Annual **Report** 2015

Consolidating innovations and tracking our progress

CGIAR

RESEARCH PROGRAM ON
Roots, Tubers and Bananas

Contents

Consolidating innovations and tracking our progress
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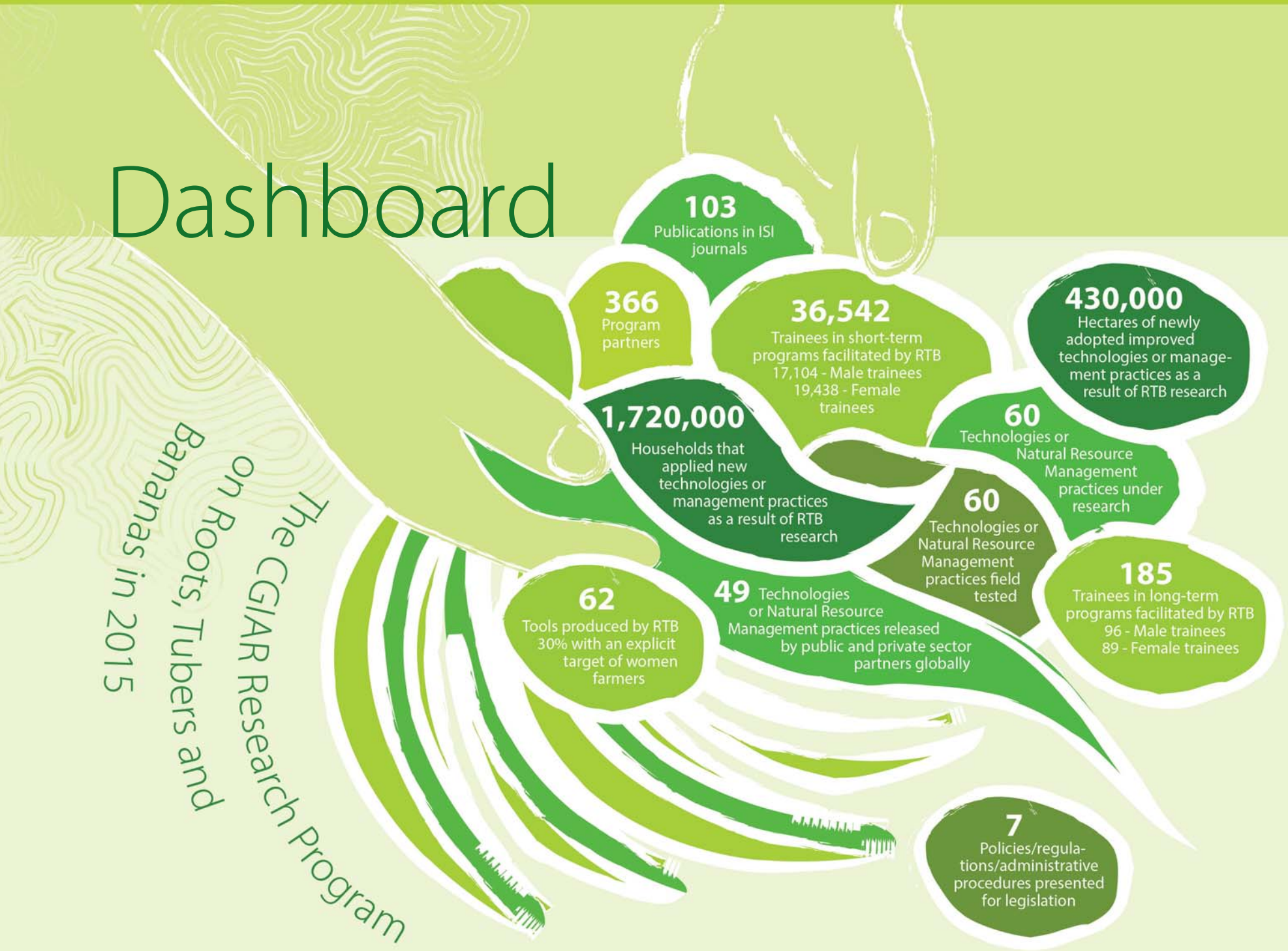
Dashboard

The CGIAR Research Program on Roots, Tubers and Bananas in 2015



Foreword

Our overall assessment of 2015 was positive, but it was a challenging year for the program! In the space of twelve months we saw changes in governance, an external evaluation, an audit review, preparation of documents for Phase II of the CGIAR Research Program and some significant budget adjustments. We made it through with some considerable achievements, thanks to our dedicated scientists, strong partnerships, engaged management team and committed governance group.

We are very pleased to report that 2015 brought continued successes in research outputs, documented in the sections which follow, and also, adoption and enhanced outcomes as captured in the dashboard, a new feature in this year's report.

We are very satisfied with our newly created Independent Steering Committee (ISC), which provided an institutional mechanism for checks-and-balances within the program, with clear and specific roles and responsibilities. The ISC comprises nine members, a majority of them are independent; Barbara Wells as the Director General (DG) of the International Potato Center (CIP) as a permanent member, a DG of another participating center on a rotating appointment, presently Bioversity International, a high-level representative of Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), and Graham Thiele the CGIAR Research Program on Roots, Tubers and Bananas (RTB) Program Director as ex-officio member. Chaired by Helen Hambly Odame of University of Guelph, in Canada, the ISC provided us with inspirational leadership in thinking about partnerships, theories of change, gender and risk management. The face-to-face meeting of the RTB ISC in Lima in September 2015 provided a critical sounding board to guide future development. Together with the CIP Board of Trustees, the ISC provided a high level of oversight and support in planning and reporting program activities. ISC was especially attentive to the preparation of our Pre-Proposal for Phase II, which was highly rated by the CGIAR.

We are proud of RTB's achievements, reflected in the 2015 Independent Evaluation Arrangement (IEA) review, which noted that "in spite of the complexities and challenges of successfully implementing a multi-crop and multi-partner CRP, RTB has made notable progress in the past four years and is already delivering results, in spite of budget cuts. RTB is well-directed and reaching a reasonable number of its near-term milestones and is working towards achieving its goals, particularly those concerning productivity and nutritional improvement". In the same positive spirit, the Independent Audit Unit (IAU) review, also carried out in 2015, commented: "RTB has done an impressive job in structuring the CRP to best minimize costs and obtain consensus".

In 2015, however, the program was challenged by two reductions in the overall level of funding. RTB and its partners managed these risks through flexibly adjusted contractual arrangements with participating centers and compromises in the achievements of originally envisaged deliverables; although, thanks to high level of support from centers and scientists, strong progress was still made.

As RTB moves to the end of the current phase, and plans for the next from 2017-2022, we are giving close attention to consolidating innovations and tracking progress in pursuance of alleviating poverty and improving food security.

Barbara H. Wells
CIP Director General

Graham Thiele
RTB Program Director

RTB at a glance

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) was launched in 2012 to harness the untapped potential of banana, plantain, cassava, potato, sweetpotato, yam, and other root and tuber crops to improve food security, nutrition and livelihoods. It brings together the expertise and resources of five centers: the International Potato Center (CIP), which leads the program, Bioversity International (Bioversity), the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA) and Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), which represents several other French partners in the research program. They have teamed up to collaborate on common issues affecting the RTB crops, mobilize complementary expertise and resources, avoid duplication of efforts, and create synergies to increase the benefits of their research and interventions for smallholder farmers, consumers, and other actors involved in root, tuber and banana value chains.

In 2015 RTB began the first year of a two-year extension period for Phase I. This gave time to strengthen and expand the program's network of partners and improve management, whilst retaining organization around seven disciplinary Themes[1]. RTB finalized the move to a new program structure, based on flagship projects (FPs) and clusters of activities (cluster), starting from January 2016. FPs and cluster business cases were laid out by RTB scientist teams, including partners, and were subjected to an intensive external review process in May/June 2015. Detailed feedback from this review, the Independent Evaluation Arrangement review, and donors, as well as broad discussions among the RTB teams, informed the cluster design, their integration into FPs and the new program structure. This laid the groundwork for the submission of the Preproposal for RTB Phase II, which was highly rated by the CGIAR Independent Science and Partnership Council.

RTB centers broadened their collaborations to 366 partners, including 91 national agricultural research organizations, 102 academic and advanced research institutions, 28 non-governmental organizations, and 45 private sector companies.

In 2015 the program had eight ongoing, internally funded competitive grants, guided by RTB Theme leaders, on discovery research and cross-center and cross-crop technological innovations, as well as four ex-post impact assessment studies. Much of the results of this research is presented in the body of this report.

The results-based management (RBM) pilot, which began in 2014, continued with banana Xanthomonas wilt, potato seed, and next-generation breeding. The pilot was extended to small-scale cassava processing in 2015 with two workshops in Nigeria, to co-develop an impact pathway and shared monitoring and evaluation. To support RBM, RTB together with the CGIAR Research Program on Dryland Systems developed a planning, monitoring, evaluation, and learning information technology platform.

RTB's targets, known as Intermediate Development Outcomes (IDOs), are fully aligned with the Sustainable Development Goals (SDGs).

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1 Theme 1: Unlocking the value and use potential of genetic resources; Theme 2: Accelerating the development and selection of cultivars with higher, more stable yield and added value; Theme 3: Managing priority pests and diseases; Theme 4: Making available low-cost, high-quality planting material for farmers; Theme 5: Developing tools for more productive, ecologically robust cropping systems; Theme 6: Promoting post-harvest technologies, value chains, and market opportunities; and Theme 7: Enhancing impact through partnerships.

RTB targets and their alignment with the SDGs

SDGs	IDOs	RTB Targets (2022)
	Increased incomes and employment Increased productivity	• 20,000,000 people (50% women) increased their income • 30,000 small and medium enterprises operating profitably in the RTB seed and processing sectors • 8,000,000 farm households increased RTB crop yield through the adoption of improved varieties and sustainable management practices
	Improved diets for poor and vulnerable people	• 10,000,000 people (50% women) have improved their diet quality
	Enhanced benefits from ecosystem goods and services More sustainably managed agro-ecosystem	• 1,900,000 ha of current RTB crops production area converted to sustainable cropping systems
	Mitigation and adaptation achieved Equity and inclusion achieved Enabling environment improved National partners and beneficiaries enabled	• Capacity to deal with climate risks and extremes increased for at least 2,000,000 households • At least 35% increase in # of female and young beneficiaries of at least 700,000 households perceived to have better control over assets and resources • Individual capacities improved for at least 9,500 individuals (50% women) in research for development partner organizations • Capacity for innovation increased in at least 60 development-focused organizations, including women's networks and alliances • At least 5 partnership and scaling models tested in a minimum of 5 target countries and adjusted to be fit for purpose • Regulatory frame works, policies, and national programs in relevant areas under implementation in at least 20 countries per policy change

Integrating gender to make crop research more effective

CROSSCUTTING THEME

While moving forward on research to improve the yield and value of roots, tubers and bananas, RTB made significant progress on the crosscutting priority of integrating gender into its research, which will make RTB's work more effective and equitable.

A concerted effort to mainstream gender during the research program's first years has resulted in a growing list of gender-responsive research. For example, six graduate students from gender and development programs at US and Canadian universities worked with RTB scientists in 2015 to integrate gender analysis into their agricultural research, thanks to an RTB-university partnership. The students' contributions ranged from identifying gender-differentiated variables that influence the adoption of improved banana cultivars in Uganda to studying women's role in cassava pest management in Laos and adapting gender sensitive farmer business schools in Ecuador.

Researchers from Bioversity, IITA and national partners developed and implemented a methodology for assessing the roles of gender norms and practices in banana farming and disease management at nine pilot sites in Sub-Saharan Africa, which resulted in gender-responsive guidelines for the management of banana bunchy top disease. CIP researchers developed a gender-responsive manual for participatory varietal selection (PVS) in potato and a PVS training module that was tested in Ethiopia, whereas IITA implemented a gender-responsive PVS methodology for yam with national partners in Ghana and Nigeria.

CIP developed a prototype guide to integrating gender into the participatory market chain approach that is being field tested under a joint initiative between RTB and the CGIAR Research Program on Policies, Institutes and Markets. CIAT, CIRAD, IITA, Natural Resources Institute and national partners in Benin, Cameroon, Nigeria, Sierra Leone and Tanzania completed a gender-differentiated assessment of consumer preferences for processed cassava products. These and other gender-responsive initiatives under RTB will promote more equitable access to technologies and knowledge being developed.

RTB crop breeding in Africa shows wide-scale adoption of improved varieties

Crop breeding and the dissemination of improved varieties has been a cornerstone of research for development in Sub-Saharan Africa (SSA) for decades, and RTB scientists contributed to research on the impact of this work which is featured in the book *Crop Improvement, Adoption, and Impact of Improved Varieties in Food Crops in Sub-Saharan Africa*, published in 2015. This ambitious review contains a wealth of information on decades of cassava, yam, potato and sweetpotato improvement in SSA, and it holds lessons for strengthening future efforts to tap the potential of RTB crops for improving food security, nutrition and livelihoods.

The book, which covers the development and distribution of improved varieties of 20 crops in 30 countries, grew out of the 'Diffusion and Impact of Improved Varieties in Africa' study funded by the Bill & Melinda Gates Foundation. It confirms the important role that RTB centers have played in strengthening crop improvement in SSA, but also shows that it takes a long time to develop and disseminate improved varieties, which is why RTB has prioritized innovations that accelerate the breeding process.

Cassava is the second most consumed staple food in SSA, and the book documents the important role that IITA has played in improving that crop. Of the 367 improved cassava varieties released in 17 SSA countries between 1970 and 2010, more than 80% were IITA-bred or from IITA parents. According to expert estimates, IITA-related varieties were grown in approximately 30% of the total cassava area in SSA in 2009. IITA's yam improvement program has also had a significant impact, with IITA-related varieties accounting for 13% of the 78 yam varieties developed or identified for release between 1970 and 2010.

The book also documents CIP's important role in potato and sweetpotato improvement in SSA. CIP was involved in the development of 42 of the 45 improved potato varieties released in Ethiopia, Kenya, Malawi, Rwanda and Uganda over the past decade. And of the 60 new sweetpotato varieties released in Burundi, Mozambique, Rwanda, Tanzania and Uganda since 2000, 19 were CIP-bred and seven were bred by national agricultural research organizations using CIP parents.

Many improved varieties have low adoption rates, and it is hard to determine whether that is due to problems with the varieties or inadequate dissemination. Yet some are widely adopted, and they offer lessons for breeding programs. One success story is the potato variety Victoria, which was selected by a CIP breeder in Uganda for release in the 1990s. By 2010, high-yielding, early-maturity Victoria covered more than half of Uganda's potato-growing area and was the second most popular variety in Kenya. There are many more success stories, such as the cassava variety Rugero (MM96/5280), released in Burundi in 2001, which covered 16.4% of Burundi's cassava area in 2009; or the variety Sauti (CH92/077), released in Malawi in 2002, which covered 16.8% of that country's cassava area in 2009.

Weighted average adoption of improved potato varieties in Ethiopia, Kenya, Rwanda and Uganda in 2010 was 37%, but the weighted average adoption of improved sweetpotato varieties in Burundi, Mozambique, Rwanda, Tanzania and Uganda was just 7% of the sweetpotato area. However, crop area may be a poor indicator of the success of CIP's efforts to get vitamin A-rich orange-fleshed sweetpotato varieties into the hands of the region's poorest farmers, especially women. In Uganda, for example, where sweetpotato covers just 2.6% of agricultural land, 8% of households grow the crop.

Nevertheless, cultivation of improved potato and sweetpotato varieties needs to be expanded in SSA, and CIP is working on multiple fronts to achieve this. The book will contribute to improving such efforts, and it has arrived just as RTB crop breeders are tapping the potential of genomic data and other scientific advances to accelerate the breeding of the improved varieties that African farmers need.

N.PALMER/CIAT

THEME 1 AND 2

Unlocking the value and use potential of genetic resources Accelerating the development of cultivars with higher, more stable yield and added value

RTB undertook an array of efforts to tap the potential of crop genetic resources for improving food security and incomes in 2015, including the use of high-throughput genotyping, phenotyping and metabolite analysis to accelerate and enhance crop improvement. Multi-center research made progress toward linking high-density genomic data to traits in cassava and banana, while genomic data were applied to potato improvement and genomic sequencing began for sweetpotato and yam.

Thousands of cassava accessions have been sequenced, and CIAT and IITA researchers used the data to reconstruct the history of the crop's domestication and diversification patterns, which can help breeders to identify populations with desired traits. CIAT completed genome-wide association studies (GWAS) for cassava in Latin America and the Caribbean, and ran trials to investigate the genetic components underlying consumer preferred traits. IITA researchers increased the accuracy and reliability of genomic selection and identified genes linked to traits of interest.

Genomic data from 400 banana accessions were generated through RAD-seq and a new bioinformatics tool called *scaffhunter* was developed to integrate multiple sources of sequencing data for improving the banana reference genome. CIRAD, Bioversity and partners released a new version of the banana gene annotation, and version two of the reference genome assembly was released on the renovated Banana Genome Hub. Bioversity also undertook GWAS on a panel of 126 diploid banana accessions to detect genomic regions involved in parthenocarpy and female sterility.

CIP breeders used genomic data to select true seed potato progenies of 24 families from crosses between parents with neutral photoperiod and earliness under warm temperatures that are undergoing field trials in Uzbekistan and Peru. In sweetpotato, the sequencing of 250 drought-tolerant and 250 drought-susceptible accessions marked the first step toward locating the genes responsible for drought tolerance. In the coming years, genomic and metabolite data will increasingly be used to enhance crop improvement.

Genetic fingerprinting reveals secrets of cassava varieties grown in Ghana

Assessing the impact of crop improvement has traditionally been hindered by the fact that varieties look very similar, but an innovative genetic analysis of the main cassava varieties being grown in Ghana marks a breakthrough for reliably estimating adoption rates in impact assessment studies.

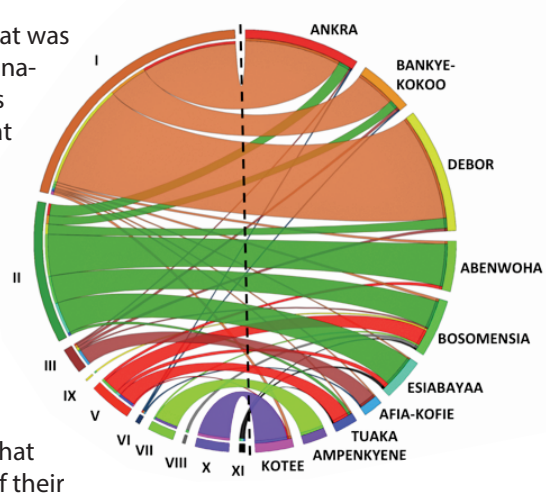
Researchers from IITA, Michigan State University and Ghana's Council for Scientific and Industrial Research – Crops Research Institute (CSIR-CRI) collected more than 900 samples of cassava grown by 495 farming households in Ghana's top cassava-producing regions, sent them to Cornell University for genotyping-by-sequencing (GBS), and compared their genetic 'fingerprints' with those of 64 cassava accessions held at CSIR-CRI (common landraces and released varieties) that were used as a 'reference library'. The results provide an unequivocal view of the actual varieties being cultivated across Ghana.

The researchers found that 30% of the cassava collected on the farms matched specific released varieties, which is consistent with the results of a prior impact assessment. However, their analysis revealed widespread discrepancies in the names of varieties and landraces. While the farmers provided 180 different variety names for the 917 cassava accessions collected, genetic analysis revealed that many were actually the same variety, whereas some accessions with the same name were genetically different.

"One of the biggest lessons is that you can't rely on common names of varieties," said Ismail Rabbi, a cassava geneticist at IITA who led the study's DNA fingerprinting component. "You also can't always rely on morphological characteristics, because these are influenced by environmental conditions and plant growth stages. The methods traditionally used to assess the impact of crop improvement are not as reliable as DNA fingerprinting."

Genetic analysis showed that 69% of the accessions collected belong to 11 major variety groups, whereas the rest are the result of inter-varietal crosses. Nearly a quarter of the accessions collected were the same landrace, which farmers identified as *Ankra, Bankye kokoo, Debor,* etc., whereas approximately 17% belonged to a landrace that was evaluated and released by Ghanaian universities in 2004-2005 as 'IFAD' and 'UCC'. This means that about 40% of Ghanaian farmers grow just two varieties.

"These two varieties are grown all over the place. We should do more research to understand why they are so popular," Rabbi said. He explained that characterizing the two varieties' traits could help cassava breeders ensure that improved clones coming out of their breeding pipelines have those traits, and thereby increase farmer uptake.



Genotypes are mapped against local variety names

A comparable but more comprehensive study underway in Nigeria, with support from RTB and the Bill & Melinda Gates Foundation, involved the collection of more than 8,000 cassava samples from 2,500 farms that will be compared to a reference library of nearly 4,000 accessions. The results of this study, to be completed in 2016, will provide a clear picture of the distribution patterns of improved varieties and landraces across Nigeria.

Rabbi observed that genetic fingerprinting can also be used to identify gaps and duplicates in genebanks, in order to make their collections more comprehensive while reducing redundancies. Several of the more common cassava landraces collected in the Ghana study weren't represented in the reference library, which also included identical accessions with different names. Moreover, genetic analysis revealed that the 64 accessions in that reference library were actually just 34 unique cultivars, 16 of which were released varieties. To avoid such problems, IITA researchers are using GBS to improve the IITA cassava genebank collection.

"Genome-wide genetic markers are useful for a variety of identification applications," said Rabbi, who explained that the study also provided information on the ancestry of and relations between specific varieties and breeding lines, which can help cassava breeders to better classify their material and identify sources of traits.

He added that such research is only possible thanks to recent advances and reductions in the cost of next-generation sequencing technologies. "This is something that we could not have imagined just a few years ago," he said.

Participatory varietal selection meets yam farmers' needs

Yam is an important source of food and income in Ghana and Nigeria, which is why RTB is supporting an accelerated breeding pipeline for yam improvement in those countries. In order to ensure that the varieties coming out of that pipeline meet the needs of farmers, and thereby improve the probability that smallholders adopt them, researchers at IITA helped breeders at national programs in Ghana and Nigeria to design and implement a participatory varietal selection (PVS) methodology for yam. That methodology, which puts farmers in charge of field trials and the selection of the varieties best suited for local preferences and environmental conditions, resulted in the selection of the five best new varieties for each of three different agroecologies.

IITA yam breeder Antonio Lopez-Montes, who led the PVS initiative, explained that breeders at the national programs didn't pay enough attention to farmer-preferred traits in the past, and largely ignored women's preferences. IITA researchers consequently worked with 23 yam breeders and technicians at the National Root Crops Research Institute in Nigeria, and the Crops Research Institute and Savanna Agriculture Research Institute in Ghana, to adapt and implement a gender-responsive PVS for yam.

The three institutes partnered with thousands of farmers who ran field trials for 24 yam varieties developed by IITA and participated in evaluations that resulted in the selection of the top five varieties recommended for release in Northern Ghana, Central Ghana and Nigeria. The initiative took place within the framework of the 'Yam Improvement for Income and Food Security in West Africa' project, funded by the Bill & Melinda Gates Foundation.

A total of 4,328 farmers in the two countries participated, including 1,323 women. Lopez-Montes explained that they made an effort to involve as many women as possible so that selected varieties would meet the needs of both women and men, in order to ensure greater adoption. He added that farmers were involved in the design of field trials – deciding issues such as plant density and fertilizer application – which they ran. Farmers evaluated the va-

OLAOLUWA/IITA

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New generation of CIP-bred potato varieties help farmers cope with climate change

In 2015, two virus-resistant potato varieties – salt-tolerant CIP-301029.18 and salt-and heat-tolerant CIP-396311.1 – were evaluated in coastal districts of Bangladesh where soil salinity is a growing threat. They had higher yields than popular varieties and were recommended for release, which means they will soon join a growing cadre of CIP-bred, climate-smart potato varieties that are helping farmers produce food in difficult environments that will become more challenging as the atmosphere warms.

In recent years, CIP breeders have prioritized developing heat-, drought- and salt-tolerant potato varieties from CIP's lowland tropics virus-resistant (LTVR) population, some of which are already being grown by farmers in countries such as Kenya, India and Vietnam. In 2015, the CIP Genebank began sending germplasm from a new, more robust generation of approximately 80 LTVR varieties to national agricultural research organizations in African and Asian countries where environmental stresses that are expected to intensify under climate change are already hindering smallholders' ability to produce food.

rieties at the bulking and harvest stages, when researchers from the national institutes recorded the criteria of individuals and groups.

The farmers also contributed to the design of agronomic packages for different production systems that were scaled out for validation with the selected varieties in 2016. Lopez-Montes noted that the farmer-led focus on production systems, rather than agroecologies, is important because the performance of varieties can vary significantly from one production system to the next.

While all varieties were bred for drought-prone environments and poor soils, the farmer evaluations included traits such as flavor and the number and size of tubers produced by each plant. Evaluation data were disaggregated according to gender and age group.

Lopez-Montes observed that while men were more interested in varieties that produce one large tuber, which demands a high market price, women preferred varieties that produce multiple tubers of different sizes, in order to sell the big ones but save the smaller ones for family consumption and seed.

He added that IITA breeders have already developed new populations of improved yams with traits preferred by women that are ready to be delivered to the three institutes, and they will continue to develop populations with combinations of the traits preferred by women and men. This should enhance adoption and improve household food security, as women pay more attention to the full spectrum of family needs.

To complement farmer criteria, breeders collected and analyzed quantitative data on traits such as dry matter content, the number of ware and seed yam per plant, and the incidence and severity of pests and diseases. However, Lopez-Montes noted that farmer criteria were the drivers of the selection process and that the quantitative data supported the farmers' selections.

"We implemented this project to demonstrate the advantages of using PVS to increase a new variety's impact," Lopez-Montes said. "The national breeders recognized that this approach can ensure greater adoption, because the farmers already accepted these varieties during the selection process."

Improved potato variety 'Qingshu 9' a success story in China and beyond

In their efforts to improve the food security and livelihoods of farmers around the world, potato breeders at CIP strive to develop marketable, resilient varieties with resistance to viruses and late blight that can be grown in an array of environments. An excellent example of the potential of such a potato is CIP variety No. 392797.22, a high-yielding clone that can be found in fields all over China and is grown in several other countries. The Chinese government is promoting potato production to improve food security, and CIP 392797.22 has proven to be an excellent option for the country's farmers.

Originally developed in Peru in the 1990s, the variety was selected from a cross of CIP No. 387521.3 and 'Aphrodite', from CIP's lowland tropics virus resistant population. It was field tested in Peru's lowlands and mountains and was first released to farmers in 1998 by the National University San Luis Gonzaga, Ica under the name 'UNICA'. Field trials showed that it has a stable, high yield in varied environments, is resistant to viruses, and tolerates drought. It also produces quality potatoes with red skin and yellow flesh that are good for fresh consumption and have the qualities needed for French fry production.

"The evaluation of improved populations in Peru's warm, arid coastal and cool, humid mountain regions is key to identifying varieties adapted to the different, challenging environments of the tropics, and can help broaden adaptation even to temperate environments such as those of Northern China and Central Asia," explained Merideth Bonierbale, who leads CIP's genetics, genomics and crop improvement research. "RTB is supporting CIP's genetic research to systematize and accelerate breeding of varieties with this combination of adaptive resistance and quality traits through genomic selection."

UNICA was introduced to China from CIP in 2001 by the Qinghai (Provincial) Academy of Agriculture and Forestry Sciences. Following evaluation by the Qinghai Crop Variety Assessment Committee, it was released as a provincial variety in Qinghai in 2006 with the name 'Qingshu 9' – *Qing* referring to the Qinghai Academy and shu being the Chinese word for potato. After


N.PALMER/CIAT

Getting women's preferences into the banana breeding pipeline

In order to ensure that the banana varieties developed by IITA and Uganda's National Agricultural Research Organization (NARO) have the traits that men and women farmers want, RTB scientists developed a methodology for a gender-differentiated baseline study that was undertaken in collaboration with NARO and the Agricultural Research Institute in Tanzania in 2015 and early 2016.

Rhiannon Crichton, a postdoctoral fellow at Bioversity who is coordinating the study, explained that its results will strengthen RTB-supported banana improvement in East Africa by ensuring that women and men benefit fully from the banana hybrids that national breeding programs develop. The study's gender responsiveness was strengthened by Bioversity researchers Susan Ajambo and Anne Rietveld, and Emily Albertson – a graduate student at Clark University who participated thanks to an RTB partnership with US universities.

K.XIE/CIP

assessment at a national level, Qingshu 9 was released as a national variety in 2011, and over the next five years, it came to be planted in China's main potato production regions. At the same time, the variety has been introduced to Kenya, Rwanda, Ethiopia, Vietnam, Tajikistan and Uzbekistan, and is slated for release in Bangladesh in 2017.

Kaiyun Xie, a potato specialist at CIP's China Center for Asia and the Pacific, explained that farmers across Northern and Southwest China have adopted Qingshu 9, primarily because it produces well and consumers like it. According to preliminary expert consultations, Qingshu 9 was grown in 13 major potato-producing provinces in China in 2015, when it covered approximately one third of the potato-farming area of Qinghai Province, 14% of the potato area in Ningxia Province and 6% of the potato area in Gansu Province.

Local experts estimated that more than 150,000 hectares in China were planted with Qingshu 9 in 2015. Given an average yield of 30 tons per hectare, compared to a national average of 20 tons per hectare, it is estimated that

Kaiyun Xie, a potato specialist at CIP's China Center for Asia and the Pacific, explained that many farmers across Northern and Southwest China have adopted Qingshu 9

Chinese farmers produced approximately 4.5 million tons of Qingshu 9 potatoes in 2015. Xie noted that various companies are selling seed potatoes for Qingshu 9, so the area planted with the variety is likely to increase in 2016.

"This variety represents a successful case of breeding broadly-adapted and marketable potatoes with combined resistance to major diseases, a feature that helps farmers lower production costs and access new markets with reduced risk of crop loss," observed Bonierbale.

G.SMITH/CIAT

Improving the management of priority pests and diseases Making available low-cost, high-quality planting material for farmers

THEME 3 AND 4

Pests and diseases cause major crop loss in developing countries and they constitute an especially serious threat for root, tuber and banana crops, which are propagated vegetatively – by planting tubers, suckers, stems or vine cuttings. This means that pests and pathogens are often passed from one planting cycle to the next, or one field to another, via planting material. RTB has addressed major pest and disease threats through initiatives that bring together experts from multiple centers and partners. These initiatives include an effort to assess the risks posed by RTB-critical pests under climate change and cross-crop research on the accumulation of pathogens in planting material, known as seed degeneration. RTB also supports efforts to improve the management of specific diseases, such as banana Xanthomonas wilt disease, an effective management package for which is being scaled out in Central Africa.

RTB initiatives to improve disease management often include the establishment of clean seed systems. CIAT, for example, has promoted thermotherapy for producing disease-free plantain and banana seed as part of efforts to control Moko bacterial wilt. CIP has long promoted clean seed systems to prevent yield loss from the accumulation of viruses in potato and an impact study of an intervention in Kenya that helped Kisima Farms Ltd. begin producing certified potato seed determined that it benefited approximately 23,000 smallholders between 2010 and 2014. Even more farmers are likely to benefit from a potato seed initiative launched by the Government of Ecuador in 2015 using CIP-validated, aeroponic propagation technology and guidance from CIP researchers. The government's goal is to expand the area planted with disease-free seed to approximately 30% of the potato-growing area in Ecuador by 2018. Such private and public uses of the technologies that RTB centers develop and disseminate confirm the value of RTB's research for development.

Assessment of pest risk under climate change strengthens management

The project team stand by a weather station used to collect data for the project

Pests and diseases already pose major threats to the food security and livelihoods of smallholders. With climate change, these threats are generally expected to grow and also expand to unaffected areas. However, knowledge is limited about exactly which threats will be more severe and in what geographic areas.

An RTB effort to fill this knowledge gap for critical banana, cassava, potato and sweetpotato pests and diseases in Sub-Saharan Africa has produced data for predicting how those threats will evolve under climate change and strengthened the capacity of government institutions to deal with them today.

RTB centers have begun analyzing data from weather stations and farm surveys at action sites in the Rwanda's Ruhengeri region and Burundi's Rusizi Valley while researchers completed laboratory experiments to determine how rising temperatures affect the lifecycles of key pests and disease vectors. Harmonized pest and disease field surveys were carried out at both actions sites during one cropping season, whereas weather data collection has been ongoing since July 2014. The goal is to compile two years of weather and farm data for use in modeling climate change impacts on pest and disease risks.

At the same time, RTB researchers and partners have worked with representatives of national research and regulatory institutions in Burundi, DR Congo, Rwanda and Uganda to strengthen the surveillance of critical pests and diseases and the capacity to elaborate effective responses using pest risk analysis (PRA) documents and pest risk maps. PRA documents and risk maps are important tools for national or regional efforts to prevent the entry of new pests and diseases and help farmers prepare for evolving pest and disease threats.

At a workshop on PRA and surveillance held in Kigali, Rwanda in October 2015, draft PRA documents were developed with national partners for the tomato/potato leaf miner (*Tuta absoluta*), whitefly-vectored cassava brown streak virus, aphid-vectored banana bunchy top disease (BBTD), banana Xanthomonas wilt (BXW) and the invasive strain of Panama Disease Foc Tr4.

According to Jürgen Kroschel, the project leader and Science Leader for Agroecology and Integrated Pest Management at CIP, RTB's support of PRA training and elaboration complements efforts by the FAO and the UK Food and Environment Research Agency and Centre for Agriculture and Biosciences International (CABI) to promote the drafting and application of PRA documents by African ministries of agriculture. He added that RTB has improved PRA documents through the addition of pest risk maps, which illustrate potential pest entry and range expansion.

PRA documents drafted at the Kigali workshop have since been refined using data from laboratory and field research. RTB researchers generated data on the prevalence of the major diseases in the region. Bioversity scientists conducted five surveys of BBTD and BXW incidence along altitude gradients in Eastern DR Congo, the Rusizi Valley/Lake Tanganyika area and Western Burundi. IITA scientists conducted biological surveys in Burundi and Rwanda to determine the phenotypic and genetic characteristics of the pathogens responsible for cassava mosaic disease, cassava brown streak disease and BBTD. And CIP researchers completed a thorough analysis of the late blight pathogen *Phytophthora infestans* population in Kenya and Uganda.

RTB scientists used a number of approaches to assess the risks that major pests pose in the region. CIP researchers used life-table data for *T. absoluta* to develop a preliminary pest phenology model and risk maps with Insect Life-Cycle Modeling software. Using the program CLIMEX, CIAT researchers developed potential distribution maps for the cassava green mites *Mononychellus tanajoa* and *Mononychellus mcgregori* – based on 1,232 occurrence records for *M. tanajoa* and 99 for *M. mcgregori*. CIAT researchers submitted distribution records of cassava green mites and cassava whiteflies – major virus vectors – to the Global Biodiversity Information Facility, ensuring open access for modeling purposes. Researchers also developed an interactive database for cassava whiteflies that will be launched in 2016.

Through a combination of scientific research and capacity building, the project will continue to help national authorities to assess and prepare for evolving pest risks so that they can deal with them proactively.

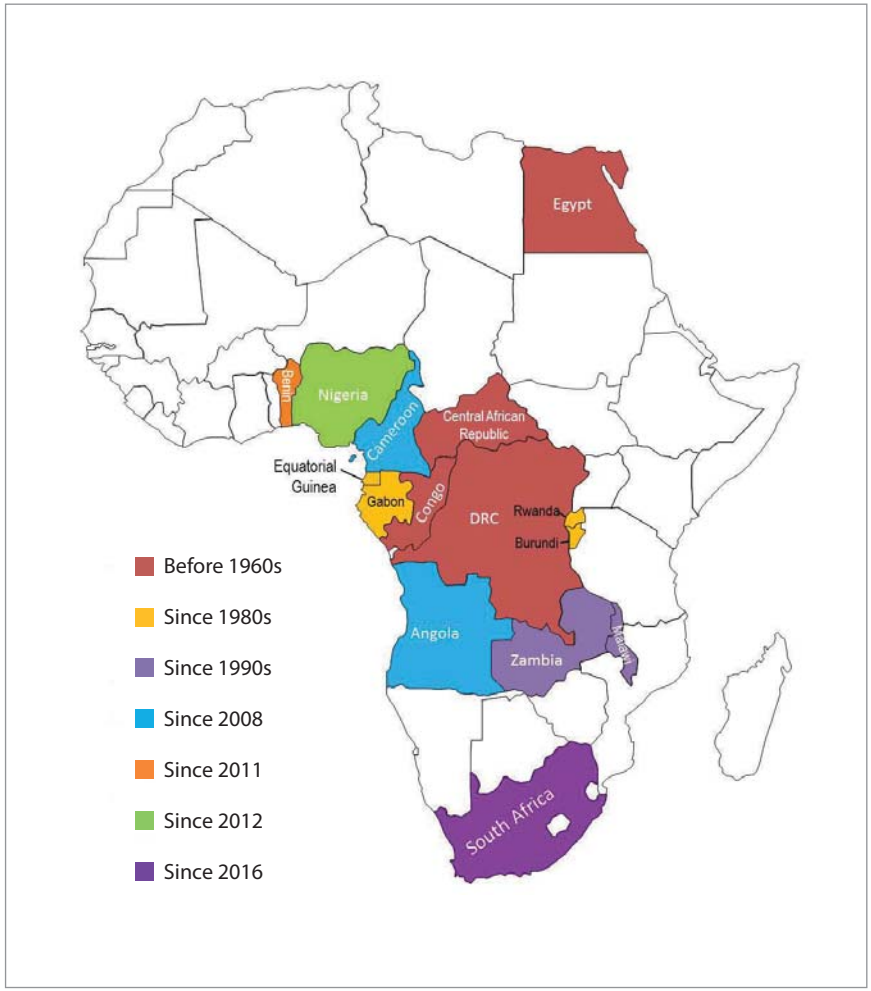
Building communities' capacity to control and recover from the banana disease BBTD

Banana bunchy top disease (BBTD) is a hugely destructive disease that is sweeping across Sub-Saharan Africa (SSA). RTB is working in eight countries in SSA and has made encouraging progress in building farmers' capacity to fight back. Action research at pilot sites tested community strategies for reducing disease pressure to facilitate recovery of banana production while scientists advanced knowledge of the disease's epidemiology, developed tests for detecting it, and raised awareness of the threat it poses.

BBTD is caused by the banana bunchy top virus (BBTV), which invades new fields or regions via the banana aphid *Pentalonia nigronervosa* or infected planting material. RTB scientists are consequently studying the virus and aphid vector while working with national partners and communities to establish systems for producing disease-free banana planting material. They've improved knowledge of the disease through laboratory research, field trials and surveys at pilot sites in Nigeria, Benin, Gabon, Cameroon, Congo, DR Congo, Malawi and Burundi to determine the extent of BBTD's impact.

"We now understand much better the serious nature of this threat," said Charles Staver, a senior scientist at Bioversity, coordinator of the BBTD initiative and RTB project leader. He explained that the disease has been reported in 14 countries in SSA, and while incipient in countries such as Benin and Nigeria, it is widespread in the Congo River Basin. Researchers at the University of Kisangani estimated that BBTD threatens the banana and plantain production of over 5 million households in the DR Congo, whereas researchers in Burundi estimated that the disease has reached 500,000 farms. Staver warned that the disease is spreading in West Africa and is poised to advance further into East Africa.

The alliance has raised awareness of this threat while working at nine pilot sites in eight countries - representing the major banana production systems in SSA – to test strategies for re-establishing banana production in areas where BBTD has devastated the crop. Results from pilot sites show that the



Year of arrival of BBTD

"We now understand much better the serious nature of this threat," said Charles Staver, a senior scientist at Bioversity, coordinator of the BBTD initiative and RTB project leader.

Sweetpotato virus database offers new tool for controlling yield loss

The accumulation and synergistic effect of multiple viruses simultaneously affecting sweetpotato constitute one of the worst biotic constraints for African farmers. CIP researchers consequently contributed to the creation of an interactive, online database of viruses affecting sweetpotato in Sub-Saharan Africa (SSA) – known as the Pan-African Sweetpotato Virome - in order to help breeders develop virus-resistant varieties and predict and control the threat posed by viruses.

The database was developed in collaboration with the Boyce Thompson Institute at Cornell University. It contains information on viruses identified in more than 1,600 sweetpotato samples collected in farmers' fields in 10 SSA countries, and includes a map of field locations and photos of infected plants. It can be used to guide breeding efforts, identify high-risk areas, and monitor the emergence of novel viral variants. It will also serve as a model for a new database on the potato virome (the viruses infecting potato) in Peru.

most effective strategy is to uproot all banana plants, maintain farms free of banana for at least six months, and replant with BBTV-free planting material while maintaining banana-free buffer zones around the replanted fields. If these practices are followed, banana production can be recovered for at least two or three harvests. However, the disease usually re-invades the farm, indicating a need for further research.

From the onset of work at the pilot sites, RTB researchers collaborated with local partners on gender research to better understand the roles of men and women in areas such as community decision-making and farm management. Staver explained that cross-site lessons learned from that gender research will enhance impending efforts to scale out successful recovery strategies.

"RTB partners have catalyzed commitments from African governments, the FAO and the Bill & Melinda Gates Foundation to strengthen efforts to study and control BBTD," affirmed IITA virologist Lava Kumar. He gave the example of collaboration between IITA and several Nigerian government agencies to launch a "Stop Bunchy Top" campaign in early 2016 to halt the disease's advance within Nigeria.

Kumar explained that an essential component of such efforts is the ability to detect BBTV in plants and aphids, and RTB has contributed to the development of two new technologies for BBTV detection: a diagnostic test based on loop-mediated isothermal amplification (CT-LAMP) and a recombinase polymerase amplification assay. Plant virologist Marie-Line Iskra-Caruana, of CIRAD, noted that one advantage of the CT-LAMP assay is that it detects the virus in low concentrations, so it is useful for testing planting material and early detection in mature plants.

Bioversity associate scientist Aman Omondi observed that another important achievement is that the RTB initiative has trained representatives of national research institutes, universities and ministries of agriculture in areas ranging from BBTD diagnostics to clean seed systems. As the disease spreads and the RTB researchers develop more tools for controlling it, this critical mass of trained people will lead the battle to defeat BBTD.

Heat can make a difference: production of disease-free banana seed

RTB researchers have shown that heat treatment can be a cost-effective tool for controlling disease transmission in banana and plantain.

In partnership with the Colombian Plantain Growers Federation (FEDEPLATANO) scientists at CIAT standardized a prototype of a thermotherapy chamber for propagating clean planting material that has proven to be effective and adaptable. Plantain corms are placed in a chamber to sprout under controlled conditions of temperature (50º-70ºC) and high humidity, with frequent fertigation, producing healthy seedlings faster than traditional methods.

The technology was further validated by Bioversity plant pathologist Miguel Dita, who built a prototype chamber at the Center for Tropical Agricultural Research and Higher Education, in Costa Rica, and has since been adopted by organizations in several countries. FEDEPLATANO and CIAT built a large thermal chamber in La Tebaida Quindío, Colombia that produces disease-free plantain planting material for approximately 7,000 farmers. CIAT also collaborated with the Brazilian Agricultural Research Corporation for the construction of another large, fully automated chamber for plantain farmers in Northeast Brazil.

"Larger thermal chambers are an efficient option for the mass production of clean seed for farmer associations," explained CIAT researcher Elizabeth Alvarez. "However, the technology has also been successfully adapted for smaller scale operations."

Alvarez cited the example of simplified thermal chambers built by farmers in El Salvador. With technical assistance from CIAT and FEDEPLATANO, and support from the NGOs Oxfam, Caritas and Catholic Relief Services, farmer associations in the department of Morazán built tunnel-formed chambers using translucent plastic sheets and other inexpensive materials that now produce clean banana seed for about 1,650 smallholders, 350 of who are women.

CIAT has promoted the technology with manuals in Spanish and English via the Latin America and Caribbean (LAC) banana network and has collaborated with CIRAD to promote it as a way to control the banana and plantain disease Moko bacterial wilt in LAC. The technology has also been tested in Peru, and there are plans to evaluate it in Ecuador, Nicaragua, Panama, Cameroon and DR Congo.

Meanwhile IITA researchers have validated an even simpler thermotherapy option for cleaning banana and plantain suckers of nematodes. IITA

N.PALMER/CIAT

researcher Stefan Hauser explained that farmers merely need to dip suckers into boiling water for 30 seconds prior to planting to kill nematodes, adding that research has demonstrated that this practice improves yields. IITA has promoted the boiling water method to African banana and plantain farmers through a manual and flyers in multiple languages, and demonstrations for more than 1,000 farmers in Cameroon, Nigeria and Zanzibar.

Alvarez noted that CIAT has also promoted thermotherapy to combat the spread of cassava frogskin disease, with thermal chambers of various sizes for producing clean cassava planting material built in several departments of Colombia, Brazil, Costa Rica and Paraguay. She added that the technology could likely be adapted for other crops as well.


S.QUINN/CIP

Research provides new insight on managing seed degeneration

A cross-center initiative to improve the understanding and management of seed degeneration – reductions in yield and quality due to the accumulation of pathogens in planting material over successive planting cycles – has shed new light on degeneration's dynamics.

Research in Africa showed that farmers maintain sweetpotato viruses in local landraces at manageable levels using rouging (eliminating diseased plants) and positive selection (choosing healthy seed for the next planting cycle). However, some viruses are asymptomatic and may cause more yield loss in the long run than viruses with visible symptoms because farmers can't identify infected plants for removal. Potato scientists in Ecuador demonstrated that reversion (natural reduction of pathogen incidence within a seed lot) takes place at higher altitudes, confirming the validity of a traditional practice of moving seed to high altitudes to 'clean' it. Data from field trials in Africa and Latin America are being used to model the effectiveness of such common approaches for controlling seed degeneration.


A.JASHO/KHCP

Breaking the bottleneck for sweetpotato planting material

Farmers in SSA often can't get enough sweetpotato vines for planting when seasonal rains begin, since vines and roots don't survive the dry season, limiting adoption. CIP has developed and tested a root-based vine multiplication system called Triple S (sand, storage and sprouting) in Uganda, Tanzania and Ethiopia to overcome this bottleneck, with promising results.

Farmers store sweetpotato roots in dry sand during the dry season and plant them in seedbeds 6-8 weeks before the rains begin. After successful trials in Tanzania and Uganda, Triple S was scaled out in five districts in northern Uganda. A seasonal calendar with information on when to store and plant roots was distributed in two local languages, 18 community facilitators were trained, and 634 farmers engaged. Triple S was also tested in a region of Ethiopia where the dry season is one month longer than Uganda's, and 82% of roots sprouted successfully after four months in dry sand.

Developing tools for more productive, ecologically robust cropping systems Promoting postharvest technologies, value chains and market opportunities

S.QUINN/CIP

THEME 5 AND 6

While supporting research on the diversification of cropping systems, RTB made major commitments to improving the postharvest handling and processing of roots, tubers and bananas, which can help smallholders access better markets, improve the incomes of value-chain participants, and create employment. RTB crops are perishable, creating special challenges for value chain interventions, but a three-year, multi-center project to improve postharvest handling and utilization in Uganda (RTB-ENDURE) is testing strategies for reducing postharvest loss in banana, extending cassava shelf life, improving potato storage, and creating silage from sweetpotato leaves and other by products that can be used as pig feed – all of which have potential for scaling out on a regional level. Cassava is especially problematic for farmers and retailers because its roots undergo rapid postharvest physiological deterioration (PPD). A south-south knowledge sharing trip organized by CIAT, CIRAD and IITA allowed seven members of the RTB-ENDURE cassava team to travel to CIAT headquarters in Colombia and learn about PPD control methods such as waxing roots. One practice that was quickly disseminated in Uganda is the pruning of plants six days prior to harvesting roots, which provides protection from PPD and makes roots sweeter.

Cassava is widely used in processed foods, and RTB researchers have developed strategies for improving processing efficiencies and using waste from processing plants in livestock feed, whereas a multi-country study of African consumer preferences for processed cassava products provided insights that can benefit processors and widen smallholder access to those markets. While Bioversity and IITA have facilitated market opportunities for banana growers, CIP has helped smallholder potato and sweetpotato growers gain access to markets for French-fries and baked goods. In fact, CIP's promotion of sweetpotato purée as a substitute for flour in baked goods was so successful in East Africa that the practice is currently being promoted in West Africa.

Banana value chain innovations create income opportunities for farmers and retailers

RTB is working with local partners along the entire cooking banana value chain in Uganda – from the farm to the market – testing strategies to reduce postharvest loss and differentiate products in order to improve incomes and food security.

Cooking banana is the main staple crop in Uganda, grown mostly by smallholders who eat about 60% of production and sell about 40%. The crop is an important source of income for farmers and other value chain actors, but a significant portion of cooking banana production is lost or damaged due to the fruit's short shelf life and poor handling.

A team of researchers from Bioversity, CIRAD, IITA and Uganda's National Agricultural Research Organization (NARO) is working with farmers, transporters, vendors and exporters in Central and Western Uganda on ways to reduce loss and increase the earnings of smallholders and cooking banana sellers – most of who are women. The collaboration is one of four subprojects under 'Expanding Utilization of RTB and Reducing Their Postharvest Losses' (RTB-ENDURE), a three-year (2014-2016) initiative working with banana, cassava, potato and sweetpotato in Uganda, funded by the European Union and the International Fund for Agricultural Development.

According to Diego Naziri, value chain expert and RTB-ENDURE project coordinator, the cooking banana research team has worked with farmers and transporters to decrease postharvest loss while testing ways for retailers to increase their earnings from cooking banana. He noted that a 2015 market study showed that women are disproportionately affected by postharvest loss, because they are largely responsible for retailing the crop and frequently have to sell damaged bananas for low prices. He added that women vendors earn smaller margins than middlemen and transporters.

Because losses are highest during peak harvest, when the banana supply surpasses demand, RTB researchers are testing staggered planting systems, with 266 farmers trained in staggered planting in 2015. They also identified cooking banana varieties that produce robust fruit with a longer shelf life that is less susceptible to damage. Although there is market demand for these kinds of varieties, few farmers grow them. The RTB-ENDURE banana team worked with smallholders to select four such varieties for planting and provided training in macro-propagation of planting material and better agronomic practices to boost farm production.

Bioversity researcher Enoch Kikulwe, the banana subproject coordinator, explained that farmer groups built macro-propagation chambers where clean planting material for the selected varieties provided by NARO is multiplied for distribution to smallholders. He cited the example of a group of women in Lwakalolo Parish, in Ddwaniro Sub-County, who also use their macro-propagation chamber for training other farmers. Researchers also helped farmers establish 10 mother gardens – four of which are managed by women – where they grow the new varieties. At the same time, CIRAD researcher Christophe Bugaud is trying to determine the best harvesting times for desired postharvest properties, combining sums concept, potential storage and sensory evaluation of fruit.

RTB researchers are also testing ways to increase retail margins by diversifying the way cooking bananas are sold, such as by breaking bunches into smaller units (clusters, fingers or peeled bananas) that are sorted, graded, and labeled by cultivar. The banana team provided business training to two women who recently moved into wholesale – an activity dominated by men – and helped them gain access to credit, markets in Kampala and banana exporters as part of a strategy to promote women's participation in market-chain links with higher margins.

"When value chains improve, men often supplant women, but we're trying to avoid this," said Naziri, who added that gender was integrated into the participatory market chain approach used for all subprojects.

Kikulwe explained that the women the project has helped move into wholesale will purchase the bananas with longer shelf life from participating farmers, which should improve smallholder incomes while reducing the risk of fruit loss for the wholesalers and vendors they sell to. This and other innovations facilitated by RTB-ENDURE have the potential to be scaled out within Uganda and beyond.

Improving cassava processing: less energy, higher efficiency and more stable prices

Much of the cassava grown in developing countries is processed to produce starch or flour used as ingredients in an array of food products. As demand for those products grows, the cassava processing industry will play an increasingly important role for farmers and local economies. RTB has consequently supported research to help starch and flour producers become more efficient.

In many countries, processing is primarily done by small- and medium-scale operations, which frequently suffer inefficiencies – particularly in energy use – that negatively affect their profitability and the environment. A cross-center team of researchers studied cassava processing operations in several countries to identify problems and measures that could be taken to correct them. Their research resulted in guidelines to improve the efficiency of small- and medium-sized processing enterprises, which can in turn ensure higher, stable prices for the smallholders who supply them.

The study was conducted by a team of researchers from CIAT, CIRAD and IITA, with support from Univalle and Clayuca in Colombia, Kasetsart University and KMUTT in Thailand, and Thai Nguyen University in Vietnam. The cooperation of industrial partners such as Niji Lukas (Nigeria), Ukaya Farms (Tanzania), Almidones de Sucre (Colombia), CODIPSA (Paraguay) was also essential.

The team determined that because artificial drying is faster than sun drying, it can be a key factor for increasing production capacity. However, artificial drying consumes 70%-75% of the total energy used by a typical cassava starch/flour factory, which means that inefficiencies in the drying process can significantly increase production costs. They determined that 'flash drying' is one of the most suitable technologies for the production of cassava starch or flour, and that large-scale flash dryers (200-300 tons of product/day) are highly energy efficient. However, on a small scale (< 50 tons of product/day), flash-dryer energy efficiency is only 40-60%, due to inadequate dryer designs.

The researchers developed a numerical model to simulate flash drying at both small and large scales and investigated ways to improve energy efficiency. Using computer simulations coupled with multi-objective optimization methods, they determined the optimal flash dryer dimensions and operating conditions for different production capacities. They then developed guidelines for the design of energy-efficient flash dryers.

Consumer preferences guide cassava breeding and processing

In Africa, cassava is commonly transformed into products ranging from traditional foods such as gari to flour or starch for food industries. Yet little is known about which varieties and processes result in cassava products that consumers prefer. In an effort to strengthen local processing and widen or facilitate smallholder access to the markets it creates, a collaborative initiative by CIAT, CIRAD, IITA, Natural Resources Institute (NRI) and national partners assessed consumer preferences and gender differences in the perception of cassava product quality in five countries.

Teams in Benin, Cameroon, Nigeria, Sierra Leone and Tanzania completed questionnaire-based surveys to assess the preferences of hundreds of consumers using samples of gari, fufu or ugali, documenting pronounced gender differences in preferences. Physico-chemical analyses of those samples and fresh roots were completed by CIRAD, CIAT and NRI. Processing enterprises and breeding programs can use the resulting data to improve final products and processes and contribute to improved livelihoods along cassava value chains.

'Waste to wealth' technology turns cassava peels into livestock feed

Cassava peels discarded during processing – approximately 20% of root weight –constitute an environmental hazard and a huge loss of value. RTB partnered with the CGIAR Research Programs Humidtropics, and Livestock and Fish to develop a technology for turning cassava waste into a dried, high-quality cassava peel (HQCP) mash that can be used in livestock feed mixtures – a breakthrough that will improve profitability and create jobs.

Multiple centers collaborated to develop a quick and cost-effective technology, while researchers estimated the product's nutritional value and expected price: approximately half the cost of maize. Feed millers found that the HQCP mash is a suitable substitute for 15% of maize in livestock feed and financed feeding trials with chicken and sheep that produced encouraging results. With 14 million tons of cassava peels discarded annually in Nigeria alone, the transformation of that waste into animal feed could reduce maize imports, generate profits and employment, and reduce pollution.

Women benefit from public private partnership for sweetpotato biscuits

An assessment of a CIP-coordinated, public-private venture in Rwanda that launched the Golden Power Biscuit and other baked products made with vitamin A-rich orange-fleshed sweetpotato (OFSP) purée found that the venture improved the earnings of both the company that produces the snacks and the smallholders who supply it with sweetpotato roots – especially women.

The 516 households that supply sweetpotato to the food company Urwibutso Enterprises also sell about a third of their crop on local markets and consume about a third. Endline studies showed that households with women as principal growers produced more sweetpotato than households with men as principal growers, sold more of their harvests to Urwibutso, and earned more from those sales: on average US $277 per household compared to US $143. Urwibutso earned US $403,599 from the sale of OFSP baked goods in 2015, so those farmers should have a reliable market for their sweetpotato in the future.

Those guidelines and research findings were shared with key stakeholders from the private and public sector at a workshop in Bangkok, Thailand in December 2015. Workshop participants included representatives of cassava processing factories, equipment manufacturers, universities and government agencies from Thailand, Vietnam, Myanmar, Indonesia, Philippines, Colombia, Nigeria, Tanzania, France and Germany.

Engineers at the Colombian university Univalle are using the guidelines to produce blueprints for an energy-efficient, small-scale flash dryer, a prototype of which is slated to be built in 2016. Other organizations in Indonesia, Myanmar and South Africa have also expressed interest in energy-efficient, small-scale flash dryers. The researchers will continue to share their findings at events in Africa and Latin America.

Knowledge products

Selected publications

Banana

Ainembabazi, J.H., Tripathi, L., Rusike, J., Abdoulaye, T. and 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(9):e0138998. http://dx.doi.org/10.1371/journal.pone.0138998

Cizková, J., Hribova, E., Christelová, P., Van Den Houwe, I., Häkkinen, M., Roux, N., Swennen, R. and Dolezel, J. 2015. Molecular and Cytogenetic Characterization of Wild Musa Species. PLoS ONE 10(8):e0134096. http://dx.doi.org/10.1371/journal.pone.0134096

Hodgetts, J., Hall, J., Karamura, G., Grant, M., Studholme, DJ., Boonham, N., Karamura, E. and Smith, J.J. 2015. Rapid, specific, simple, in-field detection of Xanthomonas campestris pathovar musacearum by loop-mediated isothermal amplification. Journal of Applied Microbiology 119(6):1651-1658. http://dx.doi.org/10.1111/jam.12959

Koberl, M., Dita, M., Martinuz, A., Staver, C. and Berg, G. 2015. Agroforestry leads to shifts within the gammaproteobacterial microbiome of banana plants cultivated in Central America. Frontiers in Microbiology 6:91 http://dx.doi.org/10.3389/fmicb.2015.00091

Tripathi, L., Babirye, A., Roderick, H., Tripathi, J.N., Changa, C., Urwin, P.E., Tushemereirwe, W.K., Coyne, D. and Atkinson, H.J. 2015. Field resistance of transgenic plantain to nematodes has potential for future African food security. Scientific reports 5:8127-8127. http://dx.doi.org/10.1038/srep08127

Cassava

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(6), 1239-1258. http://dx.doi.org/10.1007/s12571-015-0500-7

Ceballos, Hernán; Kawuki, Robert S.; Gracen, Vernon E.; Yencho, Craig G.; Hershey, Clair H.. 2015. Conventional breeding, marker-assisted selection, genomic selection and inbreeding in clonally propagated crops: a case study for cassava. Theoretical and Applied Genetics 128(9):1647-1667. http://dx.doi.org/10.1007/s00122-015-2555-4

International Cassava Genetic Map Consortium. (Alaba, O. A., Bredeson, J. V., Egesi, C. N., Esuma, W., Ezenwaka, L., Ferguson, M., Ha, C. M., Hall, M., Herselman, L., Ikpan, A., Kafiriti, E., Kanju, E., Kapinga, F., Karugu, A., Kawuki, R., Kimata, B., Kimurto, P., Kulakow, P., Kulembeka, H., Kusolwa, P., Lyons, J. B., Masumba, E., van de Merwe, A., Mkamilo, G., Myburg, A. A., Nwaogu, A., Nzuki, I., Olasanmi, B., Okogbenin, E., Owuoche, J. O., Pariyo, A., Prochnik, S., Rabbi, I. Y., Rokhsar, D. S., Rounsley, S., Salum, K., Shuaibu, K. S., Sichalwe, C. & Stephen, M.) (2015) High-resolution linkage map and chromosome-scale genome assembly for cassava (Manihot esculenta Crantz) from 10 populations. G3: Genes Genomes Genetics, 5(1), 133-144. http://dx.doi.org/10.1534/g3.114.015008

Legg, J., Kumar, P. L., Makeshkumar, T., Tripathi, L., Ferguson, M., Kanju, E., Ntawuruhunga, P. & Cuellar, W. (2015) Cassava virus diseases: biology, epidemiology, and management. Advances in Virus Research, 91. 85-142. http://dx.doi.org/10.1016/bs.aivir.2014.10.001

Precoppe, M., Chapuis, A., Müller, J., & Abass, A. (2015) Tunnel dryer and pneumatic dryer performance evaluation to improve small-scale cassava processing in Tanzania. Journal of Food Process Engineering. Published online: 3 Sep 2015 http://dx.doi.org/10.1111/jfpe.12274

Rabbi, I. Y., Kulakow, P., Manu-Aduening, J. A., Dankyi, A. A., Asibuo, J. Y., Parkes, E., Abdoulaye, T., Girma Tessema, G., Gedil, M., Ramu, P., Reyes, B. & Maredia, M. K. (2015). Tracking crop varieties using genotyping-by-sequencing markers: a case study using cassava (Manihot esculenta Crantz). BMC Genetics, 16(1), 115-125. http://dx.doi.org/10.1186/s12863-015-0273-1

Potato

Demo, P., B. Lemaga, R. Kakuhenzire, S. Schulz, D. Borus, I. Barker, G. Woldegiorgis, M.L. Parker, and E. Schulte-Geldermann. 2015. "Strategies to Im-

prove Seed Potato Quality and Supply in Sub-Saharan Africa: Experience from Interventions in Five Countries." In Potato and Sweetpotato in Africa: Transforming the Value Chains for Food and Nutrition Security, edited by Jan Low, Moses Nyongesa, Sara Quinn and Monica Parker, 155-167. Oxfordshire, United Kingdom: CABI.

Ghislain, M.; Montenegro, J.D.; Juarez, H.; Herrera, M.R. 2015. Ex-post analysis of landraces sympatric to a commercial variety in the center of origin of the potato failed to detect gene flow. Transgenic Research. (Netherlands). ISSN 0962-8819. 24(3):519-528. http://dx.doi.org/10.1007/s11248-014-9854-4

Khan, M.A. ; Saravia, D. ; Munive, S. ; Lozano, F. ; Farfan, E. ; Eyzaguirre, R. ; Bonierbale, M. . 2015. Multiple QTLs linked to agro-morphological and physiological traits related to drought tolerance in potato. Plant Molecular Biology Reporter. (Belgium). ISSN 0735-9640. 33(5):1286-1298. http://dx.doi.org/10.1007/s11105-014-0824-z

Mudege, N.N.; Nyekanyeka, T.; Kapalasa, E.; Chevo, T.; Demo, P. 2015. Understanding collective action and women's empowerment in potato farmer groups in Ntcheu and Dedza in Malawi. Journal of Rural Studies. (UK). ISSN 0743-0167. 42:91-101. http://dx.doi.org/10.1016/j.jrurstud.2015.09.002

Rolando, J.L.; Ramirez, D.A.; Yactato, W.; Monneveux, P.; Quiroz, R. 2015. Leaf greenness as a drought tolerance related trait in potato (Solanum tuberosum L.). Environmental and Experimental Botany. (UK). ISSN 0098-8472. 110:27-35. http://dx.doi.org/10.1016/j.envexpbot.2014.09.006.

Sweetpotato

Cuellar, W.J.; Galvez, M.; Fuentes, S.; Tugume, J.; Kreuze, J. 2015. Synergistic interactions of begomoviruses with Sweet potato chlorotic stunt virus (genus Crinivirus) in sweet potato (Ipomoea batatas L.). Molecular Plant Pathology. (UK). ISSN 1464-6722. 16(5):459-471. http://dx.doi.org/10.1111/mpp.12200

Kyndt, T.; Quispe, D.; Zhai, H.; Jarret, R.; Ghislain, M.; Liu, Q.; Gheysen, G.; Kreuze, J.F. 2015. The genome of cultivated sweet potato contains Agrobacterium T-DNAs with expressed genes: An example of a naturally transgenic food crop. Proceedings National Academy of Sciences (PNAS). (USA). ISSN 0027-8424. 112(18):5844-5849. http://dx.doi.org/10.1073/pnas.1419685112.

Low, J.; Nyongesa, M.; Quinn, S.; Parker, M. (eds). 2015. Potato and sweetpotato in Africa. Transforming the value chains for food and nutrition security. Oxfordshire (UK). CABI International. ISBN 978-1-78064-420-2. 632 p. http://dx.doi.org/10.1079/9781780644202.0000.

Okello, A.; Sindi, K.; Shikuku, K.; Low, J.; Mcewan, M.; Nakazi, F.; Namanda, S.; Babu, A.; Mafuru, J. 2015. Effect of technology awareness and access on the conservation of clean planting materials of vegetatively produced crops: The case of sweetpotato. Agroecology and Sustainable Food Systems. (USA). ISSN 2168-3565. 39(9):955-977. http://dx.doi.org/10.1080/21683565.2015.1053586

Zawedde, B.M.; Ghislain, M.; Magembe, E.; Amaro, G.B.; Grumet, R.; Hancock, J. 2015. Characterization of the genetic diversity of Uganda's sweet potato (Ipomoea batatas) germplasm using microsatellites markers. Genetic Resources and Crop Evolution. (Netherlands). ISSN 0925-9864. 62(4):501-513. http://dx.doi.org/10.1007/s10722-014-0175-5

Yam

Aighewi, B., Asiedu, R., Maroya, N. & Balogun, M. (2015) Improved propagation methods to raise the productivity of yam (Dioscorea rotundata Poir.). Food Security, 7: 823- 834. http://dx.doi.org/10.1007/s12571-015-0481-6

Alene, A., Abdoulaye, T., Rusike, J. ., Manyong, V. & Walker, T. S. (2015). The effectiveness of crop improvement programmes from the perspectives of varietal output and adoption: cassava, cowpea, soybean and yam in sub-Saharan Africa and maize in West and Central Africa. IN Walker, T. S. & Alwang, J. (Eds.). Montpellier, France and Oxfordshire, UK.

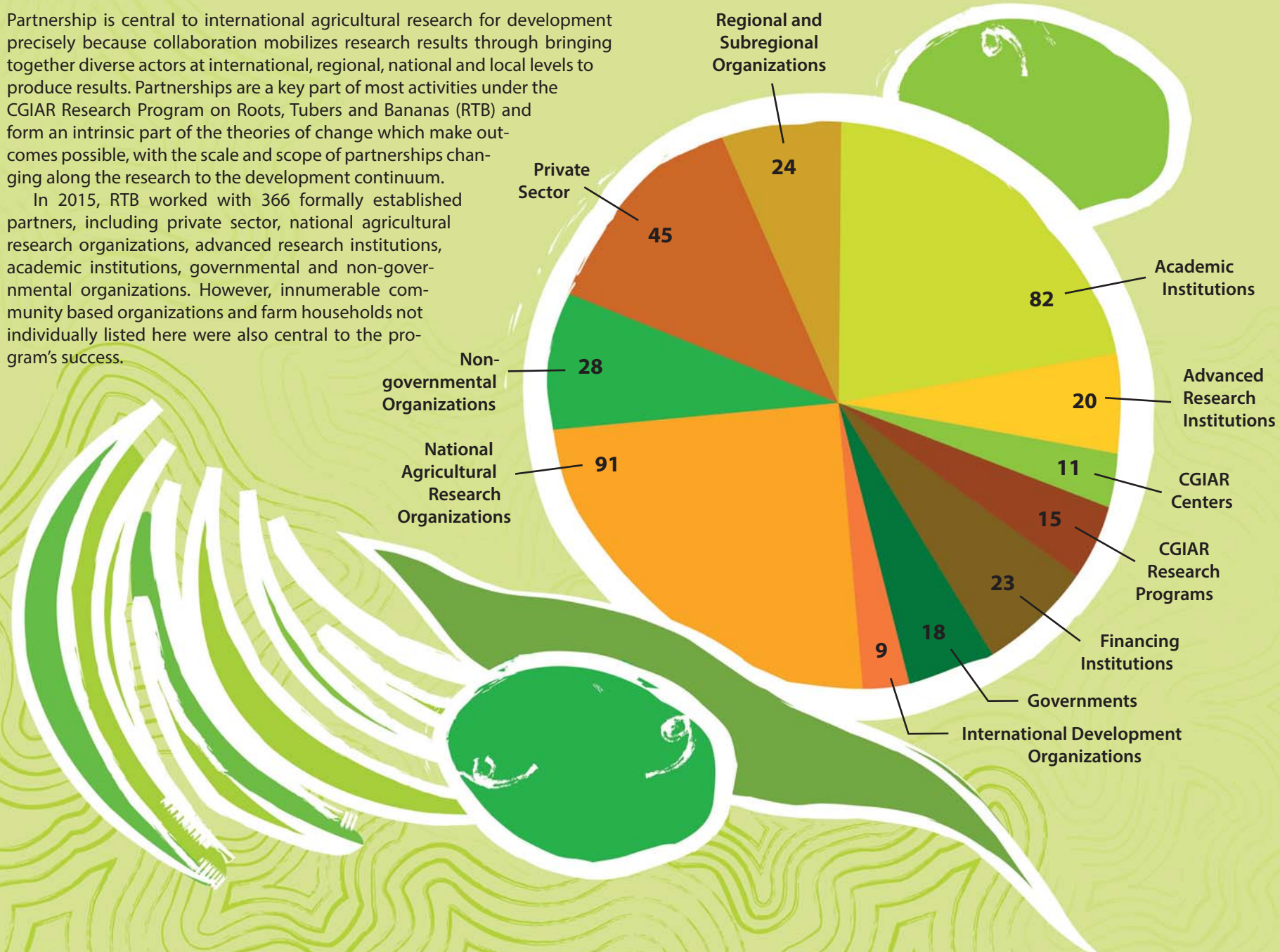
Saski, C. A., Bhattacharjee, R., Scheffler, B. E. & Asiedu, R. (2015) Genomic resources for water yam (Dioscorea alata L.): analyses of EST sequences, De Novo sequencing and GBS libraries. PLoS ONE 10(7): e0134031 http://dx.doi.org/10.1371/journal.pone.0134031

Tamiru, M., Yamanaka, S., Mitsuoka, C., Babil, P. K., Takagi, H., Lopez-Montes, A., Sartie, A. M., Asiedu, R. & Terauchi, R. (2015) Development of genomic simple sequence repeat markers for yam. Crop Science, 55(5):2191-2200 http://dx.doi.org/10.2135/cropsci2014.10.0725

RTB Partners

Partnership is central to international agricultural research for development precisely because collaboration mobilizes research results through bringing together diverse actors at international, regional, national and local levels to produce results. Partnerships are a key part of most activities under the CGIAR Research Program on Roots, Tubers and Bananas (RTB) and form an intrinsic part of the theories of change which make outcomes possible, with the scale and scope of partnerships changing along the research to the development continuum.

In 2015, RTB worked with 366 formally established partners, including private sector, national agricultural research organizations, advanced research institutions, academic institutions, governmental and non-governmental organizations. However, innumerable community based organizations and farm households not individually listed here were also central to the program's success.



RTB Donors

African Development Bank (AfDB)

Australian Centre for International Agriculture Research (ACIAR)

Bill & Melinda Gates Foundation (BMGF)

Cornell University, USA

Department for International Development (DFID)/UK Aid

Bundesministerium für wirtschaftliche Zusammenarbeit und Entwicklung (BMZ)

European Commission (EC)

Government of Nigeria (Federal Ministry of Agriculture & Rural Development, FMARD)

Government of Belgium

Government of Finland

Government of Japan

Government of India

Government of Netherlands (Sustainable Economic Development Department, DDE)

Government of Switzerland

Government of Tanzania (Ministry of Agriculture Food Security and Cooperatives, MAFSC)

Government of Uganda

International Development Research Center (IDRC), Canada

International Bank for Reconstruction and Development (IBRD)

International Fund for Agricultural Development (IFAD)

Ingredion incorporated

Irish Aid

North Carolina State University (NCSU)

Syngenta Crop Protection AG

Syngenta Foundation for Sustainable Agriculture

United States Agency for International Development (USAID)

Financial report

RTB started 2015 with a newly allocated Window 1 (W1) and Window 2 (W2) budget of US$29.6M, which was adjusted during the year to US$21.9M after funding cuts in March and October that totaled US$7.7M.

After the reductions in W1 and W2, the total 2015 budget for the program was US$78.2M: US$21.9M (28%) funded from W1 and W2, and US$56.3M (72%) from Window 3 (W3), bilateral funds and RTB participant centers' own funds.

CGIAR Funding Windows

- Windows 1&2 funds are provided by the CGIAR to RTB for allocation across the agreed product portfolio. Window 1 funds are allocated by the CGIAR Consortium to different CRPs including RTB, while Window 2 funds are designated by donors specifically to RTB.
- Window 3 funds are allocated directly to CGIAR Centers by donors and are mapped into RTB when they are consistent with the RTB product portfolio. Window 3 includes a deduction of 2% of the total budget as contribution to the CGIAR Consortium.
- Bilateral funds are contracts directly signed between a center and a donor and mapped into RTB.

The distribution of budget by funding sources between 2012 and 2015 shows a changing contribution of W1 and W2 to the RTB annual budget. While in 2012 the share of W1 and W2 was 44%, this fell to 28% in 2015 – with a respective increase in W3 and bilateral funds, from 56% to 72%, in the same period.

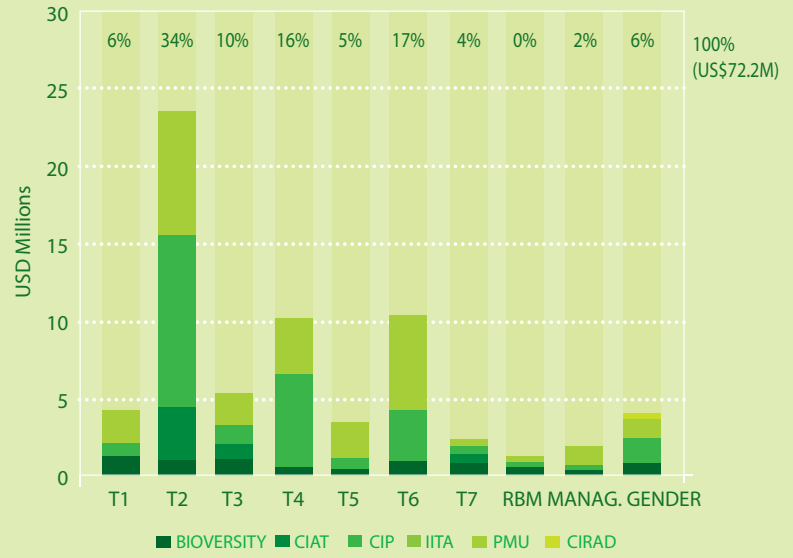
2015 Expenditure

RTB total expenditure across all funding sources in 2015 was US$72.2M. This represents execution of 92% of the budget: US$20.4M were spent from W1 and W2, and US$51.8M from W3, bilateral and center funds.

Expenditure for gender research was US$4.4M (94% of gender budget execution), representing 6% of RTB total expenditure in 2015. Management expenditure of US$1.5M represents 2% of the RTB total expenditure (74% of management budget execution), similar to 2014.

Overall expenditure

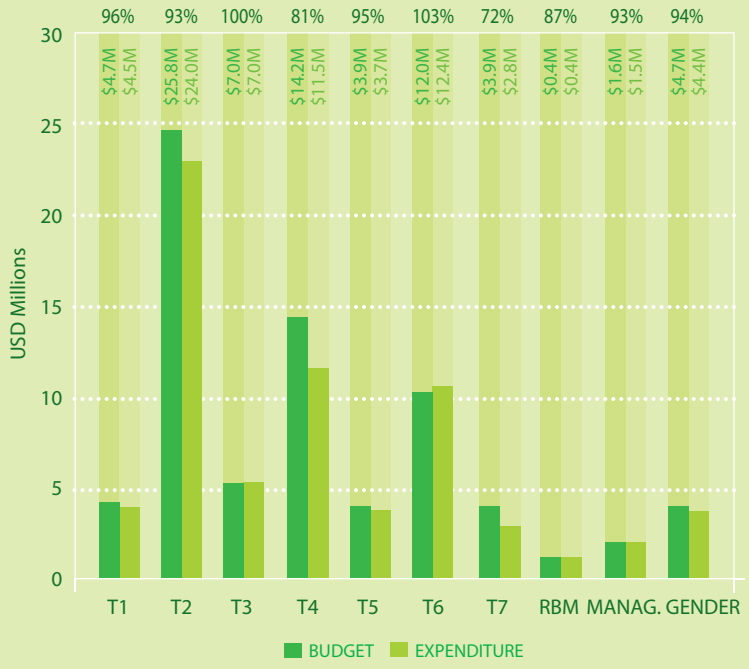
(by Theme and center as of Dec 2015)



The figure below shows the budget and expenditure by Theme. RTB had an average execution of 91% of each Theme budget, with the exception of Theme 6 which was overspent by 3%, due to the implementation of new W3 and bilateral projects not previously included in the budget.

Overall budget vs expenditure

(by Theme as of Dec 2015)

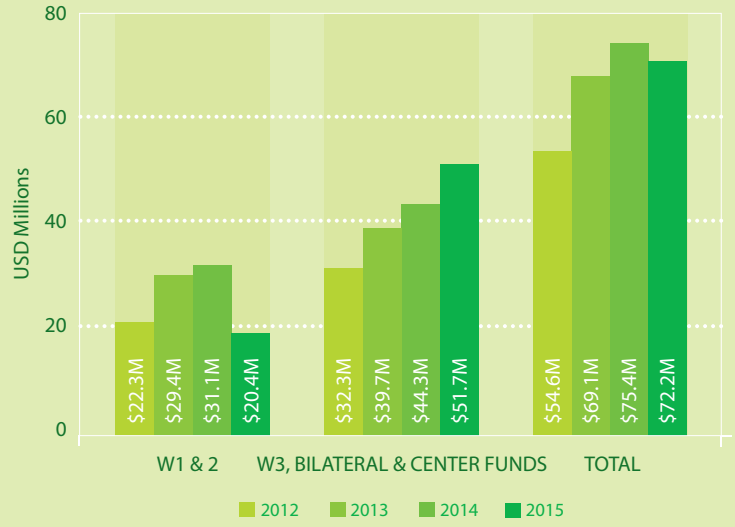


Trends in expenditure

Compared to 2012, RTB presented an overall increase of 32% in expenditure (US$72.2M in 2015 vs. US$54.6M in 2012), with a marginal reduction of 4% from 2014 to 2015 (US$72.2M in 2015 vs. US$75.4M in 2014), mainly due to uncertainties of funds from W1 and W2. The cumulative expenditure reached US$271.2M over the four years of the program (US$103.2M from W1 and W2, and US$168.0M from W3, bilateral and center funds).

Annual expenditure

(by funding source 2012-2015)



Acronyms

BBTD Banana bunchy top disease

BBTV Banana bunchy top virus

Bioversity Bioversity International

BXW Banana Xanthomonas wilt

CABI Centre for Agriculture and Biosciences International

CIAT International Center for Tropical Agriculture

CIP International Potato Center

CIRAD Centre de Coopération Internationale en Recherche Agronomique pour le Développement

CLAYUCA Consortio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca

CODIPSA Compañía de Desarrollo y de Industrialización de Productos Primarios S.A., Paraguay

CSIR-CRI Council for Scientific and Industrial Research – Crops Research Institute, Ghana

CT-LAMP Loop-mediated isothermal amplification

DNA Deoxyribonucleic acid

FAO Food and Agriculture Organization of the United Nations

FEDEPLATANO Federación de Productores de Plátano de Colombia

Foc Tr4 Fusarium oxysporum f. sp. Cubense – Tropical race 4 (a.k.a. Panama Disease)

GBS Genotyping by sequencing

GWAS Genome-wide association studies

HQCP High-quality cassava peel

IFAD International Fund for Agricultural Development

IITA International Institute of Tropical Agriculture

KMUTT King Mongkut's University of Technology Thonburi, Thailand

LAC Latin America and the Caribbean

LTVR Lowland tropics virus-resistant (potato)

NARO National Agricultural Research Organization, Uganda

NGO Non-governmental organization

NRI Natural Resources Institute, UK

OFSP Orange-fleshed sweetpotato

PPD Postharvest physiological deterioration (cassava)

PRA Pest risk analysis

PVS Participatory varietal selection

RAD-Seq Restricted site associated DNA sequencing

RBM Results-based management

RTB CGIAR Research Program on Roots, Tubers and Bananas

RTB-ENDURE Expanding Utilization of Roots, Tubers and Bananas and Reducing Their Postharvest Losses

SSA Sub-Saharan Africa

Univalle Universidad del Valle, Colombia

www.rtb.cgiar.org

ABOUT

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a broad alliance of research-for-development stakeholders and partners. Our shared purpose is to exploit the underutilized potential of root, tuber, and banana crops for improving nutrition and food security, increasing incomes and fostering greater gender equity – especially amongst the world's poorest and most vulnerable populations.

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