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IITA 2015 Annual Report

Gearing up for impact

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Cover photo: A happy farm family in Rwanda.

IITA 2015

Annual Report

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From the **Director General**

Dr Nteranya Sanginga
Director General

In 2017, we will be celebrating our 50th anniversary—half a century spent in nourishing Africa through research-for-development! I cannot imagine an Africa ~~or~~ a world for that matter—without IITA. However, as we look towards this milestone and beyond it with great anticipation, we should also not lose focus on the present. This is a world in which the agricultural and food landscapes are drastically and dramatically changing. IITA must continue to adapt if we are to remain relevant and exist for the next 50 years or more.

IITA is at the midpoint of its 2012–2020 Refreshed Strategy. If we achieve our target milestones, by 2020 we should have lifted 11 million people out of poverty and brought back 7.5 million hectares of degraded land into productive and sustainable use across Africa. And we are getting set for this result.

In 2015, we increased our human resources and accompanied this with substantial investments in research infrastructure across our Hubs to support our increased activities. We also continued to support and promote our youth-in-agriculture initiative, providing a working model that is now being replicated and adopted by many Governments and other organizations across the continent and helping to ensure that young Africans will become the drivers of economic growth—today and tomorrow.

We also focused on strengthening our research-to-commercialization pathway through our Business Incubation Platform (BIP) and publicprivate partnerships to ensure that our research results and products such as Aflasafe, NoduMax, and GoSeed get into the hands of beneficiaries.

BIP will advance Aflasafe—scaling up a proven solution for controlling hazardous aflatoxins in cereals and grain legumes; NoduMax, a legume inoculant designed to increase biological nitrogen fixation by grain, tree, and forage legumes; and GoSeed to advance breeder and foundation seed ventures for a more rapid and reliable commercialization of improved crop varieties.

As climate change is making pests and diseases yet more destructive and unpredictable, IITA scientists continued to explore new and more efficient genetic avenues to give important African crops an edge for survival. At the same time, we also undertook efforts to document lessons learned on deploying some of our climate-smart technologies.

On the home front, we initiated a serious exercise to streamline our data management systems to make sure that research data and information are efficiently organized and readily available. To ensure that staff—our most precious asset—perform at their peak, we instituted policies and initiatives that put gender equality top and center in the workplace.

This year, we continued to enhance existing relationships and reach out to new donors and partners who will continue with us, shoulder-to-shoulder, on our way to achieving our 2020 goals.

There is no question that we need to maintain our momentum, our integrated approach, our high-quality science and people, and our outstanding partnerships. We also need to continuously evaluate and reinvent ourselves as the situations demand, and stay focused and guided by the principles outlined in our Refreshed Strategy.

I invite everyone to read in more detail some of our success stories in 2015.

Nteranya Sanginga
Director General

From the **Board Chair**

The mission of IITA is to be the leading research partner facilitating agricultural solutions to overcome hunger, poverty, and natural resource degradation throughout the tropics. The Institute's 2012—2020 Refreshed Strategic Plan established an ambitious goal and IITA social scientists and natural resource management teams have developed a methodology to monitor progress which shows that significant advances have already been made. The Board of Trustees is committed to providing leadership and oversight to the Institute in the achievement of these goals.

The year 2015 was another successful period for IITA. The budget of the Institute increased by 12% over 2014, the fourth successive year of funding increases. This came in a year that has been financially challenging for the CGIAR system, with substantial reductions in funding from this very important source. Through sound financial management and increased bilateral funding, IITA did not have to lay off any of its R4D staff, even increasing the number of both national and international staff, and considerably expanding its research capacity.

IITA completed the first phase of its Strategic Plan at the end of 2014. During this phase, IITA expanded in both human resources and research facilities, particularly in the Tanzania, DR Congo, and Zambia hubs. The second phase of the Strategic Plan (2015–2017) will continue to focus on the delivery of IITA's research technologies to producers in the tropics.

To facilitate the delivery of it products, IITA established a Business Incubation Platform (BIP) at its main headquarters in Ibadan. The goal of BIP is to facilitate the scale up of technologies developed from IITA's research programs and advance public–private partnerships to deliver these technologies to African farmers. The three production components of the BIP, Aflasafe, NoduMax, and GoSeed have been fully operational for two years. In 2015, 300 tons of aflasafe were produced, much of it going to Kenya to help reduce aflatoxin contamination in maize fields. The construction of aflasafe production facilities is being planned in three other African countries.

IITA is the lead center on the CGIAR research program (CRP) "Integrated Systems for the Humid Tropics", which has been the focal point for the Institute's R4D programs. Six CGIAR centers are partners in Humidtropics and the program has numerous non-CGIAR collaborators. IITA is a partner in eight other CRPs with major research activities in Roots, Tubers and Bananas, MAIZE, and Grain Legumes. Several years ago, IITA established a "Youth Agripreneur Program" on its Ibadan campus to provide training to university graduates in agricultural business and enterprises. This has now been extended to all the IITA hubs and will be more widely instituted across Africa in a program to be funded by the African Development Bank. The goal is to get African youth more involved in agriculture, driving innovation in the sector, and addressing youth unemployment.

I am pleased serving as Chair of the Board of this well-managed Institute and would like to thank my colleagues on the Board for their dedication to IITA's success. The Board expresses its appreciation to DG Sanginga and his senior management team for the significant accomplishments over the past four years and for their vision for the future. We congratulate the scientists and support staff for the excellent research being conducted. Finally, we express our appreciation to our funders who recognize the importance of the work being done and their continued unwavering confidence in IITA's ability to do it.

Bruce Coulman
Board Chair

Dr Bruce Coulman
Chair, Board of Trustees

Gearing up for impact: **IITA's vision and mission**

In 2017, IITA—the first agricultural research center in the African link of international organizations—will mark 50 years of supporting national systems and nourishing African smallholder farmers. Our mission remains: to offer a leading research partnership that facilitates agricultural solutions for hunger, poverty, and natural resource degradation.

To make sure that we meet our goal, we continue to focus on ensuring four system-level outcomes: increase in food security, reduction in rural poverty, reduction of undernutrition, and more sustainable management of natural resources. These are aligned with the new sustainable development agenda and the 17 Sustainable Development Goals, a set of goals intended to **"end poverty, protect the planet**, and **ensure prosperity".** To ensure that the goals are met, IITA is doing its part in reaching partners in government, the private sector, and civil society, through its research-for-development efforts, capacity development, commercialization activities, special initiatives such as youth and women's engagement in agribusiness and gender empowerment, and public–private partnerships.

Specifically, IITA intends to increase the yields of major African staples such as cassava, banana/plantain, cowpea, maize, soybean, and yam, by 60%; increase average farm income by 50%; lift 50% of poor households out of poverty; reduce the number of malnourished children by 30%, and restore about 40% of degrading farmlands to sustainable management.

Through its hubs and 15 research stations across sub-Saharan Africa, IITA operates decentralized but integrated regional research programs that work on major constraints to agriculture in Africa, and participates in eight of the CGIAR Research Programs that cut across its major research themes: biotechnology and genetic improvement, natural resource management, plant production and health, and social science and agribusiness.

Strategic Initiatives

IITA Youth Agripreneurs: Building the future of Africa today

Adetola Adenmosun, IYA, IITA-Ibadan

The IITA Youth Agripreneurs (IYA) are breaking new ground and recording successes in Nigeria—its birthplace—and the hubs.

For 2015, a landmark achievement of IYA was that the proposal to train about 140 young people from the Niger-Delta region of Nigeria on agribusiness was approved. The project, which is sponsored by Chevron Nigeria Limited, will give IYA the opportunity to fully execute the Chevron Youth Agribusiness (CYAG) project using their experience and acquired skills from the various workshops, seminars, and trainings attended on agribusiness and agripreneurship in Nigeria and elsewhere.

The project, which is the first self-written proposal by the group, is worth several million naira and will run for two years. IYA will showcase to the young people and communities of implementation (Ijaw and Itsekiri) how agriculture and agribusiness can be a viable livelihood and income-generating option. Proposal writing to solicit for funds is an integral part of the project and another means of generating income for IYA.

The GreenWealth Agripreneurs, the first batch of interns being trained by the IITA Youth Agripreneurs, in Ibadan, Nigeria.

Spreading IYA's wings

During the year, IYA established affiliate youth groups in Kenya and Uganda, while in the Democratic Republic of Congo (DRC) two other youth groups in Kinshasa and Kisangani were created to complement the efforts of the already established group in Bukavu. The expansion of the IYA-affiliated youth groups in DRC attracted the attention of the government and other policymakers resulting in the first youth agribusiness exhibition co-organized by the government of DRC and IITA.

IYA also conducted a 3-day training workshop on agribusiness for members of the Nigeria National Youth Corps serving in IITA. After the training, the Corps members were screened and recruited as interns to undergo an 18-month internship program under IYA. Following the Youth Agribusiness Guidelines (YAG), these interns—called GreenWealth Agripreneurs—will be further trained on different agrobusiness enterprises, developing bankable business plans, and establishing independent business enterprises.

ENABLE Youth

Another achievement by the group was the wide acceptance and recognition of the ENABLE Youth program. The African Development Bank requested a concept note for the project and it was developed in 2014 during the Youth in Agribusiness Development Initiative (YADI) conference held at IITA-Ibadan. ENABLE Youth is a five-year program designed using the IYA model to empower young African adults through a comprehensive outreach effort by providing information, proven technologies, and opportunities to about 800,000 youth in at least 25 African countries. The program will give opportunities for more than 20,000 internships, over 10,000 agribusiness startups, and over 30,000 new jobs in rural and urban areas, leading to future incomes of at least $450 per month/person and a projected $160 million annually . ENABLE Youth will mobilize the energies and

IYA's expanded fish ponds in IITA, Ibadan, Nigeria. Photo by IYA.

ambitions of the youth as engines for employment and agricultural transformation, reduce migration to urban areas, and improve the self-image of the youth, within their communities and across society as a whole.

In 2015, the IYA model was again cited with the launching of the Agricultural Transformation Agenda Support Program (ATASP) by the Federal Government of Nigeria. Under this project, IYA plays an active role by coordinating and training young people across the agricultural value chains for cassava, rice, and sorghum in three youth training centers to be established in Onne, Abuja, and Kano. Using the IYA model, about 200,000 new jobs will be created for unemployed and underemployed young people in Nigeria. The three youth training zones, which will be handled by IYA, will cater for Kano, Jigawa, Kebbi, Sokoto, Enugu, Anambra, and Niger states in Nigeria.

Expanding business ventures

During the year, IYA continued to grow its fishery and livestock ventures with the expansion in the number of its fish ponds from four to 17. The IYA fishery and livestock unit started in 2014 with four fish ponds after being trained by the Durante Fish Industries—the largest fish company in West Africa. To meet increasing demand for catfish, IYA added 13 more fish ponds in 2015. The fish harvest also tripled from 70 tons in 2014 to about 200 tons in 2015.

The group also continued to multiply and provide high quality planting materials to banana growers. Using the macropropagation technique, IYA increased its production of plantain suckers by 25%. Six additional macro-chambers were constructed to help meet the increase in demand for plantain suckers.

The year 2015 also saw the addition of several new items in IYA's high-value snack food product lineup. These new products included Tidbit Delight, Sneh balls, and croquant which are produced from maize, cowpea, soybean, and high-quality cassava flour.

IYA was also able to acquire a modern kiln for smoking catfish during the year, which added value to the fresh catfish raised and marketed by the group. With aggressive marketing campaigns, the group was able to introduce the smoked catfish product in major markets in the southwestern zone of Nigeria. The product is expected to be available in major supermarkets and stores across Nigeria by 2016.

Influencing young minds

In 2015, IYA successfully organized a debate on the topic "Agriculture is a Sector of Economic Opportunity for Youth in sub-Saharan Africa," This was inspired by the MasterCard Foundation to enable the youth to express their views on the topic to be debated by IITA Director General, Dr Nteranya Sanginga and Prof James Sumberg, Research Fellow with the Institute of Development Studies at a summit organized by the MasterCard Foundation in South Africa. The event was attended by many young people and other interested IITA staff. More debates will be organized in 2016 to give the youth the opportunity to express their views on topical issues of interest.

Increasing visibility

IYA contributed to a chapter of the Alliance for Green Revolution (AGRA) 2015 Africa Agriculture Status Report. Writing on the topic "Youth and Agricultural Productivity in sub-Saharan Africa", IYA relayed a case study of how the youth can be productively engaged in agriculture using the experience gathered so far. Many references were made to the chapter and case study shared by the Agripreneurs at the Alliance for Green Revolution Forum held in Lusaka, Zambia, in 2015.

The group also launched its official website (www.youthagripreneurs.org) in 2015 to enable it to communicate and share information more widely. The youth group also acquired two sophisticated DJI inspired drone cameras, which help in taking aerial photographs and videos of fields for scientific analysis and documentation.

Eric Sika, a member of the group in Bukavu, DRC, was selected to participate in the Mandela Washington Fellowship for Young African Leaders in 2015. Prior to this fellowship, Eric graduated from the Catholic University of Bukavu with a Bachelor's degree in Agronomy. The fellowship was a flagship program of President Obama's Young African Leaders Initiative (YALI). The selection was keenly contested across Africa. Following his selection, Eric studied business and entrepreneurship for 6 weeks at the University of Wisconsin-Stout. The study sharpened his leadership capabilities before his attendance at the presidential summit in Washington where he had an opportunity to interact with US leaders in the fields of business and government, and the non-profit sector.

Other milestones

During the year, IYA relocated from its former office in IITA-Ibadan to the new building at the Business Incubation Platform (BIP). The building is about 516 m^2 and houses offices, seminar rooms, board rooms, and other facilities. This relocation is expected to enhance the operations of the group.

Another major milestone was the approval and the distribution of start-up grants for 40 young people in Borno State trained under the N2Africa project. In September 2014 and 2015, IYA moved from Ibadan to Kano State to train the Borno youth on agribusiness. The trained youth, who are now receiving grants based on the bankable business plans they developed, will be backstopped by IYA to offer technical support when the need arises.

Building on the momentum of activities from the previous year, IYA in 2015 continued to implement some projects such as the Cassava Transformation Agenda (CTA) and the High Quality Cassava Flour (HQCF) training of rural youth and farmers on the projects, and the establishment of cassava fields in Ekiti, Ogun, and Kwara states.

With the success of IYA, the CGIAR Consortium organized a workshop on "Mobilizing the youth in agriculture in the second phase of CGIAR Research Programs" to define the key issues to be addressed and to explore and identify good approaches to promoting youth engagement, employment, and enterprises that can be integrated into the work of CGIAR. IYA representatives participated and spoke at the workshop, which took place at the CGIAR Consortium Office in Montpellier, France.

Agripreneurs use ICT tools to take data on the field. Here, they operate the DJI inspired drone with Dr Akinwumi Adesina, President of the African Development Bank.

BIP: Business more than usual

Kenton Dashiell, IITA-Ibadan

IITA's Business Incubation Platform (BIP) supports the Institute's strategic goals and accelerates the commercial development of its proven and profitable R4D technologies, ensuring close alignment with R4D, the institute's research arm. BIP focuses on two avenues of commercial development: the creation of innovative and commercially viable products by IITA scientists, and the initiation and building of a network of public and private-sector partners that will support the activities of small to medium-scale agribusiness entrepreneurs, initially within Nigeria and, later on, elsewhere.

In 2014, the Board of Trustees conditionally approved business plans for each of the initial start-up agribusinesses of BIP: GoSeed, NoduMax, and Aflasafe; and committed funding for BIP's establishment. An IITA/BIP Advisory Council was then created to provide guidance and oversight of BIP's establishment and operation, and the feasibility of its financial performance. Additionally, IITA received legal confirmation of BIP's status and approval of ongoing operations, and a CEO, Frederick Schreurs, was recruited late in 2015 to build and grow BIP.

BIP business start-ups: roaring on

Aflasafe

In 2015, Aflasafe contributed $487,000 to the earnings of BIP, while sales of the product came to about $597,000. This figure is more than double its sales of $291,000 in 2014. The business has so far received orders amounting to $881,000 for delivery in 2016.

In terms of infrastructure development, construction of the second Aflasafe factory in Africa—in Kenya—has been started while plans are under way for the construction of three more factories in Senegal, Zambia, and Kenya. During the year, Aflasafe also received a Certificate of registration from the National Agency for Food and Drug Administration and Control (NAFDAC) in Nigeria that is valid until October 2019.

In the beginning of 2015, Aflasafe entered into the initial stage of discussion with global and local agribusinesses for technology licensing/ commercialization. Aflasafe was also cited for helping minimize aflatoxin contamination in Kenyan maize and received final sales payment from the Kenyan Ministry of Agriculture and the Kenya Agriculture and Livestock Research Organization (KALRO).

Negotiations have also been started with various private sector enterprises for different aspects of commercialization:

NoduMax

In 2015, 30,450 packets of NoduMax were produced and sold for $90,000. A few large companies such as Notore and Nigeria Flour Mills and many other smaller companies have placed orders for the 2016 June planting season. We are planning to produce 110,000 packets in 2016 with a projected income of about $330,000.

In November, NoduMax received regulatory approval from NAFDAC. With this, BIP will undertake a major marketing campaign of the product in 2016.

GoSeed

During the year, through various projects funded by the Government of Nigeria and other donors, approximately 120 tons of high quality breeder and foundation seeds of maize produced by IITA were given to seed companies in Nigeria either for free or at highly subsidized rates. GoSeed sold about $5,000 worth of seed in 2015.

Income in 2015

The actual net income for BIP in 2015 is about $380,000 (Tables 1 and 2).

Table 1. Actual cash flow (net income each month) ($) for BIP in 2015 (reported during BoT meeting, November 2015).

	January	February	March	April	May	June	July	August	September	October	November	December	Total
NoduMax	(24,571)	(33,938)	(22,100)	(6,653)	(6,730)	47,049	(5,246)	(8,050)	(45,241)	(5,597)	(5,597)	(6,622)	(123,296)
GoSeed	(2,714)	107	237	(1,483)	(57)	0	0	(864)	1,442	3,212	7,126	12,611	19,618
Aflasafe	0	0	36,890	(21,926)	0	45,648	(15,190)	(28,470)	13,466	(1)	456,590	(1)	487,006
AgriServe	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	**(27,285)**	**(33,831)**	**15,027**	**(30,062)**	**(6,787)**	**92,697**	**(20,436)**	**(37,384)**	**(30,333)**	**(2,386)**	**458,119**	**5,988**	**383,328**

Packing aflasafe at the manufacturing plant in Ibadan, Nigeria. Photo by IITA

Table 2. Actual cash balances (at the end of each month) ($) for BIP in 2015 (updated at BoT Nov 2015).

	January	February	March	April	May	June	July	August	September	October	November	December (Closing)
NoduMax	(24,571)	(58,509)	(80,609)	(87,262)	(93,992)	(46,943)	(52,190)	(60,239)	(105,480)	(111,077)	(116,674)	(123,296)
GoSeed	(2,714)	(2,607)	(2,370)	(3,853)	(3,909)	(3,910)	(3,910)	(4,773)	(3,331)	(119)	(7,007)	19,618
Aflasafe	0	0	36,890	14,964	14,964	60,612	45,422	16,952	30,418	30,417	487,007	487,006
AgriServe	0	0	0	0	0	0	0	0	0	0	0	0
Total	**(27,284)**	**(61,116)**	**(46,089)**	**(76,151)**	**(82,938)**	**9,759**	**(10,677)**	**(48,060)**	**(78,393)**	**(80,779)**	**377,340**	**383,328**

We forecast that by August 2016 NoduMax and GoSeed will break even and Aflasafe will have a profit of about $900,000.

Packing the bioinoculant NoduMax, BIP, IITA, Ibadan. Photo by O. Adebayo, IITA.

Banana scientist Delphine Amah inspects tissue culture-grown banana. Photo by O. Adebayo, IITA.

Towards a gender-equal IITA

Lilian Mendoza and Lade Oke, IITA-Ibadan

A strong point of the IITA 2012–2020 Refreshed Strategy is its emphasis on promoting gender equality across the Institute, specifically stating that "gender equity is to be ensured in all areas of operation". This means that a gender perspective is to be integrated into every aspect of the formulation, development, and implementation of IITA policies, initiatives, projects, and activities. This also means that IITA will think of, plan for, and take actions that equally and equitably promote the interests of men and women in everything that we do as an institute.

To guide specific interventions and activities towards effective gender mainstreaming, IITA's Human Resources Office (HR) conducted an internal assessment survey in October 2014 to assess staff's perception of gender mainstreaming and the general level of gender awareness and understanding. The survey results showed that only 34% of respondents were aware of the concept of gender. In 2015, IITA took steps to increase staff's level of awareness about gender and to enhance capacity for mainstreaming gender in the workplace, with the overall goal of changing mindsets, attitudes, and behaviors, and enhance consciousness in gender-related issues in the workplace and in research.

To help achieve this goal, HR engaged the services of a consultant, Prof Jane Bennett, of the African Gender Institute, University of Cape Town in South Africa, to drive the gender awareness program. Prof Bennett facilitated a gender awareness seminar at the IITA-Ibadan campus on 1 September 2015, which was attended by more than 400 staff from HQ and the Western Africa Hub, as well as the regional administrators. The seminar was also streamed online for staff located in stations outside of Ibadan. The seminar covered key concepts on gender, gender dynamics, gender inequality, and gender mainstreaming.

The awareness-raising seminar was followed by a two-day training on 2–3 September 2015 to build staff capacity in gender mainstreaming. Participants included a mix of managers and staff from R4D, Partnerships and Capacity Development, Corporate Services, and Finance Directorates. The workshop focused on the application of gender analysis to specific work activities/projects and the exploration of gender mainstreaming tools likely to generate deeper levels of gender-aware and gender-sensitive knowledge. It was also intended to deepen gender sensitivity within all areas of participants' working environments. After successfully completing the training, participants were designated as gender focal points for their respective units and hubs.

Additionally, a one-day introductory training for Dignity Advisors was also conducted by Prof Bennett. Dignity advisors are selected staff that would support the implementation of the policy on harassment and discrimination, which was also launched in 2015. The initial training was attended by 20 participants who had been preselected and had indicated their willingness to serve as Dignity Advisors. Related to this initiative, HR organized an awareness-raising seminar in May about staff's rights to dignity in the workplace, how to contribute towards a harassment- and discrimination-free workplace, and what to do and where to get help if any staff becomes a victim. HR plans to hold a more in-depth training on skills needed to handle cases of harassment, especially sexual harassment, in 2016, for the Dignity Advisors.

To help ensure that gender is mainstreamed into research at IITA, the R4D Directorate organized a special presentation by Prof Bennett during R4D Week on gender awareness and dynamics in the workplace, with the aim of integrating gender research into research planning, priority setting, and targeting. The special seminar was attended by some 200 scientists and research associates.

Other initiatives taken by HR to enhance gender equality in the workplace during the year included sustaining the practice of equal pay for equivalent work and enhancing female representation in the workforce, with the latter resulting in a substantial increase in staff female representation from 1% in 2014 to about 26%, in 2015. HR, with the Capacity Development Office, also co-hosted an African Women in Agricultural Research and Development (AWARD) Leadership and Management Course in which 14 senior female staff participated. The goal of the course was to develop women leadership as a means to promote gender equality.

HR also continued to use staff town hall meetings as avenues to encourage gender-sensitive communication and promote the use of gender-neutral language in influencing organizational culture in a gender-sensitive direction.

The Women Empowerment Platform (WEP), established in March 2014 as an initiative of the Director General, marked the 2015 International Women's month by organizing a seminar on "Celebrating Women in Science and Entrepreneurship" on 25 March. Dr Ylva Hillbur, IITA Deputy Director General for R4D, along with two notable women entrepreneurs, shared their life experiences of "making it to the top", with the aim of influencing and inspiring other women to do so as well.

The Women Empowerment Platform organizes seminars for women.
Photo by O. Adebayo, IITA.

A young researcher gathers crop data using a tablet. Photo by O. Adebayo, IITA

Innovations in big data

Peteti Prasad, Agbona Afolabi, Trushar Shah[1], and Andreas Gisel
IITA-Ibadan and [1]IITA-Kenya

Modern advancements in Internet data, computer hardware and software, global standards, online collaboration platforms, and mobile technologies now allow the easy integration of various data management processes that were previously strictly separated. In agricultural research, these advancements have revolutionized how information is captured, pre-processed, automated, analyzed, and accessed by multiple users in different locations at near real-time. This has accelerated related processes as well as improved the management, quality, and compatibility of collected data. At IITA, 2015 saw significant strides in the modernization of its data capture and management systems.

Automating field data collection

Crop breeding experiments are data intensive, with a typical breeding program producing hundreds of thousands of datasets in any given year. Inefficient and poor handling of these datasets can significantly hamper the activities of a breeding program and set back its targeted outputs. IITA researchers have traditionally used a "pen-and-paper" approach to data collection and transcription, which is time consuming and error prone.

The Cassava Breeding Program of IITA developed an innovative method to securely capture cassava field data by using electronic field book applications in tablets, which capture data in milliseconds. A barcode reader in these tablets reads barcode labels that are generated and used, for example, for accurate and efficient plot identification. The tablets are then connected to a multifunction platform called *Cassavabase* (www.https://cassavabase.org), which makes the collected data readily available in compliance with the institute's Open Access policy and can be used for downstream analysis.

The program uses *Cassavabase* as its primary data management tool for uploading both phenotyping and genotyping data. These data are useful for implementing genomic selection and will improve accuracy in estimating breeding values and genetic gain for quantitative traits compared to traditional breeding methods. Currently, *Cassavabase* has over 1500 phenotyping trials with ~8 million phenotypic observations and ~2 billion genotypic data points with more than 400 registered users.

The Cassava Breeding Program has successfully implemented tablet-based data collection in almost all its test environments. About 100 tablets are presently being used, with efforts geared towards implementation using handier smartphones in 2016. The program has also initiated several training workshops on data collection using tablets for its field technicians. These training workshops have also been extended to other crop breeding programs.

An integrated breeding management system

Modern breeding programs need to integrate diverse data types and exchange information with partners globally. IITA has developed and implemented the Breeding Management System (BMS), a comprehensive and easy-to-use software suite designed to help breeders conduct their routine activities more efficiently. Developed by the Integrated Breeding Platform (IBP) based in IITA-Nairobi in Kenya, the BMS provides interconnected tools for breeding program management, data analysis, and decision support. It also provides a database that works seamlessly to manage pedigree information, phenotypic and molecular characterization as well as germplasm evaluation.

Bioinformatics and big data

High-throughput sequencing is an emerging technology that allows for fast and inexpensive sequencing of a whole genome, which makes the process affordable to many researchers and leads to the production of large amounts of data. However, this technology demands high computer processing power to efficiently store and analyze large data sets. IITA has been using these sequencing data for more than a year for gene discovery and genotyping to accelerate breeding cycles.

The Bioinformatics Unit of IITA, based in Ibadan, offers high throughput sequencing, as well as storing and processing big data. Currently, the unit holds more than 4 TB of compressed sequencing data from different crops. To visualize this amount of stored data, if just the text of this sequencing data is printed, the printout will cover about 300 km end-to-end. For large-scale data processing, the Bioinformatics Unit is equipped with upgraded computing power consisting of 64 cores and combined 900 gigabytes of RAM. The actual capacity is set up for the storage of 30 TB of data and processing of 2 TB compressed data in a one data analysis process. This allows IITA to master large-scale genotyping, gene expression whole genome sequencing data for advanced research in plant genomics. This important capacity enables IITA researchers to increase the precision of correlating traits, also complex traits, to markers which, in turn, contribute towards faster and more efficient crop breeding.

In the pipeline

Following up on the success of *Cassavabase*, IITA is currently developing sister platforms: *Musabase* and *Yambase*. IITA is also an active contributor to the development of the CGIAR Consortium's "Big Data Platform Project". The envisaged data pool to be generated from this multi-CGIAR center platform could be used, for example, to directly feed agronomic information and advice to farmers through electronic or mobile technology-based means.

Bringing IITA research results into the open

Martin Mueller, IITA-Ibadan

For many years, one of the most common criticisms leveled against international agricultural research centers is that many of its intellectual products are usually relegated to the proverbial "shelf" once a research project is completed and the required reports have been submitted to funders. Such a practice has deprived intended beneficiaries—resource-poor smallholder farmers—the opportunity to better their lot through scientific findings locked away in some obscure knowledge vaults.

However, with the leaps in modern information and communication technology, complemented by the strong clamor to make scientific findings of publicly funded research centers freely available as being "global public goods", the Open Access revolution began. In this "revolution", all protagonists benefit, with farmers ultimately gaining the most. In 2015, IITA made significant strides towards bringing its archived research out into the open.

The beginning of the Open Access era at IITA

Open Access (OA) and Open Data offer huge opportunities to improve the impact of IITA's research and development activities as well as increase its and its researchers' visibility within and outside the science community. IITA formalized its adherence to the principle of OA by signing the CGIAR Open Access Policy in October 2013. This key document gives a clear and common definition and understanding of OA and its inclusions to which the 15 CGIAR Center signatories have to abide. The CGIAR Consortium Office, with funds from The Bill & Melinda Gates Foundation took the lead in 2015 to streamline the OA implementation activities of all centers as much as possible, initiating three task forces: the CGIAR Data Management Task Force, the CGIAR Knowledge Managers, and the individual centers' Open Access Implementation Working Group.

The Open Access Implementation Working Group drafted the IITA Open Access implementation plan. The implementation plan covers a whole gamut of activities: from strategy questions over timelines, major infrastructural investments, and internet connectivity issues to interoperability requirements, formats, transition period and embargo times, budgets, regulatory frameworks for Intellectual Property (IP), resource planning, and change management to impact assessment. This plan, together with the E-Research and Open Access communication plans, forms the basis for many OA actions for 2016, which has been declared as "IITA Year of Open Access".

Related to Open Access, E-Research is one other focus area for IITA. E-Research is the umbrella that covers all activities and initiatives that deal with data management, information management, and knowledge management. For E-Research, in 2013, IITA initiated a process involving an inventory of institutional databases to identify critical issues and concerns. In this process, IITA identified four main challenges: financial support, quality of data, awareness and training of researchers and other staff, and the IT infrastructure. This analysis highlighted the need for coordination and integration of ongoing initiatives. To manage the process, an E-research initiative was set up.

In 2015, E-Research was slightly restructured: the main body of E-Research is an Advisory Board that meets at least once every two months. All major work areas in IITA are represented. The Advisory Board makes strategic assessments and decisions on information management and their consequences on data management and data infrastructure.

The priority work areas for E-Research in 2015 included: Open Access implementation planning, SharePoint testing, HR data solution, agronomy database, IITA website revamp, metadata registry, M&E data integration, partner database, CG Space deployment, and an approved data and information management policy.

Improving Open Access infrastructure

As a direct outcome of OA implementations, a new institutional repository was introduced called CG Space (https://cgspace.cgiar.org/handle/10568/68616). It is a shared DSpace implementation hosted by the International Livestock Research Institute (ILRI). CG Space stores not only scholarly publication data (journal articles, books, etc.) but also other textual and even multimedia content such as reports, field protocols, photographs, posters, presentations, and the like. This repository fulfills all OA requirements, such as having permanent and unlimited access without a login and being free of charge, with sufficient metadata and enabling other machines or websites to harvested content. It also comes with an easier and flexible search and browsing functionality, shows use statistics about views and downloads, gives useful metadata and all this consistently across eight CGIAR Centers, seven CRPs, four CGIAR programs, and nine other CGIAR Space partners that participate in CG Space.

A week's training at IITA-Ibadan equipped eight staff and five individuals from partner institutions with the necessary know-how to run CG Space technically, use it, and manage its content. The repository was launched in October with a presentation to researchers. As IITA's Knowledge Center curates legacy publication data for upload, the institute's collections on CG Space grow day by day.

Good news also from the Breeding Management System (BMS), a collaboratively developed database suite of the "integrated breeding platform" (https://www.integratedbreeding.net/). In 2015, the cowpea and soybean programs at IITA adopted the BMS in their research activities while other crop programs are in the process of also adopting the platform. BMS deployment workshops also held during the year were welcomed by partners such as the West African Center for Crop Improvement, the Soybean Innovation Lab, and private seed companies.

Making data "talk" to each other

During the year, IITA also undertook efforts to harmonize the "understanding" of human-to-machine and machine-to-machine communication by developing and using a common subject term set and by starting to collect and systemize research metadata. Metadata are data that describe files or data (i.e., data about "Author", "Date published", "File format", "use restrictions") or simply a scientific variable (i.e., "Yield per hectare"). The first 2400 metadata will form the base of a metadata registry. One can look at this register as a central reference defining how to describe frequently used research data. It goes beyond the "crop ontologies" (collaboratively defined types, properties, and interrelationships of crops respecting crop traits) (http://www.cropontology.org/) which are already in use for cassava or cowpea.

A twin project, the IITA term store, will directly benefit from that and supplies the register back with terms out of authority lists (standard reference lists defined by authorized bodies only) especially those ones from international standardizations.

Another major step in making research data fit for cataloging was pushed by the CGIAR Consortium Office: the CGIAR core metadata schema, designed to harmonize and uplift the quality of metadata across all CGIAR centers. They are usually given as a set that belong together, often following an international standard, like the "Dublin core". A metadata set which is a fixed conceptual system is a schema. A "core schema" defines the essential part of it.

Assessing our research data management

During the year, the CGIAR Shared Services held an intensive, 10-day audit of IITA's research data management system, which covered a sample of seven existing projects and many research support units. The audit revealed strengths and weaknesses of how the institute deals with data. It resulted in and heightened sensitivity for the importance of proper data management practices. As an outcome, a work plan of improvements is now one priority issue for 2016.

Improving Crops

Genetically fortifying banana, enset, cassava, and yam against pests and diseases

Leena Tripathi, IITA-Kenya

Genetic engineering is one of the key techniques for improving crops particularly those that are vegetatively propagated or not amenable to conventional breeding. At IITA, the technique is being used for the improvement of crops that are economically important to Africa, such as banana and plantain (*Musa* sp.), cassava (*Manihot esculenta*), and yam (*Dioscorea* sp.).

Genetic transformation platform for banana and cassava

Genetic engineering of any crop requires efficient transformation protocols. However, many African laboratories lack the capacity and expertise to carry out the genetic transformation of staple crops and this work has been limited to advanced laboratories. There is a need to build the capacity of researchers in Africa to carry out the genetic transformation of staple crops such as banana and cassava.

Despite the technical difficulties of transforming a monocot species, we have developed an efficient transformation system for several banana and plantain cultivars using embryogenic cell suspensions. This, in turn, has paved the way for the genetic manipulation of banana and plantain by incorporating agronomically important traits such as those conferring resistance to diseases or pests as well as tolerance to abiotic stress factors.

The Transformation Laboratory at IITA in Nairobi, Kenya, has also successfully developed an effective transformation platform for farmer-preferred varieties of cassava that can be used to develop improved varieties with desired traits. This is the first-ever report of the successful *Agrobacterium*-mediated transformation of African farmer-preferred cassava varieties in a laboratory based in sub-Saharan Africa.

Donors and partners looking at BXW-resistant transgenic banana in confined field trial at NARL, Uganda. Photo by Leena Tripathi, IITA.

BXW-resistant banana and enset

Banana *Xanthomonas* Wilt (BXW) caused by *Xanthomonas campestris* pv. *musacearum* has caused estimated economic losses of between $2 and 8 billion over the last decade in Africa. In the absence of natural host plant resistance, researchers at IITA and National Agricultural Research Laboratories [NARL] in Uganda, have developed transgenic banana by inserting Hypersensitive Response-Assisting Protein gene (*Hrap*) and Plant Ferredoxin-Like Protein gene (*Pflp*) from sweet pepper. These genes were licensed by the African Agricultural Technology Foundation (AATF) on a royalty basis from the Academia Sinica in Taiwan. The 11 transgenic lines selected for field trials, after exhibiting strong resistance in the laboratory and greenhouse, have been shown to be 100% resistant to BXW through three successive crop cycles.

Harvesting of nematode resistant transgenic plantain. Photo by Leena Tripathi, *IITA.*

They will be further tested at multiple locations to capture the effects of different environmental conditions on disease resistance.

It is well known that pathogens can evolve and "breakdown" resistance to disease. To avoid this, we have also developed transgenic banana by stacking the two genes together in the same line to enhance durability of resistance. An *ex-ante* impact analysis conducted last year in Uganda has clearly shown that if this new technology is successfully adopted in the region, both consumers and producers will benefit. The greatest benefits would be in countries that have experienced large production losses from BXW. These transgenic lines are also currently under testing for food and environmental safety in compliance with biosafety regulations.

Based on success with transgenic banana, we are trying to transfer transgenic technology from banana to enset in partnership with the Ethiopian Institute of Agricultural Research. Enset, closely related to banana, is a staple food source for over 15 million people in Ethiopia. Its production has also been severely threatened by BXW in all the enset-growing areas. We have established a protocol for enset transformation and we are currently developing transgenic enset using *Hrap* and *Pflp* genes.

We are also identifying additional resistance genes for use in gene stacking or pyramiding strategies. We tested the potential of rice pattern recognition receptor (PRR), *Xa21* for providing resistance against *X. campestris* pv. *musacearum*. Our results confirmed that the constitutive expression of the rice *Xa21* gene in banana results in enhanced resistance to BXW disease.

Virus-resistant banana

The Banana Bunchy Top Disease (BBTD) is a serious threat to banana across the world. It is extremely difficult to control and is continuing to spread in many countries where banana are primarily produced by smallholder farmers. BBTD has already moved into Nigeria and is causing major losses in plantain, the country's third most important starchy staple. The disease has also been reported in several Central and East African countries and there is a risk of it spreading into Uganda and Tanzania where banana is a key staple crop. The virus infects all types of banana including East African Highland banana, plantain, and dessert varieties.

Host plant resistance is the most appropriate form of control. However, there is no known resistance against the *Bunchy top virus* in the *Musa* germplasm. Therefore, IITA and Queensland University of Technology (QUT), Australia, are developing transgenic banana and plantain with resistance to BBTD using the RNAi approach. About 50 transgenic lines of plantain cultivar *Gonja manjaya* have been developed in the laboratory at IITA-Kenya. These lines will be characterized at molecular level and then sent to IITA-Nigeria for glasshouse evaluation for resistance to BBTD.

Nematode-resistant plantain

Plant parasitic nematodes can cause losses of up to 70% on plantain and cooking banana in Africa. Application of nematicides is inappropriate and resistant cultivars are not available. IITA in partnership with the University of Leeds, UK, has developed transgenic plantain using an anti-feedant cysteine proteinase inhibitor (cystatin) from maize and an anti-root invasion, non-lethal synthetic peptide, either singly or by stacking these genes. The glasshouse study showed that both genes are capable of providing resistance in plantain to concomitant infection by different nematode species. Confined field testing of 12 promising lines demonstrated that transgenic expression of maize cystatin and synthetic peptide confers resistance against key nematode pests *Radopholus similis* and *Helicotylenchus multicinctus*. The best peptide transgenic line improved agronomic performance compared with non-transgenic controls and provided about 99% resistance to nematodes at harvest of the mother crop. Its yield was 186% of the nematode-challenged controls, based on its larger bunches and reduced plant toppling in storms because roots were less damaged.

Double haploid banana

Banana is a slow breeding crop and developing a pure breeding line can take up to several years. Haploid inducers are used in breeding to hasten the process. Haploid breeding could, therefore, revolutionize the improvement of slow-cycling crops. IITA and the University of California at Davis (UC Davis) are trying to develop double haploid banana. A transgenic approach developed at UC Davis previously in the model plant *Arabidopsis thaliana* was transferred to banana in an effort to develop a haploid inducer. The approach involves silencing an endogenous histone protein CENH3 and replacing it with a modified version. When plants with the modified CENH3 of the protein are crossed to the wild type (with no modification in CENH3), haploids are obtained. Under this project, we developed a genetic transformation system for the diploid banana cultivar Zebrina GF, which is a fertile parent used in breeding programs. The haploid inducers for the diploid banana cultivar Zebrina GF were developed and transferred to the glasshouse for flowering. Wild type plants of two diploid parents (Zebrina GF and Calcutta 4) were also planted in the field to be crossed to transgenic haploid inducer Zebrina GF for haploid induction. The transgenic line flowered in the glasshouse, was crossed with pollens of wild type Zebrina GF, and is currently under seed setting. Once the seeds are set, they will be tested for haploidy.

Genetic transformation of yam

Yam is an important crop in the tropics and subtropics providing food security and income to over 300 million people. However, its production remains constrained by increasing levels of field and storage pests and diseases. A major constraint to the development of biotechnological approaches for yam improvement has been the lack of an efficient transformation and regeneration system for the crop.

Recently, IITA has developed an efficient, fast, and reproducible protocol for *Agrobacterium*-mediated transformation of *Dioscorea rotundata* using axillary buds as explants. This provides a useful platform for future GE studies in this economically important crop. This is the first report of the *Agrobacterium*-mediated transformation of yam with experimental evidence of stable integration of T-DNA in *D. rotundata* genotypes. This protocol opens up an avenue for future genetic improvement of *D. rotundata* with candidate genes of proven agronomic importance to attain sustainable production.


Yam plant; Photo by IITA.

A good crop of maize.
Photo by IITA.

Streamlining the release of improved maize and cowpea varieties in Africa

B. Badu-Apraku, A. Menkir, O. Boukar, T. Abdoulaye, S. Ajala, B. Asafo-Adjei, and C. Fatokun, IITA-Ibadan and IITA-Kano

The benefits of improved varieties generated by research are realized only when these varieties are actually used and grown by farmers—the intended beneficiaries. However, the path from research farms to farmers' fields is not as simple and straightforward as it may seem.

Although the processes for approval and release of new varieties of crops such as cowpea and maize are basically similar across countries in sub-Saharan Africa, specific procedures and steps still vary from country to country. Generally, the authority to release new varieties of maize and cowpea is vested on the National Variety Release Committee (NVRC) of each country. Research organizations such as IITA and national research institutes help to push forward the release process.

The variety release process involves several steps and activities. The plant breeder of an institution that intends to release a variety completes and submits standard variety release nomination forms to the country's NVRC. Before this, the nominated variety should have undergone rigorous testing in several locations, at different levels (i.e., on-station and on-farm), and over a number of years to prove its superior qualities and performance.

A study undertaken by IITA in 2007/2008, under the auspices of the project Drought-Tolerant Maize for Africa funded by the Bill & Melinda Gates Foundation, defined the time taken to release elite maize varieties, summarized the variety release requirements and procedures in 13 project countries, identified constraints to the release of elite germplasm to smallholder farmers, and proposed strategies to speed up the release of new varieties. Results showed that the composition of the NVRCs and the variety testing and release processes differed considerably among countries. In several situations, the public sector dominated the NVRC's variety-approval meetings.

In general, the systems in place resulted in delays in the release of new varieties. In some cases, the system allowed only a few varieties to be released at any given time. As variety release is costly and repetitive (the same variety must be tested in all countries where it is being targeted for marketing), the delay means that the return on investment is also pushed back as seed companies—who often invest heavily in the development of new varieties—have no option but to wait for varieties to be released before they can start selling or marketing them.

The lack of an effective variety release system in sub-Saharan Africa was identified as a major impediment to the transfer to smallholder farmers of already available elite maize varieties and, therefore, constituted a major constraint to increased maize production and productivity. Furthermore, most of the NVRCs lacked good coordination and were holding meetings only once a year to consider varieties for release. That is not often enough, given the number of improved varieties being developed and nominated for release every year. Seed laws were also too rigid as data from one country where a variety had been tested could not be used as a basis for its release in another country, even though both countries had similar agroecologies. This further delayed the release process as the same variety needed to be retested in every country where it was intended to be released.

In addition, national variety lists and catalogues were not being updated regularly, making it difficult for seed companies to commercialize improved varieties. Only a few countries also had Plant Breeders' Rights (PBR) thus discouraging many private seed companies from introducing their best products because the protection of such products could not be guaranteed. The private sector had dominated varietal releases in Eastern and Southern Africa. In West Africa variety release had been mainly from the public sector because there were fewer seed companies operating in the region. Southern Africa has the highest rates of varietal release and adoption of improved maize varieties.

Making the variety release process more efficient

IITA, working with partners, consequently developed and recommended several strategies to streamline the varietal release process and rates based on results of the survey.

First, we recommended that regional standards for PBR should be promoted to allow plant breeding programs to generate income from the products of their research through royalties. This would allow the private and public sectors to benefit from the products of research and lead to more investments in varietal improvement.

Secondly, West Africa would benefit from the free flow of germplasm across national boundaries of the Economic Community of West African States (ECOWAS) if the regional variety release process were to be harmonized. Thus, varieties released in one country should be considered automatically released in other countries with similar agroecologies, an approach already proposed and endorsed by ECOWAS. Mega-environments and adaptation zones cut across country boundaries, therefore varieties should be released based on mega-environments to create a larger seed market and quicken the pace of diffusion and use of newly released varieties.

Thirdly, because only a few countries accept data from other countries for variety release, we recommended that testing should not be mandatory for varieties already released in other countries if the recommendation domain is the same, thereby eliminating the need for retesting of varieties from country to country, saving resources and quickening variety release.

Fourthly, it was noted that registration should be simplified so that only important VCU and DUS information would be required to distinguish a new variety from the others. The DUS information should be from one season as it is affected very little by the environment.

Fifthly, breeders' own data should be used to support variety release thereby eliminating the need for the National Performance Trials (NPTs). Few locations should be required for release and emphasis should be on locations where the variety would be recommended for production.

Finally, breeders should embark on limited production of breeder seeds and marketing rather than waiting until the variety was fully released as this prolonged the time before a variety reached the farmers.

Harvesting the fruits

The strategies adopted by IITA to promote the rapid release and registration of stress tolerant maize and cowpea varieties have resulted in a large number being released in West and Central Africa (WCA) for the past 8 years. A total of 95 maize varieties, developed under IITA's Maize Program with tolerance for drought, low soil nitrogen and/or *Striga* resistance, as well as resistance to the maize streak virus and stem borers, have been released by our NARS partners in sub-Saharan Africa since 2007. Similarly, 31 cowpea varieties developed in IITA have been released by the NARS across the target countries during the same period. The improved varieties have good adaptation to the various agroecological zones in each of the target countries in sub-Saharan Africa. Several of the maize and cowpea varieties have been commercialized in the various countries. They produce yields as high

Cowpea field.
Photo by IITA.

as or higher than the presently available commercial varieties. In addition, several of the maize varieties have elevated levels of lysine and tryptophan, and/or provitamin A.

The release and commercialization of the stress tolerant early, extra-early, intermediate, and late-maturing varieties developed in IITA and promoted by the NARS and the private sector have contributed to a phenomenal increase in maize production and productivity through the movement of maize across new frontiers. They have replaced sorghum and millet in the savanna zones of WCA (Fig. 1) resulting in the high annual growth rates of maize production shown in the table.

Similarly, the release, promotion, and adoption of IITA cowpea varieties have significantly contributed to the production increases recorded in West Africa since 2001 (Fig. 2). Results of an adoption study conducted in 2016 in Kano State, Nigeria, indicated that about 58% of the land area was devoted to improved varieties. The varietal specific adoption rates for selected improved varieties were as follows: IT99K-216, 31%,;IT90K-277-2, 9.7%; IT89KD-288, 9.4%; IT97K-499-35, 5.3%; and IT89KD-391D,1.6%. The average yield gain of improved varieties was 254% higher than the local varieties with an average grain yield of 222 kg/ha. The results also indicated that the adoption of improved cowpea varieties increased daily income by ₦64.19 ($0.32). Furthermore, adopters gained a total household asset value of ₦15, 783.81 ($74), on average.

Growth rates of maize poduction in West Africa.

Burkina Fasso	22.3%	Mali	58.2%
Ghana	7.7%	Nigeria	10.8%
Benin	4.7%	Benin	3.6%
Guinea	7.9%	Guinea	32.0%
Sierra Leone	46.9%	Sierra Leone	17.2%

Output (million tons)

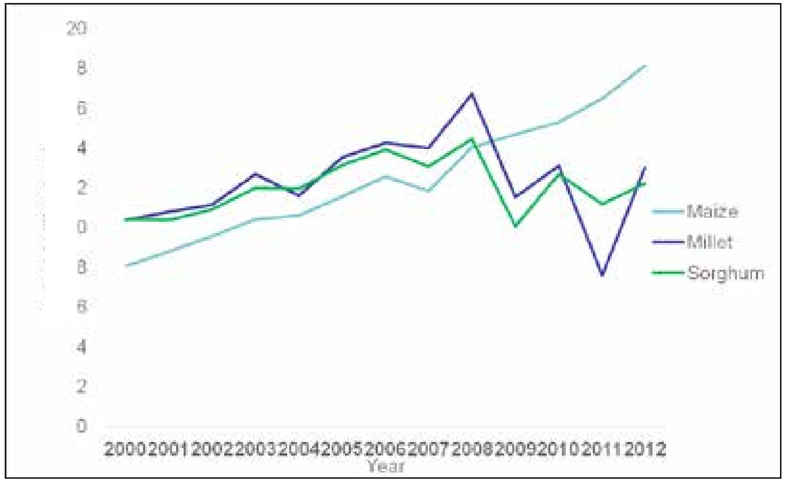


Figure 1. Total production of maize, millet and sorghum grain in11 West and Central African countries, 2000-2012 (Source FAO statistics).

Output (million tons)

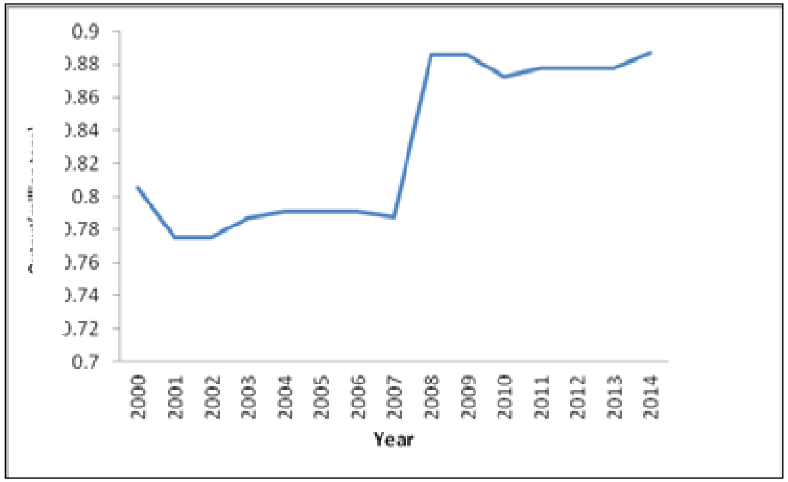


Figure 2. Total production of cowpea in six West African countries, 2000-2014 (Source: FAO statistics).

Taking the genetic superhighway in crop breeding

Melaku Gedil, Ismail Rabbi, Ranjana Bhattacharjee, Andreas Gisel, and Christian Fatokun, IITA-Ibadan

Genetic improvement is considered the major contributor to crop productivity. Advances in biotechnology, such as the availability of whole genome sequences, high throughput genotyping and phenotyping tools, as well as data management, and analytical services, enable breeders to better understand the genetic basis of agriculturally important traits in crops and predict the breeding values of individual plants or lines in a plant breeding program. Additionally, the decreasing cost of using molecular techniques enables breeders to screen large populations, thus increasing the efficiency of their application.

The various approaches for accelerated breeding include marker-assisted backcrossing (MABC), a quick and effective way of transferring a gene from a donor line to another line that is deficient in the trait of interest; marker-assisted recurrent selection (MARS), which allows the accumulation of a relatively large number of favorable alleles, represented by quantitative trait loci, using selected markers that are significantly associated with target traits, and genomic selection (GS) which helps to predict the genetic values of breeding progenies using a statistical model based on markers distributed across the genome. IITA researchers are developing and deploying these genomic tools and techniques for innovative and accelerated breeding of crops such as maize, cassava, cowpea, and yam.

Fast-track breeding of stress-tolerant maize

DNA markers linked to key traits, such as tolerance to drought and *Striga*, have been identified and applied in our maize breeding to save time and reduce the costs associated with extensive field evaluation. Two cycles of genotypic selection have been completed in four IITA MARS populations drawn from different maturity groups, adapted to the low to medium altitude, and with various agronomically superior attributes. Lines derived from the various marker-based cycles of selection have been evaluated in multilocational field trials to estimate genetic gains. The primary focus was on the performance of lines under drought and no drought conditions as well as *Striga* infestation. In the two populations analyzed so far, MARS increased the frequencies of favorable alleles, suggesting the efficiency of genotypic selection.

Technician extracting and analyzing DNA. Photo by IITA

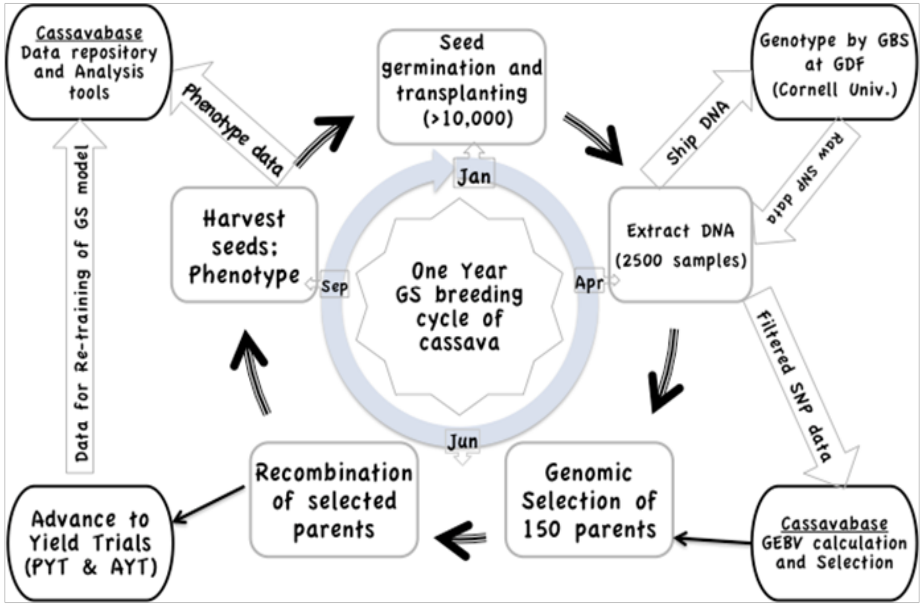
Catalyzing genetic gain in cassava through genomic selection

Cassava breeding through phenotypic recurrent selection has achieved remarkable success, with a large number of disease resistant and high yielding improved varieties being currently deployed throughout sub-Saharan Africa. However, it takes between 4 and 6

Cassava in the field. Photo by IITA

years of field phenotyping to identify good parents for generating the next cycle of selections. The breeding cycle has now been reduced to 1–2 years through genomics-assisted breeding. IITA has teamed up with Cornell University and the national programs of Nigeria and Uganda to embark on genomic selection-based breeding within the framework of the Next Generation Cassava Breeding Project (www.nextgencassava.org).

Since the onset of the project, three cycles of genomic selection and recombination have been undertaken. In each of these annual cycles, about 100 clones with good breeding values for key traits (fresh root yield, dry-matter content, and resistance to cassava mosaic disease), undergo controlled crosses producing 5000–10,000 seeds. To accelerate the breeding cycle, the seeds are germinated during the off-season and about 2500 of these are selected based on parental breeding values for genotyping-by-sequencing (GBS). Each seedling is genotyped at more than 100,000 genomic positions to generate the breeding values for traits of interest. Superior progenies are then selected for the next cycle of controlled crosses in the main season. This shortened breeding cycle allows the breeding program to respond to changes in breeding targets and meet the demands of smallholder farmers. As a result, new cohorts of improved varieties have been channeled towards the product development pipeline.



An overview of genomic selection-based annual breeding cycle implemented for cassava: reprinted from Gedil et al.

Additionally, several other aspects of this pipeline have been strengthened. For example, trait measurements on individual plants and plots are captured using android apps running on tablets and smartphones, making the data instantly available for uploading to the breeding database. To store, analyze, and ensure open access, the Cassava Breeding Program is currently depositing all field-trial data on http://cassavabase.org. This database not only provides access to data but also hosts tools for breeders and other researchers that include genomic selection algorithms and analysis capacity, a cassava genome browser, cassava ontology tools, phenotyping tools, and social networking.

The promise of molecular techniques in yam

Among the major staple food crops, yam (*Dioscorea* spp.) is a challenge to breeders. The biology of the crop makes it less amenable to genetic improvement as it is a polyploid dioecious species with a significant period of tuber dormancy that prolongs the growth cycle. The yam collections maintained at IITA have been characterized using GBS. This has allowed varietal identification and description of genetic diversity, linkage mapping, and QTL analysis of target traits (anthracnose disease, sex-determination, and other agronomic traits) for accelerated breeding through marker-assisted selection. A simple and efficient Agrobacterium-mediated transformation system for *D. rotundata* has been established, opening up an avenue for further genetic studies. Through the AfricaYam project (www.africayam.org), genomics and marker-assisted breeding platforms are being established to fast-track the development of new varieties and training of NARS partners.

Novel approaches for advancing cowpea improvement

In cowpea, genomic tools are being developed to enhance progress in breeding improved varieties with attributes preferred by farmers and consumers. To this end, the genetic diversity of 365 lines, a subset representing the entire 15,000 accessions maintained at IITA, has been characterized by GBS. This has classified the accessions into five distinct groups. In addition, a set of about 215 recombinant inbred lines (RILs) has been genotyped and phenotyped for resistance to aphids and other desirable traits. A wild cowpea relative, which is resistant to aphids, is one of the two parents for the RILs. Trait-linked candidate markers are also being tested for their efficacy in facilitating genetic gain. MABC is being used to quickly introgress resistance to *Striga* from an IITA improved breeding line to two released varieties which lack resistance to the parasitic weed.

Data management and decision support tools

As depicted in the above examples, the low cost of sequencing allows molecular breeding approaches with large populations producing vast amounts of raw data. These data need to be processed promptly to extract the information needed by the breeders for selecting progenies with good breeding values. The data analysis pipeline, including sequence cleaning, sequence polymorphism search, comparative genomics, and decision-making, needs specific hardware and software to be able to cope with the immense data load and complex analysis. By establishing a bioinformatics platform with the correspondingly adapted infrastructure, IITA is now able to efficiently analyze the big data produced by diverse breeding programs. The capacity of the computing infrastructure allows the breeders to analyze thousands of genotypes simultaneously producing up to 100,000 data points. Genotypic data, in combination with phenotypic and other metadata, are organized and stored in effective open access data management systems such as Breeding Management System (BMS, www.integratedbreeding.net) and customized crop databases (CassavaBase, YamBase, MusaBase). These systems provide the downstream decision-making tools with a vast quantity of high quality data for a precise selection of improved offspring for subsequent breeding steps.

Technician at Bioscience Center in Ibadan analyzing DNA. Photo by IITA

Making Crops **Healthy**

Untangling the coffee (root) knots in Africa

Danny Coyne, IITA-Tanzania

If you are one of those whose day *must be* jump-started by coffee, then you are part of the millions that make coffee one of the world's most important cash crops. Coffee is also the second most traded commodity, with an estimated total export value of $19.1 billion in 2012/2013. More than 100 million people, mostly from developing tropical countries, depend on coffee-growing for their livelihoods. In Africa, it is a primary source of income for an estimated 10 million households across 25 countries and yet, production has been declining here by approximately 17% since the 1970s. Elsewhere, production has doubled over the last 50 years owing to skyrocketing increases in consumption.

This decline in production in Africa is primarily blamed on losses to pests and diseases and the associated costs in managing them. Pesticides, for example, account for over 30% of production costs. Among coffee pests, root-knot nematodes (*Meloidogyne* spp.) are a special threat, significant yet often overlooked. In South and Central America from where most of the information comes, root-knot nematodes are recognized as highly destructive pests that can wipe out entire coffee plantations and force a shift to other cash crops, such as sugarcane. In Brazil, for example, there is such emphasis on their importance that the Brazilian Agricultural Research Organization (EMBRAPA) has assembled a diagnostic kit specifically designed to rapidly detect the presence and assess the incidence of *Meloidogyne* spp. in coffee plantations.

Virtually no information exists on nematode pests affecting coffee in Africa, except for some early distribution and diagnostic studies. This is despite the obvious economic value of the crop in the continent. A key obstacle has been the lack of a robust and reliable diagnostic method. Identifying which species occur and the potential damage they pose provide valuable information towards making informed decisions on pest and disease management options. This is especially important for a perennial crop such as coffee.

IITA embarked on a quest to fill this gap together with experts and their students from the various partner academic and research institutions in the countries we work in, as well as from UC Davis (USA), EMBRAPA (Brazil), Ghent University (Belgium), and National Plant Protection Organization (The Netherlands).

These efforts are now beginning to achieve results, not only in building a wealth of knowledge about the pest in Africa but also in demonstrating how advanced technologies could help to clear the diagnostic confusion.

Traditionally, researchers have relied on morphometrics to identify *Meloidogyne* species—a burdensome, labor-intensive process dependent on scarce expertise that is now known to be greatly hampered by phenotypic plasticity and inter-specific similarities. Despite its shortcomings, a biochemical-based diagnostic technique has remained one of the most reliable and widely-used differentiation methods. Over time, molecular methods have been developed, in particular, species-specific primers, but even with rapidly declining costs, DNA barcoding has continued to prove difficult, especially for the tropical root-knot nematodes. Mitochondrial genes, however, known for their uni-parental inheritance combined with high

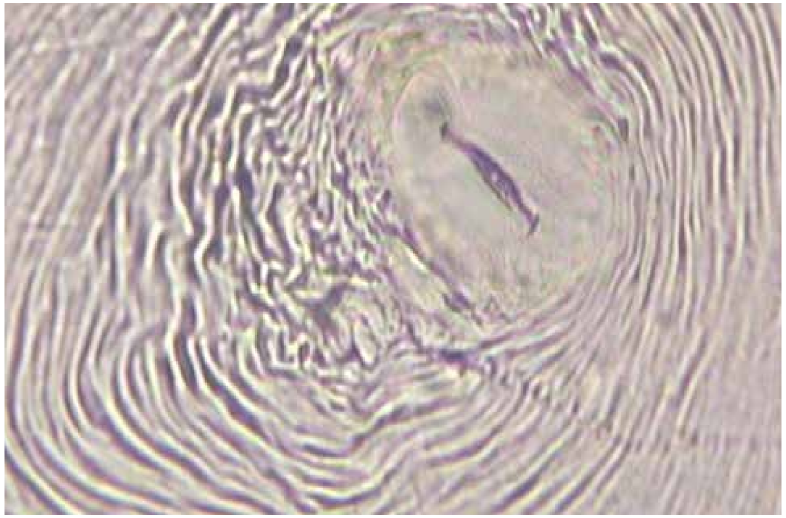
A healthy, productive coffee plant.

Left: Galling of roots by Meloidogyne africana.
Right: Coffee tree root ball, showing extensive knotting and a galled clump of roots.

mutation rates, have increasingly become a focus as a useful diagnostic barcoding region. Using hundreds of populations from widespread geographical origins and variable crop hosts we screened a selection of quickly evolving mitochondrial coding genes. Our results indicated that mitochondrial haplotypes are strongly linked and consistent with traditional esterase isozyme patterns and confirmed that these barcodes can effectively distinguish closely related species.

With this new tool in hand a rich abundance of species has recently been determined from just a handful of coffee samples from Kenya, Tanzania, and Uganda. At least six species of *Meloidogyne* have so far been identified, often demonstrating mixed species combinations from individual farms. The tropical species *M. incognita* and *M. javanica* were observed, as expected. The less commonly occurring and more temperate species, *M. hapla,* was also found, as was *M. africana*, a relatively unknown and little studied species. In addition *M. paranaensis* was collected from Uganda and *M. izalcoensis* from Tanzania, the first time either of these species had been found in Africa. At least two other populations represented new undescribed species, while a tentative identification of *M. hispanica* from Tanzania, if confirmed, would be the first known record of this species on coffee in Africa. Again, our vast lack of knowledge on pathogens in this region was underscored.

The recovery of *M. africana* from Tanzania creates interest from both taxonomic and pathological perspectives, as it is an early branching species of *Meloidogyne* that causes severe damage on coffee roots. From morphological measurements of our cultured populations, juveniles and females measured up perfectly with the description of *M. africana* by Whitehead (1959). Strangely though, the males perfectly matched the description of *M. decalineata,* which were also recorded by Whitehead (1968) from populations recovered from the same area as our *M. africana* from Lushoto, Tanzania. Sequencing of ribosomal and mitochondrial genes, however, confirmed that all specimens belonged to a single species. By carefully analyzing the typeslides, and with confirmation from the molecular analysis, it appears that the



Perineal pattern of Meloidogyne *female.*

Coffee production on the hillside.

original descriptions of *M. decalineata* and *M. africana* may have been confused.

To further complicate the situation, the other "African" coffee species, *M. megadora,* previously recovered and described from Angola and Uganda and *M. oteifae* recovered and described from the Congo, are morphologically very close to our current *M. africana* cultures. Using typeslides observation of *M. oteifae,* perineal patterns were found to be very similar to those of our *M. africana* population. Without cultures of these two species, it is not possible, yet, to clarify the link or dispel any further possible taxonomic confusion. It does, however, pose the question about which species we really have infecting our coffee, and adds great weight to the value of establishing accurate diagnostic techniques to enable sound reliable information for use in crop and pest management decisions.

A further intriguing aspect is that *M. africana* is an early branching species within the genus. This basal position is of crucial importance in determining the ancestral characteristics of root-knot nematodes. Studying this nematode will allow a glimpse into their origin, permitting us to have an insight into the evolution of their reproduction, virulence, and morphology. However, from another Tanzanian coffee field sample we recovered a population that is likely to represent a new, undescribed species, which appears to be an even earlier branching and more basal species than *M. africana*. So far, therefore, two African species from coffee, together with *M. coffeicola* (America) appear to be of a primitive nature, suggesting that coffee may have played a crucial role in the evolution of the pest. It is clear that *M. africana* substantially deforms and damages roots, and this is likely to lead to significant yield losses. It is also clear that, although there appears quite a complex diversity of *Meloidogyne* species occurring on coffee, the situation may not be as complex as the existing literature may have us believe but we have very little knowledge about the true extent of the damage they are posing to the coffee sector.

And you thought having that aromatic "African" coffee was just as simple as brewing and pouring some into a cup!

Bananas galore. Photo by IITA.

East African Highland Banana: Saving the future by understanding the past[1]

Morag Ferguson and Rony Swennen, IITA Tanzania (Dar es Salaam and Arusha)

Banana (Musa spp.) is one of the world's most popular fruits and a mainstay on the family table along with rice, wheat, and maize. Bananas produce few, if any, seeds and are instead vegetatively propagated by taking a part of the plant—an offshoot or a sucker—and sticking it into the ground to grow a genetically identical "copy" of the mother plant. However, the absence of seeds generated by sexual recombination limits the potential of banana to produce genetically diverse offspring that could withstand future environmental and biological threats.

The East African Highland Banana (EAHB) are a specific type of cooking banana in the East African Great Lakes region where they are a highly valued staple food for over 80 million people. EAHB are so important in Uganda (the second largest producer in the world) that the local name matoke (or matooke) is synonymous with food. An average Ugandan consumes about 0.7 kg of banana daily.

[1]Based on: Kitavi M., T. Downing, J. Lorenzen, D. Karamura, M. Onyango, M. Nyine, M. Ferguson and C. Spillane (2016). The triploid East African Highland Banana (EAHB) genepool is genetically uniform arising from a single ancestral clone that underwent population expansion by vegetative propagation. Theoretical and Applied Genetics 129:547-561.

Given the importance of EAHB for food security in the Great Lakes Region and in the context of a rapidly changing climate bringing with it extremes of environmental conditions and changes in pest and disease distributions and patterns, a more thorough understanding of the genetic variability—and how to tap it—is crucial to ensure their continued existence and maximize their potential. Presently, EAHB have reached only 9% of their yield potential in Eastern Africa while biotic stresses, such as nematodes, weevils, and diseases such as black sigatoka, and Banana Xanthomonas wilt (BXW), have made a heavy impact on production.

IITA conducted a study funded by Irish Aid to advance our understanding of the genetic variability in EAHB in the context of their evolutionary history and determine their potential to adapt to current and future threats.

EAHB display quite a range of variation of plant types, grouped in five clone sets: Nfuuka, Musakala, Nakabululu, Nakitembe, and Mbidde. Grouping was based on 73 morphological traits and fruit quality attributes. Simple sequence repeats (SSR)—a type of DNA molecular marker—was used to measure the genetic diversity among the different plant types. About 90 phenotypically diverse cultivars were collected from the Uganda and Kenya germplasm collections which represent the cultivated genepool. These samples were then DNA-fingerprinted using 100 SSR microsatellite markers to investigate their population genetic diversity, to correlate genetic variability with morphological classes, and to determine the evolutionary origins of EAHB from the time they were introduced into Africa.

The findings are surprising. They revealed that EAHB presently cultivated in Africa have minimal genetic variation and are largely genetically uniform, even between and within the Kenyan and Ugandan collections. Basically, the research showed that all EAHB existing today, asexually propagated over multiple generations, can trace their origins from a common ancestor. The research also indicated that EAHB have a significantly lower genetic variability than other types of banana such as plantain and the sweet Cavendish banana. The variability found in morphological traits (i.e., flower, fruit, etc.) for EAHB is not reflected at the level of genetic diversity. Consequently, the narrow genetic base means that consumption and associated food security in East Africa are highly vulnerable to environmental and biotic changes and stresses. Simply put, if the climate changes drastically, or if a new banana pest or disease comes up, we may see the end of EAHB in Africa as the crop is not genetically equipped to handle such stresses.

Cultivated banana are thought to have arisen from the crossing of two wild banana types in Southeast Asia approximately 7000 years ago. These wild species have two copies of their chromosomes in each cell (called "diploids" in genetic terminology). At some time in the course of eons of intermating, a rare genetic event happened in which an offspring was produced with three copies of their chromosomes in each cell (or "triploids"). Triploid banana—those that we commonly eat these days—are sterile and do not produce fertile seeds. EAHB are one of them.

Researchers consider that the triploid-forming hybridization event of EAHB originally occurred in New Guinea and Java. However, the lack of historical records and robust archaeological evidence means that we do not fully understand how and when triploid EAHB arrived in the Great Lakes Region from its center of origin in Asia, although it is thought that the ancestral EAHB first entered Africa about 2500 years ago. Irrespective of where they were first generated, it appears that the current day EAHB all arose from a common ancestral clone.

The absence of seeds and the increased fruit size would have made humans prefer this type, thereby giving rise to the current predominance of sterile triploid cultivars. The original ancestral triploid-forming hybridization event would have isolated EAHB reproductively from all other banana, leaving them genetically isolated with minimal genetic variability to deal with environmental changes.

This narrow genetic base is maintained through the vegetative reproduction of asexual clones (copies) that are planted as suckers. Over the past 2000 years, this has allowed a rapid expansion in the population size of EAHB in the Great Lakes Region (evident from the molecular data gathered by the research). Through this rapid expansion, somatic DNA-mutations and/or epi-mutations are thought to have accumulated, resulting in the morphologically different variants we see today.

Broadening the genetic base of EAHB, while maintaining and improving quality and yield characteristics, is a top research priority for IITA. To some extent this requires accelerated re-domestication of EAHB which involves IITA breeders replicating the crossing events that occurred in Southeast Asia centuries ago with diploid wild banana. In addition, IITA researchers are investigating the use of modern biotechnology tools and applying them to address the adaptability of current EAHB because of their lack of naturally-occurring genetic variation. All these efforts aim to ensure that future generations of Africans will still be able to enjoy an East African Highland Banana.

Banana roadside market in rural South West Uganda. Photo by Piet VanAsten, IITA.

CBSD in East Africa: The fight continues

Edward Kanju, IITA Tanzania

Cassava Brown Streak Disease (CBSD) is a viral disease that rots cassava roots and renders them useless. Before the twenty-first century it was largely restricted to coastal Eastern Africa. However, in the early 2000s, new outbreaks were reported from mid-altitude areas (>1000 m above sea level) of south-central Uganda, western Kenya, and northwestern Tanzania, precipitated by huge increases in the populations of the vector, whitefly, *Bemisia tabaci*. CBSD has subsequently been shown to be spreading as a pandemic throughout the major cassava-growing regions of East and Central Africa and threatens to spread further westwards into Central and West Africa.

Research by IITA has shown that the most effective and convenient approach, particularly for resource-poor farmers, to reducing losses from CBSD is the use of host-plant resistance or the deployment of less-susceptible cultivars. Historically, much of the breeding work to combat CBSD has focused on tolerance since complete resistance to infection is rare.

In 2015, IITA continued efforts to control, contain, and even push back CBSD on this front. In Tanzania, four IITA-developed varieties tolerant of CBSD and resistant to Cassava Mosaic Disease (CMD, another widespread disease of the crop) were officially released for use by farmers in the country. These were: KBH 2002/363 (Chereko), KBH 2002/066 (Kipusa), KBH 2006/026 (Mkuranga 1), and KBH 2002/482 (Kizimbani).

In addition, IITA is in the advanced stages of evaluating more than 30 highly promising breeding lines in Tanzania. Four of these (UKG 2009/0052, UKG 2009/0128, UKG 2009/0164, and UKG 2009/0181) have performed very well under on-farm conditions and have been proposed for a one-year evaluation under National Performance Trials (NPT)—a final step towards full official release. Once they are released, these varieties will be the first to have dual resistance/tolerance for CBSD and CMD for the Lake Zone of Tanzania, an area where CBSD is so devastating that many farmers have totally abandoned cassava production.

In Uganda, two IITA-developed varieties have been officially released during the year: TZ 130 (NARO-CASS 1) and MM 2006/0130 (NARO-CASS 2). Their release is a milestone since these are the first that offer dual resistance/tolerance for CMD and CBSD for the mid-altitude areas of the Great Lakes region.

However, IITA continues to pursue the objective of developing a variety that is truly resistant to CBSD. By definition, a truly resistant variety should not be readily infected, even when exposed to large amounts of vector-borne inoculum. If and when infected, such a variety should develop inconspicuous symptoms without adverse effects on growth and yield. It should also support low virus (if any) content and thus be a poor source of infection. Developing a truly CBSD-resistant variety will entail using different modes and new sources of resistance.

To this end, IITA breeders have started to look for and identify such sources of resistance by introducing germplasm from IITA's Genetic Resources Center in Ibadan, Nigeria. Nine Nigerian cultivars were introduced by tissue culture into Tanzania, where they were evaluated for CBSD resistance in the field for three seasons at Chambezi, a known disease hotspot. Initial findings have shown that two cultivars —TMS-IBA961089A and TMS-IBA000388—had either a significantly higher marketable yield of fresh roots or else performed as well as *Kiroba*, the improved control variety. Furthermore, the two cultivars showed no quantifiable virus concentrations. Due to their outstanding performance, TMS-IBA961089A and TMS-IBA000388 have been earmarked for on-farm evaluation across several sites after which they will be included in NPTs just before official release in Tanzania. If they consistently perform well, these cultivars will be used as new sources of resistance to generate new varieties in future that are truly resistant to CBSD.

Integrated Systems

A decade of CIALCA: Lessons learned from integrated systems R4D in the Great Lakes Region

Marc Schut, IITA-Burundi; Piet van Asten, IITA-Uganda; and Bernard Vanlauwe, IITA-Kenya

The Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA) emanated from three individual project proposals submitted by IITA, Bioversity International, and the International Center for Tropical Agriculture (CIAT) that were approved by the Belgian Directorate General for Development Cooperation (DGD) in 2006. As the projects were to operate largely in the same parts of Rwanda, Burundi, and DR Congo, with similar national partner institutes, and with complementary activities, the three institutes agreed to operate together to improve operational efficiency and livelihoods impact. Initially, their research-for-development (R4D) agenda focused on enhancing crop production technologies (i.e., improved germplasm, soil management, and pest control) in legume- and banana-based systems, while creating an enabling environment for the uptake of these practices. CIALCA was one of the first agricultural R4D projects investing in an area that was torn apart by years of civil strife and —back then—dominated by humanitarian relief aid.

Successful development, testing, and scaling of banana and legume technologies

Throughout the first phase of CIALCA (2006-2008) several cropping systems and pest management technologies were tested. CIALCA became particularly known for its work with local stakeholders on on-farm testing and validating of improved germplasm, pest control and integrated soil fertility management technologies in banana and legume systems. The project also restarted collaborative activities between the national researcher organizations from Burundi, Rwanda, and DR Congo, while providing PhD and MSc training to several of their staff in partnership with local and Belgian universities. Based on CIALCA's initial success, the consortium's contract with the Belgian donor (DGD) was approved a second phase (2009-2011). CIALCA now focused more on the scaling of agricultural innovations through communication, partner training, novel value addition options, and assisting farming communities with new business models. More than 1000 trainers from partner organizations were trained on novel production technologies, such as new varieties and improved soil management, and novel processing technologies, such as soybean milk. CIALCA was also at the forefront of combatting the BXW— the bacterial wilt disease that wiped out banana production in entire farms and villages.

Moving innovations from the plant to the plot to the farm

From 2009 onwards, CIALCA has been testing banana-coffee mixed systems for climate change mitigation, pest reduction, and diversified farmer income. It turned out to be a very good match! The story on coffee/ banana intercropping was picked up by BBC Africa Network with a live radio interview, and by AFP, Reuters, and other large media houses. It led the Rwanda Agricultural Board to start their trials on banana/coffee intercropping, which was controversial as the Rwandan Crop Intensification Program (CIP) does not promote intercropping. Based on good results, the Minister of Agriculture requested additional research on coffee cup quality. Results were supporting intercropping and—although the CIP policy was not formally adjusted—banana/ coffee intercropping was since then tolerated by the Rwandan government in large parts of the country. CIALCA also introduced novel cassava-legume, maize-legume, and banana-legume systems, increasing smallholder farm productivity by improving soil fertility management with novel intercrop arrangements and practices. Farmers that tested the innovative practices on-farm became 'technicians' and not 'unemployed' people in their eyes. Supported by local structures and partners, collective marketing and collective seed production (e.g., banana macropropagation) became important drivers for increased income and collective action. Choice experiments in Burundi showed that farmers had a strong preference for climbing bean varieties that resulted in higher yields and improved soil fertility, while the maturation period and the responsiveness to fertilizer were less important. Such choice experiments take into account farmers' preferences and accelerate the agricultural innovation processes.

From farming systems to integrated livelihood systems

By the end of its second phase in 2011, reforms had started to reshape the CGIAR landscape with the arrival of the CGIAR Research Programs (CRPs). CIALCA became a key operating platform for the CRP on Humidtropics. With its multi-CGIAR center and multistakeholder model, CIALCA was well placed in Humidtropics. By building on many years of innovation investments and partnerships, CIALCA was able to jump-start activities and mobilize multi-stakeholder networks in Burundi, Rwanda, and eastern DR Congo. The integrated systems approach includes understanding livelihood diversity, gender, value chains, nutrition, markets, natural resource improvement, institutional innovation, and scaling of successful innovations through multi-stakeholder partnerships (Fig. 1).

Major CIALCA impacts

- An impact assessment conducted in 2014 by the IITA Impact Group concluded that in South Kivu, DR Congo and Rwanda, CIALCA has contributed to lifting an estimated number of about 560,000 people out of poverty. Changes in poverty rates due to CIALCA are between 3%, 10%, and 21% for Burundi, South Kivu (DR Congo), and Rwanda, respectively.
- CIALCA's strong science capacity building resulted in the training of over 10 PhDs and 40 MSc students in a region that had lost of much of its science capacity during years of conflict. Many former CIALCA MSc and PhD students are now in key positions in Ministries and NARS in Burundi, Rwanda, and DR Congo.
- CIALCA has trained over 50 partner organizations and more than 1000 trainers in—among others—seed multiplication technologies (e.g., macropropagation) and effective pest and disease control (e.g., BXW management), good agricultural practices and intercropping techniques, new crop varieties, postharvest processing, and collective marketing.
- CIALCA has contributed significantly to advancing science related to integrated soil fertility management (Lambrecht et al., 2015b; Vanlauwe et al., 2014), climate-smart opportunities for smallholders (Ekong, 2015, van Asten et al., 2015) and the effectiveness of agricultural extension and other partnership modalities in supporting (specific groups of) farmers (Lambrecht et al., 2015c; Schut et al., 2016).

Looking to the future

CIALCA has shown to continuously reinvent and reorient itself. This will remain needed. In the field of research for development, CIALCA will further strengthen its strategic engagement with policy actors and other investment actors. CIALCA contributed to a continental study on drivers of the food security of African smallholders (Frelat et al., 2015). This study showed that while there are clear opportunities to strengthen agricultural production, marketing and income for many of the 'better-off' farmers, a large proportion of smallholders (20-40%) seem incapable to significantly improve their livelihood through agriculture and off-farm income is key. Strengthening the capable farmers with improved production, handling and marketing innovations will need to be accompanied with efforts to strengthen (agricultural) job opportunities for the vulnerable groups, including youth and women. This will require working with public- and private sector investors in a holistic approach. The multi-stakeholder platforms and tools identified a clear need for institutional innovation (e.g., with alternative land tenure arrangements, and service provision to farmers), which will require more attention and concrete investments in future integrated systems programs. Other areas that need more attention are the use of ICT in agricultural innovation processes, technology development and service provision. Reinvention and reorientation of CIALCA is ongoing to accommodate these and other future systems research and development challenges.

Figure 1. *Key building blocks of CIALCA's integrated livelihood systems R4D.*

Integrated soil fertility management and coffee-banana intercropping in climate-smart agriculture

Dries Roobroeck, IITA-Nairobi, Kenya (ICIPE); and Dennis Ochola, IITA-Kampala, Uganda

The impacts of global changes become more and more tangible, particularly on how we grow food, and governments, researchers, farmers, and other stakeholders are increasingly turning their attention to Climate-Smart Agriculture (CSA). With the rapidly changing climate, CSA builds on three dimensions: (1) intensifying productivity; (2) enhancing resilience; and (3) reducing greenhouse gas emissions.

The Global Alliance for Climate-Smart Agriculture (GACSA,) was launched during the Climate Summit in September 2014 to engage leaders and advance climate action and ambition. GACSA is led by a team from FAO and CCAFS; to date more than 100 organizations have signed up with GACSA, including the African Union Commission (AU), the World Bank, the International Fund for Agricultural Development (IFAD), and Yara International.

In July 2015, the Knowledge Action Group of GACSA released a series of practice briefs (http://www.fao.org/gacsa/resources/csa-practice-briefs/en/) that sought to provide operational information about the contributions of management practices to different indicators of CSA. Together with colleagues from the Natural Resource Management Unit and partners from the Alliance for a Green Revolution in Africa (AGRA) and the Institut des Siences Agronomique du Burundi (ISABU), we developed briefs on Integrated Soil Fertility Management (ISFM) and Coffee-Banana Intercropping (CBI). Each brief gives an overview of the practice, contributions of the practice to specific dimensions of CSA, and challenges to adoption, investment needs, metrics for evaluating impact, and case studies of implementation.

The ISFM brief was a mini review of long-term trials and large dissemination programs in cereal-based systems comparing key indicators for the three CSA dimensions of practices. It illustrated that the combinations of mineral fertilizers with inputs of biomass residues or rotation of legumes result in a consistently greater crop productivity and value-to-cost ratio of inputs that improves food security and livelihood of farmers.

Several long-term studies have shown that ISFM practices reduce the variability in production between seasons implying that crops are more resilient to climate deviations. Cases were presented illustrating how input of organic residues or mixing of legumes can maintain a greater soil carbon stock, enhance fertilizer recovery by crops, and substitute for inorganic nitrogen inputs. The brief argued that ISFM practices may largely mitigate the greenhouse gas emissions compared to practices where only fertilizer is used or without inputs at all.

Figure 1 gives the average grain productivity and seasonal variation in yield of maize cropping under different input practices across a 20-year trial at the research farm in Ibadan along with the total carbon content of soils at the start and end of the study

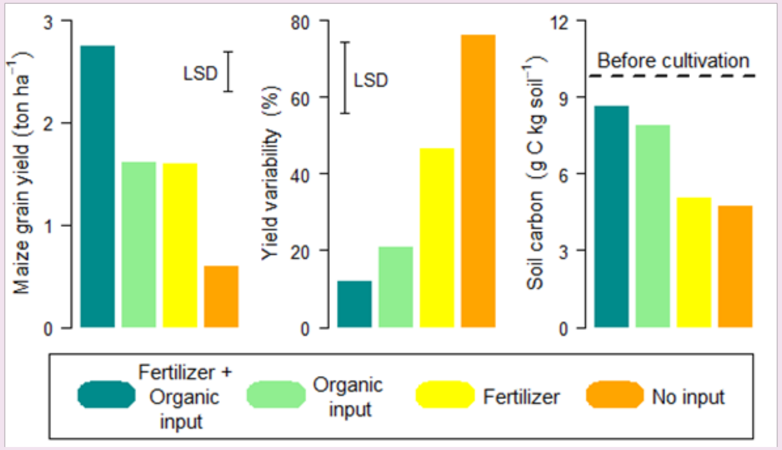


Figure 1. Maize grain productivity, seasonal variability in yield and soil carbon content under different input practices over a 20-year study. LSD= Least Significant Difference.

period. This study presents some of the most comprehensive evidence about the contributions of ISFM to CSA. It showed that the grain yield of crops, resilience to drought, and the conservation of soil carbon in maize systems are all substantially greater when inorganic fertilizers and organic inputs are combined compared to other input practices.

The CBI brief, on the other hand, revisited studies on coffee-banana intercropping trials on fields of farmers and at research stations of IITA and its partners over the last 7 years. Research from Uganda, Rwanda, and Burundi was used to demonstrate that mixed coffee and banana planting benefit household incomes, improve resilience to climatic impacts, and sequester larger amounts of carbon than when growing either of these crops on their own. Figure 2 illustrates that practicing CBI can double annual revenues on land where coffee is grown without banana. Evidence showed that growing banana in newly established coffee farms reduces the farmers' risk by offsetting cash flow constraints worth $10,000 during the first 4 years. It also described how the shading by banana reduces canopy temperatures in coffee by 2–3oC and prevents the distribution of pests and diseases. This makes the systems more resilient to climate change impacts and improves quality.

The CBI brief gave evidence that mulching of banana in intercropped systems leads to accumulation of carbon and nitrogen in the soil that may reduce greenhouse gas emissions. CBI is a traditional practice in areas with high population density due to diminishing farm size and soil degradation. It shows a great potential for adoption that could benefit 20-25 million farmers who depend on coffee and/or banana for their livelihood. It also emphasizes the need for change in the attitudes of value chain actors as well as decision support about the variety of banana, optimal planting densities, and proper timing and frequency of pruning to bring the CBI practice to scale.

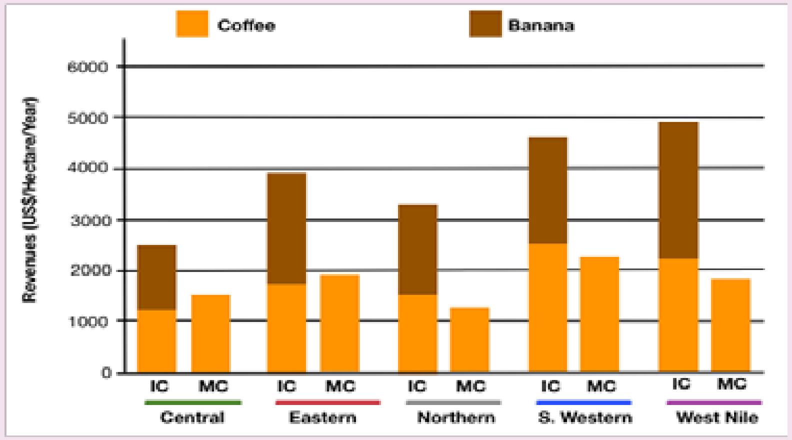


Figure 2. Annual revenues from coffee-banana intercrops (IC) and coffee monocrops (MC). Central and Northern are growing Robusta, while Eastern, South Western and West Nile are growing Arabica.

Impact and **Outscaling**

Benefits and impact of drought-tolerant maize varieties in Nigeria

Tahirou Abdoulaye, IITA-Ibadan; Tesfamicheal Wossen, IITA-Abuja; Shiferaw Feleke, IITA-Tanzania; Abebe Menkir, IITA-Ibadan; Baffour Badu-Apraku, IITA-Ibadan; Arega Alene, IITA-Malawi; Bola Awotide, and Victor Manyong

The Drought Tolerant Maize for Africa (DTMA) project was initiated with the aim of developing drought-tolerant maize varieties (DTMVs) with a potential yield of 1 t/ha under moderate drought conditions, increasing productivity under farmers' conditions by 20-30%, and producing grain with an annual average value of $160-200 million in drought-affected areas. The project was funded by the Bill & Melinda Gates Foundation and jointly implemented by the International Maize and Wheat Improvement Center (CIMMYT) and IITA in partnership with the national research and extension systems of 13 African countries.

Since it was launched in 2006, the DTMA project has documented successes in the development and dissemination of DTMVs in Africa. About 160 DTMVs were developed between 2007 and 2014. Most have been successfully disseminated to maize farmers in 13 African countries. This report provides some evidence on the productivity and welfare impacts of adoption of DTMVs in Nigeria, a country participating in the DTMA project.

Sampling and data collection

Data for this report came from a household survey conducted in Nigeria from November 2014 to February 2015. To ensure the selection of a representative sample of households, a multi-stage random sampling procedure was applied. First, based on the area of land devoted to maize production, the 36 States in Nigeria were divided into five homogenous subgroups; 18 of these States were randomly selected, accounting for about 62% of the total area of land devoted to maize production in the country. Then, following the recommendation of the National Bureau of Statistics (NBS) for a nationally representative data collection, 10% of the local government areas (LGAs) in each of the selected States and 5% of the total extension areas (EAs) per LGA were randomly selected. From the list of communities obtained from the NPC, two communities were randomly selected in each of the selected EAs. Finally from the households in each of the selected EAs, five farming households were randomly selected, resulting in a total of 2305 households. The survey questionnaire included information on socioeconomic characteristics of the households, household expenditure on food and non-food items output for maize and other notable crops, and income from various sources. The data was collected electronically using the "surveybe" software.

Measuring adoption and outcome variables

Adoption was measured based on whether or not the household was cultivating one DTMV or more in the 2014/2015 production season. The outcome variables are maize productivity as measured by maize yield (kg/ha), household welfare as measured by per capita food expenditure (N/year), and the Foster, Greer and Thorbecke (FGT) indices of poverty (head count index, poverty gap index, and poverty gap-squared index). The head count index measures the rate of poverty, the proportion of people living below the poverty line, which was computed using the World Bank's $1.25 per capita per day measured at Purchasing Power Parity (PPP)[1]. The poverty gap index measures the depth of poverty, which is the extent of income shortfall from the poverty line. The poverty gap-squared index measures the severity of poverty that indicates the degree of income inequality among the poor themselves.

Adoption rate of DTMVs in Nigeria

About 52% of the sample maize farmers reported they had access to DTMVs through the DTMA project. The adoption rate among them was about 44%, suggesting that not every farmer who had access to the DTMV seeds actually planted DTMVs. Irrespective of access to seeds, the adoption rate was 24.5% in the study sample, which is quite appreciable if we remember that the first DTMVs are not even 10 years old (Fig. 1). For estimating impact of adoption, we used 24.5% as the effective adoption rate and employed an Endogenous Switching Regression (ESR).

[1]We used per-capita expenditure to compute this value

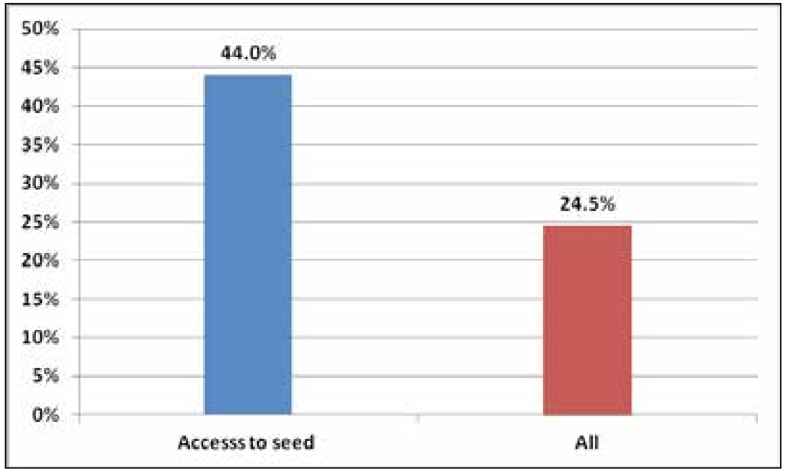


Figure 1. Adoption rate of DTMVs among households that have access to seeds through the DTMA project, and all sample households in Nigeria, 2014/2015.

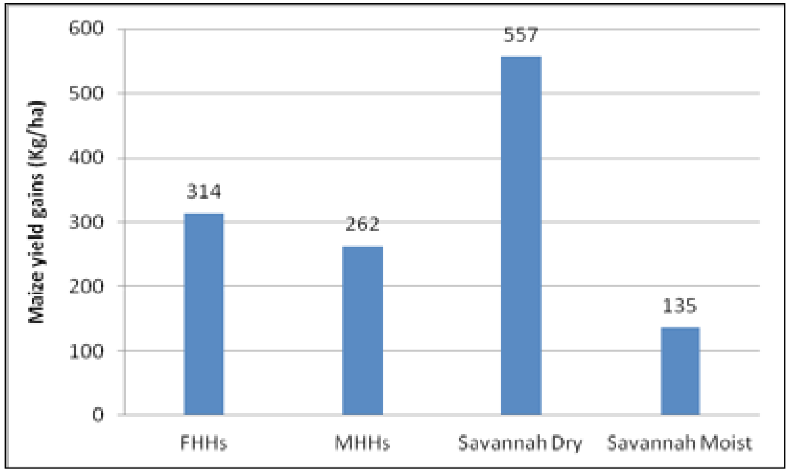


Figure 2. Maize productivity gains (kg/ha) by gender and ecology.

Productivity and welfare impacts of DTMVs

Productivity Impacts. Adoption of DTMVs in Nigeria has resulted in measurable gains in maize productivity and impacts on household welfare. Our result shows that maize yield has increased by 23% (268 kg/ha) as a result of the adoption.

Impacts by gender

Analysis of impacts by gender revealed that adoption of DTMVs has greater productivity gains on average among female-headed households (314 kg/ha) than male-headed households (262 kg/ha). In addition, average productivity gains were much higher in dry savanna agroecological zones (Fig. 2). Despite about 314 kg/ha productivity gains for female-headed households average productivity gains for the whole sample were much lower (268 kg/ha) since the these households constituted only 10.45% of the total sample.

Per-capita food expenditure. Like productivity gains, changes in per-capita food consumption were also sizable as a result of the adoption of DTMVs. Our result shows that adoption has increased per-capita food consumption by N10,683 (about $35).

Per-capita food expenditure by gender. Analysis of impacts by gender revealed that as a result of adoption of DTMVs, male-headed households increased their per-capita food consumption by N11,303 and female-headed households by N5919. Note that this should not be interpreted as a gender-biased outcome. Since the initial level of per-capita food expenditure was higher among female-headed households in our DTMA sample; it is reasonable to see such large increases among male-headed households.

Per-capita total expenditure. Changes in per-capita total consumption expenditure similar to improvements in per-capita food expenditures,were also sizable as a result of the adoption of DTMVs. Our result shows that adoption has increased per-capita total consumption expenditure by N13,907 (about $46 per year).

Per-capita total expenditure by gender. Analysis of impacts by gender revealed that as a result of adoption of DTMVs, male-headed households increased their per-capita total consumption expenditure by N14632 and female-headed households by N7384.

Impacts on poverty outcomes

Based on preliminary results from the endogenous switching regression approach using awareness about DTMV as an instrument, we estimated poverty outcomes for adopters. Using per-capita total consumption expenditure values and the World Bank's $1.25 per-capita per day measured at Purchasing Power Parity (PPP), about 62% of adopters were observed to be below the poverty line. Had they not adopted DTMVs, our preliminary results suggest that the rate of poverty among adopters would have been about 83%, suggesting that the gain in maize productivity due to adoption had eventually led to about 21% point poverty reduction (Fig. 3) among adopters of DTMV. When it comes to depth of poverty, adoption of DTMVs yielded a 15.8% point reduction in depth of poverty for the same group. Furthermore, it helped to reduce the severity of poverty among the poor by 9.4% points for the same adopters. For the population of maize farmers as a whole, this translates into an average poverty reduction point of only 4.9% in 2014/2015.

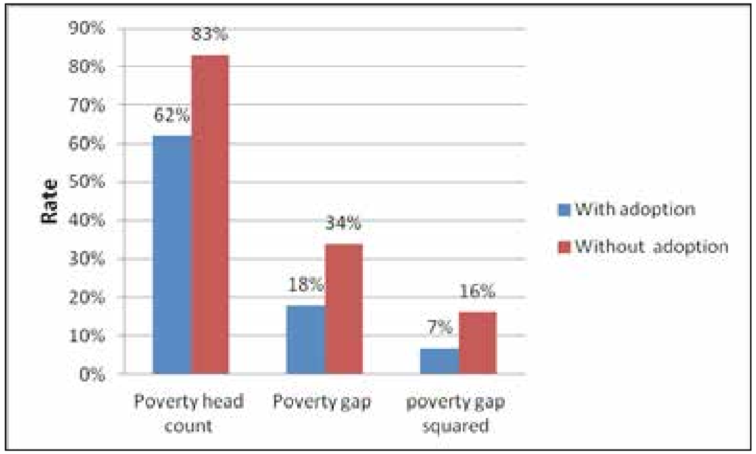


Figure 3. Poverty headcount, poverty gap, and poverty gap squared with and without adoption.

Looking at impacts by gender, we found that the poverty headcount rate declined by 23% points among male-headed households and 7% points among female-headed households. We reported a higher productivity gain ***among*** female-headed households in the previous section. However, while examining the poverty impacts of adoption by gender, we found higher effects for male-headed households. This result shows that higher productivity gains are accrued for more affluent (non-poor) female-headed households.

Individuals lifted above the poverty line

The next challenge is then to calculate the total number of households lifted above the poverty line as a result of adoption. Based on adoption rates and predicted poverty reduction rates, the total number of households lifted above the poverty line as a result of DTMV adoption is estimated to be 2.68 million individuals (0.37 million households). This result reflects only direct effects—effects on households that adopted DTMV. Indirect effects on non-adopters and consumers through reductions in prices are not included.

Conclusion

The account provided some evidence on the productivity gains and welfare impacts of adoption of DTMVs in Nigeria. The report also provided heterogeneity impacts of adoption, focusing on gender and ecological zone. Results indicate that adoption of DTMVs resulted in a 268 kg/ha gain in maize productivity and N10683 per annum in welfare benefits as measured by the gain in annual per-capita food expenditure. In terms of poverty reduction, we found a 21% point reduction in poverty as a result of adoption. An estimated 370,000 households (equivalent to 2.7 million individuals) managed to move out of poverty as a result of adoption of DTMVs. Further estimated impacts on productivity gains suggest that the program was more beneficial to female-headed households. However, estimated results on poverty outcomes suggest that the project targeted better-off female-headed households. Moving forward, there needs to be a more targeted intervention for addressing disadvantaged groups such as poor female-headed households. In particular, constraints related to access to DTMV seeds and other barriers associated with adoption have to be addressed.

A facilitator training farmers on farming as a business in Ghana (Photo by Richard Asare, IITA).

Building stronger cocoa farmer groups through ICT

Richard Asare, IITA-Ghana

Cocoa (*Theobroma cacao* L)—the main ingredient of that delectable global favorite chocolate—has been the backbone of the economies of the four West Africa countries, Côte D'Ivoire, Cameroon, Ghana, and Nigeria, which together account for about 70% of the world's total cocoa production. This top production position comes at a steep environmental price to these countries as the main mode of cultivation has been by continuous expansion into pristine forest areas in a situation called "forest rent" in which cocoa farmers cultivate newly opened, nutrient-rich forest soil as a means of reducing production costs in terms of fertilizer and agro-chemical inputs. This practice has led to widespread reductions in forest cover in these countries and has had a negative impact on the environment.

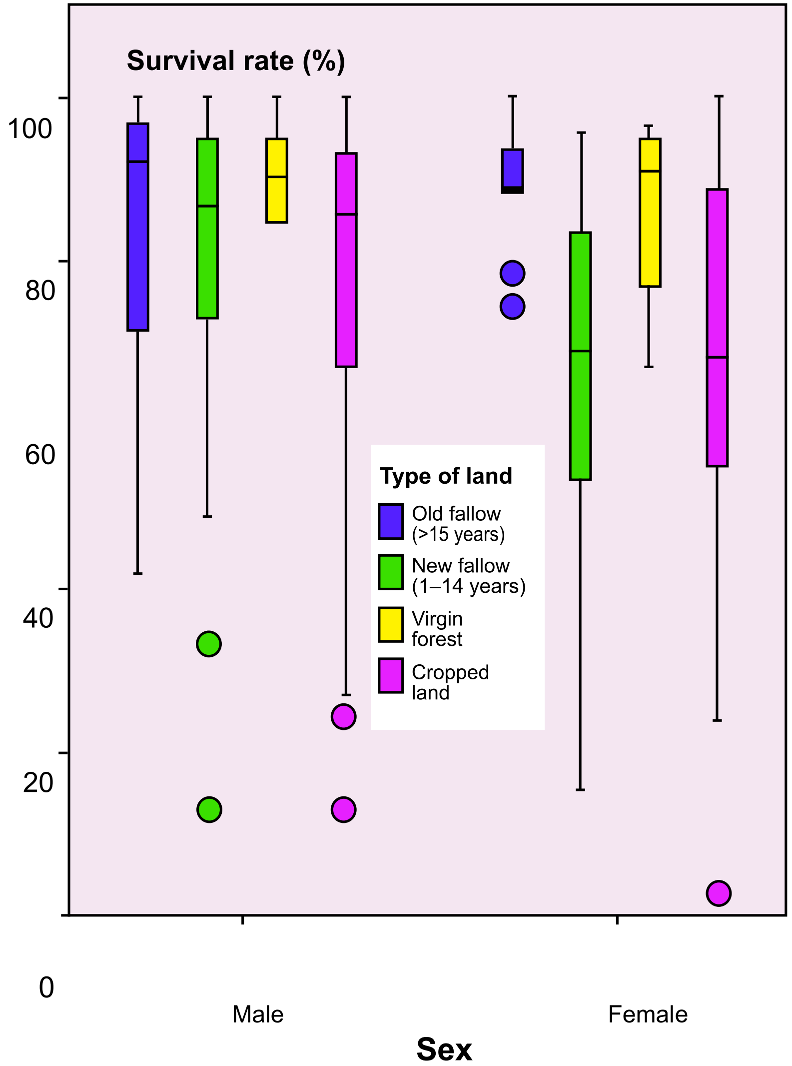
For years, stakeholders in the cocoa industry in West Africa have been trying different approaches to influence, if not change, cocoa farmers' "forest rent" practice to reduce the impact of related activities on the environment. In an effort to contribute to this cause in Ghana, IITA with the Grameen Foundation and SNV revitalized a 100,000-member cocoa cooperative called *Kuapa Kokoo* under the Humidtropics' Cocoa-Eco project by building a real-time online agricultural information and communication technology (ICT) system (http://humidtropics.iita.org/share/s/XQI33Il4RGyv2deQKdBgag), thereby strengthening the group's monitoring and evaluation (M&E) system.

With the always-available agricultural information made possible by this ICT system, the project was also able to strengthen the capacity of *Kuapa Kokoo* in helping its farmer-members modernize their cocoa farming for sustainable production through the concept of 'entrepreneurship'. Here, the cocoa farmer is taught to be an entrepreneur and an ecosystem manager and much more than just the 'owner' of the farm, thereby placing farming as a modern business venture instead of a passive activity. For a cooperative such as *Kuapa Kokoo*, it was vital to develop this perspective with the farmers for long-term buy-in. Modernizing the outlook about cocoa farming as a business also helps to erase the common image that cocoa cultivation is for old people—an attitude that ignores the vast opportunities of the sector.

To achieve this, the Cocoa-Eco project has developed and implemented participatory brokerage systems for improved planting materials and guaranteed on-time delivery of unsubsidized fertilizers to entrepreneurial members as well as providers of pest and disease management services. It is envisaged that this will help farmers to identify their needs and service providers for these needs to engender service on request for assistance rather than doing things according to traditional beliefs. The project has also developed information and decision tools to guide farmers in sustainable cocoa farming, the first of its kind for cocoa in West Africa (http://humidtropics.iita.org/share/s/fHA2WQjDR6CCeMViTpy1iA).

Similarly, Cocoa-Eco also introduced a smartphone-based 'last-mile extension' within the cooperative. This technology is essentially an offline mini encyclopedia on the latest cocoa extension knowledge on cocoa rehabilitation and new establishment (PRD). This provides information on practical and sustainable cocoa production techniques that take into account farmers' current situation, selecting suitable sites for cultivation, sources of improved planting materials and other agro-inputs, field preparation and farm management techniques, and options for tree diversification (http://humidtropics.iita.org/share/s/atiHCVRgTdmsjATEmp_KAg). This low-cost innovation has been enthusiastically received by members of *Kuapa Kokoo* and is also being adopted by other cocoa rehabilitation projects across West Africa, especially in Ghana and Cameroon.

A study conducted in Ghana looking at the adoption of this technique showed that, on average, 80% of farmers that had been trained on this technology had a cocoa seedling establishment rate of 80% over a two-year dry period, regardless of the planting location. The study also showed no significant difference in rates of cocoa establishment in different land types. This supports the argument that new cocoa plantations have equal or even better chances of establishment through land recycling than through planting in newly opened forest lands.



Differences in mean distribution of the survival rates of hybrid cocoa seedlings between gender and land use types in Ghana [Source: Asare et al. 2016].

Fields of gold: farmer-managed trials under Platform Mozambique helped determine the soybean varieties released in the country. *Photo by IITA.*

Of grains and gains: Realizing the potential of soybean in Mozambique

Steve Boahen, IITA-Mozambique

There is a lot going for soybean (or 'soya') in Mozambique. Although a relative newcomer to the country, the crop offers vast income opportunities for smallholder farmers particularly those in the high rainfall areas such as Zambezia, Lichinga, Nampula, Manica, and Tete provinces. Production and prices are improving. Back in 2004, soya production was estimated at 770-880 t with an average yield of 450 kg/ha (Estrada, 2004[1]). Today, the average yield is estimated at 1300 kg/ha and total production is about 50,000 t (Luis Pereira, Technoserve, pers. comm., 2014). In 2006, the prevailing farm-gate price/kg for soybean grain was 7-9 meticais (MZM) ($0.25-0.33). By August 2013, the price had doubled, hovering at about 18 MZM/kg ($0.64). The growing domestic poultry industry also has a high demand for soybean which is largely met through imports of soybean cake from Argentina, Brazil, and India.

[1]Estrada, J. M. 2004. Regional overview of the soybean markets: Challenges and opportunities for smallholder farmers in Southern Africa. Study commissioned by IITA.

The available regional market and attractive farm-gate prices with an inadequate domestic supply offer a huge growth potential to soybean in Mozambique. Despite the rosy outlook smallholder farmers are still hampered by low production due to a lack of good quality seeds of locally adapted varieties, and poor crop management practices. IITA and USAID, with other partners, are changing that situation.

Planting the grains of success

Through the USAID-supported Platform Mozambique Project (2009-2015) and in partnership with the *Instituto de Investigação Agrária de Moçambique* (Mozambique National Agricultural Research Institute, or IIAM), NGOs, and farmers associations, IITA introduced five soybean varieties [Sana (TGx 1485-1D), Wàmini (TGx1740-2F), Zamboane (TGx 1904-6F), Wima (TGx 1908-8F) and Olima (TGx 1937-1F)] that have been officially released in Mozambique. The varieties were selected through on-farm participatory variety selection, ensuring that their characteristics are well suited to local conditions and needs. The varieties are high-yielding, and tolerant of drought and most of the common diseases; they yield >40% more grains (2 t/ha) than the widely grown local varieties. They can also fix a large proportion of their nitrogen requirements from the atmosphere, thereby reducing the need for nitrogen fertilizers and lowering input costs for farmers.

To get the best out of these varieties, the project developed complementary management practices to maximize their potential under smallholders' farming conditions. These practices included best planting times in different production zones, appropriate row-spacing, optimum plant populations, phosphorus fertility management, inoculation, and appropriate cropping systems. These practices were then developed into 'technology packs' and disseminated to smallholders and extension agents across the soybean production zones through on-farm demonstrations, field days, field visits, and training workshops. This was done in collaboration with various other initiatives led by IIAM, IITA, CLUSA (Cooperative League of USA), Technoserve, IKURU (*Empresa Comercial dos Productores Associados*), and Inovagro. Through these channels, farmers, for example, became aware of the negative consequences of late planting, such as a yield loss of at least 50 kg/ha for every day of delay in planting after the first planting date. At the prevailing farm-gate price, this translates to a loss of $20/ha for every day that planting is delayed.

Gains on the ground

The combined efforts of IITA and USAID are already starting to change the lives of Mozambican smallholder farmers.

Take the case of 48-year old Florinda Biriate, who started producing soybean 10 years ago. "My initial foray into soya production was in 2006 when I cultivated one hectare. I harvested 13 bags (approximately 650 kg/ha at 1 bag ≈50 kg) of grains which I sold at around 5-7 MZM/kg ($0.18-0.25). Encouraged with this, I gradually increased my soybean area every year until I reached 8 ha in 2010. At that time, I produced 237 bags (about 11,850 kg) of grains, selling them at 15 MZM ($0.54)/kg".

Florinda got the highest price for her soya in 2011 when she sold it at 17-19 MZM/kg ($0.60-0.67). This, she said, was a game-changer for her. "The price and the high yield of soya motivated me to grow more of it than any other crop," she explained.

In 2014, she cultivated 6 ha of soya, with 5 ha for grain and 1 ha for certified seeds. She harvested 1,500 kg/ha from the first and 1,150 kg/ha from the second "I used to get just 600 kg/ha of soya, but now my harvests have more than doubled!"

Asked what turned things around for her, she said, "It was the support that I received through the USAID project with the technical backstopping of IITA and CLUSA. With the knowledge gained from them, not only did I get better yields but also reduced labor. I now plant my soya in early December and in straight lines of 50 cm by10 cm instead of in the traditional scattered planting. Previously, I weeded 3 or 4 times before harvest but now I weed only twice, sometimes even once. It is also easier to weed when the plants are in line."

"I lost my husband two years ago so I farm alone now. These technologies not only make things better but also easier for me and my children," added Florinda.

"With my earnings from soya, I was able to buy two refrigerators, a motorbike, two bicycles, a television with a satellite dish so I can watch news from around the world, a DVD player so that my kids can watch movies any time, and I have money to send them to school. Best of all I am building a new house," she related happily.

Another farmer, Fernando Maliango, also recounted his soya journey. He started with a half-hectare field of 0.5 ha in 2004, selling his produce at 4.70 MZM ($0.16)/kg. Today, he has 11 ha that yield 18 t. He sells his produce at 17 MZM ($0.61)/kg.

"This big improvement in my yields and income motivated me to stay with soya. I benefited a lot from IITA, CLUSA, and Technoserve through training and associated field days in which we learned how to do things better. We are grateful to USAID and all the other donors such as the Bill & Melinda Gates Foundation and the Norwegian Funds that made all these possible."

"These days I easily get between 1250 kg/ha to 2000 kg/ha following all recommendations from the technicians and also using a good variety," Fernando explained. In 2014, he planted 5 ha for certified seeds and 4 ha for grain. He sold the seeds for 25 MZM/kg ($0.89) and the grain for 13 MZM/kg ($0.46).

"With my soya I was able to buy a motorbike, two bicycles, refrigerator, a mill to make flour from maize and other crops, a TV set with a satellite dish, and other household items. I was also able to improve my house, roofing it with iron sheets," Fernando said proudly.

Other gains in a grain

The Platform Mozambique Project has trained more than 5700 farmers, 230 extension agents, and technicians on improved soybean production practices, and 1327 final-year students from local universities and polytechnics on a 6-month field training internship. In addition, it introduced soybean-fortified local dishes to more than 26,000 people to enhance the quality of their diet. The project also established 450 demonstration plots and organized more than 100 farmers' field days and field visits. More than 100 t of foundation seeds were made available to partners.

It is estimated that the project has directly benefited more than 50,000 households, and has indirectly reached even more. Farmers continue to test different varieties to find those with the highest potential on their farms. Average yields have increased from 700 kg/ha at project start to 1300 kg/ha presently. Incomes from soybean have also increased by about 56% among adopters of improved technologies introduced by the project. Such technologies, such as soybean-maize rotation planting, have also led to average yield increases of 21-1000% for maize when planted after soybean compared with the common practice of planting maize-after-maize with no fertilization.

Farmer Florinda Biriate at her 6-ha soybean farm in Ruace, Zambezia province, Mozambique.

Fernando Maliango with his harvest of soybean from his field in Ruace, Zambezia province, Mozambique.

DeMISSTifying the soybean seed system in Malawi

Akinwale Gbenga, IITA-Malawi

In Malawi, soybean is the lifeblood of thousands of smallholder farmers. It offers them a myriad opportunities: a readily available market, attractive farm-gate prices, and the potential to improve their nutritional security. However, current production levels are low, averaging less than 1 t/ha. There is minimal adoption of improved varieties and agronomic practices because these farmers, in particular, have limited access to better varieties.

The Malawi Improved Seed Systems and Technologies (MISST) project is led by IITA, supported by USAID's Feed-the-Future Initiative, and co-implemented by IITA, ICRISAT, CIMMYT, and CIP.

Recognizing the importance of seeds in improving productivity, the soybean component is making high quality seeds of three improved varieties (Tikolore, Nasoko, and Makwacha) more accessible and available. The project is working through support for seed production, increasing adoption through variety demonstration and promotion, capacity building, strengthening of seed partnerships, and by using public-private partnerships for seed production, distribution, and marketing.

IITA collaborated with the national farmers' organization, NASFAM, to establish 50 technology demonstration plots across 7 districts of the Feed the Future zones of influence: Lilongwe, Mchinji, Dedza, Ntcheu, Balaka, Machinga, and Mangochi. The aim was to create awareness and stimulate the adoption of improved varieties with appropriate crop management practices. The technologies demonstrated were Tikolore, Makwacha, and Nasoko each with inoculant and P- fertilizer and Tikolore with fertilizer only. Additionally, 8 t of basic seeds of Tikolore were distributed through NASFAM to 333 community-based seed-producing farmers to multiply certified seeds. Through the farmers' association, the selected seed farmers were trained on seed production and quality control.

IITA conducted 31 field days which attracted 2374 farmers from the 7 project districts to capture their perceptions and technological preferences. The field days established that most farmers (59%) preferred the option of Tikolore with inoculant and P-fertilizer because of its earliness and high yield (1.5 t/ha) despite adverse drought conditions. To ensure seeds of the preferred variety are available and accessible at the community level, 200 t of certified seeds were produced by 333 community-based seed producers. About 80 t of quality basic seeds were also produced through contractual arrangements with seed producers, using seed revolving funds.

Through the MISST project, IITA promotes drought resilience by promoting this early maturing, drought tolerant variety (Tikolore). The project distributes 5 kg packs to farmers in drought-prone areas. So far, the project has reached 1252 smallholder farmers with this intervention and IITA is closely working with partners to make available 400 t of certified seeds of Tikolore to affected farmers through the community-based seed production program.

Recently, drought has become a regular phenomenon in Chirombo village, causing widespread maize failure. This year, many maize farms failed completely.

In the midst of this sea of brown, one green soybean field planted to Tikolore stood out. The field is owned by Mrs Agnes Nicholas, a farmer who has been growing maize for the past 20 years. Through her local government extension agent, she received a 5 kg pack of Tikolore from IITA in 2015. "Without this soybean plot, this would've been one of the worst years in my farming life," she exclaimed.

Now her farm has become an informal farmer field school for soybean production, with many of her co-villagers coming daily to learn about soybean growing from her. Mrs Nicholas plans to expand her soybean production area to 1 ha next season

MISST is tapping into community-based seed systems to make more quality soybean seeds available to more farmers across the country. So far, the project has trained over 1279 community-based seed producers, 735 men and 544 women, supported them with basic seeds, and facilitated their registration with the Seed Service Unit as certified seed producers. These farmers are currently producing certified seeds of the three improved varieties being demonstrated by the project on 485 ha across the 7 impact districts.

As a result of this intervention, Mr Chionetsero Thomasi is now a seed entrepreneur in his home village of Napuru in the Dedza district of Malawi. In 2015, he became one of the 1279 beneficiaries of the community-based seed production program under the MISST project with the aim of selling and distributing quality seeds to farmers and seed companies within their respective communities.

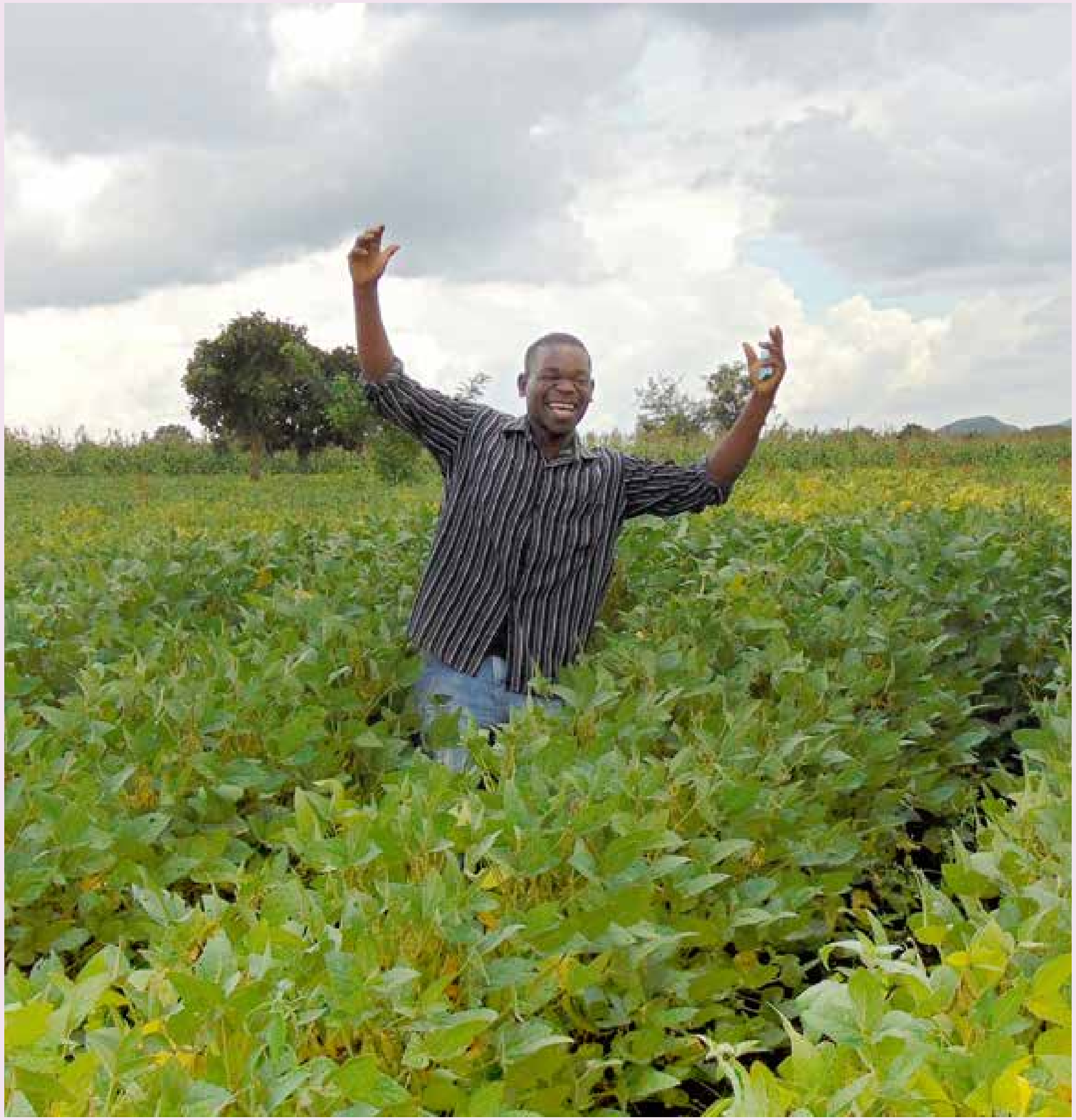
After receiving seeds from the project, Mr Thomasi dedicated 1 ha out of his 4-ha land to Tikolore seed multiplication.

"I am very excited about this project," said Mr Thomasi, "and with the way my Tikolore crop is looking it seems I am going to have a bumper seed harvest by the end of this season. From the proceeds I plan to buy a motorbike to help me market my seed business better."

Mr Tsekulani Jonasi has been farming tobacco for more than 20 years in his village of Kakopa in the Demera EPA of Lilongwe district. In December 2014, he became a host farmer for a soybean project demo. He secured more seeds from IITA through NASFAM and cultivated 0.7 ha of Tikolore following the management practices being promoted by the project. During the 2014/2015 season, Mr Jonasi harvested 30 50-kg bags of Tikolore.

Mr Jonasi decided to expand his Tikolore farm during the 2015/2016 season, acquiring 200 kg of certified seeds produced through the project last season to cover 2.5 ha of his 4-ha land originally committed to tobacco production.

"I have been farming since I was born, and I never imagined that soybean farming could be as profitable as this," Mr Jonasi said, visibly excited. "I now believe that legumes can be as valuable as tobacco. IITA and the MISST project are on the right track to promote seed production as a lucrative income generating venture," he added.



Mr Thomasi proudly showing his Tikolore seed field in Linthipe EPA, Dedza

RISING out of poverty in Tanzania

Jonathan Odhong, Africa RISING, IITA-Ibadan

The USAID-funded and IITA-led program *Africa Research in Sustainable Intensification for the Next Generation* (Africa RISING) is creating opportunities for smallholder farm households to move out of hunger and poverty through sustainably intensified farming systems that improve food, nutrition, and income security, particularly for women and children. This research-for-development project is currently being implemented in Tanzania, Malawi, Zambia, Ghana, and Mali. In a nutshell, the project pilot-tests agricultural technologies then scales them out by putting together investment plans with development agencies.

The USAID Country Mission in Tanzania was impressed by the technologies of the program and funded a $6-million, 3-year joint technology scaling project between Africa RISING and the local development programs NAFAKA and TUBORESHE CHAKULA in 2014. Its goal is to ensure that 47,000 households in maize- and rice-based smallholder farming communities in the Manyara, Dodoma, Morogoro, Iringa, and Mbeya regions of Tanzania have access to improved agricultural technologies. The project also aims to expand the area under improved technologies of rice production to 58,000 ha and increase yields of both maize and rice by 50%.

Only in its second year of implementation, the joint technology scaling project is already registering some very impressive outcomes.

No water? No problem

Masheshe Salum is a small-scale maize and legume farmer in Ngipa village, Kiteto District, in central Tanzania. Four years ago, maize yield from her 4-acre farm was barely enough to feed her family of five. Her farm is in a semi-arid region with low and erratic rainfall, so access to water was a big problem. And, just like other farmers in Ngipa village, she also planted recycled seeds. Year after year, she would use the broadcasting technique to plant her maize, and year after year, the result would be the same –a poor harvest. She knew she could get more from her farm but didn't know what to do to improve productivity.

Things started to turn around for her when she learned about, and joined the Africa RISING joint technology project.

Today, Masheshe is a model farmer in her community. In 2015, thanks to the technologies introduced by the project, she harvested an impressive 60 bags of maize despite a severe drought that affected Kiteto district.

"My life changed thanks to the Africa RISING-NAFAKA-TUBORESHE CHAKULA scaling project," said Masheshe, beaming proudly. She was one of the many beneficiaries of training on climate-smart farming in Kiteto District where she learned good agronomic practices and soil-water conservation strategies in such semi-arid areas. Eventually, her farm became one of the demonstration farms for the project.

"We learned about planting drought-resistant maize varieties, line spacing, fertilizer application, and the use of tied-ridges to conserve soil water. I implemented all the best practices I learned, and I am grateful it has paid off in such a big way!" she says with a bright smile. "My fellow

A beaming Masheshe Salum. Thanks to implementing climate-smart farming practices such as planting drought resistant maize varieties and using soil water conservation techniques, she was able to get a good harvest from her farm. Photo by Shabani Ibrahim, IITA.

farmers wondered if I used *uchawi (*magic*)* in my farm since it remained green while others were drying," she adds

"The higher yields from my farm were largely because of the tied-ridges that held the little available rain water for longer periods. My crops had access to moisture in the soil for longer periods than in the traditional flat planting which my neighbors are practicing and which I used to practice as well."

"Thanks to the technologies of Africa RISING, I now have more than enough to feed my family! And with the postharvest knowledge that I gained from training, I intend to store my surplus and sell later at the best time and price so that I can pay my children's school fees," she happily concluded.

Less postharvest losses, more food

For many farmers in Ndurungumi village of Kongwa District, Central Tanzania, maize farming is not an option. It is a stressful, laborious, and often loss-making activity, but essential if one is to eat. Such was the predicament of Yohana Isaya, a 56-year-old subsistence maize farmer.

For a start, shelling the maize harvested from his 5-acre plot is a backbreaking job which he, with his wife and their five children, can't finish on their own. They need at least eight extra pairs of hands to finish the job in three days. Isaya then stores the maize using a traditional *Kilindo,* a small cylindrical bin made from peeled *miombo* tree bark. The problem with this bin is that the stored maize will become moldy and inedible after a short time.

Then the Africa RISING joint scaling project came to his community.

"Before joining *the Africa RISING-NAFAKA-TUBORESHE CHAKULA scaling project*, I was using a raised wood platform for shelling maize. Usually it took me up to three days to shell 700 kg. We sometimes had to ask for help from our neighbors and compensate them with food, local brew, and sometimes cash. But after the project trained us on using simple and affordable machines like the motorized maize sheller, I can do the same work in only 30 minutes," explained Yohana.

Farmers using the motorized maize-shelling machine at Yohana Isaya's farm during a postharvest training organized by the Africa RISING – NAFAKA scaling project in Ndurugumi village.
Photo by Francis Muthoni, IITA.

Farmers have been introduced to other technologies, not only the maize shelling machines. The postharvest training has also focused on a complete package including collapsible drier cases capable of drying 400 kg of maize in 5 hours under the sun, and storage in hermetic bags. As a result, farmers are able to process their crops faster, reduce their postharvest losses, and provide more food for their families.

In the semi-arid areas of northern and central Tanzania, 20-40% of grains and legumes are usually lost during harvesting. A further 5% is lost during shelling, even when the amount of grains shelled per day was very small because of the drudgery and lack of improved technologies. Another 15-25% is lost during storage due to pest infestation and mold.

Practices such as drying grains on bare floors and storage when the moisture contents are too high also often lead to deterioration. These are the challenges that the postharvest technologies being promoted by the Africa RISING joint scaling project is addressing in Tanzania.

Scaling N2Africa products through Private-Public Partnerships

Edward Baars, IITA-Abuja; Fred Kanampiu, IITA-Nairobi; and Theresa Ampadu-Boakye, IITA-Nairobi

Putting Nitrogen Fixation to Work for Smallholder Farmers in Africa(N2Africa) is a project that is working to expand the farm area planted to grain legumes (common bean, cowpea, groundnut, chickpea, faba bean, and soybean) and enhance their yields to improve smallholder farmers' incomes and food and nutrition security.

At the end of Phase 1 (2010 to 2013) the project had benefited some 225,000 small-scale farmers in its target countries of Ghana, Nigeria, Kenya, DR Congo, Rwanda, Malawi, Mozambique, and Zimbabwe. Because of its success, N2Africa was approved for a 4-year Phase 2, from 2014 to 2018. In this second phase, the project will focus in scaling proven technologies from Phase 1 to reach an additional 555,000 farmers –about 800,000 beneficiaries over the course of Phases 1 and 2.

Three new countries have also been added: Tanzania, Uganda, and Ethiopia, which, together with Ghana and Nigeria, comprise the project's core countries. The six other countries are 'Tier-1" countries that will consolidate earlier achievements and have lower target numbers than the core countries. In Phase 2, the project intends to reach an additional 105,000 farmers in both Ghana and Nigeria, 65,000 in each of the following: Tanzania, Uganda, and Ethiopia, and 25,000 in each of the six Tier-1 countries.

In Phase 2, the project will specifically address the issues of (a) moving to scale the operation to reach 550,000 farmers; and (b) ensuring sustainable input and output supply chains for farmers to buy and use the N2Africa products developed and tested under Phase 1 (i.e., certified seeds of improved varieties, inoculants, legume fertilizers, and labor-saving tools and services).

Scaling operations required an innovative approach. To this end, N2Africa sought synergies and complementarities with compatible projects and implemented its activities through formalized, comprehensive, and well-defined Private-Public Partnerships (PPPs).

Over the past two years the PPP concept has been adopted by N2Africa. The project continuously receives requests for collaboration across its operational countries, making it a "go to" initiative based on the successful partnerships it has formed.

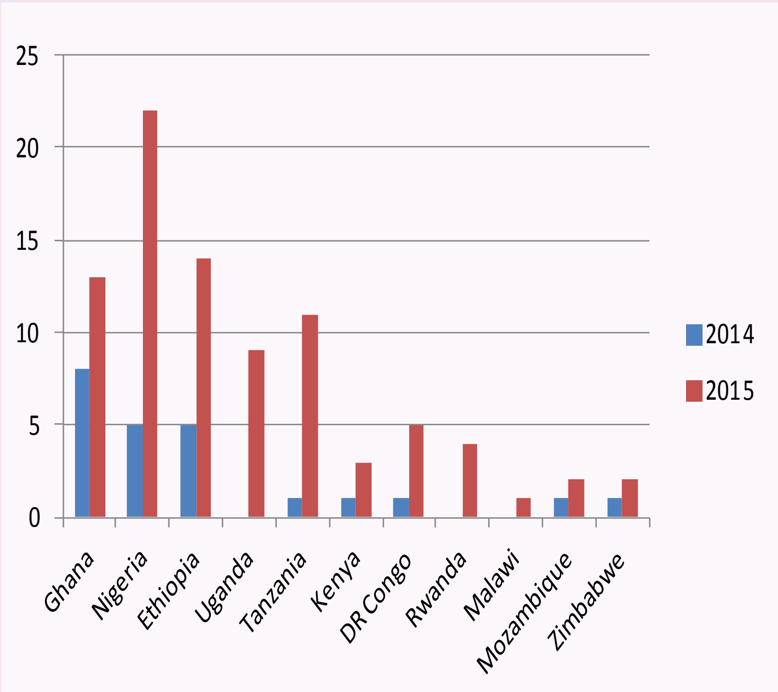


Figure 1. Number of partnerships per country (2014-2015); total 86.

To date, N2Africa has formalized 86 partnerships (Fig.1) with public and private organizations in its 11 operational countries benefiting some 260,000 farmers. Forty-four of these formalized PPPs are with dissemination and delivery entities linked to high-value supply chain projects with objectives similar to those of N2Africa, thus leveraging resources and creating synergies that benefit thousands of smallholder farmers.

Partnerships initiated by N2Africa are built on four pillars: (1) capacity building; (2) dissemination; (3) input supply including seed systems; and (4) markets. Other partnerships are research-oriented comprising diagnostics and rhizobiology.

Working within the concept of PPPs, N2Africa has ascertained that when efforts of various partners with common goals and interests join forces and resources and learn from one another's experiences, the attainment of the goals of all parties involved become exponentially higher. Therefore, in signing partnership agreements, N2Africa puts a high priority on coordination, particularly on structures and modes of operations.

N2Africa puts heavy emphasis on sustainable input and output supply chains in establishing PPPs for its scaling out efforts.

N2Africa also saw cross fertilization among partnerships. A good example of this is the Legume Alliance, coordinated by the CABI-African Soil Health Consortium (ASHC-II). The Alliance is now implementing the campaign on Maharage Bingwa (Champion Beans) in which they develop and share information on common bean technologies with different partners. One of its strengths is that different partners use different media to disseminate information, ranging from radio to comics, thereby reaching different audiences.

Participants at a cowpea demonstration site at Ujariyo in Kebbi State, Nigeria.
Photo by Charles Iyangbe, CRS.

Training and Seminars

In 2015, IITA focused its efforts on providing training for partners in the national programs, especially scientists and research technicians. Training programs include Professional Capacity Advancement Program, Graduate Research Program, and Short-Term Courses.

Table 1 shows the breakdown for degree-related training: postgraduate students recruited (54 MSc and 45 PhD with 62 males and 37 females) and those who completed the research portion of their degrees at IITA: 70 MSc and 38 PhD students broken down into 55 males (51%) and 53 females (49%).

Table 1. Summary for graduate students, 2015.

	MSc		PhD		Total		Grand total
	Male	Female	Male	Female	Male	Female	
Students commenced in 2015	31	23	31	14	62	37	99
Students completed in 2015	33	37	22	16	55	53	108
Total	64	60	53	30	117	90	207

Training courses and seminars conducted in the different hubs totaled 243 and 110, respectively. Table 2 shows the breakdown by hub/region.

Table 2. Summary for training and seminars, 2015.

Hub	Training (no.)	Seminars (no.)
Central Africa	43	25
East Africa	46	54
Southern Africa	16	17
West Africa	138	14
	243	110

Researchers inspecting cassava plants. Photo by IITA.

Training topics covered the four major research themes: biotechnology and crop improvement, natural resource management, plant production and health, and social science and agribusiness, and other topics such as monitoring and evaluation, gender, research methods, field trials and data collection and management, extension, safe handling of chemicals, value chains, production, planting technologies and practices, health and nutrition, marketing collaboration, technical and financial reporting, team building, and science writing.

Seminar presentations in the different hubs featured topics such as CGIAR Research Programs, grant policies and priorities, monitoring and evaluation, bioinformatics, ICT, partnerships, DSpace/CG Space, ICT, communication, gender, administration, food security, proposal development, and tablet-based data collection and management, among others.

Effective Project Administration

IITA's success depends largely on our partnerships, hence, external capacity building of national partners is very important to IITA. Over the years, IITA has been working with partners to achieve this. Last year staff from the Project Administration Office (PAO) participated in several launching meetings or annual project meetings to train and work with the partners on project administration and reporting, and visited some partners who needed capacity development in these areas.

There has been a progressive growth in large projects over the last years, increasing the number of IITA subcontractors or partners, as under larger projects there is more cooperation with partners. The subcontract agreements issued to partners under the projects increased almost 3 times from 248 in 2011 to 703 in 2015. Some partners are subcontracted under several projects, but the number of partners also increased substantially, from 176 in 2011 to 455 in 2015.

PAO, being the focal point for the CGIAR Intellectual Assets (IA), is also responsible for IA compliance. A list of 108 project-related agreements and 48 memoranda of understanding and other non-project related agreements signed in 2015 by IITA was reviewed for their compliance by our IP consultant, who concluded that all signed agreements complied with the IA principles. Aflasafe and NoduMax registration was reported, but in 2015 IITA did not sign any Limited Exclusivity or Restricted Use Agreements. In November 2015, during R4D week, PAO organized IA and Open Access (OA) quizzes during the lunch-time seminars, to create more awareness among staff. These quizzes were lively occasions, with the active participation of quiz contestants and the audience.

In 2015, IITA also started an IP Register. The purpose of this register is for IITA to have a better understanding of the IA that is part of—or generated by—projects. Knowing our IA is increasingly important to donors, and hopefully this register will be a fairly easy way of capturing it.

In 2015 PAO administered a total of 210 projects. Of those, 9 were the CRP projects and 11 were CRP additional/related projects (windows 1&2 funds with a separate agreement), 49 were window 3 projects, and 141 were bilateral projects.

Figure 1 shows the allocation of the 2015 projects (windows 1, 2, 3 and bilateral) under disciplines or research themes. The largest proportion of projects falls under Plant Production and Health (32%), followed by Biotechnology and Genetic Improvement (28%). Social Science and Agribusiness make up 25%, and Natural Resource Management, 15%.

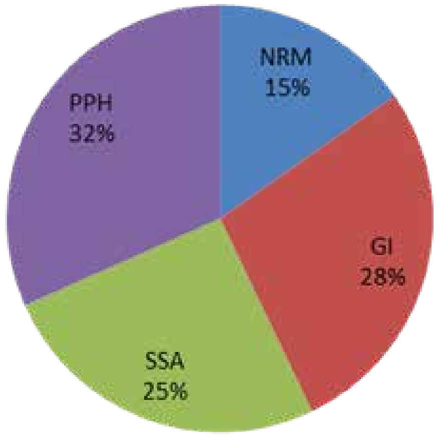


Figure 1. Allocation of projects per discipline for 2015.

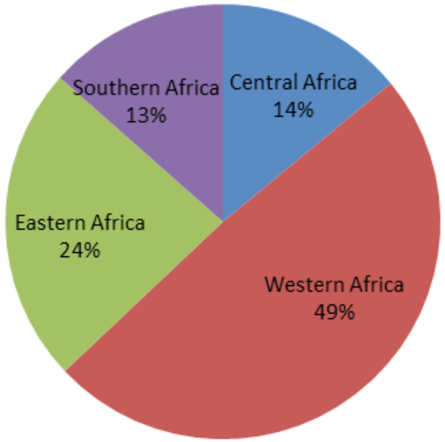


Figure 2. Allocation of projects by hub for 2015.

NRM = Natural Resource Management
PPH = Plant Production and Health
SSA = Social Science and Agribusiness
GI = Biotechnology and Genetic Improvement

Figure 2 gives the distribution of the 2015 projects (windows 1, 2, 3 and bilateral) under the four hubs. Almost half of the projects (49%) fall under the Western Africa Hub, followed by Eastern Africa (24%), with the least projects allocated to Central and Southern Africa, with 14% each.

Publications

In 2015, IITA scientists published 154 publications in peer-reviewed, Thomson-indexed journals. Selected articles from the different hubs are presented here by research theme.

Natural resource management

Craparo, A.*, Van Asten, P., Laderach, P., Jassogne, L. & Grab, S.* 2015. Coffea arabica yields decline in Tanzania due to climate change: global implications. *Agricultural and Forest Meteorology*, 207. 1—10.

Giller, K., Andersson, J.A., Corbeels, M., Kirkegaard, J., Mortensen, D., Erenstein, O. & Vanlauwe, B. 2015. Beyond conservation agriculture. *Frontiers in Plant Science*, 6. 1— 16.

Hernandez, R.R., Debenport, S. J., Leewis, M.-C., Ndoye, F.*, Nkenmogne, I.E.K.*, Soumare, A.*, Thuita, M., Gueye, M.*, Miambi, E., Chapuis-Lardy, L.*, Diedhiou, I.* & Dick, R.P. 2015. The native shrub, Piliostigma reticulatum, as an ecological "resource island" for mango trees in the Sahel. *Agriculture, Ecosystems and Environment*, 204. 51—61.

Kintche, K., Guibert, H., Sogbedji, J.M.*, Leveque, J., Bonfoh, B.* & Tittonell, P. 2015. Long-term mineral fertiliser use and maize residue incorporation do not compensate for carbon and nutrient losses from a ferralsol under continuous maize-cotton cropping. *Field Crops Research*, 184. 192—200.

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Rutting, T., Cizungu-Ntaboba, L.*, Roobroeck, D., Bauters, M., Huygens, D. & Boeckx, P. 2015. Leaky nitrogen cycle in pristine African montane rainforest soil. *Global Biogeochemical Cycles*, 29. 1754—1762.

Struthers, R., Ivanova, A., Tits, L. A., Swennen, R. & Coppin, P. 2015. Thermal infrared imaging of the temporal variability in stomatal conductance for fruit trees. *International Journal of Applied Earth Observation and Geoinformation*, 39. 9—17.

Plant breeding and biotechnology

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Atkinson, H. J., Roderick, H. & Tripathi, L. 2015. Africa needs streamlined regulation to support the deployment of GM crops. *Trends in Biotechnology*, 33. 433—435.

Cizkova, J., Hribova, E., Christelova, P., Van den Houwe, I., Hakkinen, M., Roux, N., Swennen, R. & Dolezel, J. 2015. Molecular and cytogenetic characterization of wild Musa species. *PLoS ONE*, 10. 1—19.

De Vega, J.J., Ayling, S., Hegarty, M., Kudrna, D., Goicoechea, J.L., Ergon, A., Rognli, O., Jones, C., Swain, M., Geurts, R., Lang, C., Mayer, K.F., Rossner, S., Yates, S., Webb, K.J., Donnison, L.S., Oldroyd, G.E., Wing, R., Caccamo, M., Powell, W., Abberton, M. & Skot, L. 2015. Red clover (Trifolium pratense L.) draft genome provides a platform for trait improvement. *Scientific Reports*, 1—10.

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Kole, C.*, Muthamilarasan, M.*., Henry, R., Edwards, D., Sharma, R.*, Abberton, M., Batley, J., Bentley, A., Blakeney, M., Bryant, J., Cai, H., Cakir, M., Cseke, L.J., Cockram, J., Costa de Oliveira, A.*, De Pace, C., Dempewolf, H., Ellison, S., Gepts, P., Greenland, A., Hall, A., Hori, K., Hughes, S., Humphreys, M.W., Lorizzo, M., Ismail, A.M., Marshall, A., Mayes, S.*, Nguyen, H.T., Ogbonnaya, F.C., Ortiz, R., Paterson, A.H., Simon, P. W., Tohme, T., Tuberosa, R., Valliyodan, B., Varshney, R.K., Wullschleger, S.D., Yano, M. & Prasad, M.* 2015. Application of genomics-assisted breeding for generation of climate resilient crops: progress and prospects. *Frontiers in Plant Science*, 1—16.

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Patil, B.L.*, Legg, J., Kanju, E. & Fauquet, C. 2015. Cassava brown streak disease: a threat to food security in Africa. *Journal of General Virology*, 96. 956—968.

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Ainembabazi, J.H., Tripathi, L., Rusike, J.*, Abdoulaye, T. & Manyong, V. 2015. Ex-ante economic impact assessment of genetically modified banana resistant to Xanthomonas wilt in the great lakes region of Africa. *PLoS ONE*, 10. 1—21.

Awotide, B.*, Alene, A., Abdoulaye, T. & Manyong, V. 2015. Impact of agricultural technology adoption on asset ownership: the case of improved cassava varieties in Nigeria. *Food Security*, 7. 1239—1258.

De Moura, F.F., Moursi, M., Lubowa, A., Ha, B., Boy, E., Oguntona, B.E.*, Sanusi, R.* & Maziya-Dixon, B. 2015. Cassava intake and vitamin A status among women and preschool children in Akwa-Ibom, Nigeria. *PLoS ONE*, 10. 1—14.

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Khonje, M., Manda, J., Alene, A. & Kassie, M. 2015. Analysis of adoption and impacts of improved maize varieties in Eastern Zambia. *World Development*, 66. 695—706.

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* indicates author with affiliation in a developing country institution.

Our Finances and Supporters

Funding overview

Funding for 2015 was $107.315 million, of which 99.3% came from CGIAR investors and 0.7% from other sources. (net of indirect cost recovery of $10.711 million), Expenditures were $106.422 million of which 91.1% was used for program expenses and 8.9% for management and general expenses.

Figure 1 shows the governments and agencies that provided the largest share of our funding in 2014 and 2015 (top 10 donors).

IITA`s 2015 total budget-cum-total expenditure are reflected in Figure 2 while 2015 investment by CGIAR Research Program is shown in Figure 3.

Table 1 lists the investments by CGIAR Research Program, whereas Table 2 shows financial performance indicators for 2015. The list of investors are shown on Table 3.

An experimental cowpea field in IITA, Ibadan.

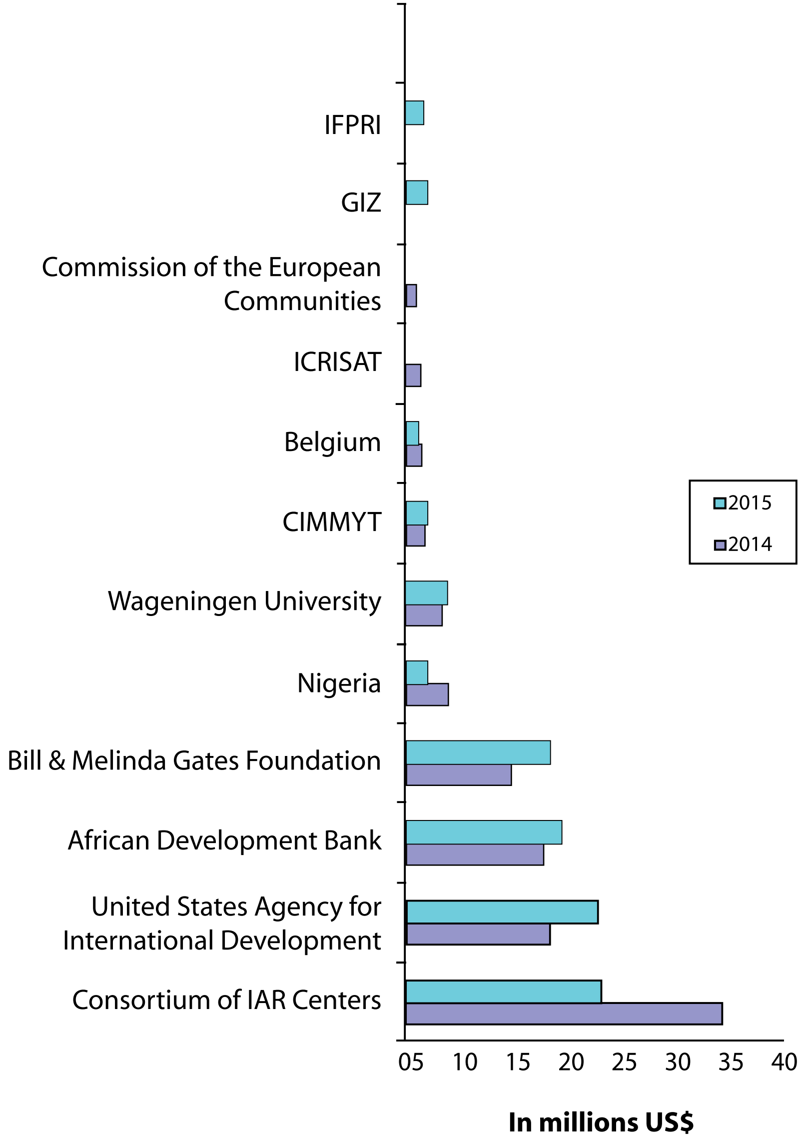

Figure 1. Funding: top 10 donors, 2014 and 2015.

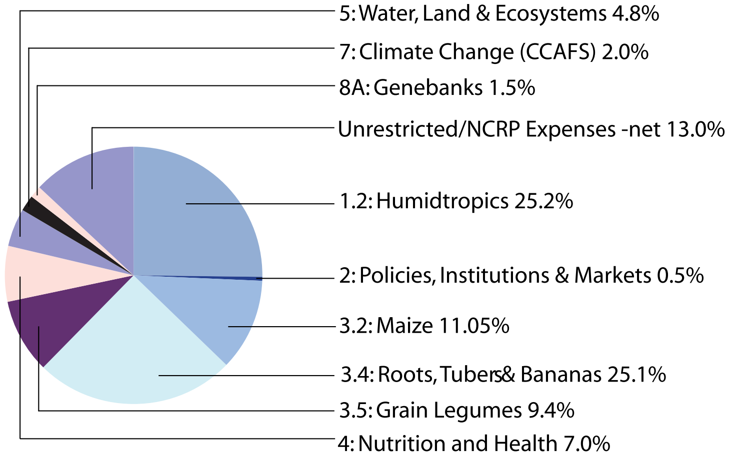

Figure 2. 2015 investment by CRP budget.

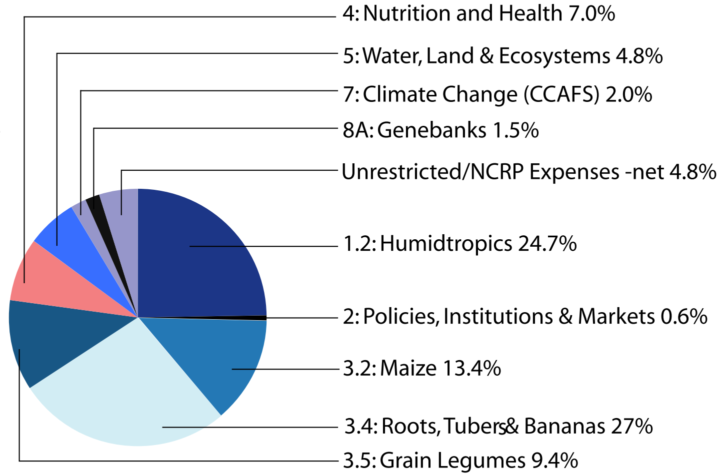

Figure 3. 2015 investment by CRP expense.

Table 1. 2015 Investment by CGIAR Research Programs.

	Budget ($`000)			Actual expenses ($`000)		
CRP title	**W1/W2**	**W3 / Bilateral Project**	**Total**	**W1/W2**	**W3 / Bilateral Project**	**Total**
1.2: Humid Tropics	9,311	24,661	33,972	9,810	16,518	26,328
2: Policies, Institutions & Markets	300	356	656	300	361	661
3.2: Maize	1,594	13,971	15,565	1,594	12,698	14,292
3.4: Roots, Tubers & Bananas	2,813	31,066	33,879	4,577	24,143	28,720
3.5: Grain Legumes	806	11,803	12,609	806	11,304	12,110
4: Nutrition and Health	1,277	8,159	9,436	1,277	7,198	8,475
5: Water, Land & Ecosystems	120	6,321	6,441	120	6,565	6,685
7: Climate Change (CCAFS)	0	2,693	2,693	1,160	926	2,086
8A: Genebanks	1,018	999	2,017	1,036	886	1,922
CRP	**17,239**	**100,029**	**117,268**	**20,680**	**80,599**	**101,279**
Unrestricted /NCRP	549	4,838	5,387	684	4,459	5,143
	17,788	**104,867**	**122,655**	**21,364**	**85,058**	**106,422**

1 Includes CRP1.2 Windows 1&2 Partners' expenditures (2015: 5.026 M and 2014: $8.909 M) per CGIAR Advisory Note

Table 2. Performance indicators: Financial health.

	2014	2015
Short-term Solvency (or Liquidity)	37 days	39 days
Long-term Financial Stability (adequacy of Reserves)	37 days	39 days
Indirect Cost Rates	18.61%	14.96%
Cash Management on Restricted Operations	0.30	0.33
Audit Opinion	Unqualified / Clean Bill of Financial Health	

Table 3. List of IITA investors.

	2014	2015
Investor	(expressed in US$ thousands)	
African Agricultural Technology Foundation (AATF)	44	16
African Development Bank	14,599	16,660
AGRA	752	819
Austria	13	92
Belgium	1,890	1,409
Bill & Melinda Gates Foundation	11,331	15,157
BMZ, Germany	1,124	321
California University	159	183
Catholic Relief Services	88	12
CIMMYT	1,999	2,361
CORAF/WECARD	-	77
Commission of the European Communities	1,279	727
Common Fund for Commodities	822	91
Cornell University	851	999
Consortium of IAR Centers	33,583	20,680
Delloite Consulting LLP	506	1,090
Denmark	24	6
DDPSC	-	177
DRC	1,011	-
FARA	60	
Food and Agriculture Organization	91	72
France	330	-
GIZ	995	2,369
Global Crop Diversity Trust (GCDT)	173	235
ICIPE	13	-
ICRISAT	1,287	670
Illinois University	168	328
International Fund for Agricultural Development	1,200	-
IFPRI	552	2,001
ILRI	267	
Ireland	43	-
Japan	1,196	936
Leventis Foundation	75	-
Meridian Institute	-	657
Michigan State University	368	
Netherlands	1,262	900
Niger	352	269
Nigeria	4,656	2,453
Purdue University	292	411
Sierra Leone	238	207
Sweden	1,054	65
Switzerland	231	604
United States Agency for International Development	15,297	20,436
Wageningen University	4,306	4,884
World Bank	-	-
Miscellaneous projects	3,831	5,501
Challenge Programs	986	1,989
Grand Total	**108,703**	**106,559**

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Headquarters and Hubs

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