CGIAR

RESEARCH PROGRAM ON
Roots, Tubers and Bananas

Annual Report 2014

Envisioning Impact: Pathways to Action

WHERE DOES **RTB** WORK?

Bioversity International

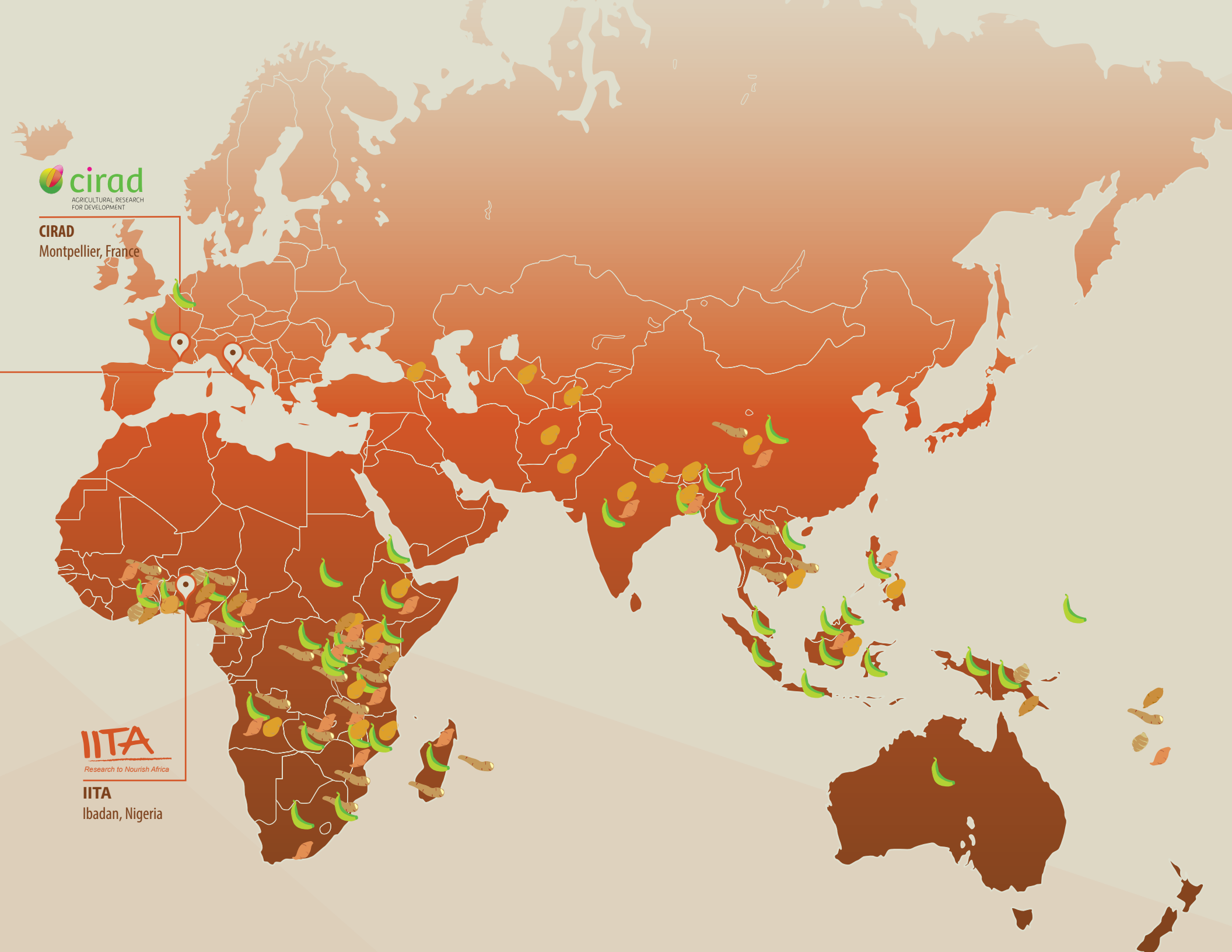
Bioversity International
Rome, Italy

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

CIAT Cali, Colombia

CENTRO INTERNACIONAL DE LA PAPA
CIP

CIP Lima, Peru


cirad
AGRICULTURAL RESEARCH FOR DEVELOPMENT
CIRAD
Montpellier, France
IITA
Research to Nourish Africa
IITA
Ibadan, Nigeria

CONTENTS

THEMES

Envisioning Impact: Pathways to Action
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THEMES

THEMES

Foreword

2014 was a year of consolidation for the CGIAR Research Program on Roots, Tubers and Bananas (RTB), as scientists made significant progress in the laboratory and on the ground, initial investments in gender integration resulted in more gender-smart research, and we made several changes to improve program management.

Based on recommendations from the CGIAR Consortium, a Program Advisory Committee (PAC) was constituted with six nominated members from complementary backgrounds. With their extensive experience and great enthusiasm for our work, they have already begun to contribute significantly to helping RTB reach its objectives. At the end of 2014, the PAC was merged with some members of the Steering Committee to form an Independent Steering Committee.

We developed a new program structure to facilitate results-based management (RBM) that organizes RTB research around a linked set of discovery, delivery and impact-at-scale flagship projects. These flagships will be composed of clusters of activities and will replace the current disciplinary themes starting in 2016. The transition from output-based to results-based management is one of the objectives for the program extension of 2015-2016. Other key elements include increasing integration of gender and the implementation of strategic gender research to enhance gender equity, expanding linkages with regional and sub-regional organizations, building broader alliances of partnerships, and maintaining a longer-term pipeline of discovery research.

We are proud of the progress that has already been made on integrating gender into our work. A significant amount of RTB research in 2014 was gender-responsive and nearly a dozen gender strategic research case studies were completed that will feed into a CGIAR global study. RTB gender specialists have also engaged in new initiatives with partner institutions that are very promising.

While our financial resources increased slightly in 2014, a retroactive budget reduction of 9% announced during the last quarter of the year impacted funding commitments and disbursement. We wish to see this risk reduced, especially because it affects funding that includes many partners, and time-bound projects.

We are looking forward to continued progress towards our aims of alleviating poverty and increasing food security.

Barbara H. Wells
CIP Director General and Chair of RTB Steering Committee

Graham Thiele
RTB Program Director

Executive Summary

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) made important progress towards its goals of reducing hunger, malnutrition and poverty in 2014. Efforts to mainstream gender produced important results that include gender integration in interventions to improve the management of the banana diseases Banana Bunch Top Disease (BBTD) and Banana Xanthomonas Wilt (BXW), and the collection of sex-disaggregated data on crop traits preferred by farmers, in order to enhance crop breeding. RTB also contributed to a CGIAR global study on gender and agricultural innovation, and launched a university partnership initiative that is connecting RTB researchers with graduate students in gender and development studies.

RTB supported gap analyses of global genebank collections of potato and sweetpotato crop wild relatives (CWR) that revealed that many CWR species are underrepresented in genebanks and at risk in the field due to habitat destruction. Researchers also undertook a mass field screening of 1,973 sweetpotato accessions from the CIP Genebank for heat tolerance, identifying 21 that are especially good candidates for breeding efforts.

A cross-center initiative to unravel the genetic mechanisms behind key crop traits and harness them for next-generation breeding has resulted in the gene sequencing of nearly 6,500 RTB crop accessions and metabolite profiling that has led to the identification of 7,000 metabolic features per RTB crop. CIAT researchers identified 181 genetic markers in the cassava genome linked to important traits, whereas IITA completed genome-wide association studies of cassava and applied the data to genomic selection. An impact study of a CIP project that promoted orange-fleshed sweetpotato consumption to pregnant or lactating women through a health program in western Kenya showed a doubling of dietary vitamin A intake for both mothers and infants.

Bioversity, CIAT, CIP and IITA collaborated with an array of partners on an effort to help farmers manage RTB-critical pests and diseases under climate change, installing networks of weather stations and completing a socioeconomic survey of more than 400 farm households at action sites in Rwanda and Burundi. The centers also made progress on laboratory research to better understand temperature-dependent pest development. A cross-center initiative to improve management of seed degeneration – the transmission and accumulation of pathogens via planting material – resulted in the development of preliminary process models, which will be improved through ongoing, multi-year field studies in nine countries.

RTB supported a meeting of cassava experts from research centers in Europe and Africa that resulted in the creation of the Pan-African Cassava Surveillance Network (PACSUN), which will add value to the work of existing organizations and networks by providing diagnostic expertise and information

on cassava diseases, and by coordinating responses to halt their spread. RTB scientists continued to play a key role in coordinating an international response to the first African outbreak of the banana disease Foc TR4, working with national institutions, regional organizations and the Food and Agriculture Organization of the United Nations (FAO) on a pan-African strategy.

RTB supports efforts to combat banana diseases in sub-Saharan Africa that include an alliance to contain and help farmers recover from BBTD led by Bioversity, CIRAD and IITA. Those centers helped local partners in eight countries to establish pilot sites and send 20 researchers to Montpellier, France for training in banana virus diagnostics. Bioversity, IITA and the Institutional Learning and Change (ILAC) Initiative collaborated on efforts to get banana farmers in Eastern and Central Africa to adopt a 'single diseased stem removal' (SDSR) approach to managing the disease BXW, which allows them to control the disease while still producing bananas.

CIAT, CIRAD and regional and national organizations in Latin America and the Caribbean are collaborating on solutions for managing the banana disease Moko bacterial wilt that include the use of thermotherapy chambers for mass propagation of disease-free planting materials and a Moko-resistant cultivar. IITA researchers tested aeroponic and immersion bioreactor technologies for producing pathogen-free yam planting material that hold promise. Smallholders in the Tanzanian highlands significantly increased their harvests in 2014 thanks to CIP's efforts to strengthen the production and distribution of clean seed potato in their country. RTB researchers also made progress on a cross-crop initiative to develop a conceptual framework for evaluating and improving seed systems, which was strengthened through 10 case studies.

IITA researchers completed a study of smallholder plantain systems in West and Central Africa that documented beneficial intercropping, fertilization and pest-and-disease management strategies. IITA scientists also undertook a field trial on intercropping yams with trees, identifying two tree species that boosted yam yields.

A cross-crop initiative was launched to improve postharvest management practices for banana, cassava, potato and sweetpotato in Uganda, with four business cases implemented by teams composed of more than two-dozen organizations. RTB also teamed up with the CGIAR Research Program on Policies, Institutions and Markets (PIM) to support efforts to integrate gender into RTB value chain tools and interventions. CIP began testing sweetpotato storage innovations in Ghana and Malawi using dry sand, the results of which indicate sweetpotatoes could be stored for months without major losses. RTB also funded research on cassava processing that should result in technologies to optimize key unit operations to enhance energy efficiency, among other improvements.

Acronyms

APHIA Plus AIDS, Population and Health Integrated Assistance Program

ASARECA Association for Strengthening Agricultural Research in Eastern and Central Africa

BBTD Banana Bunch Top Disease

BBTV Banana Bunchy Top Virus

BGI Beijing Genomics Institute

Bioversity Bioversity International

BXW Banana Xanthomonas Wilt

CABI Commonwealth Agricultural Bureau International, UK

CATIE Center for Tropical Agricultural Research and Higher Education

CBSD Cassava Brown Streak Disease

CGIAR Global research partnership for a food-secure future

CIAT International Center for Tropical Agriculture

CIMMYT International Maize and Wheat Improvement Center

CIP International Potato Center

CIRAD Centre de coopération internationale en recherche agronomique pour le développement, France

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

CMD Cassava Mosaic Disease

COVA Cohort for Vitamin A

CRRD Cocoyam Root Rot Disease

CWR Crop Wild Relatives

DNA Deoxyribonucleic acid

FAO Food and Agriculture Organization of the United Nations

FAQ Frequently-Asked Questions

FERA Food and Environment Research Agency, UK

FMARD Nigeria's Federal Ministry of Agriculture and Rural Development

Foc TR4 Fusarium oxysporum f.sp. cubense – Tropical race 4 (a.k.a. Panama Disease)

FONTAGRO Fondo Regional de Tecnología Agropecuaria

FSRP Farming Systems Research Programme

GCP21 Global Cassava Partnership for the 21 Century

GWAS Genome-Wide Association Studies

Humidtropics CGIAR Research Program on Integrated Systems for the Humid Tropics

ICIPE International Centre of Insect Physiology and Ecology

ICRAF World Agroforestry Center

IFAD International Fund for Agricultural Development

IFPRI International Food Policy Research Institute

IITA International Institute of Tropical Agriculture

ILAC Institutional Learning and Change Initiative

ILCYM Insect Life Cycle Modeling

ILRI International Livestock Research Institute

INERA Institut National pour l'Etude et la Recherche Agronomiques, France

INRA Institut National de la Recherche Agronomique, France

IRD Institut de Recherche pour le Développement, France

ISFM Integrated Soil Fertility Management

LAMP Loop Mediated Amplification

NaCRRI National Agricultural Crops Resources Research Institute

NARES National Agricultural Research and Extension Systems

NARO National Agricultural Research Organization, Uganda

NEXTGEN Cassava Next Generation Cassava Breeding Project

NGO Non-Governmental Organization

NRCB National Research Centre for Banana, India

NRCRI National Root Crops Research Institute, Nigeria

NRI Natural Resources Institute, UK

OFSP Orange-Fleshed Sweetpotato

PACSUN Pan-African Cassava Surveillance Network

PAC Program Advisory Committee

PIM CGIAR Research Program on Policies, Institutions and Markets

PMCA Participatory Market Chain Approach

PRA Pest Risk Assessment

PVS Participatory Varietal Selection

R4D Research for Development

RBM Results-Based Management

RTB CGIAR Research Program on Roots, Tubers and Bananas for Food Security and Income

SARI Savanna Agriculture Research Institute, Ghana

SASHA Sweetpotato Action for Security and Health in Africa

SDSR Single Diseased Stem Removal

SNP Single Nucleotide Polymorphisms

SPHI Sweetpotato for Profit and Health Initiative

TBRI Taiwanese Banana Research Institute

TLB Taro Leaf Blight

TRCP Taxonomic Reference Collection Project

USAID United States Agency for International Development

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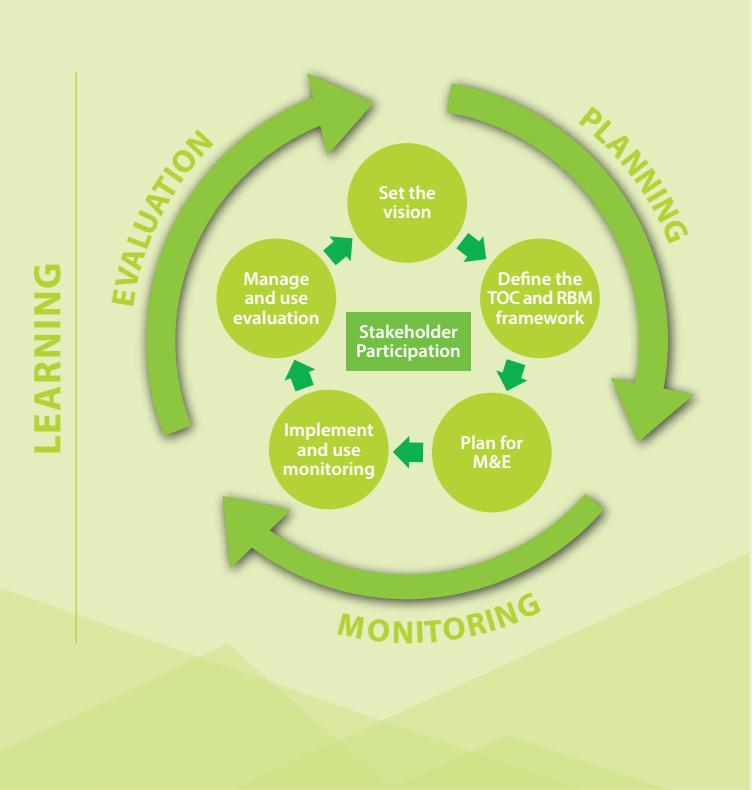
Introduction

Introduction

During its third year, the CGIAR Research Program on Roots, Tubers and Bananas (RTB) strengthened and expanded its network of partners and began implementing a more effective management structure that will greatly enhance its ability to track and achieve outcomes and impacts in the future. RTB funded an array of initiatives under its seven Themes, among them cutting-edge genomic research, international collaborations to improve the management of priority pests and diseases, and research to help farmers increase their harvests and improve postharvest options. Together, those initiatives are helping the RTB centers and their partners harness the full potential of roots, tubers and bananas for reducing hunger, improving diets, and helping people work their way out of poverty.

Envisioning Impact

An RTB priority in 2014 was facilitating a fundamental change in the way the research centers and their partners do business. The idea is to help the centers and partners



RBM life cycle

move from a focus on outputs to an approach that prioritizes evidence-based outcomes and measureable impacts on food security, nutritional uptake, livelihoods and gender equity. This change involves participatory planning with an array of NARES, NGOS, farmer groups and the private sector to transform the way we plan, execute and monitor research for development interventions through the application of results-based management (RBM).

This new way of doing business asks scientists and development professionals to envision the impacts that they want to have, and then work backwards to identify all the actions and collaborations, outputs and outcomes needed to achieve them. This includes paying special attention to the needs and constraints of end users, and identifying the actors who need to be engaged or influenced to reach those end users. The focus of this approach, and the consequent framework for managing and monitoring research for development, is the 'impact pathway' – a conceptual tool that allows researchers and development professionals to identify and map the outputs and linkages needed to produce the outcomes leading to impact. An impact pathway places emphasis on the process of change and the partners required to make it happen. Putting it into practice involves the identification of output, outcome and impact indicators for monitoring evaluation and learning (MEL). Those indicators play a key role in implementation, since the feedback they provide allows researchers to make adjustments to an intervention as it progresses and check that it is on track to achieve the desired impacts.

The adoption of RBM is one component of a transition from a structure-based on seven disciplinary themes, under which RTB's work was organized during its first three years, to one organized around outcome-focused flagships. RTB researchers made major progress in 2014 on the construction of RTB flagships, each of which is composed of various related 'clusters of activities,' through which the centers and their partners conduct research and effect change. Each of those clusters will have its own theory of change, impact pathway and MEL indicators. As RTB enters its second phase, all research will be organized within flagships and their component clusters, and theories of change and impact pathways will form the basis for all planning, monitoring and evaluation.

Piloting RBM

RTB became a leader in a Consortium-wide effort to transform the planning and tracking of research for development when it was one of five CGIAR Research Programs chosen to implement an RBM pilot. Progress in 2014 included the design of a

Seed potato workshop in Kenya

RTB: Collaborating to Improve Food Security and Incomes

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) was launched in 2012 to harness the untapped potential of bananas, plantains, cassava, potatoes, sweetpotatoes, yams, 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 research program, Bioversity International (Bioversity), the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA) and the French Agricultural Research Centre for International Development (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.

preliminary MEL framework and the introduction of RBM into three research initiatives, (clusters of activities).

This process was launched with an inception workshop where 20 participants from three RTB centers were trained as 'process coordinators,' whose job it is to facilitate the understanding and adoption of RBM concepts and tools among their colleagues. A flexible RBM methodology was designed for implementation in participatory planning workshops, which focus on the construction of impact pathways, and indicators of progress linked to the MEL framework.

RBM was introduced through the planning workshops for three clusters: a CIP initiative to improve seed potato systems in Sub-Saharan Africa, a cross-center collaboration to control the disease banana Xanthomonas wilt (BXW) in Eastern and Central Africa, and a multi-center initiative to implement next-generation breeding for the main RTB crops. During workshops,

stakeholders shared knowledge, discussed the changes needed to achieve common goals, and constructed an impact pathway which linked these changes together.

"The idea of the pilot is to use the first experiences to design and improve a harmonized process for introducing results-based management across the research program," explained Claudio Proietti, a consultant who is supporting the RBM pilot. "For participatory workshops, we need a methodology and tools for designing an impact pathway and developing a shared results framework together with partners."

Based on the experience of the first three workshops, the coordinators of the RBM pilot produced an RTB Brief titled: Planning Workshop: Co-Constructing Impact Pathways with Stakeholders for Results-Based Management, (http://www.rtb.cgiar.org/publication/co-constructing-impact-pathways-stakeholders-results-based-management/).

Participants in planning workshop that introduced RBM into a cluster of activities for improving seed potato systems in sub-Saharan Africa

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Enhancing Impact Through Partnerships

Efforts to build effective partnerships, promote communication and knowledge sharing, and make research more gender responsive strengthen everything else the Research Program does. In 2014, RTB engaged more than 200 partners comprising 66 national agricultural research systems, 63 universities and advanced research institutes, 14 non-governmental organizations (NGOs), and 18 private sector companies. Networks supported by the RTB umbrella grew measurably, and major progress was made toward the goal of mainstreaming gender across the Research Program.

Growing RTB Networks

As research initiatives were launched and fieldwork began in 2014, networks were established or expanded and communities of practice were formed, resulting in synergies and collaborations that are enhancing the Research Program's ability to achieve its goals. French partners CIRAD, IRD and INRA increased their contribution to RTB research, especially for controlling banana diseases and improving cassava processing. RTB catalyzed greater cooperation between the cassava breeding programs at CIAT and IITA and the banana programs at Bioversity and IITA through an initiative to generate genomic and metabolomic data and harness it for next-generation breeding (see Harnessing Genetic Resources, Developing Improved Varieties, p. 28). There was also greater collaboration among RTB centers and partners on efforts to improve the management of specific crop diseases and pests, promote postharvest innovations, and make research more gender-responsive.

The Research Program's promotion of partnering is especially apparent in Uganda, where a three-year project to test and disseminate postharvest innovations was launched in 2014. The project has brought together more than two-dozen organizations on collaborative research to improve postharvest management practices and identify value chain opportunities for banana, cassava, potato and sweetpotato (see Uganda Postharvest Project, p. 69).

Ivan Rwomushana, manager of the Staple Groups Program at the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA) and a member of the Uganda project's steering committee, lauded RTB's approach of

promoting collaboration among an array of actors. "It is exciting that the breeders are talking to the postharvest experts and they are all talking to the farmers and consumers. This participatory approach will ensure that the needs of all stakeholders are met," he said.

Assessing ProMusa's Contribution to Banana Knowledge Sharing

As part of its efforts to promote collaboration among researchers and development professionals, RTB has been funding ProMusa, a knowledge-sharing platform on bananas and plantains managed by Bioversity. In order to gain insight on how people use the platform and understand its role in facilitating research for development around the world, RTB commissioned an evaluation of ProMusa that was completed and released in 2014.

NARITA 22 (left) is a high-yielding, disease-resistant hybrid named after NARO and IITA, the institutes that jointly developed it. The photo belongs to the collection available on the ProMusa platform

ProMusa has been facilitating dialogue among scientists and other stakeholders working on banana since 1997, both in developed and developing countries. It is especially popular among researchers in poorer countries, who have a harder time accessing information than their colleagues in developed nations. Its resources and tools include an online compendium of banana knowledge (Musapedia), a bibliographic database (Musalit), an image bank (Musarama), an electronic newsletter (InfoMus@) and a contact database (Musacontacts). It also provides a platform where scientists and other stakeholders can interact and encourages discussion through an online forum, a community blog and mailing lists.

To complement its online services, ProMusa organizes a biennial scientific symposium to help its members stay up-to-date on the latest research, encourage exchange of ideas, and facilitate collaboration among scientists and across disciplines. The ultimate goal of both the knowledge platform and the symposium is to help banana farmers make a better living and ensure that bananas – in all their diversity – continue to thrive in a healthy environment.

The assessment was completed by Bioversity scientist Elisabetta Gotor and the consultant Genowefa Blundo Canto. They undertook online surveys of 322 ProMusa members

in early 2014 followed by interviews with key informants in order to assess the effectiveness of ProMusa using a number of selected indicators. The results were crosschecked with a literature review. The goal was to determine what outputs ProMusa produces and how they are translated into outcomes and disseminated outside the network.

"ProMusa's competitive advantage is its global reach, providing access to free and updated information, with live feedback and sharing between experts from different fields all over the world," said Gotor.

She explained that ProMusa users see it both as a hub for dissemination of information on banana and a platform that facilitates collaboration and networking among the banana community, which includes researchers, donors, practitioners, farmers and other stakeholders. Members appreciate the fact that ProMusa provides easy access to an array of updated information – from news to scientific research, disease alerts, funding opportunities and events. They also appreciate that ProMusa provides a space for sharing opinions and information that don't appear in journals, including hot topics and research needs.

"According to the survey's respondents, the unique added value of ProMusa is that it provides reliable, well-respected and updated information on banana production and research in one place, and that it connects different people worldwide with the same goal", observed Inge van den Bergh, a senior scientist at Bioversity, ProMusa coordinator and RTB theme leader for communications, knowledge management and capacity strengthening.

Weaving Gender into Agricultural Research

Efforts to mainstream gender across participating centers bore significant fruit in 2014, as gender was integrated into several research initiatives with an array of gender responsive tools. RTB also assumed a leading role in a CGIAR global study that analyzes the way gender norms – deep-seated beliefs, expected roles and behaviors and permitted practices associated with men and women – interact with and condition the capacity of farmers for agricultural innovation.

RTB's gender team designed and ran workshops in 2013 on making agricultural research more gender responsive, which involved 81 scientists from multiple disciplines in Africa, Asia, and Latin America and the Caribbean. The effectiveness of that capacity building was evident in 2014 in an increase in number of gender-responsive milestones reported by all RTB centers in technical themes. A significant amount of RTB research initiatives – ranging from the understanding of preferences

Gender workshop in Mukono, Uganda

for certain crop characteristics or traits (productivity, taste, nutritional value, etc.) to value chain interventions – are now gender-responsive.

"I think that there has definitely been a change in attitude; people are very supportive of the need to look at gender aspects of agricultural research, recognizing that it has a big influence on making research effective," said Gordon Prain, Science Leader for the Social and Health Sciences Global Program at CIP and RTB Theme Leader for Gender and Partnerships.

Gender Integration

One example of gender integration was the inclusion of gender-specific questions – such as which family members are responsible for different farm activities – in a household baseline study conducted in more than 400 households in Rwanda and Burundi as part of a cross-center project to assess the risk posed by RTB-critical pests and diseases under a changing climate (see Predicting Climate Change's Impact, p. 46). The results of that gender-responsive study will help researchers to develop and target technology and training for adaption to changing pest and disease risks and the application of integrated pest management.

Another example was the development by Bioversity and IITA gender specialists Anne Rietveld and Holger Kirscht of a two-phased protocol to strengthen the effectiveness of an alliance for containment and recovery from banana bunchy top disease (BBTD) in eight African countries (see Learning Alliance Creates Synergies, p. 50). The protocol began with the collection and analysis of sex disaggregated data on farm, household and community levels, the results of which were used by the multi-disciplinary science team, partners and community representatives in the participatory development of a gender-responsive curriculum to train community members on BBTD control.

CIAT gender focal point Kayte Meola coordinated a study in the Colombian departments of Sucre and Cordoba on gender roles in the production of cassava for varied markets in a region where a large cassava starch plant was opened in recent years. The research included surveys of 583 smallholders and analysis of the intra-household distribution of the benefits of traditional and industrial markets. The field instrument for assessing intra-household income allocation developed for this research was improved and will be piloted in other studies in Colombia and Nigeria in 2015.

CIP gender specialist Netsayi Noris Mudege worked closely with potato scientists in Malawi to develop a gender strategy for seed potato interventions. The Malawi gender strategy addresses ways to mainstream gender into socio-economic research and data analysis used in project design, capacity strengthening and coordination with partners, farmer recruitment and training, technology development and dissemination, and the commercialization of potato seed systems.

Mudege also participated in an effort to improve the effectiveness of participatory varietal selection (PVS) of potato in Ethiopia by training local partners to differentiate the preferences of women and men for agronomic, harvest and taste characteristics of varieties and to understand the rationale for those differences during the implementation of PVS processes. With colleagues Gordon Prain and Nadezda Amaya, she also

helped to revise a manual for implementing the 'Mother and Baby' approach in PVS in order to strengthen researchers' ability to characterize and explain gender differences in preferred varietal characteristics.

Bioversity gender focal point Anne Rietveld coordinated a study on banana-beverage value chains and associated livelihoods in five East-African countries with a specific focus on gender, because of the widespread involvement of women in banana beverage production and commercialization. The study involved partners from the NARS in those countries who received mentoring in gender-responsive value chain analysis.

Cover of the gender-responsive PVS manual (drawing by Peruvian artist Josué Sánchez)

In an initiative supported by RTB and the Next Generation Cassava Breeding Project (NEXTGEN Cassava), IITA gender focal point Holger Kirscht worked with cassava breeders and researchers to design a methodology to collect gender-disaggregated data on the trait preferences of Nigerian farmers and to organize that information in a way that is useful for the country's cassava breeding programs (see Incorporating Women's Needs and Preferences, p. 38).

The RTB postharvest project in Uganda is serving as a laboratory for the integration of gender into value chain interventions. Mudege and CIP researcher Sarah Mayanja helped develop work plans and a monitoring and evaluation framework that includes gender indicators, such as numbers of women participating in trainings and workshops, or engaged in prototype value chains or other postharvest activities (see Uganda Postharvest Project, p. 69). A workshop held in Entebbe, Uganda in April 2014 resulted in the development of new gender integration tools, including guidelines for making RTB value chain interventions more gender responsive, and a prototype trainer's guide for integrating gender into the Participatory Market Chain Approach (PMCA) (see RTB and PIM Collaborate on Gender, p. 72).

CGIAR Global Study

RTB also played an important role co-leading a CGIAR global study of the way gender norms interact with and condition the capacity of farmers for agricultural innovation. The study involves 12 CGIAR Research Programs that will together implement approximately 120 case studies in more than 25 countries.

Prain observed that: "The global study is groundbreaking in

the way it is moving gender research into the realm of big science and away from small, fragmented data sets which don't allow us to reach conclusions with any generalizable validity. This is a study on gender and agriculture and natural resource management that is large scale and comparative, with a rigorous, qualitative methodology which allows comparison across a large number of cases."

He explained that RTB participated in the adaptation and testing of the study's qualitative tools and in the training of researchers in the methodology. RTB researchers completed 11 case studies in 2014 that will feed into the global study, and should complete eight more. Cases completed included studies on cassava, banana, potato and sweetpotato in Colombia, Malawi, Uganda and Bangladesh. The global study should identify norms that favor equitable access to and uptake of innovations leading to bigger development outcomes, as well as those that lead to inequality, exclusion and, consequently, less effective outcomes.

"If we understand these issues better, we can make RTB research and innovation processes more equitable and more efficient," said Prain.

RTB Partners with Universities to Strengthen Gender Research

As part of its efforts to make crop research more gender-responsive, RTB teamed up with Cornell University in 2014 to launch a university partnership initiative that connects researchers with graduate students in gender and development studies in order to tap their skills and knowledge while providing them with opportunities to work in the field.

One of those students is Lisa Anderberg, a Masters candidate in international development at Clark University who will spend several months in 2015 conducting research on women's role in cassava pest and disease management in Laos as part of an RTB project led by CIAT researcher Kris Wyckhuys. Anderberg will be an asset to CIAT, since she has more than two years of development and research experience in Laos and speaks the language, and she is excited about contributing to the project.

"For me, this opportunity means that I will be able to apply my contextual and cultural knowledge of Laos and the theoretical and analytical skills that I have been developing in graduate school," she said.

Anderberg is one of several graduate students who signed up in 2014, but the partnership initiative is poised to make a major contribution to RTB's gender research goals in the coming years. The initiative was supported by the United States Agency for International Development (USAID) and was administered by Cornell University. Hale Ann Tufan, who manages the NEXTGEN Cassava project at Cornell, coordinated the project.

Workshop to launch the RTB-US universities initiative in Cali, Colombia

Tufan works closely with Kayte Meola, the RTB gender focal point at CIAT and an associate research fellow at the International Food Policy Research Institute (IFPRI). Meola organized a meeting to launch the partnership at CIAT headquarters in Cali, Colombia in October 2014 that brought together 36 crop scientists and gender specialists from four RTB centers and six US universities.

"I am glad to see these partnerships develop and to welcome our first students on board," said Meola. "There is so much to gain on both sides. Through working with universities, RTB will increase its capacity to conduct gender research while graduate students will have the opportunity to gain field experience in collaboration with professional researchers throughout Asia, Africa and Latin America."

Meola worked with two graduate students in 2014 to develop a tool to measure intra-household income allocation, which could be useful for any RTB project that aims to increase household income in an equitable fashion. University of San Francisco graduate student Philip Jakob helped Meola develop the tool and began testing it in Colombia in January 2015, with support from Professor Teonila Aguilar Jiménez and a team of students at the University of Cordoba. Djeinam Toure, a PhD candidate at Cornell University, joined Jakob in Colombia to further refine the tool before piloting it in Nigeria in collaboration with Tufan and Holger Kirscht, the gender focal point at IITA.

"Skills in gender analysis and ways to collect gender-disaggregated data, which are important for RTB, are things that we teach at Clark University," said Professor Cynthia Caron of Clark's Department of International Development, Community and Environment. She noted that many of her students are former Peace Corps volunteers or have comparable oversees experience. "This really is a partnership. The students and universities will be providing a service to RTB scientists, while RTB provides the students with opportunities to do meaningful field research."

Meola was pleased by the number of RTB researchers who submitted project descriptions at the initiative's launch, as the first step toward linking with university scholars. An online platform will be introduced in 2015 to facilitate matches between graduate students and RTB project leaders.

She explained that by the end of 2014, the initiative was working with seven US universities – the Universities of Florida, Minnesota, San Francisco, Pennsylvania State, Clark University, Cornell and University of Illinois at Chicago – as well the Universidad de Cordoba in Colombia and the University of Guelph in Canada.

"Our next step will be to broaden the partnership to include graduate students and faculty in our project countries and potentially foster North-South connections between universities," she said. "The door is wide open for universities from other countries to join us."

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Harnessing Genetic Resources Developing Improved Varieties

1 Harnessing Genetic Resources Developing Improved Varieties

The closely-linked themes of 'Unlocking the value and use potential of genetic resources' and 'Accelerating the development and selection of cultivars with higher, more stable yield and added value' have been priorities during RTB's first years, in part due to their potential to strengthen the Program's work in other areas – from controlling crop diseases and pests to improving postharvest options. The RTB centers and their partners made important progress in 2014 toward improving the collection, conservation and evaluation of germplasm, and unlocking the potential of those genetic resources for the development of new varieties. Studying the genetic diversity of RTB crops and their wild relatives and harnessing that information for the development of more resilient, productive and nutritious varieties will be key to feeding a growing population in the face of limited farmland and a changing climate.

Unlocking the Value and Use Potential of Genetic Resources

The RTB centers and their partners conserve the most important germplasm collections in the world for their crops of specialization, and they continue to collect landraces and crop wild relatives in the field. In 2014, RTB supported initiatives to improve the collection and identification of germplasm, and to better understand the value and use potential of genetic resources held in genebanks. This included extensive field trials to identify specific traits in crop accessions, which is known as phenotyping.

RTB has made a major investment in a cross-center initiative to unravel the genetic mechanisms behind key crop traits – such as high starch content in cassava, high vitamin and micronutrient content in potato, drought or heat tolerance in potato, sweetpotato or plantain, and resistance to some of the many pests or diseases that attack RTB crops – and to use that information for next-generation breeding. The centers have sent Deoxyribonucleic acid (DNA) from thousands of accessions to laboratories for gene sequencing. The resulting data are being used for genome-wide association studies (GWAS), and diversity analysis. GWAS involves comparing the DNA sequences of hundreds of accessions with phenotypic information to identify which DNA markers (usually single nucleotide polymorphisms (SNPs) are associated with specific traits, and then developing

systematic selection schemes based on those markers. GWAS can identify SNPs and other variants in DNA that are associated with a trait, but cannot on their own specify causal genes.

Undertaking GWAS for RTB crops has only become possible in recent years, since the first draft of the cassava genome was published in 2009 and the first genome sequences for potato and banana were completed and published in 2011 and 2012 respectively. The genomes of sweetpotato and yam have yet to be completely sequenced, and RTB is supporting efforts to construct reference genomes for these species. Though genomic research was launched in the Research Program's first year, it hit full steam in 2014. By the end of the year, nearly 6,500 RTB crop accessions from the genebanks and elite breeding pools had been sequenced and scientists at the RTB centers were organizing and analyzing vast amounts of data.

RTB is complementing the genomic analysis with metabolite profiles for a portion of the accessions being sequenced, in partnership with Royal Holloway University of London. The metabolomic research, which is led by Professor Paul Fraser, has already resulted in the identification of approximately 7,000 metabolic features per RTB crop – biomarkers that can help researchers link crop traits to genomic data and accelerate next-generation breeding. Breeders will be able to use metabolomic data to better understand crop traits such as nutritional content, pest and disease resistance and resilience in a changing climate.

RTB Genomic Research Progress by Crop:

Banana: Bioversity coordinated the genotyping of 1,200 banana accessions from the International Transit Center, at Katholieke Universiteit (KU) Leuven. This includes a set of 126 diploid accessions that was specifically selected for GWAS. IITA sent 782 banana accessions for sequencing, including populations segregating for resistance to weevils, nematodes and the disease Fusarium wilt, and a training population of 320 genotypes that will be used to develop predictive models for genomic selection of East African Highland Bananas. Bioversity, IITA and KU Leuven are also collaborating on a study to identify genes linked to drought tolerance in banana.

Cassava: CIAT sent 700 accessions from its collection of cassava from Latin America and the Caribbean to the Beijing Genomics Institute (BGI) for restricted-site-associated-DNA (RAD) sequencing, and coordinated the RAD sequencing of 297 accessions from IITA's collection of African landraces. Metabolite profiling was completed for 120 field-grown cassava accessions. IITA has coordinated the sequencing of more than 3,000 cassava landraces from across sub-Saharan Africa during the past three years.

Cassava for sale in a Ugandan market

Potato: CIP genotyped 150 landraces from groups Phureja and Stenotomum/Goniocalyx – which have relatively high levels of micronutrients. An additional 95 accessions of 21 wild species suggested as ancestors of cultivated potatoes were also genoypted. GWAS was performed in a panel of 171 tetraploid potato breeding lines to identify genomic regions underlying traits for adaptation to long photoperiod and warm conditions. High quality phenotypic data were also generated for heat and drought tolerance. Metabolomic analysis resulted in the calibration of 20 metabolites found to increase during drought stress.

Yam: IITA, which has the world's largest collection of yam germplasm (3,500 accessions of 8 different Dioscorea species) sent DNA samples from 810 D. rotundata accessions to Cornell University, 553 of which were sequenced in 2014. A set of 49 yam genotypes were also sent to Royal Holloway University of London for metabolite profiling.

Protecting Crop Wild Relatives of Potato and Sweetpotato for the Future of Genetic Enhancement and Food Security

Crop wild relatives (CWR) share common ancestors with cultivated crops, and can often be used for crop improvement. Because CWR have been exposed to natural selection in diverse climates and habitats, they have genes that can help crops adapt to varied environmental stresses. While CWR have been used to introduce pest or disease resistance, or tolerance to heat and drought into a range of major crops, scientists agree that their potential is still largely untapped.

"Their contribution to agriculture should only increase as the development of molecular technologies makes identification and utilization of diverse genetic materials more efficient," said Colin Khoury, a member of the CWR research team at CIAT.

However, two studies carried out in 2014 under the umbrella of RTB showed that the collections of potato and sweetpotato CWR in genebanks are incomplete, and that in situ preservation of many CWR species is at risk because their habitat is threatened. "This puts the conservation of potato and sweetpotato genetic diversity in danger, which potentially dramatically limits future crop improvement," warned Stef de Haan, a CIP researcher who co-authored "Ex situ conservation priorities for the wild relatives of potato (Solanum L. section Petota)," which was published in PLOS ONE. "At times when new collection expeditions are difficult to conduct, climate change is a reality

Wild potatoes

and habitat destruction abounds, it is essential that in-situ reserves are established. In-situ conservation is complementary to genebanks and can support ongoing evolution and adaptive shifts in population genetics."

Scientists from CIP and CIAT led genebank gap analyses with partners around the world to identify gaps in potato and sweetpotato collections and geographic areas were further collecting is needed. A total of 32 species of potato wild relatives (43.8% of those studied) were assigned high priority status due to significant gaps in genebank collections. In the Andean highlands specifically – potato's center of origin – potato crop wild relatives are threatened as their habitats are impacted by climate change, land use intensification and the construction of roads and villages. The researchers recommended immediate action on both ex situ and in situ conservation.

The gap analysis for crop wild relatives of sweetpotato yielded even more dramatic results: a total of 78.6% of the species considered in the study were assessed as high priority for further collecting and conservation in ex situ collections. The research findings, published in the journal Frontiers in Plant Science, also indicate that diversity gaps in ex situ collections largely align with the geographic distribution of species richness of sweetpotato CWR, such as "hotspots" in central Mexico and Central America, and in the extreme southeastern USA. Further collecting of CWR germplasm should consequently be focused on these regions.

"Not only do we need more germplasm collecting activities," said Bettina Heider, a genetic resources specialist at CIP and co-lead author of the scientific paper, "we also need more research on sweetpotato overall, including its wild relatives, to better understand the genetic diversity of the crop and tap its potential for food security."

For Rick Miller, professor of biological sciences at Southern Louisiana University, field trials can be combined with genetic approaches to identify characteristics like drought resistance in populations of the Batatas complex from around the world to be used for sweetpotato breeding. "This may sound like an ambitious goal, but for many crop species, like tomato, corn and rice, it is a reality," he said.

Both studies were undertaken as part of the project on "Adapting agriculture to climate change: collecting, protecting and preparing crop wild relatives," managed by the Global Crop Diversity Trust, Germany and the Millennium Seed Bank of the Royal Botanic Gardens at Kew in the UK.

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Mass Field Screening of Sweetpotato Germplasm Reveals that CIP Genebank Holds Many Heat-Tolerant Clones

Scientists in CIP's Global Program for Genetic Resources undertook a mass field screening of 1,973 sweetpotato accessions from the CIP Genebank in the lowlands of northern Peru that resulted in the identification of 146 accessions that

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Sweetpotato germplasm preserved in CIP's genebank

performed well under heat-stress conditions. The results show that CIP has ample genetic material for breeding improved sweetpotato varieties for marginal regions or the extreme conditions predicted under climate change.

"We knew that sweetpotato was a robust crop, but the results of this study show that it is very heat tolerant," said researcher Bettina Heider, who led the field screening.

She explained that the accessions were planted in Peru's northern desert, near the city of Piura, for two cropping cycles: the southern winter of 2013 and summer of 2014. Summer temperatures near Piura can reach highs of 40 °C during the day and between 20 °C and 30 °C at night. Warm soil at night typically causes sweetpotato to produce "pencil roots" with little or no value. At the end of each cycle, the researchers recorded details for each accession such as total yield, root conditions, leaf and vine biomass and any pest problems detected.

At least 21 of the accessions showed high yields and early bulking under heat-stress conditions, which makes them good candidates for further selection and breeding efforts. Heider noted that the test site has poor, sandy soil and some plants suffered drought stress, which means the accessions that performed well have real potential for relieving hunger and malnutrition on marginal lands.

"This is really promising because we now know that we have germplasm that we can send to areas that suffer heat and related stress. In many areas of Africa and Asia, all the good farmland is already dedicated to other crops, and as the population grows, farmers are moving into marginal areas," Heider said.

She explained that her team separated accessions according to know traits such as roots with high beta-carotene, or that are sweet or not sweet, which scientists in different countries are already breeding for. She added that the accessions in the CIP genebank are from all over the world, and some of the ones that performed best under heat stress are from Asia.

"The idea is that this information strengthens the breeding program," she said. "The next step is to send the accessions that performed well for multiple testing in other regions."

In addition to producing useful information for CIP's genebank and sweetpotato breeding program, the field study was innovative in its use of remote sensing data, thanks to a collaboration with the IRD office in Ecuador, a member of RTB's global partnership with French organizations. Information from remote sensing has not only enhanced the sweetpotato mass screening, it will strengthen the future use of this type of data for evaluation of sweetpotato in the field.

"The good news is that enough of the clones performed well that we have a lot of germplasm that could be used in marginal areas or under climate change conditions. If you look at the clones that performed well under both the heat-stress and winter scenarios,

they could be well adapted to the kind of weather extremes that climate change models predict," Heider said.

Drone Technology Brings Remote Sensing to a New Level

Emile Faye, a PhD student at the Sorbonne University who is working at IRD's Ecuador office, travelled to northern Peru to collect remote sensing data for the sweetpotato heat-stress screening. Faye used a drone mounted with visual and thermal cameras to record leaf temperature and canopy cover in the sweetpotato plots at 60 days and 90 days from planting. By correlating that data with the survival rate, root weight and other information recorded during the screening harvest, Heider and Faye hope to establish thermal and visual indicators that can help scientists to evaluate the development of sweetpotato and other crops using remote sensing data.

"We hope that we can use this technology for future evaluations and that it will make it easier to do phenotype analysis earlier in trials," said Heider, noting that it could be used for "high-throughput, early analysis of sweetpotato development."

Faye will use the data to strengthen a methodological framework that he is constructing for the use of remote sensing in landscape ecology. Working with Olivier Dangles, the head of IRD in Ecuador, Faye uses drone technology to study how microclimates affect crop pests. Most remote sensing data comes from satellites and is too low-resolution for application to microclimates. Drones permit the collection of high-resolution data for a small area, and allow scientists to bridge the gap between the climatic data used in models and the conditions on the ground experienced by the organisms they study.

Global Musa Experts Improve Banana Taxonomy

In December 2014, the Global Musa Genetic Resources Network, MusaNet, held a workshop in India to address the urgent need of Musa collection curators for an unequivocal standardized characterization of germplasm and its associated management of information. This includes ensuring the correct identification of the germplasm conserved and making the information available to all users. The workshop was held at the National Research Centre for Banana (NRCB), in Tamil Nadu, India. Participants included 22 representatives of the 13 partners of the Taxonomic Reference Collection Project (TRCP), and national and regional curators, as well as NRCB scientific staff. Sessions covered topics such as field characterization, field management, documentation and information exchange, global and regional contexts, and next steps planned by the TRCP.

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2 Accelerating the Development and Selection of Cultivars with Higher, more Stable Yield and Added Value

While conventional breeding programs at CIAT, CIP and IITA continue to develop and deliver improved varieties to their national partners for release, RTB is helping them to compile and analyze vast amounts of genomic, metabolomic and phenotypic data. Scientists of the RTB centers are in the process of linking these data and making results accessible to crop breeders around the world.

Through GWAS, researchers at CIAT have identified 181 genetic markers linked to important cassava traits that can be used to enhance breeding, such as root dry matter content, beta-carotene content, and resistance to diseases endemic to cassava's center of origin. They have also used genomic data to better understand the domestication of cassava in Latin America, which provides insight into the relationships among breeding populations and possible sources of useful genes.

CIAT molecular geneticist Luis Augusto Becerra Lopez-Lavalle, RTB Theme leader for: Development of Varieties, explained that metabolomic data can complement genomic data in helping scientists to understand the biological mechanisms behind important traits such as adaptation, resilience or pest and disease resistance. For example, metabolites that are always produced at high levels in varieties with good disease resistance, relative to susceptible varieties, can indicate a mechanism of resistance, which breeders and pathologists can exploit to accelerate resistance breeding.

"The RTB metabolomic research has produced the first metabolome diverse libraries for banana, cassava, sweetpotato and yam, which will be analyzed and made available to the RTB community in the next 18 months," he said.

Becerra explained that the metabolomic data can also be used for the identification of biomarkers for optimal adaptation of specific genotypes to specific environments, whereas they are particularly useful for understanding plant-pest interactions. He added that CIAT plans to do metabolomic analyses of cassava landraces that are either resistant or susceptible to whiteflies in 2015.

IITA is deploying genomic selection to breed for resistance to cassava mosaic disease and cassava green mite, among other traits. By the end of 2014, IITA had completed several cycles of genomic selection, with support from the NEXTGEN Cassava

project, managed by Cornell University and funded by the Bill & Melinda Gates Foundation. RTB has partnered with NEXTGEN Cassava to promote knowledge sharing and gender-responsive research on farmer trait preferences, which range from agronomic advantages such as high yield and disease resistance, to traits critical for processor and consumer acceptance for varieties processed into traditional food products.

"Genomic selection is the frontier of breeding. It's something that a lot of big companies are investing in and it could have some major benefits for these crops," said Hale Ann Tufan, NEXTGEN Cassava project manager.

A key component of NEXTGEN Cassava's work is using genomic selection to speed up the breeding process. In traditional crop improvement, breeders need to evaluate many progeny to identify viable new varieties. Because cassava is slow to mature and produces limited planting material, it takes years to obtain enough plants to perform this evaluation. Genomic selection could significantly speed up this process because breeders can predict the value of a new variety by analyzing DNA obtained from a young seedling. Varieties predicted to be good can then be used as parents to start a new breeding cycle, rather than waiting for lengthy evaluations. Nonetheless there are a number of factors that influence the efficacy of genomic selection, and high quality phenotyping, to accurately relate genotype with phenotype, is key among them.

Jean-Luc Jannink, a geneticist with the U. S. Department of Agriculture, an adjunct professor at Cornell and a member of the NEXTGEN Cassava team, is helping breeders at IITA, Nigeria's National Root Crops Research Institute (NRCRI) and Uganda's National Crops Resources Research Institute (NaCRRI) to implement genomic selection. IITA breeders Peter Kulakow and Ismail Rabbi have already completed several cycles of genomic selection with cassava and breeders at NRCRI and NaCRRI are following suit.

Jannink explained that the prediction accuracy of genomic selection in these first cycles was lower than anticipated, but the team is making changes in the process and incorporating genomic data from almost 10,000 cassava clones, which should improve the results of the next breeding cycles. Nevertheless, he noted that the process had already improved the effectiveness of participating breeding programs.

"I think that the project has helped each program improve its evaluation network. Data collection has gotten tighter in terms of reducing errors, improving experimental designs, timely delivery of data, and those kinds of things are really important for effective breeding," said Jannink. "I'm not saying that they weren't doing good work before, but I'm very impressed with the work they're doing now."

Breeders of the other RTB crops will need to wait for further development of each of the crop-specific components of genomic selection, such as development of training populations with high-precision phenotyping, but NEXTGEN Cassava's experience will provide lessons for the other RTB crops. CIP scientists have already evaluated the potential of using genomic selection for biofortification and adaptation to a long photoperiod and warm conditions for 150 diploid potato landraces and 171 tetraploid breeding lines. They found that best models for most of those traits were sufficiently predictive of breeding progress to merit implementation of genomic selection.

Making Genomic Data Accessible and Applicable to Crop Improvement

Bioinformatics – the use of computers to organize, analyze and share biological data – is a crucial component of efforts to unlock the genetic potential of RTB crops and help the centers and their partners use the resulting information for next-generation breeding. RTB is supporting the development of web platforms to manage the vast amounts of genomic and related data that are currently being generated for RTB crops, and is promoting collaboration among geneticists and bioinformaticians at various institutions to make that information accessible to breeders around the world.

RTB is promoting knowledge sharing and harmonization among the managers of existing bioinformatics platforms for RTB crops and has partnered with the Boyce Thompson Institute (BTI), an affiliate of Cornell University, for the development of shared databases for RTB crops and new breeding databases for banana and yam. RTB supported learning trips and other exchanges among scientists at BTI, Bioversity, CIAT, CIP, CIRAD, IITA and IRD in 2014 to help them learn about each other's programs, establish common bioinformatics protocols, and address emerging challenges. This has resulted in the creation of a community of practice of bioinformaticians working on RTB crops and a new level of collaboration that will greatly enhance efforts to develop improved varieties in the coming years.

While these scientists have years of experience in genomics and bioinformatics, and some were involved in the first complete genome sequencing of their crops of specialization, they face a major task in managing and making sense of the data currently being generated. Ongoing high-throughput genotyping, metabolite profiling and phenotyping of RTB crops by the centers and their partners is generating massive amounts of data that need to be cleaned, organized, and analyzed.

"There is an explosion of data. We've had a lot of discussions about how to clean and handle it," observed Lukas Mueller, an Associate Professor at BTI who is coordinating bioinformatic collaboration on RTB crops. Mueller developed the SOL Genomics Network, a collaborative platform that curates genomic data from Solanaceae species such as tomato and potato. He more recently developed CassavaBase, as part of the NEXTGEN Cassava project, which has partnered with IITA, NaCRRI and NRCRI. CassavaBase began hosting genomic data from CIAT's cassava sequencing efforts in 2014. Mueller's team is developing a platform called MusaBase for data on banana genomic breeding trials, and one called YamBase for comparable data on yam.

"The idea is to expand the cassava platform to the other RTB crops, so that everything we've learned and all the systems that we've created for cassava can be applied to other RTB crops," said Mueller. "Creating the system was a big effort, but once you've created the system, it isn't that expensive to apply it to other crops."

Mathieu Rouard, a Bioversity bioinformatician who collaborated with CIRAD on the first sequencing project for the banana genome and has worked on the Banana Genome Hub and the Musa Germplasm Information System, as well as the GreenPhyl comparative genomics platform, spent July working with Mueller at BTI and then accompanied him to CIAT and CIP for meetings with scientists there. He observed that cross-

center collaboration makes it easier to manage the "data deluge" created by RTB genomic and metabolomic research, adding that the effort is benefiting from contributions from several scientists involved in the South Green Bioinformatics Platform, which curates genomic information on tropical and Mediterranean plants.

"The good thing about bioinformatics is that what is developed for one crop can be used for another crop," Rouard said. "We are trying to have a consistent approach, and to avoid reinventing the wheel."

RTB scientists have already identified tens of thousands of genetic markers that can be linked to traits, but the challenge is to confirm which genes are responsible for key traits – various genes may interact to determine one trait – and make that information available to crop breeders.

"Most breeders lack the tools needed to use genomic data," observed CIP bioinformatician Reinhard Simon. One of Simon's priorities in 2014 was the establishment of 'phenotypic ontologies' – standardized terms for specific traits – for potato and sweetpotato, which will be linked to the genomic and metabolite data being generated for those crops. "There is still a lot of work to be done to build tools to make this data accessible to breeders," he said.

Bioversity scientist Elizabeth Arnaud is coordinating the development of RTB crop ontologies with Simon and colleagues at Bioversity and BTI. Mueller's team has largely standardized the cassava trait ontology based on phenotypic information from decades of field trials at IITA and CIAT.

"We want to create better tools for breeders and we want to integrate all the tools that have already been created," said Mueller.

Incorporating Women's Needs and Preferences into RTB Breeding

There have been many cases in which improved crop varieties released by NARES were poorly received by farmers because they lacked the flavor or another trait that farmers or consumers wanted. To ensure high adoption rates for the varieties they develop, breeding programs usually survey farmers about the traits they prefer, but all too often, those researchers rely disproportionately on the opinions of men. However, specialization of household roles means that women and men have different knowledge about and preferences for varietal traits. Women are usually responsible for food preparation and small scale processing, but their knowledge is rarely used for the varietal development process.

As RTB works to unlock the genetic potential of roots, tubers and bananas for improving food security, nutrition and incomes, it is also supporting field research to document gender-disaggregated trait preferences. The aim is to ensure that the improved RTB varieties developed in the coming years will have as widespread and gender-equitable an impact as possible.

"Next-generation breeding is helping breeders to speed up the process of developing new RTB varieties, but if we overlook the traits that farmers want, if we don't have the right targets, then

next-generation breeding could simply get us to the wrong place faster," observed RTB Program Director Graham Thiele.

An example of this problem was discovered by CIP gender researcher Netsayi Noris Mudege in a project promoting the cultivation and consumption of nutritious orange-fleshed sweetpotato varieties in Malawi. Farmer consultations had resulted in the release of a variety that produces large roots, which men prefer because they fetch a good market price. However, most women prefer another variety that wasn't released, because sweetpotato leaves are an important part of the local diet and the lobe-shaped leaves of that variety are better for cooking.

To avoid such oversights, RTB supported various initiatives in 2014 to get the trait preferences of both men and women into breeding pipelines. For example, Mudege and CIP potato breeder Asrat Amele produced an FAQ sheet on integrating gender into the participatory varietal selection of potato in Ethiopia and organized a training workshop in Addis Ababa for 20 representatives of CIP's main partners there.

RTB and NEXTGEN Cassava have co-funded the collection of gender-disaggregated trait preference data for cassava in Nigeria, using a methodology developed by NEXTGEN Cassava Project Manager Hale Ann Tufan and IITA Gender Focal Point Holger Kirscht. Tufan and Kirscht coordinated research in 2014 by interdisciplinary teams from IITA and NRCRI in eight farming communities in southeast and southwest Nigeria. The teams interviewed 10 women and 10 men of diverse ages and marital status in each village and conducted sex-disaggregated focus groups with 20-30 participants in most of them.

Potato farmers engaged in participatory varietal selection in Peru

Traditional cassava processing in Cameroon

"We're trying to bring diverse voices, including those of women and youth, into the breeding process. We're trying to tailor breeding programs for the diversity of users rather than opting for one-size-fits-all solutions," said Tufan.

Tufan explained that traits mentioned by the farmers range from agronomic advantages such as good yield to things like 'drawing' when cooked, which is important for making the traditional cassava dish gari. The goal is to get those most difficult quality traits into selection indices, to translate them into standardized, measureable breeding variables, and to link them to genetic markers for genomic selection. Cassava breeders Peter Kulakow (IITA) and Chiedozie Egesi (NRCRI) have helped to tailor the data collection tools in order to ensure that they yield data that will be useful for breeding.

RTB and NEXTGEN Cassava are also co-funding Cornell PhD student Paula Iragaba, who will return to her native Uganda in 2015 to conduct gender-differentiated field research on cassava trait preferences. Iragaba will work closely with Kirscht, CIRAD postharvest expert Dominique Dufour and breeders at NaCRRI to help them incorporate the preferred cassava traits that she documents into their cassava improvement program.

"This is really exciting because there is an opportunity for Paula to provide information and set up a model on how to capture and integrate gendered trait preferences into breeding programs," said Tufan.

Iragaba had an opportunity to explain her research to Bill Gates in October, when he visited Cornell campus to learn about the work of NEXTGEN Cassava, which the Bill & Melinda Gates Foundation funds. She was one of several graduate

students who gave short presentations about their research and answered questions from Gates.

"I talked about how women play a vital role in cassava production and processing in Uganda, and how their role needs to be considered by breeding programs in order to improve the adoption rates of new varieties," Iragaba said. "I'm sure that if gender issues are taken into consideration by our breeding programs, we are going to have tremendous improvements in adoption rates."

Tapping the Potential of Yam Bean in Benin

In 2014, CIP concluded the project entitled "Enhancing the nutrient-rich yam bean (Pachyrhizus spp.) storage roots to improve food quality and availability and sustainability of farming systems in Central and West Africa." Funded by Belgian Development Cooperation and RTB, the project was implemented in Benin, Ghana, Uganda, Rwanda, Burundi, and DR Congo. In Benin, the project comprised a dissemination component mainly conducted by the National Agricultural Research Institute of Benin (INRAB) and the non-governmental organization BØRNEfonden-Bénin, with promising results for the adoption of the crop in that country.

Farmer with the yam bean roots harvested on her farm in Zakpota, southeast Benin

The advantages of the yam bean, also known as ahipa or jicama, include good organoleptic taste, energetic and nutritional quality, low production costs, and enhancing soil fertility. "Yam bean can contribute to the sustainability of farming systems and can generate new resources of revenue for poor farmers," explained CIP sweetpotato breeder Wolfgang Grüneberg, who coordinated the project.

"Ahipa is well adapted to the growing conditions in Benin, and it's relatively easy to supply farmers with seeds. Also, the storage roots yield of the crop is remarkably high," he added.

CIP began introducing different yam bean accessions in the country in 2009, but only two accessions with low dry matter content were used in the distribution of the crop to farmers. Project partners INRAB and BØRNEfonden-Bénin also provided the farmers with basic training.

A first analysis of the dissemination and adoption of yam bean in six of the total eight agro-ecological zones of Benin showed an adoption rate of 47%. A survey of 75 villages, for a total of 101 producers, revealed that the main advantages of cultivating ahipa are the high storage root yields, high seed yields, which

facilitates rapid propagation and dissemination, and the various options for small-scale root processing, including gari (mixed with cassava), flour, juice or chips. However, the study concluded that currently, yam bean cultivation can only be profitable in Benin if producers process the crop.

"Training in processing is definitely needed to introduce ahipa in local diets in Africa, and to help farmers to improve revenues. This is a striking result, because in Central America and Asia, the crop is so far only used unprocessed," Grüneberg said.

Study Confirms that Novel Approach of Promoting Orange-Fleshed Sweetpotato through Antenatal Care Clinics Increases Vitamin A Consumption

Vitamin A deficiency (VAD) causes significant rates of blindness, disease, and premature death in Sub-Saharan Africa (SSA), and young children and pregnant or lactating women are particularly at risk. CIP promotes the cultivation and consumption of orange-fleshed sweetpotato (OFSP) because it is an important source of beta-carotene, which is converted to Vitamin A in the body.

One medium-size sweetpotato can provide enough beta-carotene to meet the recommended daily allowance of vitamin A for a child or non-lactating woman. It can, however, be a challenge to get women in SSA to farm and consume the crop. Nevertheless, a recent study on the impact of a CIP project promoting OFSP production and consumption to pregnant or

Mother and children celebrate OFSP during a special event at a health clinic in Bungoma, Kenya

lactating women in Kenya shows that linking OFSP provision to health delivery is an effective way to promote uptake.

Pregnancy is a particularly opportune time to reach women with nutritional and health interventions, which can lower their risk of VAD and enhance the survival and growth of their children during their first two years. CIP promoted OFSP through a novel intervention at selected health facilities in Busia and Bungoma districts of Kenya's Western Province within the AIDS, Population and Health Integrated Assistance Program (APHIA Plus), supported by USAID. The intervention, which ran from 2010 through 2014, successfully introduced farming and consumption of beta-carotene–rich sweetpotato as part of ante and postnatal care services. Community health workers encouraged pregnant

women to seek early care while pregnant women's clubs were established with monthly meetings focused on nutrition and health. During antenatal care visits, nurses provided nutrition counseling and vouchers that women could use to obtain OFSP vines to plant.

As of September 2013, over 5,900 pregnant or lactating women had received 7,159 pairs of vouchers. Out of this, 4,464 pairs of vouchers (63%) were redeemed for vines. Community health workers established 215 pregnant women's clubs made up of 2,764 members and, together with agricultural extension agents, disseminated information on the production and consumption benefits of OFSP through community field days and food preparation activities.

To assess the intervention's nutritional and health impact, a longitudinal cohort study of vitamin A (COVA) was undertaken from 2012 to 2014 with 505 women from mid-pregnancy through nine months postpartum. At the end of the study, dietary vitamin A intake among both mothers and infants in the intervention areas was nearly twice that of controls. VAD also decreased among mothers in the intervention areas compared to those in control areas.

"Vitamin A deficiency in pregnant and breastfeeding women is a significant public health problem," said Dr. Amy Webb Girard of Emory University, one of the lead researchers. "Finding solutions for pregnant and breastfeeding women that are safe, accessible, sustainable and acceptable is a challenge. When linked with public health efforts, OFSP holds significant promise as a strategy to overcome these challenges."


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Improving Pest and Disease Control and Farmer Access to Clean Seed

3 Improving Pest and Disease Control and Farmer Access to Clean Seed

RTB supports an array of research to improve the understanding and management of major pest and diseases affecting roots, tubers and bananas, as well as cross-crop research on the transmission of pathogens by planting material. At the same time, the Research Program is supporting the development of a cross-crop seed system framework, to strengthen interventions aimed at improving the availability of low-cost, high-quality planting material for farmers.

Improving the Management of Priority Pests and Diseases

RTB has catalyzed or contributed to collaborative research to improve the monitoring, containment and on-farm management of some of the most destructive diseases and pests affecting root, tuber and banana crops. With RTB support, new alliances and networks have been created and knowledge sharing and capacity building have increased, which should greatly enhance the ongoing research. Examples of this range from a cross-center effort to better understand seed degeneration in RTB crops to an array of initiatives to improve the management of specific pests or diseases.

Predicting Climate Change's Impact on RTB Pests and Livelihoods in Africa

Bioversity, CIAT, CIP and IITA are collaborating with UK government agencies, US universities and East African NARES on an effort aimed at helping the region's NARES manage RTB-critical pests and diseases under changing climates through risk assessment, surveillance and modeling.

At a planning workshop in January held in Kabale, Uganda, researchers identified two action sites – the Ruhengeri area of Rwanda and Burundi's Rusizi Valley – that represent a wide diversity of RTB farming systems along an altitudinal gradient. CIP, IITA, Bioversity and national partners subsequently coordinated a socioeconomic baseline survey

of more than 400 farm households at the two actions sites. Networks of weather stations were also installed at various altitudes in the action sites to provide a regional climatic database for climate change and pest and disease modeling.

"We are going to study the impacts of climate change not only on pests and diseases but also on the livelihoods of farmers in those areas," said Jürgen Kroschel, Team Leader for Agroecology and Integrated Pest Management at CIP.

At the same time, the centers moved forward on laboratory research to better understand temperature-dependent pest development in order to predict how climate change may affect pests using Insect Life Cycle Modeling (ILCYM) software, which was developed by CIP under a previous project. Both CIAT and CIP made good progress toward understanding how temperature effects virus transmission, and CIAT documented distribution records of cassava green mites and whiteflies – important virus vectors.

A key focus of the project is to strengthen capacity within the region's national plant protection organizations to produce and act upon pest risk assessment (PRA) documents. The UK Food and Environment Research Agency (FERA) and CABI are import partners in this area, and IITA has worked closely with FERA and CABI to provide partners with guidance on the theoretical basis for PRA and its application in the project target region. FERA hosted a joint training course in the UK, whereas CABI facilitated access for all project partners to documents of relevance to PRA and the description and management of target pests and diseases. IITA also partnered with Ohio State University to provide expert training in plant disease diagnostics for African researchers.

Working Toward an Integrated Approach to Seed Degeneration in RTB Crops

A cross-center initiative to improve the management of seed degeneration – the transmission and accumulation of viruses and other pathogens in crops via planting material – has brought together scientists from CIP, CIAT, IITA and Bioversity and several universities in an effort to better understand the dynamics of degenerative diseases and determine the most effective strategies for controlling them. Their collaboration over the past two years has resulted in the development of preliminary seed degeneration process models and the collection of data from the first growing cycle of multi-year field studies for the main RTB crops.

Degenerative diseases are one of the primary constraints for RTB crops, reducing yield and quality. While systems that

Yellow leaves of a potato plant infected with a virus transmitted by seed potatoes

produce and sell pathogen-free seed have been successful in controlling potato degenerative diseases in developed countries, few farmers in the RTB target countries have access to such 'clean seed systems.' The RTB seed degeneration team is thus promoting an integrated approach to the problem in the developing world that combines host plant resistance and clean seed replacement with on-farm management practices such as positive selection. The initiative has combined field research and modeling with a goal of producing crop-specific guidelines for which strategies are most appropriate for different biophysical and socioeconomic contexts.

Karen Garrett, a professor at the University of Florida's Global Food Systems Institute, is coordinating the development of models for predicting seed degeneration in RTB crops based on biophysical factors, such as climate, pathogen pressure and host-plant resistance, under different management approaches. Scientists from CIP, IITA, CIAT, the University of Western Australia, Imperial College London and Swedish University of Agricultural Sciences have provided input for the development and improvement of those models. However, they need to be further validated and fine-tuned using data from field trials.

"Models allow us to test hypotheses, but they depend on a lot of specific information that we don't have," observed CIP plant pathologist Greg Forbes, who is coordinating the initiative. "We still need to collect more field data to make the qualifiers more specific."

Forbes explained that seed degeneration research requires data from several planting seasons, so multi-year research on the main RTB crops is underway at more than a dozen sites on several continents. CIP has begun field trials to study sweetpotato virus degeneration in Tanzania and Peru, and trials with two potato cultivars in Ecuador. The potato modeling is also using data from relevant research in Ethiopia, Kenya, Uganda and China. Bioversity and IITA collaborated on a first season of field trials with several banana varieties to study transmission of the banana bunchy top virus by planting material. IITA and CIAT have conducted complementary cassava field trials in Tanzania and three regions of Colombia to study the transmission of several cassava viruses via planting material and whitefly vectors. IITA researchers have also completed a first season of yam seed degeneration trials in Nigeria and Uganda with eight cultivars belonging to three common yam species.

"As information comes in, we will plug in specifics to improve the models, in order to get management estimates for particular locations," said Garrett. She explained that one of the goals is to develop 'management performance maps' that will provide location-specific management guidance for farmers and extensionists. Work has also begun on a gender model that would be applicable across crops and pathogens.

In 2015, the seed degeneration research will be incorporated into an RTB initiative to develop a cross-crop seed systems framework, which will strengthen both lines of research. Garrett noted that she learned about the existence of data sets that could be used to improve the seed degeneration models at a meeting with the seed systems team in December of 2014. She added that an initial area of collaboration will be the application of impact network analysis to better understand how the biophysical and socioeconomic aspects of seed degeneration management interact. This tool will help to link the seed degeneration data with the research done for the framework and thereby improve the scientists' understanding of seed systems.

International Meeting Engenders African Network to Control Cassava Diseases

RTB supported a gathering of cassava experts from international agricultural research centers and an array of African institutions in June of 2014 that resulted in new collaboration and proposals for improving the monitoring and management of cassava diseases and pests.

More than 40 scientists from CIRAD, IRD, IITA and African national and regional organizations gathered in Saint-Pierre, on the island of La Réunion, for a three-day meeting. It was organized by the Global Cassava Partnership for the 21st Century (GCP21) as a first step toward implementing a roadmap to improve the management of the viral and bacterial diseases that are destroying cassava harvests across much of Africa. The roadmap, which was published in the journal Food Security in 2014, resulted from an earlier RTB-supported gathering of cassava specialists held at the Rockefeller Foundation Center in Bellagio, Italy in May of 2013.

Participants in the international workshop on surveillance and control of cassava diseases in Africa held in Saint-Pierre-de-la-Réunion

The principal accomplishment of the meeting in La Réunion was the creation of the Pan-African Cassava Surveillance Network (PACSUN), which aims to add value to the work of existing organizations and networks by providing diagnostic expertise and information on viruses and bacteria affecting cassava, as well as their whitefly vectors, and by coordinating appropriate responses to halt or slow their spread.

"With partnerships of over 10 institutions, we will have more knowledge, more funds and more speed in tackling the problem of cassava diseases," said Maruthi Gowda, a scientist at the Natural Resources Institute (NRI), University of Greenwich, UK.

Specific proposals for PACSUN include harmonizing protocols for proper and efficient diagnosis of cassava diseases, promoting the use of mobile phone technology for diagnostic purposes, consolidating information on cassava diseases in one website, and mapping the incidence of those diseases across Africa.

Hortense Atta Diallo, Director of the Plant Production Research Pole at Nangui Abrogoua University, in Côte d'Ivoire, is enthusiastic about PACSUN's potential. "I already lead a project that mapped cassava diseases in my country. Through this new network, we can pool all our activities and find solutions that will improve the lives of cassava producers," she said.

Workshop participants visited the state-of-the-art laboratory and field station at the Plant Protection Platform (3P Centre) in Saint-Pierre and met with the Centre cassava specialists. One of the proposals that came out of the workshop is the establishment of an international cassava transit site at the 3P Centre that would allow for the exchange of cassava material between countries in Africa or other continents via La Réunion, which is free of cassava diseases. Moving cassava germplasm

across African borders is currently banned due to the risk of spreading cassava mosaic disease (CMD) and cassava brown streak disease (CBSD). However, given La Réunion's remote location in the Indian Ocean yet relative proximity to the African continent, it could be an ideal site for certified pathogen-free cassava cultivars to be propagated and exchanged between continents.

"Having an International cassava transit center such as the one proposed in La Réunion would allow the global cassava community to exchange cassava genotypes in complete security," said GCP21 Coordinator Claude Fauquet. "Scientists need to have access to cassava diversity for gene mining, breeding and research purposes, and having such a center would permit the resumption of cassava germplasm exchange."

Supporting Collaboration to Confront TR4: the Latest Threat to Bananas in Africa

Scientists at Bioversity and IITA played a key role in efforts to forge an international response to the first African outbreak of an extremely destructive race of the banana disease Fusarium wilt known as Foc TR4, which was discovered on a banana farm in Mozambique in late 2013. Bioversity and IITA were instrumental in the creation of an African consortium to deal with the threat of TR4, which includes the main national and international research, regulatory and trade organizations. They have since supported efforts to help the farm in Mozambique where TR4 was discovered to implement the recommended containment and management practices, and were instrumental in the delivery of three TR4-resistant somaclonal variants from the Taiwan Banana Research Institute (TBRI) to Mozambique in 2014 for evaluation.

Bioversity and IITA scientists played active roles in expert consultations in 2014 held in South Africa in April and Uganda in October to develop a regional strategy and advance risk-management frameworks for East and Southern Africa. They have participated in national workshops in Asia, East Africa, Latin America and the Caribbean (in conjunction with FAO), and collaborated closely with FAO in a global expert meeting to develop a multi-million dollar program to strengthen the global response to the threat of Foc TR4.

Learning Alliance Creates Synergies to Help Farmers Beat BBTD in Africa

One of the most extensive networks that RTB supports is the 'learning alliance' created to contain and help farmers recover from banana bunchy top disease (BBTD) in Sub-Saharan Africa. Bioversity, CIRAD and IITA are coordinating and backstopping the Alliance, which includes an array of national and local partners in Benin, Nigeria, Cameroon, Gabon, Congo Brazzaville, DR Congo, Burundi and Malawi.

The initiative's partners include government ministries, national research centers, universities and communities. Together, they are testing approaches to help farmers recover from BBTD, develop supply chains of uninfected planting material, and build knowledge of the virus that causes the disease and its insect vector.

BBTD is caused by the banana bunchy top virus (BBTV), which can be transmitted by the banana aphid Pentalonia

Mottled inflorescence of a banana plant infected with the banana bunchy top virus (BBTV) at a late stage of development

nigronervosa or infected planting material. It has been reported in 14 countries in Africa, where it has caused food insecurity and income loss for millions of families. The learning alliance is working with rural communities in the eight target countries to develop containment and recovery strategies that can be scaled out to other affected regions and nations.

Charles Staver, a senior scientist at Bioversity and co-coordinator of the initiative, observed that the Alliance's success lies in the strength of its partnerships. He said that while RTB is building on previous work to assess the extent of the BBTV's spread and raise awareness, it has resulted in unprecedented cooperation and field research on the disease in Africa.

"All pilot sites have partnered with new communities to establish banana-free periods and a supply chain for BBTV-free planting material. The partnerships between the CGIAR Centers, national research organizations and community organizations are working well," Staver said.

Work at pilot sites began after a planning workshop in Bujumbura, Burundi in January 2014, whereas delegations from the target countries travelled to CIRAD headquarters in Montpellier, France in July 2014 for diagnostic training. A total of 20 researchers, including five women, received training in banana virus diagnostics for clean seed production, safe germplasm exchange and surveillance.

"Training in developing diagnostic skills is one of the focus areas of the project. Researchers at the pilot sites have improved the quality of their diagnostic protocols for virus indexing since the training in Montpellier," said CIRAD virologist Marie-Line Iskra-Caruana.

According to IITA virologist Lava Kumar, a co-coordinator of the Alliance, its focus on building research capacity includes the involvement of three PhD students and five MSc students. In addition to backstopping research at the pilot sites, the RTB centers are tracking BBTD's expansion in Africa, and assessing the resistance of banana and plantain landraces and synthetic hybrids, and the dynamics of virus-vector-host relationships. Molecular epidemiology on the virus and aphid vector has begun in Benin, Nigeria and Cameroon. Diagnostic tools for virus detection have also been improved, including the adoption of Loop Mediated Amplification technology for rapid BBTV detection in the field.

"The pilot sites are proving to be effective platforms for testing new strategies and technologies and excellent in-situ venues for learning, training, and capacity strengthening. The pilot zone concept can be scaled up and scaled out in the eight

target countries, and expanded to the other five BBTD-affected countries – Angola, Central African Republic, Equatorial Guinea, Rwanda, and Zambia – in the next phase," said Kumar.

Assessing Disease Threats to Taro and Cocoyam in West & Central Africa

The edible aroids taro (Colocasia esculenta) and cocoyam (Xanthosoma sagittifolium) can be grown on marginal land and are crucial for the food security, nutrition and livelihoods of millions of poor farmers – especially women – in West and Central Africa. However, these vital crops are increasingly threatened by two diseases – taro leaf blight (TLB) and cocoyam root rot disease (CRRD) – that have led many African farmers to abandon the crops.

Whereas CRRD has been affecting cocoyam in the region for decades, TLB was unknown in West Africa until 2009, when outbreaks were reported in Nigeria, Cameroon and Ghana. Outbreaks have since been reported other countries, and the disease is estimated to be incurring losses of more than US$1.4 billion in the region annually.

RTB commissioned Joseph Onyeka, a senior plant pathologist and the coordinator of Farming Systems Research Programme (FSRP) at NRCRI, to undertake a scoping study of the crops' status in West and Central Africa. The study, which was completed in early 2014, provides an overview of the situation of the two crops and specific recommendations for confronting the disease threat.

"These crops are not only very important for the livelihoods

Cocoyam leaves for sale in Cameroon

of poor farmers, they are food security crops in West and Central Africa, particularly in Nigeria, Ghana and Cameroon," said Onyeka. "They also have better nutritional qualities than other root crops such as cassava and yam, with relatively higher protein, vitamin and mineral content."

Onyeka noted that farmers across the region are suffering the effects of the diseases' destruction. In a survey of 70 taro fields in Nigeria, he found that the incidence of TLB ranged from 65% to 90%. He explained that because farmers in West Africa had never seen the disease before 2009, they have no idea how to manage it. He added that these two diseases not only constitute threats to incomes and food security, but they could also deplete diversity in the crops' already narrow genetic base.

Onyeka's recommendations include: creating a regional network of specialists on the two crops in West and Central Africa; completing a comprehensive assessment of TLB and CRRD in the region; conserving and characterizing the genetic diversity of the two species in West and Central Africa; improving the genetic base of the two species in the region through

germplasm exchange; and initiating breeding for resistance to CRRD and TLB.

"Those who depend heavily on these crops for survival – the most vulnerable groups – have neither the resources nor the voice to influence their future. It is the responsibility of scientists and policymakers to change this situation through strategic interventions," Onyeka said.

Supporting Efforts to Control Emerging Threats to Cassava in Asia

RTB has supported recent efforts by CIAT and local partners to confront emerging cassava pest and disease threats in Southeast Asia. In recent years, the pink mealybug appeared in Indonesia's major cassava producing areas, and CIAT has moved quickly to avoid the kind of destruction that pest inflicted in Thailand, where it caused a 30% reduction in the country's cassava production in 2009. CIAT has taken initial steps toward the introduction of a parasitic wasp (Anagyrus lopezi), which successfully brought the pink mealybug under control in Thailand.

Another emerging threat in the Southeast Asia is cassava witches' broom disease, caused by a phytoplasm (a bacteria without a cell wall). The disease is reported broadly in the region, but is of special concern in Cambodia, where recent surveys found that 80% of fields have plants with symptoms.

RTB has supported CIAT's efforts (also funded by the European Commission through the International Fund for Agricultural Development) to develop surveillance and integrated pest management systems together with national partners in all the cassava-growing countries of Southeast Asia, especially Vietnam, Laos, Cambodia and Thailand. Those national partners have little experience with these threats to cassava production, since they are new to the region, so both IITA and CIAT can provide a wealth of information and experience to efforts to control them in Southeast Asia.

A network of researchers spearheaded by CIAT and regional partners is undertaking diagnostic and training programs to speed up pest and disease detection. Scientists are developing low-cost rapid pathogen detection kits, while gaining valuable insights into the biology and ecology of non-native cassava threats. In the long-term, CIAT and national and international partners will continue investigating more resilient cassava varieties and integrated pest management systems while promoting quarantine measures to stem the spread of pests and diseases in the region.

Promoting a Farmer-Friendly Method to Control Banana Xanthomonas Wilt (BXW)

Bioversity, IITA and the Institutional Learning and Change (ILAC) Initiative are collaborating on efforts to get banana farmers in Eastern and Central Africa to adopt a new approach to managing banana Xanthomonas wilt (BXW) that enables them to contain that devastating disease without having to destroy large amounts of plants. Widespread adoption of this 'single diseased stem removal' (SDSR) technique has the potential to bring the disease under control while saving labor and money.

BXW first struck East Africa in the early 2000s, and by 2004, 33% of farms in Uganda were infected and yield losses were estimated

A shriveled male bud and uneven ripening are characteristic symptoms of BXW

to be 30-52%. Agricultural extension officials advised farmers to remove all infected 'mats' (two or more banana stems growing together) and replant with clean planting material. While this strategy proved effective, it is costly, labor-intensive and results in a major loss of food and income – not to mention banana biodiversity – so many subsistence farmers resisted implementing it.

Scientists from IITA and Bioversity collaborated with Uganda's National Agricultural Research Organization on field studies at a site in Kifu, Uganda from 2008 -12 to assess the systemicity of the bacteria that causes BXW in plants and mats. The results indicated that few stems in an infected mat will show disease symptoms. The researchers also noticed that some farmers who were reluctant to destroy entire mats of bananas had resorted to cutting only the visibly infected plants, and continued to harvest bananas.

While IITA began work to develop BXW-resistant bananas in Uganda, a Bioversity team led by scientist Guy Blomme tested a management approach using SDSR in eastern DR Congo. They began at the village of Katana centre, in South Kivu, where BXW incidence averaged 80% in February 2013. Within one month, BXW incidence had dropped to below 10%, and within three months of application, it was below 2%.

"Results across the pilot sites are very consistent," said Blomme. "If farmers cut all diseased shoots off at soil level, incidence can easily be kept below 1%."

By the end of 2014, SDSR was being evaluated on 540 smallholdings across 10 pilot sites in South and North Kivu and initial results showed that SDSR can reduce disease incidence from as high as 90% to less than 1% in 6 to 10 months. The Katana pilot site now serves as a demonstration farm where more than 500 representatives of government agencies, NGOs and farmer associations, and individual farmers have learned about the technique.

"We show them photos of what the site looked like two years ago. It's like day and night," Blomme said.

The control package was fine-tuned through transdisciplinary research conducted in South Kivu in 2013 and 2014 by a team that included social and biophysical scientists from ILAC and Bioversity who analyzed results together from agronomic and social science perspectives. The researchers worked with farmers' groups to test

the recommended package under farmer conditions. Results in farmer-managed plots showed that SDSR and sterilizing machetes with fire after cutting diseased stems could keep incidence below 1% under the agro-ecological conditions of South Kivu.

"Our results have all sorts of implications, not only for scaling out SDSR but also for research priorities," said ILAC coordinator Javier Ekboir. He added that the team reached conclusions that will facilitate the tailoring of the SDSR package to different agro-ecological conditions and identified general principles for the implementation of transdisciplinary research.

Blomme noted that BXW poses a major threat in Burundi and especially in North and South Kivu. FAO studies have found that the disease is moving into the Congo Basin, where millions more depend on bananas and plantains for food and income. The good news is that government agencies and NGOs are interested in promoting SDSR.

In September 2014, Bioversity and IITA researchers gathered with government and NGO representatives in Kampala, Uganda to plan an RTB initiative for managing BXW that includes both SDSR and breeding for resistance. The workshop resulted in an impact pathway for improving management of BXW and catalyzed greater cooperation around the issue.

Group meeting on BXW in Bugohre, Kabare Territory, South Kivu, DR Congo

Emmanuel Njukwe, an associate scientist at IITA, said that many workshop participants attended a follow-up meeting in Bukavu, South Kivu, after which the FAO and the DR Congo National Institute for Agronomic Study and Research began organizing monthly meetings on BXW in South Kivu with more than a dozen organizations. "We have been doing a lot of training in stakeholder workshops and we are trying to engage policy makers so that we have synergy and an approach to scale out this technology," he said.

The provincial branch of the DR Congo Ministry of Agriculture in North Kivu has already commissioned a BXW management project based on SDSR. RTB scientists are helping the international NGO Food for the Hungry to promote the SDSR package in South Kivu. They are providing comparable support for Catholic Relief Service's BXW work in Burundi's Muyinga province, where Bioversity and ILAC will collaborate on further transdisciplinary research to determine the most appropriate management strategy for that region.

RTB scientists envision promoting SDSR and other BXW management options to half a million smallholders who currently lose up to one third of their banana production to the disease – equivalent to an annual loss of more than US$200 million. This will be accomplished by partnering with government agencies, NGOs and farmer associations, as well as through linkages to the CGIAR Research Program on Integrated Systems for the Humid Tropics (Humidtropics) R4D and innovation platforms.

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4 Making Available Low-Cost, High-Quality Planting Material for Farmers

RTB crops are propagated vegetatively: by planting tubers, suckers, stalks or vine cuttings, which are commonly referred to as 'seed.' The bulkiness and perishability of that 'seed,' combined with relatively low multiplication rates for RTB crops, create serious challenges for smallholders and programs that aim to help them improve their agricultural production. The RTB partnering centers have implemented seed system interventions to reduce yield loss due to seed degeneration, disseminate improved varieties, and help farmers recover from the devastation of crop diseases. At the same time, RTB is funding a cross-crop initiative to develop a conceptual seed systems framework that will be used to assess and improve seed system interventions in the future.

New Technologies Developed to Boost Yam Seed Production in West Africa

Traditional seed production for yams is expensive and inefficient. Farmers save 25% to 30% of their harvests for planting the following season, which means less income and food for their families. At the same time, the accumulation of viruses in seed yams causes significant yield loss. IITA researchers have thus been testing new technologies for producing pathogen-free yam planting material. Aeroponic and temporary immersion bioreactor systems have been set up and tested at IITA headquarters at Ibadan, Nigeria with good results. Aeroponic propagation, which CIP has widely promoted for potato, consists of growing plants in the air in a misty environment without the use of soil or aggregate media. IITA successfully used aeroponics to produce seed yams in 2013, but a cost-benefit analysis in 2014 demonstrated the need to improve the system's efficiency and increase the propagation ratio to reduce the unitary cost.

A more cost-effective alternative for yams may be bioreactor systems, which produce plantlets in enclosed, sterile units with a liquid medium and inlets and outlets for airflow under pressure. So far, 128 bioreactor units have been installed at IITA and 11 Dioscorea genotypes (3 D. alata, 8 D. rotundata) have been successfully propagated in them. Between 50 and 100 plantlets were produced per bioreactor, with a total of approx. 10,000 plantlets produced in 2014.

Aeroponic seed yam production in Nigeria

IITA has also trained seed producers in efficient seed multiplication techniques, breeder and foundation-seed yam production sites have been established in Nigeria and Ghana, and public and private-sector capacity in application of cost-effective and high-ratio seed yam propagation techniques has been improved. Capacity has also been strengthened in seed yam quality certification and the production of certified seed yam.

Building Capacity to Produce Quality Seed Potatoes for Farmers in Tanzania

Potato yields in Africa tend to be far below the international average, but smallholders in the Tanzanian highlands who benefited from CIP's efforts to strengthen the production and distribution of clean seed potato significantly increased their harvests in 2014. Under a three-year initiative funded by the Government of Finland and co-implemented with the University of Helsinki, CIP strengthened the capacity of three Tanzanian institutions to test potatoes for pathogens, produce clean seed potato, and help farmers and the private sector to multiply clean seed for sale.

CIP provided equipment and training for clean seed reproduction using tissue culture and aeroponics, and supported the training of private and community seed multipliers in four districts, to ensure that the intervention has as wide an impact as possible. Farmers were also taught positive selection techniques for collecting healthy seed from their own harvests, and a CIP positive selection manual

was translated from English to Kiswahili – the local language – for the training of trainers.

"This project has set a foundation that had been long overdue. It has opened new possibilities in potato research and seed production," observed Dr. Zacharia Malley, a zonal director of research and development based at Uyole Agricultural Research Institute.

Clean Planting Material to Combat Banana Moko Disease in Latin America

Moko bacterial wilt is the principal bacterial disease limiting plantain production in Latin America and the Caribbean, and it is primarily spread between farms and regions via planting material. Moko disease can destroy up to 75% of crop production in an affected area, and annual losses in the region have been calculated to be more than US$100 million. Most farmers use agrochemicals to combat the disease, but interdisciplinary teams of scientists from CIAT, CIRAD and regional and national partners have been working on sustainable solutions for managing the disease, where improving the production of clean planting material has played an important role.

A significant development is the use of a thermotherapy chamber for mass propagation of disease-free planting materials. CIAT designed and piloted an inexpensive, efficient and completely automatic system to produce clean planting materials. Once the conditions needed to propagate planting materials were determined, a larger thermal chamber was constructed that is currently producing pathogen-free planting material for 7,000 farmers in central Colombia.

The technology has since been adopted by at least 10 nurseries or planting material production centers in Colombia. CIAT scientists helped nursery entrepreneurs to improve their production processes and scale the technology out, while involving female household heads in preparations for planting material production and caring for plantlets. Field studies found that monthly production increased by as much as 90 plantlets, from 15 suckers per square meter, with a total production of 980,000 plantlets propagated and distributed to farmers in 2014.

Developing a Cross-Crop Seed Systems Framework

While the RTB centers and their partners have executed an array of seed system interventions over the years, they have reached only a small portion of the farmers who need affordable access to high-quality planting material. To address this shortcoming, RTB has funded a cross-center initiative called: "Accelerating learning and tackling bottlenecks through a conceptual framework for roots, tubers and bananas seed systems." The project catalyzed the creation a community of practice by researchers at Bioversity, CIAT, CIP, IITA and Wageningen University, in the Netherlands. Together, they have studied the scientific literature and specific cases of seed system interventions for RTB crops in an effort to identify common obstacles and factors for success, and to apply those lessons to the development of a conceptual framework for assessing such

Transporting cassava roots in Benin

interventions. That team's aim is for the framework to be used to systematically evaluate RTB seed systems, in order to improve their design and implementation, and to help scientists develop hypotheses for future research in this area.

"It is an iterative process," said Jorge Andrade-Piedra, CIP scientist and the RTB theme leader for planting material. He explained that after designing a preliminary framework, the seed systems team developed a series of research questions that they tried to answer through the documentation of case studies. In 2014, the team completed 10 case studies of seed systems interventions: potato projects in Ecuador, Peru and East Africa, a banana intervention in East Africa, yam in Nigeria, cassava

in Nicaragua and Africa's Great Lakes region, and sweetpotato projects in Rwanda, Malawi and Tanzania. They then analyzed those case studies at a workshop held in December 2014 in Wageningen, focusing on three issues: farmer demand for planting material, policy and regulation of certified seed, and multiplication techniques.

"The case studies documented common problems with seed system interventions. For example, in many cases the perspective of the beneficiaries wasn't taken into account," said Andrade-Piedra. "We need to better understand the demands of farmers, their perception of quality, and the seed practices that they use."

Andrade-Piedra noted that another common problem hindering seed system interventions is that their design isn't based on hard data. "People have ideas, but they don't have the data to show what approach is better. One of the issues we are trying to address is to have interventions based on data. We need evidence-based interventions."

Conny Almekinders, a member of the Knowledge, Technology and Innovation group at Wageningen University, noted that seed system interventions are often too short to have a lasting impact, and based on the cases studied, they seem to pay insufficient attention to the work of national seed programs and the needs of farmers. She expressed frustration that organizations continue to fund or implement seed systems strategies that have had limited success in the past. "There has been so little reflection and drawing out of lessons learned that we have no justification for continuing to repeat the same cycles," she said.

While she admitted that there is no "silver bullet" to correct the deficiencies of all seed systems strategies, Almekinders believes that most interventions lack a full scope of the seed system's functions and all the actors involved. She hopes the conceptual framework will help to fill this gap. The framework will be applied to the Marando Bora sweetpotato project in Tanzania in 2015, in order to test and improve the framework and draw lessons from the project that might be applied to other seed system interventions.

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Improving Cropping Systems and Postharvest Technologies

5 Improving Cropping Systems and Postharvest Technologies

RTB is keen to understand the role that cropping systems can play in enhancing crop yields and farm sustainability, and has supported studies on plantain and yam cropping systems in West and Central Africa. RTB also supported varied research on postharvest and value chain innovations that have benefitted from cross-center collaboration and shown real potential for improving smallholder incomes and the social and environmental impacts of postharvest processing.

Developing Tools for more Productive, Ecologically Robust Cropping Systems

Scientists recognize that there are opportunities for improving RTB crop production through the diversification and intensification of cropping systems, which can increase yields and provide resilience in the face of climate change and other stresses. RTB has supported IITA research on inter-cropping systems with plantain or yam in West and Central Africa that produced important results in 2014.

Keys to Improving Plantain Yields for Smallholders in West and Central Africa

Originally from South East Asia, the plantain (Musa spp.) is an important staple across West and Central Africa, where it is primarily grown by smallholders. It is the third most important starchy staple in the populous countries of DR Congo and Nigeria. The region is also the world's secondary center of plantain diversity, with more than 100 cultivars identified. However, plantain yields in West and Central Africa are considered to be low, though on-farm data is scarce.

Stefan Hauser, an agronomist at IITA and the RTB theme leader for cropping systems, recently completed research on smallholder plantain systems in the region with the objective of improving yields. With Lindsey Norgrove, a tropical agroecologist at the University of Basel, Switzerland, Hauser began by collating and synthesizing regional research results. The two then estimated actual yield on smallholder farms, summarized the results of research on innovations in the region, and calculated estimates of attainable yields if 'best-

Cocoyam intercropped with banana

bet' innovations, or combinations of innovations, were adopted. They also calculated the gaps between actual, attainable and potential yields. The results of their research are available in an open-access scientific paper published in the journal Food Security.

"We first screened and reviewed the available literature – more than 350 articles, mostly peer-reviewed and published between 1976 and 2013. Only articles containing original yield data, given as bunch mass, bunch yield per hectare and/or bunch yield per hectare per year, were included," said Hauser. He explained that only publications with clear methodologies and reporting only plant crop yields (not "ratoon yields" from suckers) were considered. Given a lack of on-farm yield data, they complied data from FAOSTAT and compared it with data from no-input controls of researcher-managed experiments, as a proxy for actual on-farm yields.

Hauser and Norgrove identified five common plantain cropping systems across the region: food intercropping systems; home garden systems; plantain-cacao systems; other agroforestry systems; and monocropping systems, the latter being the least common. "Plantain is traditionally intercropped, whether with yam, beans, cassava, okra and others," said Hauser, noting that research indicates that only 13.5% of plantain production in Africa is from smallholder monocropping systems.

The researchers also looked into abiotic factors such as fertilizers, mulch application and irrigation, as well as biotic factors such as sucker sanitation methods. Several experiments assessed the impact of intercropping other food crops with plantain, generally showing a positive or neutral impact on yield.

The exception was intercropping with cassava, which negatively impacted the plantain yield unless large amounts of potassium fertilizer were applied.

Although fertilizer application is usually very low in sub-Saharan Africa, the authors concluded that inputs such as potassium and mulch could reduce plant loss and increase bunch mass. The research also indicates that the application of hot water to plantain suckers effectively controlled nematodes and weevils. Experiments in central Cameroon showed 17% and 47% yield increases in false horn and French cultivars from this practice. When combined with fertilizer, this resulted in 48% and 135% yield increases, respectively.

Norgrove, L., Hauser, S. (2014) Improving plantain (Musa spp. AAB) yields on smallholder farms in West and Central Africa. Food Security. DOI 10.1007/s12571-014-0365-1. (http://nextgen-agronomy.org/publications/)

Boosting Yam Productivity Through Intercropping and Soil Enhancement

As part of research to improve yam productivity in low fertility soils, scientists at IITA undertook a field trial on intercropping yams with trees and tested integrated soil fertility management with farmers.

Researchers established an agroforestry plot with 30 local tree species at the IITA campus in Ibadan, Nigeria in order to identify which tree species are highly compatible with yam. During the first year, the trees were intercropped with cowpea, and during the second year, yam was planted among the trees at a density of 10,000 plants per hectare. The yams were harvested seven months after planting and the results were analyzed. They found that yam yield was especially good when intercropped with the tree species Funtumia elastic (Apocynaceae) and Milletia aboensis (Fabaceae). The researchers will establish plots with these two species for further screening and select improved yam varieties for use in this cropping system.

Yam for sale in a Benin market

IITA also contributed to integrated soil fertility management (ISFM) interventions with farmers in Ghana and Nigeria to increase yam productivity in areas of low fertility soil and high poverty. Using a participatory approach, ISFM was planned, adjusted, established, and evaluated by farmers and scientist from IITA, Ghana's Savanna Agricultural Research Institute (SARI) and Nigeria's NRCRI. In Ghana, farmers selected two ISFM interventions that combined organic and synthetic fertilizer and applied them to the most popular landraces in densities of 10,000 plants per hectare. In Nigeria, the two best ISFM interventions included soil fungi (micorrhizae) and synthetic fertilizer. Plans were made for scaling ISFM out to more areas and increasing technology transfer during the next two years.

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6 Promoting Postharvest Technologies, Value Chains and Market Opportunities

Roots, tubers and bananas present particular postharvest challenges, given their bulkiness and perishability, yet those challenges can also lead to opportunities, since improvements in storage, marketing or processing can significantly boost the incomes of smallholders, traders and processors. RTB funded an array research in 2014 to improve the storage or handling of root and tuber crops, facilitate market opportunities, and improve value chain participation.

Uganda Postharvest Project to Test Value Chain Innovations for RTB Crops

RTB launched a three-year initiative in 2014 to improve postharvest management practices for banana, cassava, potato and sweetpotato in Uganda through collaborative research. The project, which is funded by the European Commission through the International Fund for Agricultural Development (IFAD), began with a participatory process to catalyze cooperation and identify postharvest research needs for the four crops, followed by the selection of a best-bet intervention for each one.

Banana, cassava, potato and sweetpotato are the principal food security and income-generating crops in Uganda, which makes it an ideal country to test innovations and share knowledge on cross-crop issues. Diego Naziri, a value chain expert who is coordinating the initiative for CIP, explained that its areas of action include developing local capacity and improving postharvest handling and processing in order to exploit emerging market opportunities.

"We'll be testing technological, commercial and institutional innovations within Uganda that will hopefully have relevance for other East African countries," he said.

The project was launched with a workshop in March, which resulted in the creation of multi-agency teams that are currently studying business cases for each crop. One business case aims to improve farmer access to specialized ware potato markets through improvements in storage technologies. Another will test techniques for extending the shelf life of cassava such as high relative humidity storage and coating roots with paraffin wax. Another aims to improve the utilization of sweetpotato and root-and-tuber waste products as pig feed.

Sweetpotato for sale in Uganda

Another aims to identify cooking banana varieties and farming practices that will facilitate a steadier market supply, while diversifying the way cooking banana is presented and sold.

Bioversity researcher Enoch Kikulwe, who is coordinating the banana initiative, noted that the variety of expertise within that team – which includes representatives of CIRAD, IITA, Bioversity, NARO, KAIKA Investment Company, the Ssemwanga Centre for Agriculture and Food Ltd. and the Mbarara District Farmers Association – is a real asset.

"I think that this subproject will move forward faster and more concretely thanks to the diversity of this collaboration," Kikulwe said.

Kikulwe explained that the highest margins in cooking banana value chains are earned by (mostly male) middlemen, whereas women dominate the retail market, where the margins are relatively low. The team is consequently looking for ways to increase the retail margins and promote women's participation in market-chain links with higher margins.

A capacity building plan for the four business cases was developed in the first half of 2014 and training in the Participatory Market Chain Approach (PMCA) began in June. PMCA was developed more than a decade ago in Peru to bring smallholders, traders and companies together to jointly identify, analyze, and exploit potato market opportunities. Naziri said that PMCA has played an important role in getting Uganda's private sector involved in the project, adding that about 10 companies have already joined it and hundreds of traders and smallholders are expected to participate. He added that to strengthen cooperation around the project, a steering committee was established that includes representatives of the RTB centers, NARO, Makerere University and the Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA).

Ivan Rwomushana, manager of the Staple Groups Program at ASARECA, said he expects lessons learned from the project to be scaled out to other countries where RTB crops are important, such as Kenya, Rwanda, Burundi and Tanzania. "ASARECA anticipates that the exciting innovations from this project will be shared to benefit the millions of people who depend on RTB crops for their livelihood," he said.

Measuring the Environmental Impact of Cassava Processing

While millions of people consume fresh cassava roots, much of the cassava produced in developing countries is turned into starch and food products at processing centers that range from small-scale operations to industrial-sized plants. Each of those plants has environmental impacts that include the emission of greenhouse gasses, wastewater and solid waste, as well as water use. However, environmental impacts vary widely from one processing unit to another, and the use of energy and water per ton of product isn't necessarily linked to production capacity.

RTB funded research in 2014 on the environmental impacts of cassava processing and lifecycle assessments, to generate information on how efficiencies might be improved. The research included the participation of CIRAD, IITA, CIAT, UK's Natural Resources Institute, Colombia's Universidad del Valle, and Kasetsart University and King Mongkut's University of Technology Thonburi (KMUTT) in Thailand, and was undertaken simultaneously in Colombia, Nigeria, Tanzania, Thailand and Vietnam. Thierry Tran, a CIRAD researcher based in Thailand, coordinated that project, with significant support from Arnaud Chapuis and Marcelo Precoppe, post-doc fellows at CIRAD and IITA.

Their research focused on energy and water use, and greenhouse gas emissions from the transformation of cassava roots into starch. Economic aspects, such as the structure of production costs and profits, were also investigated. A model for flash drying of starch and high quality cassava flour was developed and validated, which should accelerate the development of more energy efficient dryers.

"There is a clear demand for improved processing in these countries," said Tran. "To this effect, we considered three different benchmarks: production costs, energy and water costs, and environmental impacts. The re-engineering work had to focus on modeling the technical and economic performance of current technologies, and on providing optimization tools," he explained.

The research revealed that, after the roots themselves, energy is the second highest cost of production, and that rasping and drying – crucial steps for making starch, flour, gari and fufu - were the most energy-consuming processes.

Cassava flour packaging in Sincelejo, Colombia

"Improved process yield and energy efficiency can make all the difference between profitable and unprofitable operations," Tran said.

The researchers recommend further experimental characterizations and modeling to improve and optimize key unit operations such as rasping and drying, particularly at the small scale, in order to enhance energy efficiency. They also highlighted the need to integrate more socio-economic data to predict the effect of such innovations on women, who tend to be displaced from value chains when cassava processing is mechanized.

RTB and PIM Collaborate to Make Value Chain Work Gender-Responsive

With the aim of making postharvest work more inclusive, effective and equitable, RTB teamed up with the CGIAR Research Program on Policies, Institutions and Markets (PIM) in 2014 to support efforts to integrate gender into value chain tools and interventions.

This initiative builds upon knowledge sharing between CIP researchers in Africa and South America who had been integrating gender into PMCA. It gained impetus when CIP and PIM co-funded a workshop in April 2014 in Entebbe, Uganda, where researchers from Bioversity, CIP, CIAT and IITA analyzed the potential for integrating gender into PMCA and 5Capitals, a methodology for assessing the impacts of value chain development on poverty that was developed by researchers at Bioversity, the World Agroforestry Center (ICRAF) and the Center for Tropical Agricultural Research and Higher Education (CATIE).

The workshop resulted in the development of guidelines for making RTB value chain interventions more gender-responsive and a roadmap for strengthening gender in PMCA and 5Capitals. André Devaux, CIP's Regional Leader for Latin America and the Caribbean, and Dietmar Stoian, Leader of Bioversity's Commodity Systems and Genetic Resources Program and RTB Focal Point, subsequently joined colleagues from ICRAF and CIAT in developing a proposal for a two-year initiative for enhancing value chain tools and improving smallholder participation with a gender lens. PIM approved funding for the project in September, and Bioversity, CIAT, CIP and ICRAF began collaborating on it in early 2015.

"For me, one of the important things about the workshop was that it facilitated the link between RTB and PIM," said Devaux. He

Harvesting the 'bola' potato variety in Huancayo, Peru

added that it also resulted in the development of the guidelines and a prototype of a trainer guide for introducing gender into PMCA, which will be validated under the PIM-funded project.

Devaux admitted that when he and his colleagues developed the PMCA in South America in the early 2000s, they didn't pay specific attention to gender aspects. "It was gender-neutral. I think we missed some opportunities in some value chain interventions where women were playing key roles, such as with the traditional processed potato product 'tunta,' which is very common in Peru's southern highlands and in Bolivia," he said.

Efforts to integrate gender into PMCA began in East Africa in 2012, when CIP researcher Margaret McEwan and research associate Sarah Mayanja developed gender-responsive tools for the approach with help from Jacqueline Terrillon, a consultant with the professional network AgriProFocus. Mayanja helped partners apply those tools in Kenya, Tanzania and Uganda in 2013, as part of her PMCA work under the CIP Sweetpotato for Profit and Health Initiative.

"We realized that male and female value chain actors have different needs, interests and challenges. And when it came to strategies to overcome those challenges, men and women often had different views of how to go about it," Mayanja said. "Previously, we had used a one-size-fits-all approach, but the gender responsive tools helped us use a differentiated strategy. For example, for improving access to credit for value chain investments, the partners helped men access loans from banks, while women were linked to a microfinance provider that developed a table loan, which better suited their needs."

Like PMCA, the 5 Capitals approach was developed with little consideration of gender. Stoian, who developed 5 Capitals with Jason Donovan of ICRAF, said that their emphasis was on asset building at household and smallholder enterprise levels. He explained that 5 Capitals is complementary to PMCA, since it is primarily used for monitoring and assessing the impact of value chain interventions and, based on this, to adjust them to increase smallholders' capacity to benefit from them.

Stoian explained that the project will facilitate the development of gender-responsive versions of PMCA, 5 Capitals and the Link methodology – a value chain tool developed by CIAT. Those tools will then be shared with other centers and tested in different countries in Africa, Asia and Latin America.

"This is the way we envision our development-oriented research to work, with centers collaborating within and across Research Programs," Stoian said.

Searching for Technologies to Improve Traditional Cassava Processing

In Benin and Cameroon, women spend countless hours grating cassava to make the traditional products *gari* or *attiéké* in a labor-intensive and potentially dangerous process. Switching to a mechanical grating processing could reduce injuries, save time and energy, and result in a more homogeneous product. To understand the potential for mechanizing the production of such traditional cassava semolina, CIRAD supported research by French engineering student Timothée Gally on technologies for replacing the tiresome, manual process in West Africa and Latin America.

As part of his thesis for a degree in engineering from Montpellier SupAgro, France, Gally carried out research at CIAT headquarters in Cali, Colombia under the supervision of Dominique Dufour,

food technologist and RTB theme leader for postharvest technologies and value chains. Gally studied the influence of different grating parameters on the physical features of cassava pulp and characterized the different products resulting from grating in order to measure the impact of the different parameters before trying to mechanize the process. To this end, he used gari samples sent from Benin and Cameroon. A secondary objective of Gally's work was to measure the impact of the same parameters on the starch content in the fibers, since cassava starch production is an important industry in Colombia, Brazil and Asian countries such as Thailand and Vietnam.

Results showed that factors such as the rotational speed, water flow and distance between the block and drum affect characteristics such as the granulometry of cassava pulp and the starch content of the fibers. These effects were quantified with models and two desirability profiles were created for gari production. Based on this information, CIAT partnered with Colombia's Universidad del Valle to build a pilot grater at a partner starch plant.

"We managed to produce garis similar to those consumed in Benin and Cameroon," Dufour commented. "We hope that eventually the results obtained could translate into technology transfers from Colombia to Africa."

CIP Research on Sweetpotato Storage Options Can Help Farmers Enjoy Higher Prices and Better Diets

With proper handling and refrigeration, orange-fleshed sweetpotato (OFSP) can be stored for a year and retain good levels of beta-carotene, a precursor of vitamin A. In Sub-Saharan Africa, however, few farmers have access to cool storage and traditional storage methods can result in rotting or destruction by weevils and other pests. Most farmers consequently sell their sweetpotatoes shortly after harvest, which results in market gluts and low prices, while home consumption is largely limited to the harvest months.

With the aim of helping farmer's get higher prices for their sweetpotato harvests and making the vitamin A-rich crop accessible to families throughout the year, CIP has begun testing sweetpotato storage innovations in Ghana and Malawi. The research, which is supported by USAID, is part of the Sweetpotato for Profit and Health Initiative.

Together with partners, CIP researchers tested several sweetpotato storage systems, such as an improved ventilation system that was successful for Solanum potato storage in Afghanistan and a modified "Triple-S" method, in which small sweetpotatoes are stored in dry sand and later planted to produce sprouts for planting. That method is being tested to see if larger sweetpotatoes can be stored for eventual sale or consumption.

In Ghana, which has a long, hot dry season, sand storage was compared with a traditional system of storing sweetpotatoes in a grass-covered heap that is regularly sprinkled with water. The dry sand box storage gave better results than the traditional heap storage, retaining root freshness and keeping them free of weevils for two months.

In Central and Northern Malawi, where temperatures are cooler, preliminary results show that storage in modified traditional granaries filled with dry sand can be more efficient than the

ventilated pits, with a potential storage capacity of up to six months. CIP sweetpotato breeder and seed system specialist Putri Ernawati Abidin explained that OFSP was known for having a shorter shelf life than white- and yellow-fleshed varieties, but it proved to be more durable when stored in modified granaries with dry sand.

"An exciting finding from the research in Malawi was that the beta-carotene content of the roots has remained high after 6 months of storage in dry sand," explained Abidin. "With this modified granary, the problem of rats and termites was also solved, the quality of the roots was fairly good, and sensory observation showed acceptance by consumers."

Abidin noted that only one sweetpotato variety was tested in Malawi, and though it is widely grown there, other OFSP varieties will need to be tested in 2015. Nevertheless, preliminary results indicate that these innovations could allow smallholders to store their sweetpotatoes for months after harvest without major losses or degradation, which would help them sell their crop when prices are high, and ensure that women and children enjoy the nutritional benefits of OFSP for more months of the year.

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CIP sweetpotato storage units in Malawi

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RTB 2014 Financial Report

At the beginning of 2014, a total budget of US$ 37.1M was approved for Windows 1 and 2 of the CGIAR Research Program on Roots, Tubers and Bananas (RTB). However, this budget was reduced in October 2014 to US$ 33.9M. With this change, the total 2014 revised budget for the program was US$92.7M: US$33.9M (37%) of which was funded from CGIAR Funds Window 1 (W1) and Window 2 (W2), and US$58.8M (63%) of which came from Window 3 (W3) and bilateral donors.

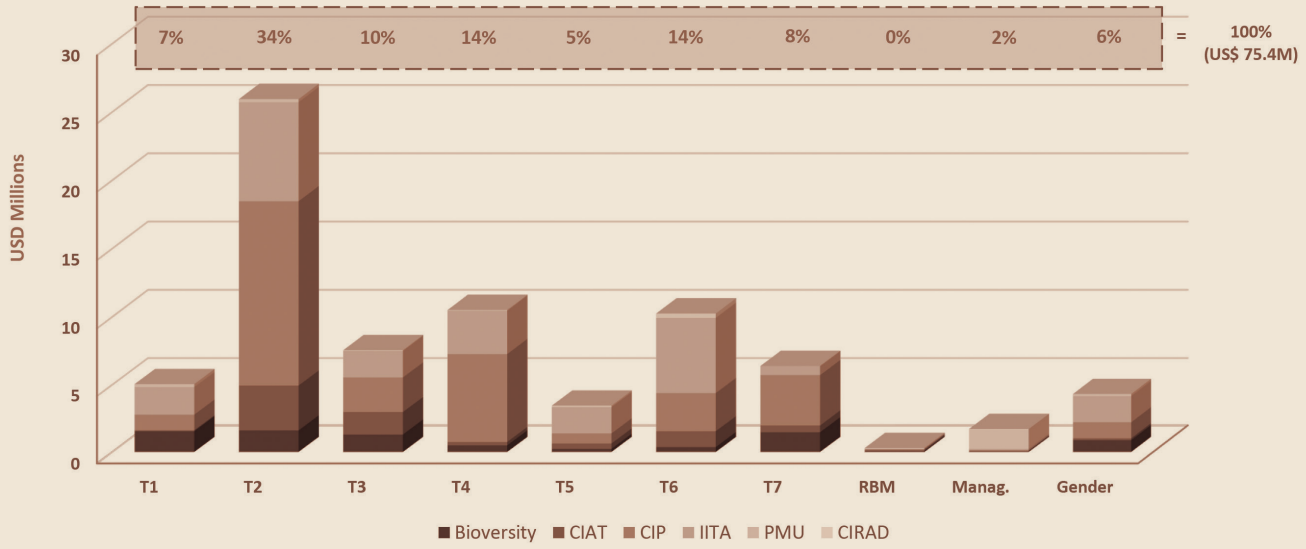
After the US$3.3M reduction in the 2014 RTB budget for W1 and W2, the year-end total of W1 & W2 expenditures was US$ 31.1M (92% of the US$ 33.9M budgeted); while W3, Bilateral and Center Fund expenditures were US$44.3M (75%) with a total expenditure of US$75.4M (81% of total 2014 revised budget).

CGIAR Funding Windows

Windows 1 & 2 funds are provided by CGIAR to RTB to use as it chooses across the agreed product portfolio.

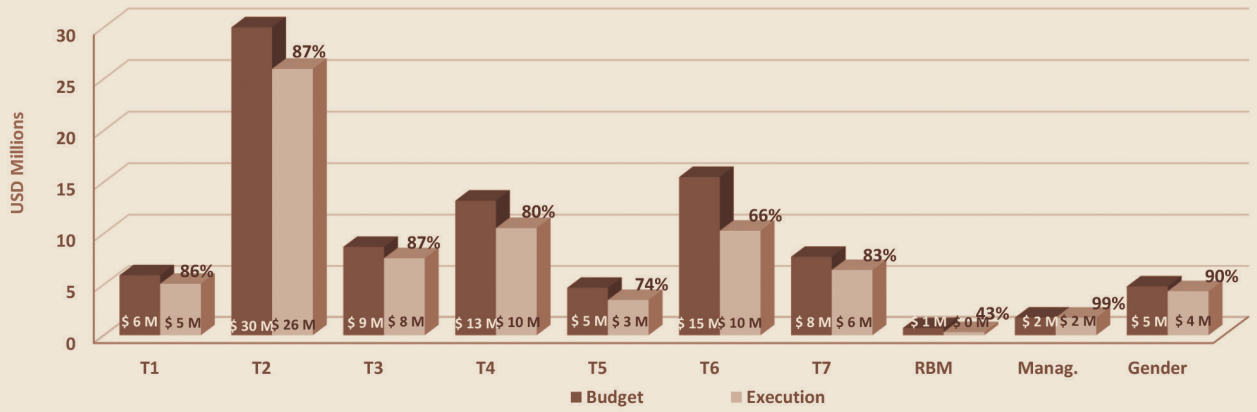
Window 3 and bilateral funds are awarded to CGIAR Centers directly when they are consistent with and mapped into the RTB product portfolio. Window 3 includes a 2% contribution to the Consortium.

Themes Overall Execution as of Dec 2014 by Center

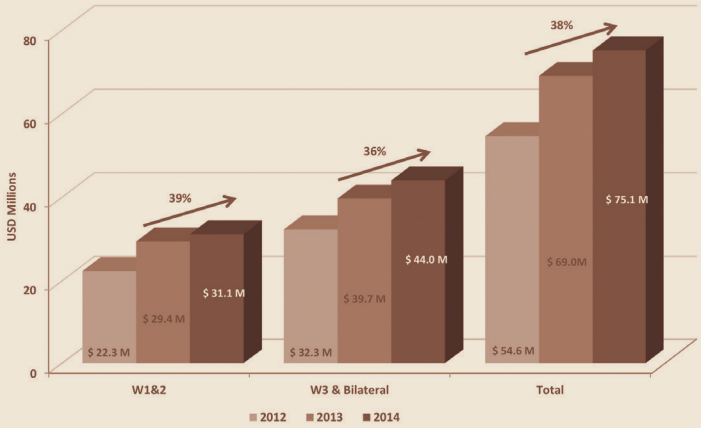


Gender research represented 6% of total 2014 expenditures. While that research was undertaken within the different Themes, it has been extracted for better visibility in the graph below. A total of 17% of expenditures went to collaborations with non-CGIAR partners. Execution by Themes averaged 80% of budgeted funds. Expenditures for themes 5 and 6 and the RBM pilot were below that average due to delays in some activities and components.

Themes Overall 2014 Budget vs. Expenditure



Cumulative RTB Expenditure 2012-2014



2014 Cumulative Results

Compared to 2012, there was an increase of 38% in the execution of the RTB budget (US$75.4M vs. US$54.6M) and 9% compared to 2013 (US$75.4M vs. US$69.0M), resulting in a cumulative execution of US$199.0M over the first three years of the Research Program (US$82.8M from W1 & W2 and US$116.2M from W3, Bilateral and Center Funds).

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Faculté d'Agronomie et de Bio-Ingénierie (FABI), Université du Burundi
Farmer's Choice, Kenya
Federal Ministry of Agriculture and Rural Development (FMARD), Nigeria
Federal University of Agriculture, Abeokuta, Nigeria
FIT Uganda Limited
Fondo para el Financiamiento del Sector Agropecuario (Finagro), Colombia
Food and Agriculture Organization of the United Nations (FAO)
Food and Environment Research Agency (FERA), UK
Food for the Hungry
Forum for Agricultural Research in Africa (FARA)
Fruit and Vegetable Research Institute, Vietnam
Fundación ACCIÓN CONTRA EL HAMBRE
Fundación Hondureña de Investigación Agrícola (FHIA)
Fundación para la Investigación y Desarrollo Agrícola (FIDAR), Colombia
Fundación M.A.R.CO, Ecuador
Fundación PROINPA, Bolivia

G

Generation Challenge Program (GCP)
Ghent University, Dept. of Molecular Biotechnology, Belgium
Global Alliance for Improved Nutrition (GAIN)
Global Cassava Partnership for the 21st Century (GCP21)
Global Crop Diversity Trust
Global Forum on Agricultural Research (GFAR)
GOAL Ethiopia
Grains and Legumes Development Board, Ghana
Graz University, Austria
Grupo Yanapai, Peru
Guangxi Cassava Research Institute, China

H

Hanoi Polytechnic University, Vietnam
Hanoi University of Agriculture, Vietnam
HarvestPlus
Helen Keller International, Africa Region
Horticultural Crop Research and Development Institute, Sri Lanka
Huazhong Agricultural University, China
HZPC, Netherlands

I

IMBARAGA Farmers Syndicate, Rwanda
Imperial College London
Indian Council of Agricultural Research
Indonesian Centre for Horticulture Research & Development
Indonesian Legumes and Tuber Crops Research Institute (ILETRI)
Indonesian Tropical Fruit Research Institute
Industrial Crop Research Institute, Yunnan Academy of Agricultural Science, China
Inner Mongolia University (China)
Institut National pour l'Etude et la Recherche Agronomiques (INERA), DR Congo
Institut National de Recherche Agronomique (INRA), Centre de recherche Angers-Nantes, Equipe Matériaux Création Comportement - MC2, France
Institut National des Recherches Agricoles du Bénin (INRAB)
Institut de Recherche Agronomique et Zootechnique, Burundi
Institut des Sciences Agronomiques du Burundi (ISABU)
Institut Togolais des Recherches Agronomiques (ITRA)
Institute for Agricultural Research and Training, Ibadan, Nigeria
Institute of Bioorganic Chemistry, Uzbek Academy of Sciences
Institute of Experimental Botany, Czech Republic
Institute of Fruit Tree Research, Guangdong Academy of Agricultural Sciences, China
Institute for Tropical and Subtropical Crops (ARC-ITSC), South Africa
Institutional Learning and Change (ILAC) Initiative
Instituto de Investigação Agrária de Moçambique
Instituto Colombiano de Estudios Superiores de Incolda
Instituto Dominicano de Investigaciones Agropecuarias y Forestales
Instituto de Investigaciones Agropecuarias, Chile
Instituto de Investigaciones Agropecuarias de Panamá
Instituto de Investigaciones de Viandas Tropicales (INIVIT), Cuba
Instituto Nacional de Investigaciones Agropecuarias (INIAP), Ecuador
Instituto Nacional de Innovación Agraria (INIA), Peru
Instituto Nacional de Innovación Agropecuaria y Forestal, Bolivia
Instituto Paraguayo de Tecnología Agraria
Inter-American Institute for Cooperation on Agriculture (IICA)

International Atomic Energy Agency (IAEA)
International Centre of Insect Physiology and Ecology (icipe)
International Development Research Centre (IDRC), Canada
International Fund for Agricultural Development (IFAD)
International Livestock Research Institute (ILRI)
International Society for Horticultural Science (ISHS)
International Society for Tropical Root Crops (ISTRC)
International Trade Center (ITC)
Iwate Biotechnology Research Center (IBRC), Japan

J

James Hutton Institute (The), UK
J. Craig Venter Institute (The), USA

K

Kaika Investment Company
Kansas State University, USA
Kasetsart University, Cassava and Starch Technology Research Unit (CSTRU), National Center for Genetic Engineering and Biotechnology (BIOTEC - NSTDA), Thailand
Katholieke Universiteit (KU) Leuven, Belgium
Kenya Agricultural Research Institute (KARI)
Kenya Plant Health Inspectorate Service (KEPHIS)
Kerala Agricultural University, India
King Mongkut's University of Technology Thonburi (KMUTT), Excellent Center of Waste Utilization and Management (EcoWaste), National Center for Genetic Engineering and Biotechnology (BIOTEC - NSTDA)
Kisima Farm, Kenya

M

Makerere University, Department of Crop Science, Uganda
Malaysian Agricultural Research and Development Institute
Mbarara District Farmers Association
McKnight Foundation Collaborative Crop Research Program
Mikocheni Agricultural Research Institute, Tanzania
Ministerio de Agricultura, Oficina de Estudios Económicos, Peru
Ministry of Agriculture, Ecuador
Ministry of Agriculture and Forestry, Lao PDR
Montpellier SupAgro, France

N

National Agricultural Crops Resources Research Institute (NaCRRI), Uganda
National Agricultural Research Institute, Papua New Guinea
National Agricultural Research Organisation (NARO), Uganda
National Agriculture and Forestry Research Institute, Lao PDR
National Crops Resources Research Institute, Uganda
National Horticultural Research Institute, Nigeria
National Institute for Agronomic Study and Research, DR Congo
National Potato Research Program, DR Congo
National Research Centre for Banana, India
National Root Crops Research Institute (NRCRI), Nigeria
National University of Ireland
Natural Resources Institute (NRI), University of Greenwich, UK
N.I. Vavilov Research Institute of Plant Industry, Russia
Nong Lam University, Vietnam
Northeast Agricultural University, China
Northern Agriculture and Forestry College, Lao PDR
Northern Mountainous Agriculture and Forestry Institute, Vietnam

O

Oficina para Estudios del Agro, Ecuador
Ohio State University, USA

P

Padjadjaran University, Indonesia
PATH
Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
Plant & Food Research, New Zealand
Plant Protection and Regulatory Services Directorate, Ghana
Plant Protection Research Institute, Vietnam
Potato Engineering & Technology Research Center of Inner Mongolia University, China
PRISMA, Peru
Programa Mundial de Alimentos, Bolivia
Proshika, Bangladesh
Provincial Dept. of Agriculture, Kampong Cham, Cambodia

R

Regional Fund for Agricultural Technology, Technical Administrative Secretariat (FONTAGRO)
Regional Strategic Analysis and Knowledge Support System (ReSAKSS)
Rimisp - Centro Latinoamericano para el Desarrollo Rural
Royal Holloway University of London (RHUL), UK
Royal Tropical Institute, Netherlands
Royal University of Agriculture, Cambodia
Rural Energy and Food security Organization (REFSO), Kenya
Rural Initiative for Children's Hope, Zambia
Rwanda Agricultural Board (RAB)

S

Savanna Agricultural Research Institute (SARI), Ghana
Savannah Seeds and Livestock Limited, Nigeria

Sierra Leone Agricultural Research Institute
SINA Gerard Ese Urwibutso, Rwanda
Sociedad Peruana de Derecho Ambiental (SPDA), Peru
South China Botanical Garden
Ssemwanga Centre for Agriculture and Food, Ltd.
Swedish Co-Operative Centre (SCC- VI), Uganda
Swedish University of Agricultural Sciences (SLU)
Swiss Agency for Development and Cooperation (SDC/DEZA)

T

Taiwan Banana Research Institute
Tanzania Food and Nutrition Centre (TFNC)
Technical Assistance for Sustainable Trade & Environment, Netherlands
Thai Farm International Ltd, Nigeria
Thai Tapioca Development Institute, Thailand
Tigray Agricultural Research Institute, Ethiopia
Tigray Bureau of Agriculture and Rural Development, Ethiopia
Tigray Bureau of Health, Ethiopia
Tigray Regional Bureau of Education, Ethiopia

U

United States Agency for International Development (USAID)
United States Department of Agriculture, Agricultural Research Service, Tropical Agriculture Research Station (USDA-ARS-TARS)
Universidad Agraria La Molina (UNALM), Peru
Universidad Austral de Chile (AUCh), Chile
Universidad de Córdoba, Montería, Colombia
Universidad de Desarrollo Andino (UDEA), Peru
Universidad de la Salle, Colombia
Universidad Nacional Autónoma de Nicaragua
Universidad Nacional de Colombia
Universidad Nacional Hermilio Valdizán (UNHEVAL), Peru
Universidad Pública de El Alto (UPEA), Bolivia
Universidad del Valle (UNIVALLE), Colombia
Universitat de Valencia, Spain
Université d'Abomey-Calavi, Faculté des Sciences Agronomiques, FSA/UAC, Bénin
Université Catholique de Louvain (UCL), Belgium
Université de Kinshasa, République démocratique du Congo
Université de Liège, Gembloux Agro-Bio Tech, Belgium
University of Agriculture, Umudike, Nigeria
University of Basel, Switzerland
University of Battambang, Cambodia
University of Brasilia
University of California, Davis (UC Davis), USA
University of Copenhagen, Denmark
University of Flinders, Australia
University of Florida, USA
University of Goettingen, Germany
University of Helsinki, Finland
University of Hohenheim, Germany
University of Kisangani, DR Congo
University of Leeds, UK
University of Nairobi, Dept. of Animal Production, Kenya
University of Nigeria
University of the Philippines at Los Baños
University of Puerto Rico Mayaguez
University of Reading, UK
University of Queensland, Australia
University of Sierra Leone
University of Stellenbosch, South Africa
University of Surrey
University of Western Australia
University of Wisconsin, USA
Uzbek Research Institute of Vegetables, Melons and Potato

V

Venganza, Inc.
Virginia Polytechnic Institute and State University, USA
Vision Mundial Bolivia
Vision Mundial Ecuador
Volunteer Efforts for Development Concerns (VEDCO), Uganda

W

WACCI (West Africa Centre for Crop Improvement), Ghana
Wageningen University - Plant Research International, Netherlands
Waite Analytical Services, University of Adelaide, Australia
Wayamba University of Sri Lanka
West and Central African Council for Agricultural Research and Development (CORAF/ WECARD)
Women's Association of Tigray, Ethiopia
World Agroforestry Centre (ICRAF)
World Bank

Y

Young Women Christian Association, Rwanda
Yunnan Agricultural University, China
Yunnan Normal University, China

Z

Zambia Agriculture Research Institute
Zanzibar Agricultural Investment and Development Inc., Tanzania

Selected Publications

Banana and Plantains (Musa)

Journal Articles

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Cassava

Journal Articles

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Potato

Journal Articles

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Sweetpotato

Books

Tumwegamire, S., Mwanga, R.O.M., Andrade, M.I., Low, J.W., Ssemakula, G.N., Laurie, S.M., Chipungu, F.P., Ndirigue, J., Agili, S., Karanja, L., Chiona, M., Njoku, J.C., Mtunda, M., Ricardo, J., Adofo, K., Carey, E., Grüneberg, W.J. (2014). Catalogue of orange-fleshed sweetpotato varieties for Sub-Saharan Africa. Lima (Peru). International Potato Center. ISBN 978-92-9060-439-6. 2. ed. 74 p. http://dx.doi.org/10.4160/9789290603832

Journal Articles

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Yams

Journal Articles

Adaramola, T. F., Sonibare M. A., Sartie, A., Lopez-Montes, A., Franco J., Albach, D. C. (2014). Integration of ploidy level, secondary metabolite profile and morphological traits analyses to define a breeding strategy for trifoliate yam (Dioscorea dumetorum (Kunth) Pax). Plant Genetic Resources: Characterization and Utilization, 1–10. http://dx.doi.org/10.1017/S1479262114000975

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Tropical and Andean Roots and Tubers

Journal Articles

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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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