyi Makinde, requested a replication and expansion of the STEP model across its six geopolitical areas.

To commence expansion activities, STEP conducted an inception workshop, where it developed an implementation plan. It also conducted surveys in some schools in the geopolitical zones to gather baseline information to aid its intervention in the schools.

The survey aimed to understand the students' perception of agriculture and determine appropriate/customized training strategies of modern agriculture and agribusiness management for each school.

Five hundred and three students participated in the survey—71% from Bishop Philips Academy (BPA) and 29% from Methodist High School (MHS). Of the total respondents, only 17% of the MHS and 7% of BPA students affirmed that agriculture is their first career ambition. Other students said that they could practice agriculture as a secondary activity (51%). In comparison, 26% would avoid any agricultural activity because they believed it is hard to secure land or agriculture is labor-intensive and has meager returns. Interestingly 84% of the surveyed students expressed their interest in becoming a member of a new agricultural club.

The STEP initiative is now active in four Nigerian states—Kaduna, Kano, Lagos, and Oyo.

COVID-19 intervention by STEP

In the face of the COVID-19 pandemic in 2020, STEP leveraged the lockdown to strengthen students' agribusiness skills with further training in secondary schools. There was a series of training on value addition, small-scale mechanization, ICT, and crop production. A total of 150 students were engaged in STEP agribusiness training across four schools in Nigeria during the period.

In DR Congo, 300 students benefited from the training organized by STEP during the lockdown while they also continued to manage the established enterprises. The **STEP Educ** application, a training tool installed on phones and computers to enable students to learn about agriculture, livestock, and entrepreneurship, was also used to train students during the lockdown.

To continue engaging the students during the pandemic and subsequent restrictions in Kenya, the STEP team introduced the **STEP Home Challenge**. The challenge targeted promoting a "Do It Yourself" mentality that enables students to be creative and involved in every step of the life cycle of their enterprises. Interested students were given seedlings to start their home gardens. Fertilizers and pesticides were not given so the students could learn to recognize deficiencies and pest and disease infestations and seek corrective measures, which STEP provided. The e-learning platform was another means devised by STEP to reach out to students in secondary schools in Kenya.

Launching youth activities through partnerships

Through some partnerships established during the year, youth in agribusiness-related interventions were launched across five states in Nigeria. IYA had existing programs in some of these states, while others were new areas of intervention following partner recommendations. These states include Imo, Kaduna, Kano, Lagos, Oyo, and the Federal Capital Territory in Abuja. This has now extended IITA's youth in agriculture intervention to 10 states in Nigeria.

Crop production	Planting maize, cassava, soybean, orange-fleshed sweet potato (OFSP), vegetables
Value addition	Soymilk production, bread, cake, doughnut, sausage, meat pie, tidbits etc.
Mechanization	Use of small-scale machines such as rototiller, brush-cutter, two-wheel weeder, and motorized sprayer
ICT	Using the internet and Microsoft Office
Livestock	Poultry production (broiler and layer birds), aquaculture

The partnership with the Mastercard Foundation under its Young Africa Works strategy officially commenced in May 2020. The partnership aims to equip 242,724 young Nigerian women and men between 15 and 35 years with skills to secure gainful employment in the agri-food system or become independent agribusiness owners in the agricultural value chain of choice. This would create sustainable means of income generation for themselves and employment opportunities for others.

The beneficiaries are categorized into employment and entrepreneurship tracks with 70% and 30% distribution in the respective paths. The project also pays particular attention to women's participation and intends to attract 70% of them into the agri-food system through its intervention. The project will develop an agribusiness support strategy and financial schemes that consider and encourage women's participation. The project will leverage and scale existing IITA youth initiatives, including STEP.

During the year, the project recruited 17 staff to implement its strategy.

The first major activity of the project was an inception workshop that served as a platform for bringing together relevant stakeholders to sensitize them about the project, seek their buy-in for an enabling environment, and design an implementation plan to guide and address critical areas of intervention. It was also an opportunity for the team to present their work plans. The team also conducted a baseline survey across the three states to design strategies that will meet the needs of its targeted beneficiaries.

Since training is a principal component of the project, the team rolled out a training application where over 60,000 applications were received. The training commenced fully in 2021 and focuses on agricultural technologies on various crops, agroprocessing, agribusiness operations, soft skills in partnership with Jobberman, business planning courses, etc.

Through partnership with the International Fund for Agricultural Development (IFAD), the Youth in Agribusiness office focuses on equipping young people in Imo and Oyo states and the Federal Capital Territory with agribusiness skills through the "Rural Youth Employment Opportunities: Support to integrated agribusiness hubs (Agrihub) in Nigeria" project. The project, otherwise known as IFAD-Agrihub, aims to realize IFAD's vision of empowering African youth by establishing a network of youth-centered Agribusiness Hubs in Nigeria. These Hubs are intended to transform and integrate agricultural production and processing through skills impartation among employment and entrepreneurship track youth.

Apart from offering capacity building, training, and mentoring, the IFAD-Agrihub pilot enterprises test and refine modern agricultural technologies while demonstrating them to the broader agricultural community to attract the growth of advisory services around them. As the agribusiness hubs grow in number and sophistication, they form mutually beneficial networks in technology transfer, market intelligence, digital agriculture, and policy advocacy. The hubs serve as magnets for commercialization, attracting both new products and financial services. Over the next five years, the project will target 2,200 direct beneficiaries, 70% of whom are expected to find meaningful employment and 30% to start independent agribusiness enterprises.

The project activities in 2021 also commenced with the recruitment of staff. IFAD-Agrihub project has seven full-time staff. The inception workshop of the project was also conducted during the year.

Our impact through the Innovation Award

In 2019, the youth program received recognition for its commitment to improving agribusiness opportunities and the creditworthiness of youth

across Africa. This first of its kind award, funded by the government of Switzerland, was presented during the 41st conference of the Food and Agriculture Organization (FAO) at the organization's headquarters in Rome. The award included a $20,000 cash prize, which was pledged to establish a Youth in Agribusiness program in the Republic of Benin.

In 2020, IYA partnered with the IFAD-funded Youth Employment in Agribusiness and Sustainable Agriculture (YEASA) Project to train 25 youth in the Republic of Benin, fulfilling its pledge. The project also provided them with inputs to start their businesses through the IFAD window for supporting small and medium enterprises. The beneficiaries established enterprises along the value chain of rice and aquaculture.

Youth Employment in Agribusiness and Sustainable Agriculture (YEASA)

YEASA started in February 2019. It is funded by IFAD. It aims to build the technical, entrepreneurial, and soft skills of young adults (18–35 years) to improve their productive capacity and increase their benefits from existing agri-food systems. Three institutions are implementing the project: the grant recipient, Afe Babalola University Ado-Ekiti (ABUAD), and sub-recipients IITA and the AfricaRice Center.

In 2020, the project adjusted its implementation strategy due to the challenges posed by COVID-19. . As a result, the training program was modified to accommodate both online and onsite sessions, an arrangement that permitted batching of selected beneficiaries into smaller class sizes in both Nigeria and the Republic of Benin.

The major activities carried out in the year included:

- The expansion of training manuals to accommodate technical, entrepreneurial, and soft skills
- The development of audiovisual training sessions
- Grant monitoring visit for some youth who received the grant award in 2019
- Facilitation of training sessions for 146 youth online and 123 onsite participants.

Youth who expressed interest in training during the lockdown on

the project's website (https://www.yeasa.org/#apply) were selected and asked to maximize the online training modules. Courses were uploaded on the website (designed specifically for the YEASA project) with specific log-in details for commodity and corresponding courses, allowing concurrent training delivery for all enterprises - (http://eduapps.startthemearly.org/courses/cassava-production/). The primary learning tool was audiovisual presentations.

Some of the project's milestones in the year include:

- Training 123 youth; 62 in Nigeria and 61 in the Republic of Benin. This means 90% (180) of the target youth have been trained from project inception to date.
- Award of grants to 103 youth in Nigeria (52) and Benin (51), representing about 62.4% of the total grant award. From the project inception to date, grant disbursement is about 91% (150) of the total.
- Translation of training manuals along the value chains of cowpea, soybean, maize, plantain, maize and cassava into French.
- Development of audiovisual presentations for all crop commodity enterprises in French and English.
- Development of business plans by trained youth along the value chain enterprises assigned to IITA.

Wrapping up on youth from the creeks

In 2015, the Youth in Agribusiness office commenced a mission in the Niger-Delta region of Nigeria to move youth from the creeks to the farm and help them explore opportunities available along the value chains of aquaculture, cassava, and plantain.

The project Community Youth in Agribusiness Group (CYAG), funded by Chevron Nigeria Limited (CNL), closed in November 2020.

The project had the mandate to train 120 youth across selected communities in the Ijaw and Itsekiri axis in Delta State on the value chains of cassava and fish (processing and service provision). The trainees were engaged in classroom sessions with lectures and presentations before the experiential learning process at the newly constructed processing centers, built in one of the selected communities in the Itsekiri axis (Omadino).

The CYAG project established over 10 hectares of agribusiness demo sites containing fish ponds, ProVitamin A and TME 419 cassava, plantain and banana macro chamber and field. In addition, the project constructed a cassava processing center, fish processing center, and catfish hatchery section to engage all the 120 trained youth across the project enterprise value chains of cassava, fish, and plantain.

Youth entitlement mindset, low level of agribusiness activities within the project site, and community interference on activities were the major challenges encountered on the project. Still, the management team was able to resolve these highlighted challenges through sensitization and educational tours for beneficiaries outside the project location, partnership with existing agro-related organizations, and executing activities with a conflict-resolution approach.

A walk in the park

The Youth in Agribusiness park is located in Awe, Oyo State, about 56 kilometers from IITA, Ibadan. The youth use it as an agribusiness incubation center, agribusiness park, a hub for establishing pilot learning enterprises, and a training center. The center, previously known as Rural Community Development Center (RCDC), has now been named the Oyo State-IITA Youth Agribusiness Incubation Park Center. The center was a farmers' academy owned by the Oyo State government but will now be used by IYA to expand its activities and give young people the opportunity to have hands-on experience in agribusiness.

IYA has requested the use of 100 hectares of land, access to the training rooms, dormitories, and processing facilities. Although situated in a rural community, IYA, through the state government's approval and assistance, is transforming the center to a modern agribusiness training center where innovative and modern agricultural practices are being taught.

IYA had taken a bold step in June 2020 to transform the center into an agribusiness park where pilot enterprises could be established to support the development of youth-led agribusiness start-ups through training and a low-cost incubation model. The center will also provide agribusiness support services to youth and farmers in and around Awe.

Presently, the youth have cultivated about 40 hectares of cassava and renovated the abandoned cassava processing center, scheduled to commence full operations in February 2021. There are plans to establish a livestock enterprise comprising sheep, goats, and rabbits. Poultry raising, aquaculture, beekeeping, and modern vegetable production using screen houses, are also part of the plan. The cultivation of maize, soybean, potato, cowpea, and other crops will be introduced in the next planting season.

Through the partnership, IYA has acquired the oil palm and cashew plantation on the farm. Some of the renovation activities at the park include the conversion of the administrative buildings to offices and training rooms, the construction of a 2,500-capacity poultry house and a sheep and goat pen, and the digging and expansion of fish ponds. Having prioritized the provision of electricity, boreholes, and renovating the hostel facilities at the center, the state government also commenced the construction of a fence around the facility. IYA has posted four of its staff to the center.

About the Author

Adetola Adenmosun is a graduate of Mass Communication. She is the Communication Officer for the Youth in Agribusiness office at the headquarters in Ibadan. She joined IYA in 2014 after completing her National Youth Service Corp Scheme in IITA. Adetola has contributed to various journals and reports, including the Africa Agriculture Status Report 2015. She has also written reports and some editorials published in reputable media organizations to promote the role of youth in the advancement of agriculture in Africa.

Legume-based entry points towards improved food security and soil health

Jonathan Odhong', Africa RISING program Communication and Knowledge Sharing Coordinator, IITA

Depleted soils are a major underlying cause of poverty and hunger in Africa. With a bulging population currently pegged at 1.2 billion people and at least 20% being food insecure, food and nutritional demands must be met without further degrading the natural environment. Therefore, recommended technologies of crops and cropping systems that promote soil sustainability should be encouraged to contribute to the fight against poverty and hunger.

Legume crops play a vital and multipurpose role. In addition to serving as a source of high-quality food and feed, leguminous crops also fix atmospheric nitrogen into the soil to improve fertility, enhance soil structure, and add organic matter to the soil. They can also be used as an intercrop when planted with cereals for diversified farm production and cover crops to reduce erosion and weed pressure on farms. These crops can therefore contribute to achieving the objectives of sustainable food production and environmental security.

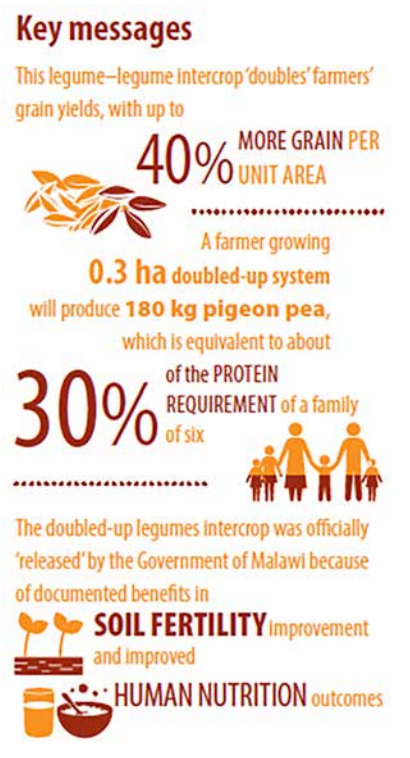
Over the past six to eight years, IITA researchers, collaborating with various partners, have developed and shared three legume-based technologies that are helping smallholder farmers in West, East, and Southern Africa rejuvenate their soils while keeping their plates full. These technologies are: (a) the doubled-up legumes technology, (b) optimal spacing for groundnut, and (c) conservation agriculture in maize–legume systems.

Funded by USAID through the Africa Research in Sustainable Intensification for the Next Generation (Africa RISING) program, each of these technologies has proven effective in boosting soil fertility, improving family nutrition, and other tertiary benefits documented through a broader sustainable intensification assessment.

Doubled-up legumes technology

The doubled-up legumes system is based on intercropping grain legumes, with pigeon pea (*Cajanus cajan*) as one component—increasing the total legume yield per unit area. Doubling-up legumes fulfills multiple objectives, including (a) integrating more grain legumes when land is limiting, (b) rehabilitating fields with poor soil fertility, and (c) extending ground cover in cropped lands as pigeon pea can be in the field for 6 to 8 months, depending on the variety used.

Intercropping two grain legumes exploits their complementary growth habits and plant architecture. The most successful doubled-up legumes system is pigeon pea with groundnut (*Arachis hypogaea*). Both crops are planted at their typical monocrop densities (additive) or one or both crops are planted at a lower density (partial substitutive), depending on the level of water stress in a site. Groundnut and pigeon pea are planted at the same time. Pigeon pea grows very slowly during the



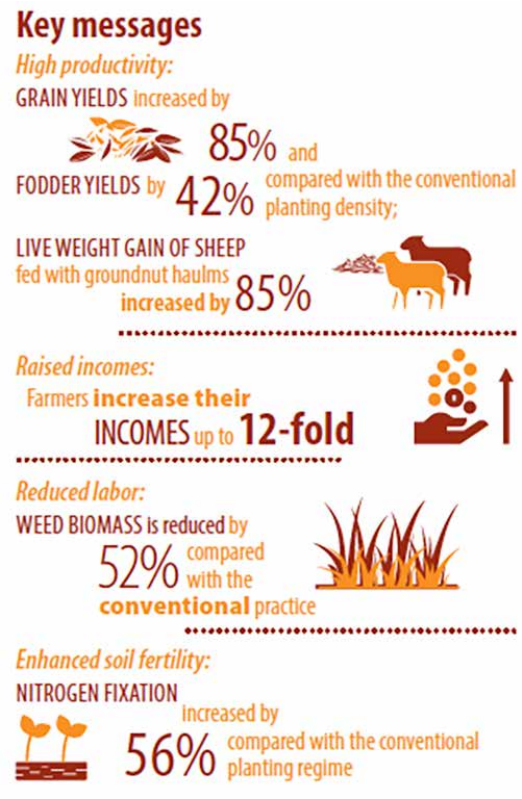
first three months, only starting rapid growth as the groundnut approaches maturity. After groundnut harvest, pigeon pea grows as a sole crop. Groundnut is often considered the main crop in the intercrop and is planted at its ordinary 'sole cropping' density. Pigeon pea is planted at 50–100% of its sole cropping density.

Large-scale research and scaling were done in the central districts of Malawi (Dedza and Ntcheu). In 2017, the Government of Malawi officially 'released' the doubled-up legumes technology as an innovation that can be mainstreamed across the country for soil fertility improvement and improved human nutrition outcomes.

Partners: Michigan State University, LUANAR, IITA, and Malawi's Department of Agricultural Research Services.

Optimal spacing for groundnuts in smallholder farming systems

Africa RISING scientists have found that increasing the groundnut planting density confers numerous benefits. The new technology specifies an inter-row spacing of 30 cm and intra-row spacing of 15 cm, giving a 22 plant per square meter planting density. Compared with farmers' traditional practices, the higher density of plants increases the rate of canopy closure over the soil surface by 25% at every 10-day interval from 30 days after planting to harvest. The more profuse plants and the earlier closure of the canopy over the soil improve the soil microclimate, conserve moisture, and enhance



plant growth. It also protects the soil from erosion and improves water infiltration and soil moisture retention.

Grain yields increased by 85% in on-farm trials and fodder yields by 42% compared to conventional planting density. Feeding groundnut haulm from the 22 plants per square meter density to sheep increased dry matter digestibility by 28% and live weight gain by 85%. It also improved the nitrogen concentration of the manure by 12% when compared with that of sheep fed with groundnut fodder from the conventional planting density. Additionally, biological nitrogen fixation is boosted by 56% relative to conventional practices, while reduced weed infestation is another key benefit.

The technology was validated jointly with farmers in six districts and 12 communities of northern Ghana during the 2016, 2017, and 2018 cropping seasons.

Partners: IITA

Conservation agriculture in maize–legume systems

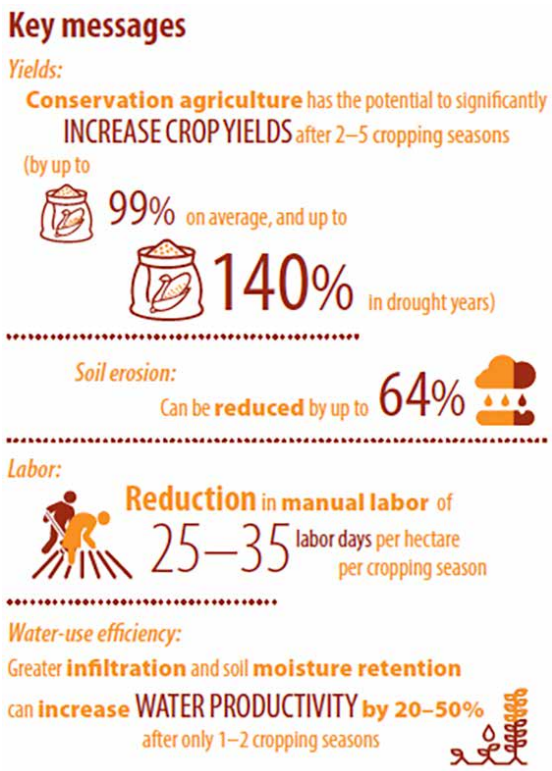
Conservation agriculture is a crop management system based on three main principles: (a) minimum soil movement (no soil inversion, i.e., no-tillage); (b) surface cover with crop residues and/or living plants; and (c) diverse crop rotations or intercropping strategies. The technology can be supported and improved with additional crop management practices, such as timely application of operations, the precision of seeding, adequate application of

nutrients, and efficient control of weeds and pests, including the use of herbicides.

In Malawi and eastern Zambia, farmers practice manual conservation agriculture systems with maize by making small planting holes with a pointed stick (dibble stick) or hoe. The seed is then planted in rows at a spacing of 25 cm between plants and 75–90 cm between rows. For rotational legumes, the spacing can be halved (to 37.5–45 cm while maintaining in-row spacing at 25 cm) to make full and more efficient use of the land area. Cereals and legumes can also be grown as intercrops under no-tillage in the conservation agriculture system.

The technology was validated extensively in southern and central Malawi and eastern Zambia through long-term conservation agriculture trials. An estimate of more than 1 million farmers in Malawi and Zambia have adopted conservation agriculture.

Partners: CIMMYT and IITA



Impact stories of IITA interventions: the case of hub-based African farmers evaluation

Hope Webber and A. Solomon Adebayo

Under the IITA institutional strategy a study was undertaken to determine the impact and contribution of the Institute's interventions to address sustainable nutrition and food security among African farming households. Based on the refreshed 2012-2020 strategy, 13 institutional key performance indicators (KPIs) were formulated from the strategic objectives and targets.

As part of its mandate, the M&E Unit implemented a hub-based farm households survey with two objectives: (a) evaluate the progress of the KPIs through the collection of data from farmers in the IITA Hubs—action sites, where IITA's projects are active on the ground (treatment group) and non-action sites, where its projects are not active on the ground (control group), and (b) assess the impacts of its interventions among African farmers.

The survey results will enable scientists to target farmers better with improved crop technologies and management practices to increase adoption, yield, and income and reduce poverty among African farmers. The learnings from the study will also improve farmers' farming practices and livelihoods.

The systematic random sampling method was used to sample farmers from villages within districts/Local Government Areas and states/regions in three intervention countries in Africa—Democratic Republic of Congo (DRC), Nigeria, and Tanzania.

The beneficiary-farmers from Nigeria were divided into the treatment group located in Umudike (Abia State), Kano State, Onne (Rivers State), Saki, Ibadan (Oyo State), and Abuja (Federal Capital Territory), and the control group in Taraba State. The treatment group farmers from DRC are located in three districts in South-Kivu province—Walungu, Kabare, and Uvira, and the control group in Mwenga. Those from Tanzania are located in Arusha, Dodoma, Morogoro, Mwanza, etc.

A questionnaire designed in ONA/ODK, deployed on mobile phones and laptops, was used to collect data through face-to-face and mobile phone interviews. M&E Unit staff, Hub M&E officers, and trained enumerators with local knowledge of the states or regions/villages administered the survey instrument to the respondents. Key among the interview questions posed to the farmers was the success/impact stories of IITA interventions in their farming activities and value chain.

On completion of the data collection, the success stories module of the questionnaire was extracted, cleaned, and a qualitative dataset of farmers per country with credible impact stories was established. Content analysis of the data revealed that the impact stories pointed to six key performance indicators (see graphs below). The indicators of success were used to transform the qualitative impact stories into quantitative data, and percentages of farmers' responses (gender-disaggregated) per indicator were computed. Subsequent interviews of farmers with fascinating impact stories were conducted to probe further how IITA interventions and technologies resulted in notable changes in their household living conditions. The interviews also determined whether they plan to continue adopting and disseminating the interventions/technologies to their family, friends, and communities.

Evidence of IITA impacts and success stories in Africa

Below are the testimonies from some farmers and graphical presentations of the impact stories per country.

Interview with a farmer from DR Congo

"Once you give someone one thing, it helps them in many things."

The testimony of a female farmer from Luvungi, DR Congo

I want to thank IITA for a lot of things it has done in relation to our project, for example, the distribution of improved maize and cassava varieties and crop management practices in 2019. Capacity building was given *[sic]* to people on the varieties and the management practices. People were happy because it helped to reduce famine. In the past, we worried because we had no good seeds to plant in a timely fashion, but today, we eat and even store seeds for the next planting season.

The change came through IITA because it awakened people, and we began to support the interventions. We have seen great change as a result of IITA's work. Once you give someone one thing, it helps them in many things. The change is that I was missing *[sic]* the money to send my kids to school, but as soon as I got the improved seeds, I planted, and it increased my production. I sold some, and the rest we consumed at home. I experienced the change personally and for my family as we have enough food, and our health has improved. I thank IITA as my daughter got a well-deserved award.

Interview with a farmer from Abia State, Nigeria

"I use improved varieties of cassava now. IITA has taught me much and helped me a lot. I now use TME0419 and TMS 98/0505, which I got from my state ADP and the research at Umudike. Those are the two major varieties I use. I also have pro-vitamin varieties from Umudike. Those are the three main varieties, and I will continue to grow these varieties.

I started farming in 2001; I have been on it for 20 years! For the past 15 years, I have been using improved varieties. At the onset, I was mixing the improved varieties with the local best we had. The main variety being grown in our community is TME0419. It has an advantage over others because the moisture content is not that high, unlike the other varieties.

Yes, I have told others. I sell cassava stems every year to other farmers; they have tried it and have come to know that it is better than the local ones they are used to.

When the yield improves, my income will also increase, and I have been able to cope with my family challenges to some extent anyway. I intercrop cassava with maize and egusi. Cassava is the main crop from which most of my income comes. I am also an egg dealer. I have a shop where I sell table eggs, and I get supplies from the poultry people..."

Interview with a farmer, Codes Mwitea, from Tanzania

"I am a farmer from Kiloasa, Morogoro of Tanzania. Researchers from IITA/MEDA project exposed me to new good agricultural practices (GAP), which are different from the normal practice I am used to. After attending the training, I tried to practice all the procedures on how to grow cassava, and finally, I realized that if you follow all the procedures well, you will produce more. I started implementing these good agricultural practices in 2019, and I have witnessed increased production resulting in increased income. This has continued from 2019 till now. By using good agricultural practices, I have nearly doubled my income, which helps me spend the additional money to bring about other developments and feed my family. Personally, I got more yield in a way that surprised my neighbors. I am now able to visit other farmers who were not part of the demonstration plots and teach them for them also to realize changes in their farm practices."

KPIs from DR Congo impact stories

The graph below shows that about 57% of the sampled farmers in DRC indicated that IITA interventions/technologies improved their livelihood and economic conditions. Household food security was mentioned as the second indicator, followed by increased yield, increased income, increased agricultural training and knowledge, and education for children. It is noteworthy that, in DRC female farmers scored high in all six indicators of success compared to men. Therefore, IITA/CGIAR research and development should focus more on promoting women-led agricultural initiatives to improve livelihoods, economic conditions, and household food security in DRC.

Here are other testimonies from DRC farmers:

a. A good development, especially with the help of the IITA and other NGOs. We want their support to continue to be successful,
b. I was able to buy my plot and my house, thanks to the IITA agribusiness training.
c. I started farming with only one field, but today I have three fields.

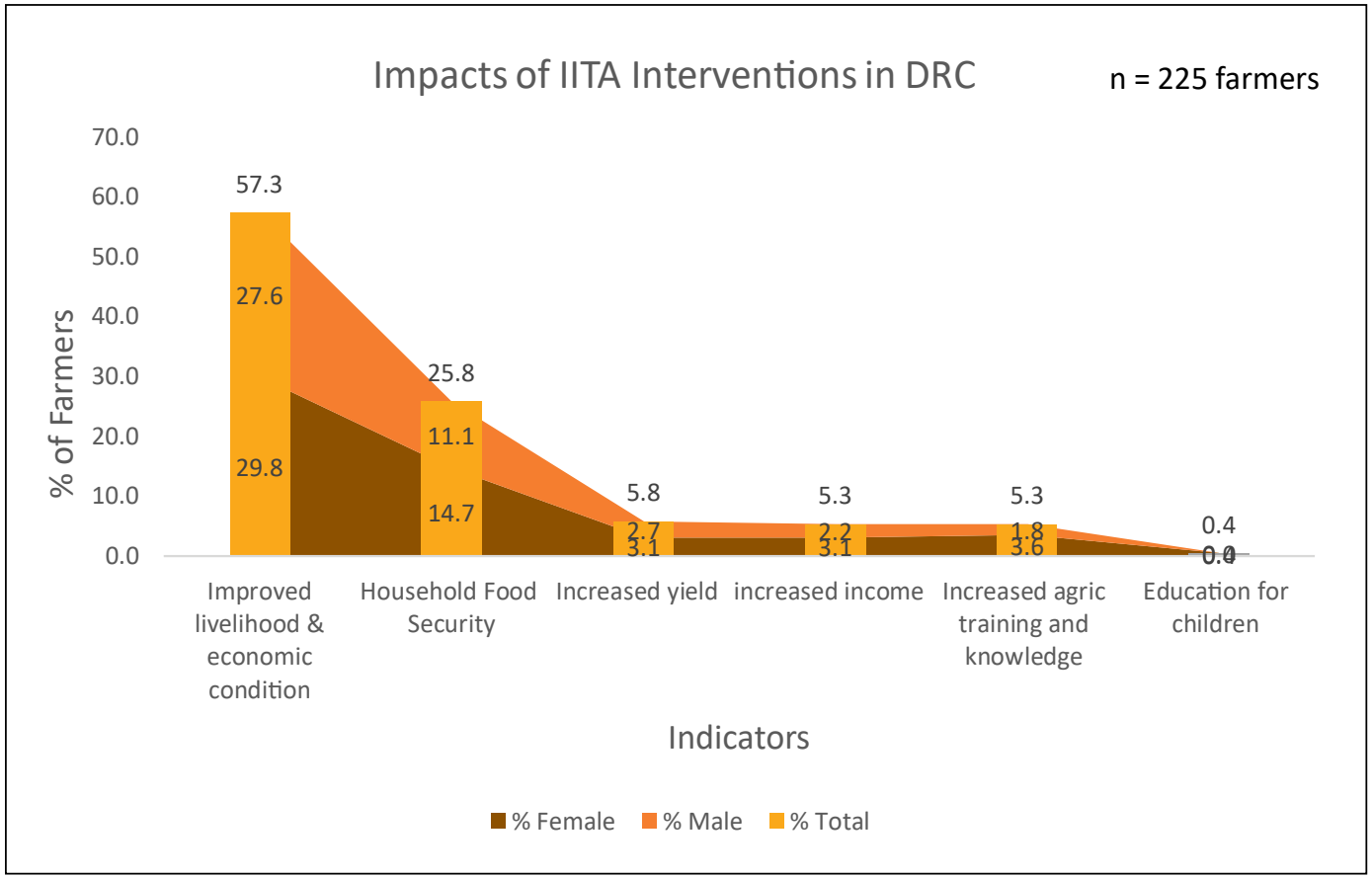


Figure 1. Impacts of IITA Interventions in DR Congo.

KPIs from Nigeria impact stories

The graph below shows that about 39% of the sampled farmers in Nigeria indicated that IITA interventions/technologies improved their household food security. They mentioned improved livelihood and economic condition as second, followed by increased income, education for children, increased yield, and increased agricultural training and knowledge. Men farmers scored high in all six indicators in Nigeria.

Here are other testimonies from Nigerian farmers:

a. Value addition in cassava has earned me more income which helps me to support my family.
b. The vitamin A cassava I adopted gave me better yield, and it is a point of reference because I introduced it to many people.
c. The extension officers of OYSADEP have been very instrumental to my progress, and IITA and GIZ contributed significantly to my wealth creation.
d. The little knowledge I gained and applied from just one IITA training improved my yields and income. I am taking care of my family in terms of food, health, and education.

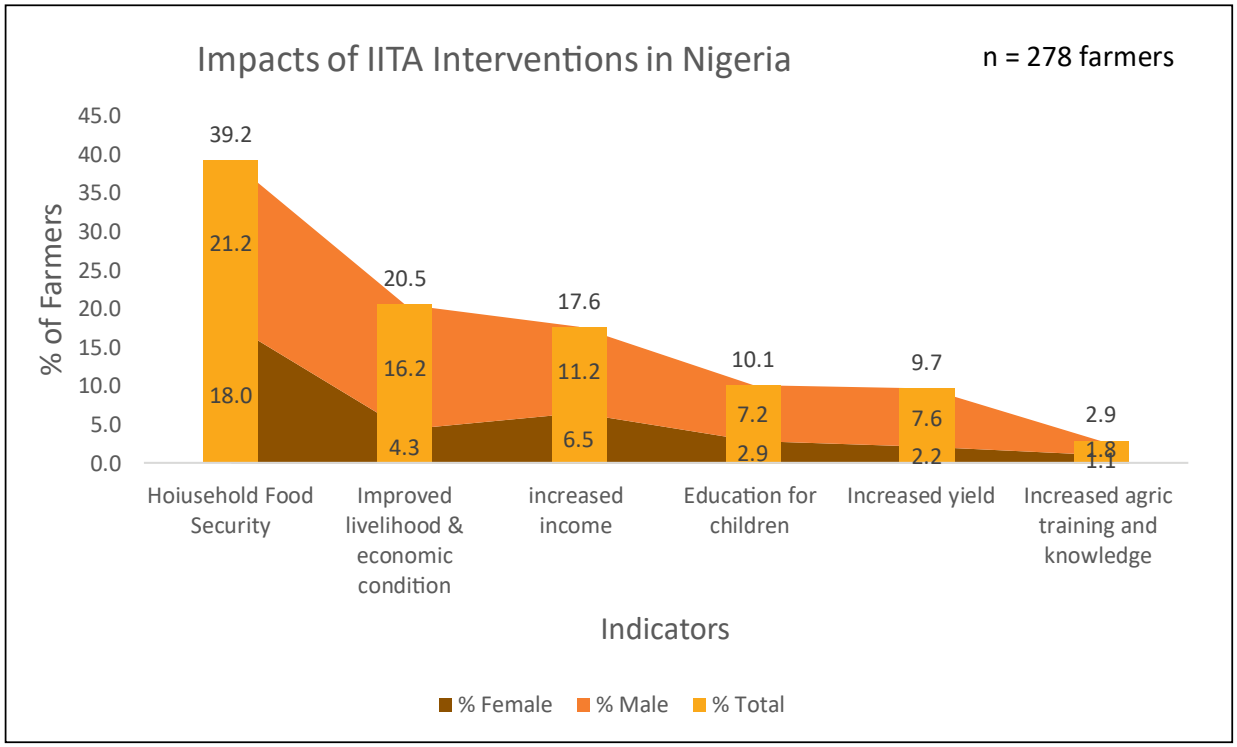


Figure 2. Impacts of IITA Interventions in Nigeria.

KPIs from Tanzania impact stories

The graph below shows that about 44% of the sampled farmers in Tanzania indicated that IITA interventions/ technologies improved their household food security. Improved livelihood and economic condition were sighted as second, followed by increased income, increased agricultural training and knowledge, increased yield and education for children. Men farmers scored high in all six indicators in Tanzania.

Here are other testimonies from Tanzanian farmers:

- My life has changed since the day I started using the knowledge I got from IITA, and I have been trying to provide this same knowledge to our people.
- After using the knowledge I got from IITA, my life has changed because I got more yield as a result, and my income has increased as well as food security in my household.

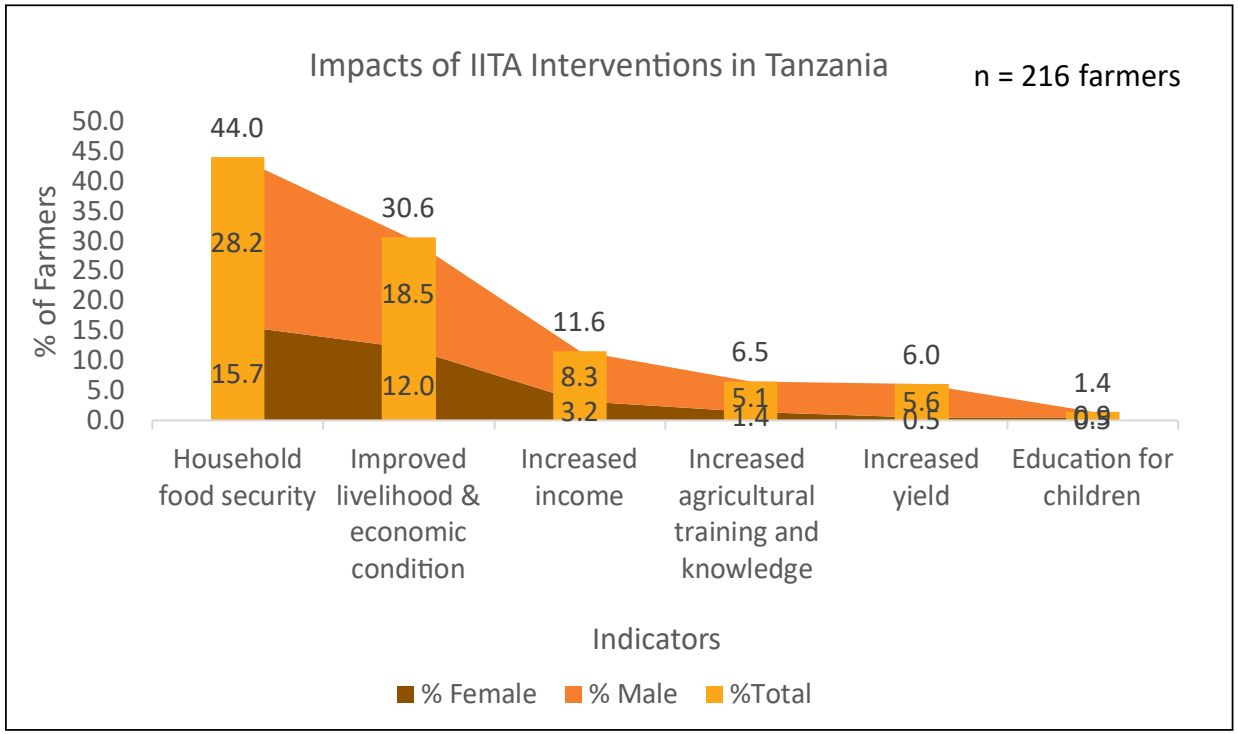


Figure 3. Impacts of IITA Interventions in Tanzania.

Implications on future research or development

Based on the content analysis of the sampled farmers and the testimonies of individual farmers per country, we can deduce that two KPIs (Household food security and improved livelihoods and economic condition) scored high as indicators of success from IITA interventions among African farmers.

Female farmers compared to men in DRC scored high in all six indicators of success, focusing more on improved livelihoods and economic conditions. Men farmers scored high in Nigeria and Tanzania, focusing more on household food security as an indicator of success. Consequently, future IITA/CGIAR research and development should focus on promoting women-led agricultural initiatives in DRC and other African countries to improve livelihoods and economic conditions, and household food security.

Collaborators

DRC: Sergie Amato and team, Rachel Zazo, and enumerators.
Nigeria: M&E Unit Staff, IITA Station Managers from Abuja, Kano, Onne and Umudike, enumerators, IITA scientists who provided the lists of farmers and crop varieties.
Tanzania: Hub Director Dr Victor Manyong, Daniel Mgalla and enumerators.
IITA M&E Unit: Joy Chiagoziem, Elizabeth Babalola, and Ramota Bankole.
IITA ME&L-CoP members.

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Nutrition and human health

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Plant production/health

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Our finances & supporters

Funding Overview

Funding for 2021 was US$103.855 million, of which 99.64% came from CRP and Non-CRP funding windows and 0.36% from other sources (Table 1). Table 1 shows Investment by CRP and Non-CRP funding windows. Expenditures were US$103.717 million (net of indirect costs recovery of US$10.857 million) of which 89.3% was used for program expenses and 10.69% for management and general expenses.

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The governments and agencies that provided the largest share of our funding in 2020 and 2021 are shown in Table 2 and Figure 1 (top 10 donors). Table 3 lists the various investors.

IITA`s 2021 total budget-cum-total expenditure are depicted in Figures 2 (Budget) and 3 (Expendture).

Table 4 gives an indication of the financial health of IITA

Table 1. 2021 Investment by CRP and Non-CRP Funding Windows

CRP / Non-CRP	W1/W2	Window 3 / Bilateral Proj.	Total	W1/W2	Window 3 / Bilateral Proj.	Total
23 - Policies, Institutions and Markets	514		514	90	-	90
14 - Maize agri-food systems	1,641	19,191	20,832	1,961	12,922	14,883
16 - Roots, Tubers and Bananas agri-food systems	5,321	32,264	37,584	4,967	24,946	29,913
18 - Grain Legumes and Dryland Cereals agri-food systems	663	4,183	4,846	955	6,129	7,084
21 - Agriculture for Nutrition and Health	1,322	2,647	3,969	2,183	3,042	5,225
22 - Climate Change, agriculture and food security (CCAFS)	1,370	455	1,824	902	12,141	13,043
33 - Genebank Platform	3,249	504	3,753	2,845	495	3,340
Big Data in agriculture	110	360	470	105	346	451
PTF 31- EiB		4,515			3,625	3,625
Gender	176			176		176
CRP / Platform	**14,363**	**64,119**	**73,791**	**14,184**	**63,646**	**77,830**
Non-CRP	**-**	**33,921**	**33,921**	**-**	**25,887**	**25,887**
	14,363	**98,040**	**107,712**	**14,184**	**89,533**	**103,717**

Table 2. Top Ten Donors: 2020 and 2021

Donor	2020		2021	
	$`000	Placement	$`000	Placement
United States Agency for International Development	15,663	1st	17,683	1st
Bill & Melinda Gates Foundation	13,930	2nd	16,952	2nd
CGIAR System Organization	12,393	3rd	14,184	3rd
PICAGL	5,478	4th	6,406	4th
UNICEF			5,358	5th
MFA	4,802	5th	3,853	6th
African Development Bank	3,079	6th	3,367	7th
CIMMYT	1,686	9th	2,777	8th
Cornell University	2,129	8th	2,609	9th
NORAD	2,546	7th	2,437	10th
ANADARKO	1,477	10th		

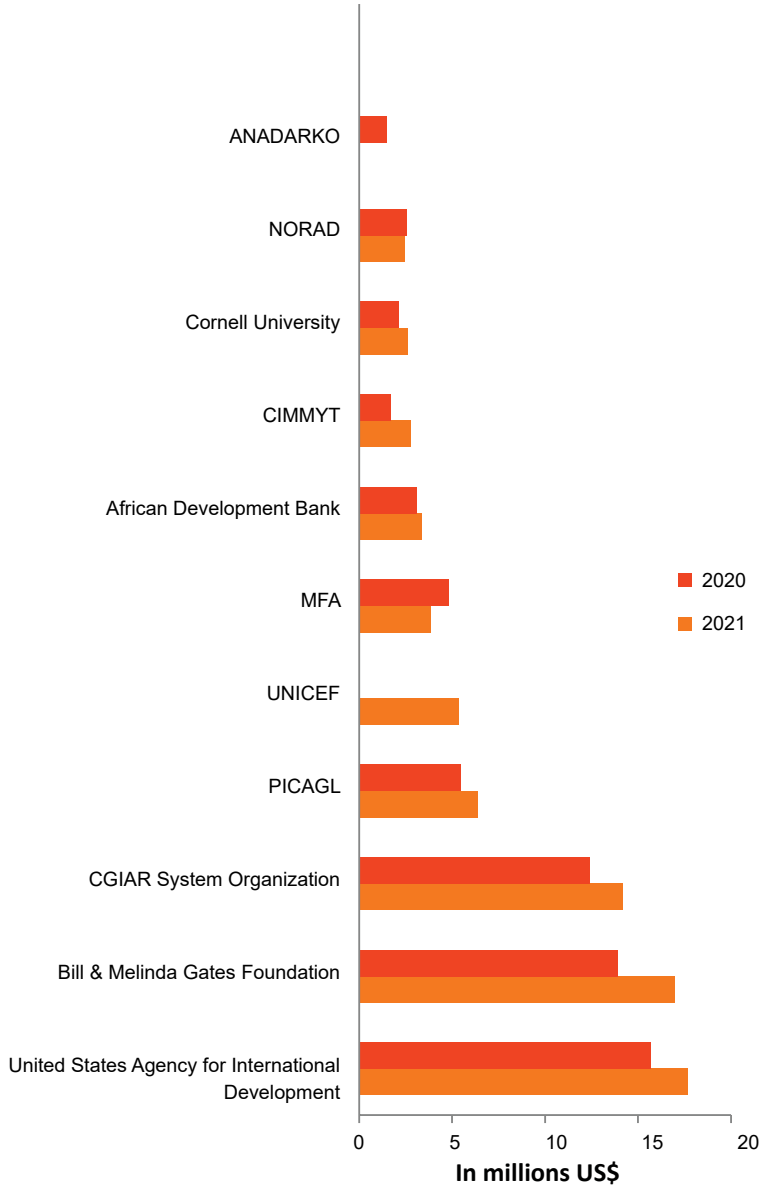

Figure 1. Funding: top 10 donors, 2020 and 2021

Table 3. List of IITA investors

	2020	2021
IITA Investors		**(expressed in US$ Thousands)**
Deloitte	(41)	(0)
Closed Projects	(7)	22
NETHERLANDS	(0)	-
IWMI	-	-
WORLD BANK	-	-
Austria	-	0
NIGERIA	0	-
Nutrition International	27	-
WAGENINGEN	45	12
FAO	49	50
JAPAN	58	61
ILRI	113	220
EU	150	75
CIRAD	236	196
IFAD	317	580
CIAT	392	407
AGRA	431	34
JAPAN	437	235
CIP	492	9
Total Challenge	494	349
MEDA Tanzania	565	880
GIZ	696	580
USDA	739	393
ETH	746	478
Belgium	845	791
CIMMYT	1,256	1,762
IFPRI	1,795	2,079
CORNELL UNIV	2,129	2,195
ICRISAT	2,139	2,386
NORAD	2,546	2,437
MFA	4,802	3,853
Miscellaneous Projects	6,594	13,084
CGIAR System	9,717	14,184
USAID	11,975	15,152
BMGF	13,927	16,952
Total N-CRP	23,675	25,887
IFPRI		150
Grand Total	**87,339**	**105,493**

Table 4. Performance Indicators: Financial Health

	2020	2021
Short-term Solvency (or Liquidity)	51.5 days	44.6 days
Long-term Financial Stability (Adequacy of Reserves)	46.9 days	41.6 days
Indirect Cost Rates	16.20%	16.13%
Cash Management on Restricted Operations	0.82	1.03
Audit Opinion	Unqualified / Clean Bill of Financial Health	

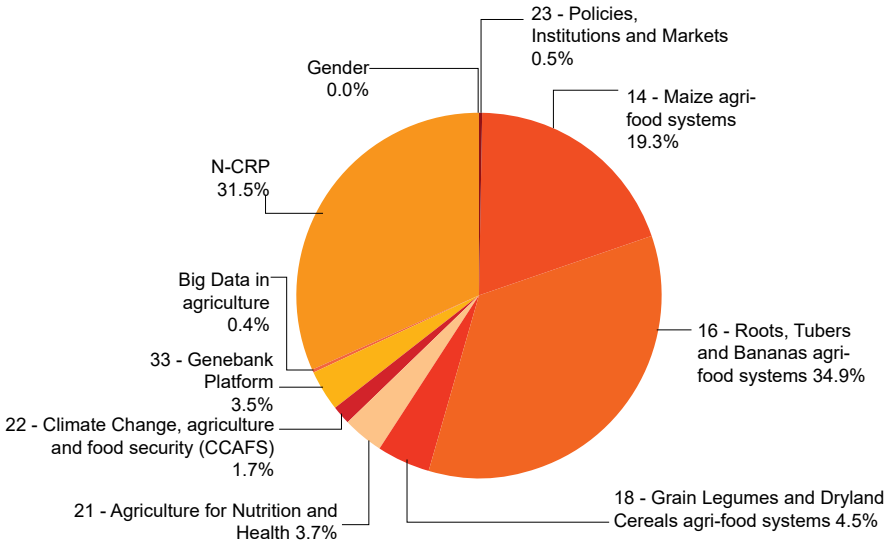

Figure 2. 2021 Investment by CRP and Non-CRP Funding Windows - Budget

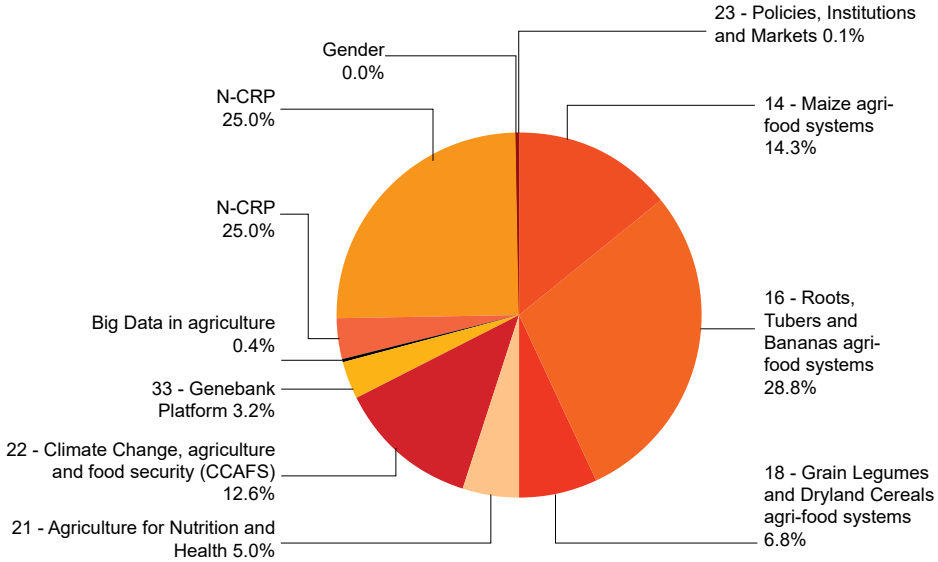

Figure 3. 2021 Investment by CRP and Non-CRP Funding Windows - Expenditu

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Centre of Excellence in Food Systems at the University of Pretoria, in South Africa

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Member, CGIAR System Board

Patrick Caron
Vice President
International Affairs, University of Montpellier

Rhoda Tumusiime
Former African Union Commissioner for Rural Economy and Agriculture
Chairperson, HOPE
P.O Box 383
Entebbe, Uganda

Shenggen Fan
Chair Professor
College of Economics and Management
China Agricultural University, Beijing

Nteranya Sanginga
Director General
IITA, Oyo Road,
Ibadan, Nigeria

Headquarters and hubs

Headquarters, hubs, and stations

Headquarters and Western Africa Hub

PMB 5320, Oyo Road, Ibadan 200001
Oyo State, Nigeria
Tel: +234 2 751 7472 | USA Tel: +1 201 633 6094 |
Fax: +44 208 711 3786

Central Africa Hub

IITA Central Africa Hub Coordination Office
icipe, c/o IITA Projects
Duduville Complex, Kasarani off Thika Road
PO Box 30772-00100
Nairobi, Kenya
Tel: +254 020 863 2900

IITA-DR Congo (Kinshasa)
4163, avenue Haut-Congo
Quartier Revolution, Commune de la Gombe
Kinshasa, Republique Democratique du Congo
Tel: +243 99 021 2603
Email: admins@iitadrc.org

Eastern Africa Hub

IITA-Tanzania (Dar es Salaam)
Plot 25, Mikocheni Light Industrial Area
Mwenge Coca-Cola Road, Mikocheni B
PO Box 34441
Dar es Salaam, Tanzania
Tel: +255 22 270 0092 | Fax: +255 22 277 5021
E-mail: iita-tanzania@cgiar.org

Southern Africa Hub

IITA-Zambia
Southern Africa Research and Administration Hub (SARAH) Campus
Plot 1458B, Ngwerere Road (5 km off Great North Road and adjacent to ZamSeed Farms)
Chongwe District, Lusaka Province, Zambia
Tel: +260 211 840 365 | Fax: +260 211 285 417
PO Box 310142, Chelston
Lusaka, Zambia

Sahel Hub

IITA, Bamako, Mali
c/o ICRISAT WCA
(+223) 20 70 92 00
(+223) 20 70 92 01

Stations

IITA-Benin

08 BP 0932 Tri Postal
Cotonou, Republic of Benin
+229 6418 1313, +229 6418 1414, +229 6418 1515, +229 9596 1159
E-mail: iita-benin@cgiar.org

IITA-Burundi

PMB 1893 Bujumbura-Burundi
Quartier Kabondo
Avenue du 18 Septembre, 10
+257 (0) 79 33 1024 / +257 (0) 76 19 4193
E-mail : IITA-Burundi@cgiar.org

IITA-Cameroon

Ecoregional Center, BP 2008 (Messa)
Yaounde, Cameroon
Tel: 237 2 223 7434, 2 223 7522
E-mail: iita-cameroon@cgiar.org

IITA-Côte d'Ivoire

2pltx, 7eme Tranche, Rue L54-27
BP 696 Abidjan 27, Cote d'Ivoire
Tel: 225 22 52 37 32

IITA-DR Congo (Kinshasa)

4163, avenue Haut-Congo
Quartier Revolution, Commune de la Gombe
Kinshasa, Republique Democratique du Congo
Tel: +243 99021 2603
Email: admins@iitadrc.org

IITA-DR Congo (Kalambo)

Route Kavumu, Km 18, bifurcation Birava
Site UCB (Université Catholique de Bukavu)
Phone +243 999 78 82 78 | +243 979 30 22 03

IITA-Ghana (Accra)

Council for Scientific and Industrial Research (CSIR)
INSTI Building
Off Augustinho Neto Road
Airport Residential Area
PO Box M32, Accra, Ghana
Tel: + 233 303931 023
E-mail: iita_ghana@cgiar.org

IITA-Ghana (Tamale)

Near Tamale Sport Stadium
1st Road, Off Sagnarigu Main Rd.
PO Box TL 6, Tamale-Ghana
Tel: +233 37 202 8913

IITA-Nigeria (Ibadan)

PMB 5320, Oyo Road, Ibadan 200001
Oyo State, Nigeria
Tel: +234 2 7517472 | USA Tel: +1 201 6336094 |
Fax: +44 208 7113786

Abuja R4D Station

Beside Old Water Works, Kubwa
PMB 82, 901101, Abuja
Federal Capital Territory, Nigeria

IITA Research and Training Center

Ago-owu Farm Settlement Road
Ikoyi, Osun State, Nigeria

Kano Station

Sabo Bakin Zuwo Road
PMB 3112, Kano, Nigeria
Tel: +2348060522205, +2347034847459

Ikenne Station

Ikenne-Ayepe Road
IAR&T Farms
Ikenne, Ogun State, Nigeria

Mokwa Station

Km 8 Mokwa-Kainji Road
Abu Farms
Mokwa, Niger State, Nigeria

Onne Station

IITA Road, Onne
Eleme LGA, Rivers State

IITA-Kenya (Nairobi)

c/o International Livestock Research Institute (ILRI)
PO Box 30709 – 00100, Nairobi, Kenya
Tel: +254 20 422 3350/422 3000
E-mail: iita-kenya@cgiar.org

IITA-Malawi

Chitedze Research Station
Off-Mchinji Road
PO Box 30258
Lilongwe 3, Malawi
Tel: +265 (0)1 707 014/022, Fax: +265 (0)1 707 026
Email: iita-malawi@cgiar.org

IITA-Mozambique

Av. FPLM, Via Corrane, Km 8
PO Box 709, Nampula, Mozambique
Tel: +258 2 6216381
E-mail: iita-mozambique@cgiar.org

IITA-Rwanda

KG 563 street, Solace Way
PO Box 1269, Kacyiru
Kigali, Rwanda

IITA-Senegal

CORAF/IITA,7 Avenue Bourguiba B.P. 48. cp 18523
Dakar RP, Senegal
Tel: Standard +221 33 869 9618

IITA-Sierra Leone

SLARI Building, Tower Hill
PMB 134
Freetown, Sierra Leone

IITA-Tanzania (Arusha)

c/o AVRDC- The World Vegetable Centre
PO Box 10, Duluti, Arusha, Tanzania
Tel: +255 27 255 3051

IITA

c/o The Nelson Mandela African Institution for Science and Technology (NM-AIST)
PO Box 447, Arusha, Tanzania

IITA-Tanzania (Dar es Salaam)

Plot 25, Mikocheni Light Industrial Area
Mwenge Coca-Cola Road, Mikocheni B,
PO Box 34441