Annual Report 2012
Teaming Up for Greater Impact
WHERE DOES RTB WORK?

CIP Lima, Peru

CIAT Cali, Colombia

Bioversity International
Rome, Italy
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Foreword

CGIAR Research Programs are new, ambitious and innovative initiatives that seek to make the most out of research by bringing human and financial resources together for their optimal use. We believe the Research Program on Roots, Tubers and Bananas (RTB) is one of the most promising. Not only because of the largely untapped potential of roots, tubers and bananas, but also because of the way RTB program participants have come together as a team to pave the way for lasting changes that positively impact those who depend on these crops for food, nutrition and income.

2012 was a milestone year as the new RTB, under the leadership of the International Potato Center (CIP), brought together Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA) and their partners into a new and clearly-structured set of collaborative arrangements that seeks to move from the fragmented projects of the old model to a more coherent, impact-focused program.

This first year - a year of setting foundations, of sitting together to share experiences and decide on the way forward - was rich in cross-center collaboration and partnership building. We put in place management and governance mechanisms to implement the joint research program and successfully made them operational. The Research Program was organized around seven themes under the leadership of science leaders. A product portfolio was created that represents the scope of work for the partners and the six sets of crops (banana, cassava, potato, sweetpotato, yam, and other tropical and Andean roots and tubers). New crosscutting projects, which combine crops and centers, stimulated inter-center synergy and collaboration and engaged more upstream and strategic research partners. We established the basis for gender mainstreaming in the Research Program, and we made a start at identifying a subset of high impact 'flagship products' that should lead us to successful development outcomes.

The biggest risk that was identified was the lack of a multi-year funding commitment, which inhibits the ability to gear up for bigger projects, and especially to bring more partners on board, as agricultural research needs a longer timeframe for planning.

We are excited by the challenges that lie ahead and we are looking forward to another year of collaborative work towards outcomes.

Pamela K. Anderson
CIP Director General and Chair RTB Steering Committee

Graham Thiele
RTB Program Director
Acronyms

AVRDC World Vegetable Center
BBTD Banana Bunchy Top Disease
BGI Beijing Genomics Institute
BXW Banana Xanthomonas Wilt
CABI Commonweath Agricultural Bureau International
CCAFS CGIAR Research Program on Climate Change, Agriculture and Food Security
CGIAR Originally, the acronym for the ‘Consultative Group on International Agricultural Research’
CIAT International Center for Tropical Agriculture
CIMMYT International Maize and Wheat Improvement Center
CIP International Potato Center
CIRAD Agricultural Research for Development (France)
CSI CGIAR Consortium for Spatial Information
CWR Crop Wild Relatives
DAPA CGIAR Decision and Policy Analysis Program
DNA Deoxyribonucleic acid
FAO Food and Agriculture Organization of the United Nations
FERA Food and Environment Research Agency
FHIA Honduran Federation for Agricultural Research
FIDAR Foundation for Agricultural Research and Development (Colombia)
FONTAGRO Fondo Regional de Tecnología Agropecuaria
FSD Frog Skin Disease
GIS Geographic Information Systems
GWAS Genome-Wide Association Studies
icipe International Centre of Insect Physiology and Ecology
ICRISAT International Crops Research Institute for the Semi-Arid Tropics
IFAR International Fund for Agriculture Research
IITA International Institute of Tropical Agriculture
ILAC Institutional Learning and Change Initiative
ILCYM Insect Life Cycle Modeling
IMTP International Musa Testing Programme
INIAP National Autonomous Institute for Agricultural Research (Ecuador)
IPM Integrated Pest Management
IRRI International Rice Research Institute
ITC International Transit Center
KCDP Kagera Community Development Programme
KU Leuven Catholic University of Leuven
NARO National Agricultural Research Organization (Uganda)
NARES National Agricultural Research and Extension Systems
NARS National Agricultural Research Systems
NGO Non-Governmental Organization
NRCRI National Root Crop Research Institute (Nigeria)
PPD Postharvest Physiological Deterioration
RAD Restricted-Site Associated DNA (genotyping)
R4D Research for Development
SASHA Sweetpotato Action for Security and Health in Africa
SNP Single Nucleotide Polymorphisms
SPHI Sweetpotato for Profit and Health Initiative
SLU Swedish University of Agricultural Sciences
TLB Taro Leaf Blight
UC Davis University of California, Davis
USAID United States Agency for International Development
VAD Vitamin A Deficiency
Harnessing the Potential of Root, Tuber and Banana Crops
Harnessing the Potential of Root, Tuber and Banana Crops

It is estimated that around 200 million people depend on root, tuber and banana crops for food and income in developing countries, particularly in the poorest regions of Africa, Asia and the Americas. The CGIAR Research Program on Roots, Tubers and Bananas (RTB) was born out of the belief that by tapping the potential of these crops, we can have a significant, positive impact on the food security, nutrition and livelihoods of those populations.

What are Roots, Tubers and Bananas?

RTB crops are potatoes, sweetpotatoes, cassava, yams, bananas, plantains and tropical and Andean roots and tubers such as aroids, maca or ahipa. They are among the most important crops in the world’s poorest regions, especially in Sub-Saharan Africa, and they are frequently grown by women and marginalized populations. RTB crops can produce plenty of calories per hectare and some varieties can also provide vitamins and essential minerals. They are also important cash crops and can be used to prepare processed products, which can add value to harvests. Scientists have pointed out that these crops share commonalities: they are vegetatively propagated and relatively perishable, which means they pose common challenges for farmers. But they also have common strengths, since they can be grown in marginal soils or conditions with few inputs, some have short growing cycles, so they can be produced during the fallow time for grains, and they can be used in the development of sustainable cropping systems. And since they are largely traded locally, RTB crops are less vulnerable to abrupt swings in international markets than grains, which strengthens their contribution to food security.

Why a Research Program?

Four CGIAR centers work on RTB crops, as do various partners in agriculture for development such as national research programs, other international entities and non-governmental organizations. In 2010, it was proposed that they should join forces to avoid duplicating work, address common constraints, and increase the results and impact of research for the benefit of smallholder farmers, consumers, and everyone else involved in RTB value chains.

Since January 2012, the RTB Research Program has brought together the expertise and resources of four research centers in the CGIAR Consortium: the International Potato Center (CIP), which serves as the lead center, Bioversity International, the International Center for Tropical Agriculture (CIAT) and the International Institute of Tropical Agriculture (IITA). These centers have partnerships with an array of international organizations, government institutions, non-governmental organizations and stakeholders’ groups, and RTB is strengthening and building upon those network to achieve the greatest possible impact.

Partnering and Innovating for Greater Impact

RTB was created to move the centers from a fragmented model toward a more cohesive approach to common challenges and goals. It is changing the way they work and collaborate in an effort to create new synergies through knowledge
sharing, multidirectional communications, communities of practice and crosscutting initiatives.

This change began with a participatory process for assessing RTB research priorities, which received input from more than 1,500 crop experts and other stakeholders around the world (see Engaging Stakeholders, page 14). That exercise, which utilized online surveys in five languages, helped to establish a culture of transparency and communication that will guide the research program in the future.

Partnerships are key to a successful RTB, and the four participating centers have identified various common priorities and cross-crop issues. In 2012 the Research Program provided complementary funding for projects that have created new opportunities for cooperation across centers. These range from partnerships aimed at managing a specific crop disease (see A Collaborative Response to a Threat, page 42) to more ambitious projects, such as an effort to sequence genes and produce metabolite profiles for hundreds of crop accessions in order to accelerate trait selection for breeding (see Harnessing the “Omics” Revolution, page 33) and an effort to develop strategies for reducing the transmission of diseases via planting material in various RTB crops (see Controlling Seed Degeneration, page 45).

By participating in these and other RTB initiatives, the research centers and their partners have begun to engage in new, dynamic partnerships that ensure a two-way flow of information between researchers and stakeholders, which will increase the pertinence and impact of all RTB products. RTB has mapped those networks and will monitor their growth and evolution as the research program moves forward (see Analyzing Partnerships, page 21). One finding was that the intensity of network links between CGIAR partners had increased substantially but linkages to development partners was lagging, and this was flagged for special attention. RTB will also monitor the program’s impact pathways to enhance their effectiveness, while strengthening the capacities of partners to improve their ability to achieve desired outcomes.

Because women are especially active in the production and marketing of RTB crops, and face a different set of constraints than men, gender issues are being mainstreamed within all RTB themes (see A Gender Focus, page 19). The integration of gender responsiveness into RTB work makes the program more equitable and effective. A gender strategy was developed to that effect.

Addressing Major Challenges

Various challenges were addressed from the start to strengthen and inform work by the four research centers, among them improving data quality and analysis for RTB crops, mitigating the impacts of climate change, aligning research objectives with farmers’ needs, and analyzing the yield gaps for the principal RTB crops.

Yield Gap Analysis to Guide RTB Strategies

Yields of banana, cassava, potato, sweetpotato and yam in developing countries tend to be well below their potential. In order to improve the food security and incomes of rural farmers, RTB needs a better understanding of the yield gap – the difference between attainable and actual yield.

RTB began addressing this issue with literature reviews on the effects of soil fertility, nutrients, water, light and biotic stresses such as pests, diseases and weeds on the yields of the main RTB crops in Africa, Asia and Latin America. Scientists at Bioversity International and IITA reviewed the literature on banana and plantain, experts at CIAT and IITA collaborated on cassava, whereas CIP undertook literature reviews for potato and sweetpotato and IITA was responsible for yam.

These reviews will be used to identify and evaluate the causes of yield gaps and design research products that address them in 2013. The results will also be translated into GIS data for the creation of map layers on RTBMaps that will be accessible to scientists around the world.
The RTB strategy is built around seven themes:

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

During 2012, workshops under several themes brought teams from the different research centers together with key partners to share experiences and plan the way forward. The first was a proposal planning workshop in Kampala, Uganda, in June, 2012, when representatives of RTB research centers and partner institutions selected an initial set of product lines, partners and pilot sites to reduce postharvest losses and expand utilization in Uganda, a country with an especially diverse and important RTB crops production. In December of 2012, a workshop was held in Lima, Peru on possible impacts of climate change on RTB pests and diseases, whereas another workshop in Montpellier, France focused on gender, capacity building, knowledge sharing and communications. Workshops on Banana Bunchy Top Disease (BBTD), seed systems and seed degeneration that were planned in 2012 took place in early 2013.

A product portfolio compiled at the beginning of 2012 set up the objectives for the next three years of the program. This included tentative impact pathways showing the contribution to
outcomes and eventually impacts through the production and dissemination of key research outputs. Within impact pathways, research outcomes which involve next-users (who RTB can influence directly) are differentiated from development outcomes with end-users (with whom influence is limited). Outcomes should eventually result in impacts – improvements in food security, nutrition and livelihoods, gender equity or a reduced environmental footprint. Impact pathways for agricultural research are relatively complex and depend upon many actors. The timeframe for achieving impacts, even after products are available, can be quite long because of adoption lags. The RTB Management Committee ensures that research is clearly oriented to achieving impacts and will use evidence of outcomes and impacts to guide allocation decisions. Impact pathways will be monitored for results and adjusted as needed. During 2012, the original impact pathways developed during program design were improved and linked to Intermediate Development Outcomes (IDOs), which guide implementation. Work on impact pathways will continue in 2013.

### THEMES

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<td>Enhancing impact through partnerships</td>
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<th>Research outcomes</th>
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<th>Intermediate Development Outcomes</th>
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<td><strong>Next-Users</strong></td>
<td><strong>End Users</strong></td>
<td><strong>Improved productivity in pro-poor RTB cropping systems</strong></td>
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<td>Increased access to, and enhanced use of RTB genetic resources</td>
<td>Farmers adopt new varieties with pest/disease tolerance, improved agronomic characteristics, nutritional attributes &amp; market acceptability and higher value</td>
<td>RTB cropping systems with reduced risk of disease and higher resilience to climate shocks</td>
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<td>NARS have increased capacity for RTB research in breeding, pest and disease management, quality seed systems, and value addition</td>
<td>Accelerated development of RTB varieties with pro-poor traits by NARS</td>
<td>Increased and more equitable income of poor actors and improved gender equity in RTB value chains</td>
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<td>NARS have better pest and disease detection and modeling tools for risk assessment and decision making</td>
<td>NARS, farmers, and value-chain actors have better options for production of quality seed and adding value</td>
<td>Increased consumption of safe and nutritious RTB foods by the poor especially nutritionally vulnerable women and children</td>
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<td>NARS, farmers, and value-chain actors have better options for production of quality seed and adding value</td>
<td>Increased attention to end-user needs and gender in research planning and implementation</td>
<td>Minimized adverse environmental effects of increased RTB production, processing and intensification</td>
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<td>Innovative RTB partnerships bring together CGIAR centers, NARS, farmers, and value-chain actors for learning, dissemination, and feedback to R4D agenda</td>
<td>Innovation processes and policy environment favor poor RTB producers and value chain actors especially women</td>
<td>Policy environment enables and supports development and use of pro-poor and gender-inclusive RTB technologies and RTB consumption</td>
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Impact pathways for agricultural research are relatively complex and depend upon many actors. The timeframe for achieving impacts, even after products are available, can be quite long because of adoption lags. The RTB Management Committee ensures that research is clearly oriented to achieving impacts and will use evidence of outcomes and impacts to guide allocation decisions. Impact pathways will be monitored for results and adjusted as needed. During 2012, the original impact pathways developed during program design were improved and linked to Intermediate Development Outcomes (IDOs), which guide implementation. Work on impact pathways will continue in 2013.
Some of the most important decisions to be made in the Research Program’s first years concern where its resources and activities can achieve the greatest impact. RTB managers need to consider the distributions of the principal pests, diseases and other production constraints, what areas present the greatest opportunities, and where the research program’s product lines can go the farthest in improving food security, nutrition and incomes.

Geographic Information System (GIS) specialists at the four RTB centers have collaborated to help RTB decision makers and others to grapple with such issues by creating an online tool to visualize production, constraint and social indicators associated with RTB crops. That online RTB atlas, called RTBMaps, is the work of the GIS teams at Bioversity International, CIAT, CIP and IITA, and is hosted by the CGIAR Consortium for Spatial Information (CSI). Together, those organizations have created a series of maps on ArcGIS Online, which uses cloud technology for GIS and allows users to build their own maps by combining layers.

“With this project, we want to move the power of maps out of the GIS lab and into the hands of the RTB science community – CGIAR scientists and our partners worldwide,” said Glenn Hyman, who is coordinating the project. He noted that the website is user friendly, accessible to all and free of charge. “Anybody can use these maps. You don’t need specific software. You don’t need any GIS training. All you need is a web browser.”

Hyman said that RTBMaps is the most comprehensive and collaborative GIS web-mapping project to be undertaken within the CGIAR system to date. He noted that the cloud technology that it is based on has only become available in recent years.

RTBMaps was launched in early 2013 with approximately 25 map layers based on data for RTB crop distribution, indicators for poverty and food-security and some production constraints. However, the number of layers will grow as the GIS specialists at the research centers upload maps for additional pests and diseases, social indicators and other pertinent issues. The team has also developed a priority-setting application that allows users to weight the
importance of different criteria – based on their own research, or consultations – and run analyses that result in unique maps.

Bernardo Creamer, an agricultural economist with the CGIAR Decision and Policy Analysis Program (DAPA), came up with the idea and worked with Hyman on the priority-setting tool. He explained that it could be used by anyone from breeders to social scientists to donors who are trying to decide where to focus their efforts or resources.

“I’m an economist, I don’t have a GIS background, but I can see the power of these maps,” Creamer said. “If all you look at are numbers, you may miss some important things. This tool helps you take criteria into consideration that you might otherwise ignore.”

According to Henry Juarez, who heads the GIS laboratory at CIP and has been working on GIS for more than a decade, the cloud technology and collaborative nature of RTBMaps are groundbreaking. He noted that the initiative also resulted in unprecedented knowledge sharing among the GIS experts at the research centers involved.

“This is the first time I’ve been connected with the GIS specialists at the other research centers. I didn’t realize that there was so much information available,” he said.

Juarez was one of more than a dozen GIS experts and social scientists from the four RTB research centers who attended a workshop in November, 2012, at CIAT to learn ArcGIS Online, resolve technical issues, and set priorities for the mapping initiative. He noted that in addition to creating a tool with great potential, the initiative has catalyzed knowledge sharing and collaboration, which are central to the RTB mission.

“One of the great things about this project is that it has gotten the research centers involved in RTB to share their data,” Juarez said.
Engaging Stakeholders to Identify Research Priorities

To ensure that RTB prioritizes areas of research with the greatest potential for improving the food security, diet and incomes of as many people as possible, the program began with a global consultation of research priorities for banana, plantain, cassava, potato, sweetpotato and yam that included input from more than 1,500 experts and stakeholders.

From potato breeders in Bolivia to plantain pathologists in East Africa to extensionists in India, experts on the principal root, tuber and banana crops filled out surveys on production constraints and research options in 2012 and early 2013 at international conferences, or online. At the same time, scientists at the four CGIAR research centers participating in RTB completed a literature review and compiled the latest data on crops, yield gaps, poverty and other pertinent indicators for the creation of an online GIS tool (see Online Mapping Tool, page 12).

It is all part of a dynamic, six-stage process to assess research priorities and guide decisions on the investment of RTB funds that consists of the following six steps:

1. Mapping agro-ecological zones, crop production, poverty and food security indicators in order to identify target areas where research is most needed.
2. Analysis of the key constraints for banana, plantain, cassava, potato, sweetpotato and yam production for each agro-ecological zone.
3. Identification of the most promising research options to address those constraints.
4. Quantification of parameters of models for formal impact assessment.
5. Estimation of expected impacts under different adoption scenarios.
6. Communication of results to stakeholders and the general public.

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**Stakeholder Engagement and Communication**

- **Stakeholder Engagement:**
  - Literature review of production constraints
  - Expert survey to elicit major constraints and research options
  - Consultation of stakeholders to finalize list of selected research options to be included in the ex ante impact assessment
  - Literature review of adoption and impact
  - Literature review of market and demand trends
  - Expert consultation to quantify parameters (workshop/interview/survey/online tools)
  - Impact models (incl. estimation of impacts by region/target group)
  - Sensitivity analysis: adoption scenarios
  - Weight environmental and social impact
  - Combine quant. and qualitative assessment
  - Interpretation of findings (incl. results of local/focal studies)
  - Flag information gaps and research needs
  - Share results with wider scientific and stakeholder community

- **Communication:**
  - Final RTB report, (online) newsletter, journal paper(s)
  - Feedback on study approach and process

**Engaging Stakeholders to Identify Research Priorities**

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Guy Hareau, an agricultural economist at CIP who coordinated the assessment with colleagues from the four centers, explained that they gave presentations on RTB at various international conferences, where hundreds of researchers completed crop surveys. Hundreds more completed surveys online via SurveyMonkey, where they were available in English, Spanish, French, Portuguese, Chinese and Russian.

Upon completion of the survey process, the priority assessment team analyzed the results and discussed them with a wide range of stakeholders to come up with a shortlist of 6-8 research options for each RTB crop. That stage includes the identification of research priorities for specific regions and agroecologies and ex-ante impact assessment of shortlisted options. Results of the process will be posted online and feedback solicited from the global RTB research community.

“It is important that the stakeholders not only have an opportunity to provide their input, but also that we share the results with them,” Hareau said.

He observed that in addition to providing quality information for RTB decision makers, the assessment has contributed to a process of cooperation and knowledge sharing that will be key to the research program’s success.

“The RTB priority assessment exercise is a good example of how CGIAR research centers can come together, define an agenda, and implement it as group,” said Tahirou Abdoulaye, an agricultural economist at IITA and a member of the priority assessment team. “It’s more than just a sum of contributions from each center. We agreed to share methods, data and communication among all centers involved.”
Promoting Partnership, Knowledge Sharing and Gender Equity
Promoting Partnership, Knowledge Sharing and Gender Equity

Scientists from the four RTB research centers engaged in dynamic partnerships around various common priorities, projects and cross-crop issues during the research program’s first year, which included participants from an array of other institutions and organizations. Those nascent but growing networks will ensure a steady flow of information and cooperation among researchers and stakeholders, which will increase the uptake and impact of RTB’s products.

At the same time, RTB began working to mainstream gender across the four centers. As RTB moves forward, this gender focus should significantly boost its impact by making its work more equitable and effective.

Enhancing Impact Through Partnership

Partnering is the key to mobilizing complementary expertise, facilitating knowledge sharing and synergies, and ensuring that the resulting research products have the greatest possible impact. The partnerships that were formed or strengthened during 2012 are generating innovative research products, and they will contribute to a favorable context for those products to have the desired outcomes and impacts.

The program’s first year was marked by significant outreach and engagement with stakeholders in the CGIAR Consortium and beyond it. This was primarily accomplished through traditional and Web 2.0 communications, presentations about the research program and networking at an array international conferences and symposia, and by inviting crop experts around the world to participate in the RTB research priority assessment (see Engaging Stakeholders, page 14).

RTB’s first year also included the initiation of several cross-center projects that will rely upon and strengthen growing networks of partners. An example is the collaboration between RTB and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) to assess and predict how climate change affects RTB crop pests and diseases. In addition to the CGIAR research centers, the workshop to design that project included the participation of university-based research centers and international organizations which participate in extensive networks of organizations that could contribute to, or benefit from the climate change project (see Assessing Climate Change, page 40).

Another project has brought together a team of experts from CGIAR research centers, several universities and other organizations to study and develop tools for managing RTB diseases that are passed from one generation to the next via planting material (see Controlling Seed Degeneration, page 45).

Networks and Knowledge Sharing

To get an idea of how science teams at the CGIAR research centers function in house, how they collaborate with other partners, and how many new partnerships were created during RTB’s first year, the research program’s
management commissioned the Institutional Learning and Change Initiative (ILAC) to undertake a social network analysis of existing RTB collaborations, which will serve as a baseline for future analyses (see Analyzing Partnerships, page 21).

The most extensive knowledge-sharing network within RTB is currently the ProMusa network, based at Bioversity International, which is dedicated exclusively to banana and plantain (Musa sp.). ProMusa combines traditional knowledge sharing activities such as workshops and a biennial symposium with various online tools that recently underwent improvement and expansion (see Sharing Knowledge, page 22).

**A Gender Focus to Benefit Women and Men Alike**

Women across the developing world grow roots, tubers and bananas, often in family gardens or other mixed plots, for home consumption and as cash crops. They perform much of the work that RTB production entails, from selecting planting material to harvesting and processing the crops. Yet despite the fact that women frequently face more production constraints than men and have a different perspective on many agricultural issues, agricultural research has all too often been gender blind. RTB has thus made gender a high priority from the start, to ensure that the research products developed under the program respond to the needs and priorities of men and women alike.

Studies have shown that women often have less productive, or poorly located farmland, and are less likely than men to have access to extension services, agricultural knowledge, inputs or credit. Women also prioritize different qualities in RTB crops, such as variety traits with higher nutritional value, better flavor, or qualities that make them easier to process into marketable products. There is also evidence that when RTB crops or products become more commercially viable, men may take over their production and marketing, reducing gender equity.

By ensuring that researchers take such issues into consideration, RTB can improve the food security, diets and incomes of a greater number of households. And by enhancing the productivity and nutritional characteristics of RTB crops, and integrating them into well-balanced local food systems, the program can have a major impact on vulnerable populations and such priority groups as children and pregnant or lactating women.

**Setting the Foundation of Gender Equity**

The goal is to achieve two types of gender outcomes under RTB: gender responsive, in which both men and women benefit from research products and neither are harmed, and gender-transformative, in which both men and women are helped while gender roles are transformed and more gender-equitable relationships between men and women are promoted. Gender will be mainstreamed by the four participating research centers and woven into all the program’s themes. This is no small task, but the foundation for it was set during the program’s first year.

Initial steps have included a public consultation during the program’s planning phase, a literature review of gender in the research programs of the four RTB centers, the drafting of a gender strategy and a gender impact pathway, and the participation of RTB management and internal stakeholders in gender workshops. A workshop attended by approximately 25 people – CGIAR Consortium Office representatives, RTB managers, gender focal points and gender specialists – was held in Montpellier, France in December 2012. It included the presentation of a review of the gender work done by the participating centers and the identification of flagship products that will be the first to include gender-responsive or gender-transformative research.

According to Gordon Prain, Science Leader for Social and Health Sciences at CIP and the RTB gender coordinator, the review confirmed that very little gender work had been done at the four centers in the past five years. “We are starting with a low baseline, so we need to be strategic about where we do gender work in the beginning,” he said.

Prain explained that one of the first challenges has been the limited capacity for doing gender research within the centers, which led RTB to recruit more social scientists with gender expertise, and to form partnerships with organizations that focus on gender-equitable approaches. The program recruited gender specialists for each of the four centers, who use workshops and other capacity building exercises to help RTB scientists to identify gender dimensions and be more gender-responsive in their research. Those gender focal points are: Anne Rietveld (Bioversity International), Kayte Meola (CIAT), Netsayi Noris Mudege (CIP) and Holger Kirscht (IITA).

RTB has begun to identify key questions and design strategic gender research that can produce results that are applicable to all areas of the program, and research for development in general. Gender indicators were established.
through a process of consultation with program partners and progress toward them will be measured by the RTB monitoring and evaluation system.

Gender Responsive Research

While some research areas are gender-neutral, all RTB themes have at least some areas that will require gender research. Prain noted that areas where gender research will be a priority include in situ conservation of crop diversity, participatory varietal selection, value chains and postharvest processing.

Busie Maziya-Dixon, a crop utilization specialist at IITA who primarily works with cassava, observed that men and women in Nigeria have very different roles in that product’s value chain. Women are traditionally responsible for much of the labor in cassava harvesting, processing, transportation, yet as processing becomes more mechanized and commercialized, men’s involvement increases. Maziya-Dixon observed that women have limited opportunities for improving their status along the value chain, since they lack access to capital to make investments on a local level, and there are few opportunities of permanent employment or management-level positions in commercial operations.

“It is important to address gender issues along the value chain in order to have an equitable and positive impact on the livelihoods of men and women.

We need to mainstream gender on our postharvest research, developing and adapting labor-saving devices, and training women in enterprise development,” she said.

RTB has begun its gender mainstreaming efforts by focusing on a few areas with the greatest potential for gender-responsive and gender-transformative research, but the results of that research will inform all areas of RTB. An example of this is a horticulture project in Bangladesh, where CIP has partnered with the World Vegetable Center (AVRDC) to improve the nutritional security and incomes of 100,000 poor households over the course of four years through the production, consumption and sale of potatoes, orange-fleshed sweetpotatoes and targeted vegetables. That gender-responsive project, which is supported by the United States Agency for International Development (USAID) under the Feed the Future initiative, includes various components specifically targeting women, most of whom have little or no access to, or control over land. In addition to training groups of women in areas such as improving their homestead gardens and multiplying sweetpotato vines for planting and sale, it will include strategic gender research that will inform future research for development activities.

By the end of 2013, RTB should be conducting strategic gender research in South Asia, Africa and Latin America and the Caribbean.
RTB requires high levels of coordination among the collaborating research centers and their partners to achieve its varied goals. To better understand those partnerships and foment the synergies needed to make the program as effective as possible, RTB managers are taking a systematic look at how partnerships are formed, maintained and perceived within research networks.

The current enquiry evolved from a literature review on partnership undertaken by CIP’s Global Program on Social and Health Sciences (GP-SHS) and authored by Douglas Horton, a consultant, Gordon Prain, the leader of GP-SHS, and Graham Thiele, the RTB Program Director.

“We wanted to understand what the literature had to say about the functioning of different kinds of research partnerships, what drives their dynamics, and what are the success factors for good partnerships,” said Prain.

To build upon the lessons learned from that review, Prain and Thiele asked the experts at the Institutional Learning and Change Initiative (ILAC), a CGIAR initiative on organizational dynamics hosted by Bioversity International, to undertake a systematic analyses of partnerships within RTB.

ILAC Coordinator Javier Ekboir and his colleagues collected information via a questionnaire that was completed by 92 RTB researchers. Based on their responses, the ILAC team mapped the networks that connect 578 researchers in 315 organizations, creating a baseline that can be used to monitor RTB’s evolution in coming years. The resulting picture shows how RTB activities are distributed across geographies, disciplines and institutional landscapes, and how its networks can change in relatively short periods of time. It shows that a large number of new linkages were created as a result of RTB, but these have been mostly between CGIAR partners and with advanced research institutes. This signals an important gap to be addressed in bringing in development partners with key capacities to ensure outcomes are achieved.

“We expect the social network analysis to be an instrument to monitor how RTB moves through its impact pathways and what changes take place on an almost real-time basis,” Ekboir said. He added that this information could help RTB managers implement adaptive management approaches as needs and opportunities arise.

Ekboir explained that ILAC has also begun action research on partnerships in Africa. He said the goal is to explore new models of partnership, collaborative research, knowledge sharing, capacity development and collective learning, and to develop new approaches in response to the complex and evolving situation in the field.

“We are establishing action research to contribute to the development of all the CGIAR Research Programs. This research is focused on the change process, and it should provide the CGIAR with instruments for managing that process,” he said.
Every year, thousands of articles on banana are published in scientific journals, not to mention the large and growing ‘grey literature’ and new media outlets talking about the crop. That information is often confusing, and it is becoming ever harder to distil out the relevant and reliable pieces, not to mention the problem of accessing knowledge locked up behind pay walls.

In view of the increasingly critical role that knowledge sharing plays in the uptake of research outputs, the ProMusa network has steadily strengthened its long-standing commitment to connecting stakeholders and facilitating the exchange of information and knowledge on banana. It does so by combining traditional scientific activities and face-to-face interactions, such as workshops and a biennial symposium, with new approaches that embrace the opportunities offered by online tools. Its website (www.promusa.org), which is managed by the ProMusa secretariat based at Bioversity International, in Montpellier, France, was redeveloped in 2011 to accommodate an expanded news section (www.promusa.org/infomusa), a community blog, a discussion forum, and a wiki-powered knowledge resource centre developed for and by the community (www.promusa.org/musapedia). More than 23,000 people visited the ProMusa portal in 2012.

Setting up a wiki was identified as the top priority through a user needs assessment carried out with ProMusa members from different regions, user groups and levels of engagement. Created as a space where experts share knowledge and validate contents, Musapedia has been adopted by new partners. For example, the World Banana Forum, which is led by the FAO, has set up a portal to document the best practices that have been shown to be effective in reducing, or avoiding, the use of pesticides in banana production systems.

Throughout the website, links to references, photos and contact details are channeled through the other online resources managed by ProMusa: Musalit (www.musalit.org), a bibliographic database that strives to record every publication on banana and to provide a direct link to the open access ones; Musarama (www.musaramama.org), an image bank of fully annotated banana-related photos, and Musacontacts (www.musacontacts.org), a database containing expertise and contact details of people working on banana and a link to their publications in Musalit.

ProMusa also has an outreach strategy that makes use of social media. In addition to managing a Twitter account (https://twitter.com/promusa_banana) and a Facebook page (http://www.facebook.com/promusa.banana), the secretariat regularly sends out email alerts to the more than 1,800 subscribers of InfoMus@. Participation in RTB has provided ProMusa with new opportunities for broadening its stakeholder engagement and building new strategic partnerships. RTB management is planning a survey to better understand who is using those online tools and what they are doing with the information, in order to contribute to their improvement and design comparable online resources for other crops, and its lessons learned will guide RTB as it promotes knowledge sharing in the future.
Given RTB’s global reach and expanding network of partners and stakeholders, communication will play an important role in weaving its varied research communities together into a cohesive, collaborative program. Online tools were chosen as the primary means of informing participants and interested parties about the research program’s work and activities, and to get as many people as possible involved in public consultations and an ongoing discourse about RTB themes.

Following the creation of a graphic line and a general brochure introducing the research project, a website was launched in June of 2012 featuring the RTB team, proposal, organization, news and basic information on the RTB crops. Facebook and Twitter accounts were also created that month, in order to harness the potential of those rapidly growing, far-reaching social media networks. By the end of 2012, 206 people had ‘liked’ the RTB Facebook page and 176 were following RTB on Twitter. Those virtual communities are very international, with many members in Africa and Asia, and include scientists, farmers, journalists, development experts, representatives of NGOs, industry, regional organizations, and various other interested parties.

To better organize information disseminated via social media, each weekday has been dedicated to a different crop: Sweetpotato Monday, Potato Tuesday, Cassava Wednesday, Yam and other-root-and-tuber Thursday and Banana Friday. While Facebook and Twitter are used to alert the growing online communities about the latest news, events and publications on RTB crops, the priority is to inform them about the research program’s accomplishments and direct them to the RTB Blog, which has been increasingly active since its launch in late 2012.

The communications team also played a supporting role in the RTB priority assessment exercise that was launched in 2012. The RTB website not only hosted the page where experts accessed online surveys on research priorities for the different crops, but social media where used to inform people about the surveys and urge them to fill them out, with messages posted in several languages (see Engaging Stakeholders, page 14).
3 Conserving Genetic Resources and Developing Improved Varieties
Conserving Genetic Resources and Developing Improved Varieties

The four CGIAR research centers collaborating on RTB play a leading role in the global conservation of genetic resources and their use for the development of improved varieties. The centers and their partners conserve banana, cassava, plantain, potato, sweetpotato and yam accessions with great potential for improving yields and resilience of those crops. The challenge that the research program faces is how to accelerate the translation of that genetic diversity into robust varieties with enhanced yield potential, nutritional content, characteristics demanded by markets and resistance to diseases, pests or drought.

Because they are vegetatively propagated, RTB crops present special challenges for breeding, which is one of the reasons yield increases for them have largely fallen behind those of major cereals. Genome sequencing of roots, tubers and bananas has also lagged behind other crops, which created a barrier to accelerating breeding efforts. In order to increase RTB yields and enhance resistance to varied threats, scientists need to better understand the genetic and metabolic composition of the plants and link that data to phenotypes (physical and physiological traits) and agronomic performance (in the field).

RTB has initiated cross-center efforts to optimize the conservation, assessment and exchange of genetic resources while helping the research centers move forward on ambitious projects for genetic sequencing and metabolite profiling of hundreds of crop accessions, and associating that information with phenotypic and field data. At the same time, RTB is supporting cooperative initiatives to improve the management and exchange of germplasm, and enhance established crop breeding programs in order to accelerate the development and delivery of new varieties that can improve yields, diets and livelihoods.

Conserving and Accessing Genetic Resources

Together, the research centers collaborating on RTB conserve more than 30,000 accessions of banana, cassava, plantain, potato, sweetpotato and yam varieties. Depending on the crop and center, that germplasm is maintained in field, in-vitro and cryobanking conditions, as plants, plantlets or seeds. Germplasm conservation and exchange are particularly difficult for RTB crops, which is why the research program is trying to improve the management of ex-situ collections through knowledge sharing, best practices and improved technology, while working with varied stakeholders to promote on-farm management of genetic resources and the conservation of endemic varieties and species in their natural habitat.

Progress was made on improving in-situ and ex-situ conservation during the first year, when important steps were taken to better catalogue and assess RTB germplasm through collaborations across participating centers and with varied stakeholders. The research program initiated the development of shared criteria for assessing the health of plant material in collections and harmonizing protocols to ensure that centers can exchange germplasm without the risk of spreading crop diseases. Participating centers identified...
priority pathogens for the different crops and regions for indexing, among other initial steps.

To optimize the use of financial and physical resources while responding to the risk of material degradation at the centers and threats to germplasm in the field, RTB promoted the application of a Weitzman-type decision support tool to assess the risks of threats to in-situ genetic resources and prioritize the conservation of ex-situ accessions of banana, cassava and potato.

Bioversity International made significant progress in standardizing methods for safety backup at the Global Musa Collection, also known as the International Transit Centre (ITC), which it manages. Bioversity International produced illustrated guidelines for the minimum set of descriptors of banana (Musa sp.) and set up a genotyping center open to the scientific community.

This work complements collection missions to areas of high banana diversity, which have allowed the organization to fill gaps in identified taxonomy and broaden the collection’s gene pool. Field verification of Musa accessions held in the ITC is ongoing, with more than 100 accessions already validated. These achievements have been made possible through the MusaNet network, led by Bioversity International, and will ensure more effective management and rationalization of the ITC collection, while working with other ex-situ collections of Musa germplasm, such as IITA’s and national collections worldwide.

Bioversity International also added genomes of banana and cassava to the GreenPhyl database (http://www.greenphyl.org), a web tool for comparative genomics that comprises 22 completely sequenced plant genomes and provides useful information for geneticists and breeders. The clustering of proteins in 22 plant genomes, including Banana and cassava, was completed and the results were added to GreenPhyl.

CIAT, CIP and Bioversity International began collaborating in 2012 on a spatial assessment of the status of RTB crop wild relatives to identify gaps in ex-situ gene banks. Experts from the three centers agreed to use a gap analysis methodology that is based on an eight-step process to evaluate conservation deficiencies on taxonomic, geographic and environmental levels (see Assessing and Georeferencing, page 29).

CIAT significantly expanded its germplasm collection for the South American root crop ahipa (Pachyrhizus sp.), also known as yam bean. More than 70 new ahipa accessions were added to the CIP genebank in 2012, increasing the collection to about 130 accessions. Some of that germplasm was screened for starch, protein, sugars, amino acids and minerals, including micronutrients such as zinc and iron.

CIAT, which has approximately 6,000 cassava clones, and IITA, which has approximately 2,500, improved knowledge sharing on that genetic diversity and protocols for the exchange of plant material. CIAT sent clones with desirable traits such as pro-vitamin-A content to IITA for crossing with African landraces.

RTB facilitated the creation of a network of stakeholders in South America that includes indigenous communities, NGOs and government institutions to identify and study potato genetic diversity at the species’ region of origin – the Andes. Called the Chirapaq Ñan (“Rainbow Route” in the Quechua language), the initiative launched its work in four potato diversity hotspots in 2012. CIP started collaborative baseline research at two of those areas, which will be used for an in-depth study of ongoing evolution and dynamic adaption to socioeconomic and environmental change (see Conserving and Monitoring, page 30).

Accelerating the Development and Selection of Varieties with Higher, More Stable Yield and Added Value

While conserving and improving access to the genetic diversity of RTB crops is essential, the research program is focusing a significant portion of its resources on efforts to study that genetic diversity and harness it for the development of improved varieties. By enhancing breeding programs and addressing the needs of rural men and women, consumers and industry, RTB is helping to guarantee food availability, decrease vitamin deficiencies, and the increase incomes of smallholder families.

RTB is supporting cross-center efforts to compile genetic data the next-generation sequencing technology on a large selection of crop accessions, and to match that data to metabolic markers, phenotype and agronomic performance. The association of genetic, metabolic and phenomic data could significantly accelerate the process of developing improved varieties and advance the frontiers of clonal crop breeding. CIAT and IITA have led this collaborative effort by launching the genetic sequencing of approximately 1,200 cassava accessions from Latin America and Africa over the next two years (see Harnessing the “Omics” Revolution, page 33).
Bioversity International has made comparable progress on its efforts to genotype banana species and groups. A genome-wide study of the main gene families involved in the carotenoid biosynthesis pathway in Musa was performed, and a set of orthologs of enzymes responsible for the accumulation of pro-vitamin A carotenoids in Musa fruit were identified. A better understanding of these pathways will enhance conventional breeding and other approaches for releasing banana varieties with high vitamin A content and consumer acceptability to combat micronutrient deficiencies.

At the same time, geneticists have made progress on transgenic varieties, by introducing genes from other species into banana to enhance resistance to pests and diseases. Screen house trials provided evidence that the maize cystatin and pepid are capable of providing resistance in plantain to concomitant infection with multiple species of nematodes. More than 100 transgenic lines were screened with the 12 best transgenic lines showing more than 67% resistance against nematodes.

Experiments have shown that the constitutive expression of the sweet pepper Hrap or Pflp gene in banana result in enhanced resistance to the bacterial disease Banana Xanthomonas Wilt (BXW), which has devastated the crop in parts of Africa. Because most of the transgenic lines with BXW resistance are for only for two cultivars, IITA scientists began modifying additional farmers’ preferred cultivars, such as Gonja Manjaya, Gros Michel and Cavendish.

CIP geneticist Hannele Lindqvist-Kreuze and colleagues made progress toward locating complementary genes underlying resistance to potato late blight disease in the Center’s B3 tetraploid breeding population. Identifying multiple genes involved in late blight resistance is important for strengthening breeding efforts because of the pathogen’s ability to rapidly evolve races that tolerate the plant’s defense mechanisms.

Scientists at CIAT and IITA have made progress on the search for cassava genes linked to tolerance to postharvest physiological deterioration (PPD), which destroys harvested tubers and is one of the biggest constraints for that crop. Tubers from transgenic plants with the GPX gene that were exposed to PPD exhibited less black discoloration than tubers from wild type plants, indicating a delayed onset of PPD (see Progress Toward Longer-Lasting Cassava, page 29).

### Improved Varieties

Scientists at CIAT and IITA have collaborated on the breeding of improved cassava varieties with high pro-vitamin-A carotenoid, which can reduce the risk of various human health problems associated with vitamin A deficiency, such as childhood blindness. One such variety that was bred and field tested by IITA was the focus of intensive multiplication efforts in 2012. More than 500 hectares of the cuttings were planted in preparation for a 2013 release to approximately 100,000 farmers in Nigeria (see Developing Orange Cassava, page 31).

Bioversity International contribution to the dissemination of the FHIA-17 and FHIA-23 banana varieties in Tanzania bore significant fruit in 2012, literally, as small holders in the Kagera region reported harvests of banana bunches weighing more than 100 kg. Those high-yielding, disease-resistant varieties are improving the calorie intake and incomes of impoverished Tanzanian families (see Strategic Partnerships, page 32).

Two CIP potato clones – one with early bulking traits and one with resistance to late blight disease – underwent final testing for release in Bangladesh in 2012. CIP is also making a growing contribution to smallholders in Rwanda, where 58,000 hectares were planted with improved potatoes varieties in 2012, out of 150,000 total hectares of potato in the country (38.7%).

In Ethiopia, 28.5% of the 164,000 hectares of potatoes planted in 2012 were improved varieties, the vast majority of which resulted from collaboration between CIP and National Agricultural Research and Extension Systems (NARES). Those include the ‘Jalene’ and ‘Gudene’ varieties, which are resistant to late blight disease.

In Latin America, the RedLatinaPAPA network facilitated the release of new varieties in Guatemala and Colombia in 2012. That brings the total of varieties released by the network to 12 during the past four years (in Colombia, Costa Rica, Guatemala and Peru). A participatory variety selection method based on the ‘mother & baby trial design’ from the Andean region is now used in Bangladesh, Bhutan, Kenya, Nepal and Uzbekistan.
Assessing and Georeferencing the Status of Wild RTB Germplasm

As part of RTB’s efforts to strengthen global conservation of crop genetic diversity, CIAT, CIP and Bioversity International began working together in 2012 on a spatial assessment of the status of RTB crop wild relatives to identify gaps in ex-situ gene banks. Experts from the three centers decided to use a gap analysis methodology for collecting crop gene pools described by Ramirez and al.1, which is based on an eight-step process to evaluate conservation deficiencies on taxonomic, geographic and environmental levels. They chose the methodology because it is flexible, allowing for the incorporation of additional aspects such as threats, soil data, climate change, genetic traits, and includes interaction with experts to evaluate results.

Henry Juárez, who heads the GIS laboratory at CIP, explained that choosing a common methodology was an essential first step to ensuring an efficient and effective analysis. “CIP has years of experience collecting data on wild and native potato, sweetpotato and oca, but to have CIAT and Bioversity share their knowledge on gap analysis with us was very beneficial,” he said. “This project has gotten us to sit down and plan together, which has taught us to speak the same language. In the process, we’ve learned from one another in areas such as GIS techniques, gap analysis methodologies, and using and processing data.”

The RTB centers are also participating together in a project called “Adapting Agriculture to Climate Change: Collecting, Protecting and Preparing Crop Wild Relatives”, which is led by the Global Crop Diversity Trust in partnership with the Millennium Seed Bank, Royal Botanic Gardens, Kew. That project’s goal is to make data and other resources freely available to the global community for use in conservation and related research, which is why its data will be made available online and shared under a Creative Commons License.


Progress Toward Longer-Lasting Cassava is Good News for Farmers

Cassava is an excellent cheap source of carbohydrates and a cash crop for farms of all sizes, but the tendency of its roots to spoil in a matter of days remains a major constraint for smallholders, especially when it comes to marketing the crop. CIAT cassava breeder Hernán Ceballos is consequently excited about progress he and his colleagues have made with varieties that have at least twice the shelf life of most cassava under production.

Cassava roots naturally perish quickly after harvest due to a process known as postharvest physiological deterioration (PPD), which usually leaves them completely spoiled within three days. This is a major constraint for cassava farmers, who have to rush their harvests to markets or processing centers for the many products made from cassava, which include starch, flour, chips, farinha, fufu, gari and ethanol. It is especially problematic for small farmers in remote areas with poor roads and scarce transportation.
In early 2009, Ceballos and his colleagues at CIAT made the chance discovery that a cassava variety bred for enhanced levels of pro-vitamin-A carotenoids that they were studying (GM 905 family) was able to delay PPD for up to two months. However, subsequent research found that the roots’ starch content fell considerably over time – and it is the starch that makes cassava such a valuable food and industrial crop.

“After you harvest it, the root is still breathing; the starch turns into carbon dioxide and water, and some starch is turned into its basic component, sugar,” explained Ceballos. “The roots are not spoiled, but the quantity of starch gradually falls. In a month, we estimate that the starch content is 30-40 per cent less, which is unacceptable.”

Ceballos is consequently focusing on roots that can survive the first week to ten days after harvest, which is when 90 percent of the losses occur in the cassava processing chain. His colleagues and he have also found tolerance to PPD in the variety AM 206-5, which is known for its amylose-free starch, a trait in high demand in the starch industry. In 2012, they undertook a detailed analysis of the biochemical changes that take place in roots from that variety during the two weeks after harvest, which they describe in a paper submitted for publication in 2013.

“This clone is primarily good for the starch industry, but it will also be good for smallholders who supply the industry,” Ceballos observed.

He added that the tolerance found in it is believed to be an inherited trait that could be transferred to varieties preferred by local farmers. Both varieties have great potential for improving the lives of smallholders, who face the constant threat of losing part or all of their cassava harvest to PPD. CIAT has shared varieties with enhanced carotenoid levels with IITA, which has crossed them with African landraces and collaborated with national and international organizations to get the improved varieties released to farmers.

“The fact that we can delay PPD for a week will have huge implications for everyone, particularly for African farmers and processors. It is there that a lack of adequate roads or a broken truck can result in a 100% loss of a harvest,” Ceballos said. “With these varieties, if a truck breaks down and a farmer can’t get the roots to the processing plant right away, they won’t lose everything. The starch content of the roots may end up slightly lower, but they will still be valuable, so the farmer will have a few days to get the truck fixed. It’s buying time at the most sensitive time in the processing chain.”

Conserving and Monitoring Native Potato Diversity in the Field

The potato may be popular around the word, but much of the crop’s genetic diversity remains in South America’s Andean region, where potatoes were domesticated more than 7,000 years ago. Communities there continue to grow rare varieties and the region remains home to wild potato relatives that could be used for improving cultivated accessions; yet changes in land use, farming traditions and the climate threaten that potato biodiversity.

To strengthen conservation of native potato varieties and wild relatives while improving the wellbeing of Andean farmers, the CIP launched an innovative initiative in 2012 called Chirapaq Nan (“rainbow route” in Quechua). The initiative has begun working with communities in four crop-biodiversity hotspots in three Southern Cone countries – Bolivia, Chile and Peru – where it is helping smallholders to conserve and monitor native potato varieties and species. The hotspots were selected in geographically distant areas to increase the probability of diversity, but the plan is to expand the “route” to

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include four more hotspots in Argentina, Bolivia, Colombia and Ecuador.

Chirapaq Ñan, organized by CIP’s Genetic Resource Program, is the first initiative in the world to work with local people to monitor crop genetic diversity in-situ systematically over time. It is also innovative in its focus on the wellbeing of local farmers. The goal is to make rural communities the protagonists of in-situ conservation by recognizing the role they play as custodians, or guardians, of the native potato varieties they inherited from their ancestors.

“The idea is to promote the transfer of knowledge from one generation to the next,” explained Stef de Haan, leader of Genetic Resources at CIP. “We seek to ensure that the knowledge remains there at the local level, and that the young people have an active participation.”

Chirapaq Ñan is consequently developing an educational program in the Peruvian departments of Apurímac, Cusco, and Huancavelica. In collaboration with partner NGOs, CIP seeks to involve teachers, children and parents in the investigation of traditions and customs surrounding native potatoes and document the information in a DVD.

Another noteworthy aspect of Chirapaq Ñan is the involvement of an array of stakeholders, including scientists, public officials, development professionals and the farmers themselves. Ten local consortia have been identified in six Andean countries (Argentina, Bolivia, Chile, Ecuador, Peru, and Venezuela), in which groups of approximately 100 families will participate. Despite the diversity of those communities and countries, it is hoped that they will join in the creation of a network to share information and experiences among diversity hotspots over the long term.

Developing Orange Cassava Varieties to Prevent Vitamin A Deficiency

Each year, about half a million children worldwide become blind because of vitamin A deficiency (VAD), a tragedy that is avoidable. RTB is consequently promoting the cultivation and consumption of sweetpotato and orange-fleshed cassava varieties with pro-vitamin-A carotenoids (which the body converts into vitamin A) as a way to prevent childhood blindness and an array of other health problems associated with VAD.

In the early 2000s, researchers at CIAT and IITA identified genetic variation for carotenoid content in cassava roots, which was encouraging because cassava is a staple in Sub-Saharan Africa, where VAD is a major problem. They have since collaborated on the development and multiplication of bio-fortified cassava varieties, and have joined local and international organizations in an effort to get them into the hands of African farmers.
Several of those varieties of orange-fleshed cassava are being distributed in Nigeria, where they have the potential to improve the health of hundreds of thousands of children in the coming years. That release is the result of years of work by scientists at CIAT and IITA to identify cassava clones with high carotenoid content and use them to improve African landraces, in collaboration with Nigeria’s National Root Crops Research Institute (NRCRI).

Though cassava roots with high carotenoid content tend to be yellow or orange, scientists had to find ways to quantify carotenoid content quickly, in order to screen an array of accessions. Teresa Sánchez and her colleagues at CIAT developed various methods for screening roots for carotenoids, the most promising of which uses near-infrared spectroscopy, which has accelerated the process. At the same time, CIAT and IITA have made significant progress on developing rapid-cycle breeding approaches that allow for finalizing a selection cycle of just 2-3 years.

In 2010, CIAT transferred cassava clones with high carotenoid content to IITA, where they were crossed with African landraces and field tested in collaboration with the NRCRI. In December of 2011, the Nigerian government released three cassava varieties with pro-Vitamin-A content from CIAT germplasm, which were the focus of a massive multiplication effort in 2012.

“The big challenge with cassava, as with other clonal crops, is multiplying enough material of the improved varieties to get them to a significant number of farmers,” observed Peter Kulakow, a cassava breeder and RTB focal point at IITA. He explained that CIAT and IITA have developed rapid multiplication techniques to accelerate the transition from breeding to release. “The multiplication ratio for cassava is typically 1 to 10, but we’ve been able to get more than 15 new plants from each parent, and sometimes more.”

Kulakow said that more than 500 hectares were planted with cuttings of the bio-fortified cassava varieties in 2012, in preparation for distribution to farmers in 2013. He explained that the Nigerian government and Harvest Plus are distributing the resulting planting material to smallholders in approximately 400 villages in 10 regions of Nigeria, so approximately 100,000 families should benefit from the bio-fortified cassava varieties in the short term.

“It is exciting, and hopefully it will translate into better nutrition and health for women and children, who have the greatest need for vitamin A,” Kulakow said.

Strategic Partnerships Result in Record Banana Harvests in Tanzania

2012 was a good year for smallholder banana growers in the Kagera region of Tanzania, since they began harvesting bunches that weighed more than 100 kg – four to five times the national average. The cultivars responsible this boom in productivity are FHIA-17 and FHIA-23, named for the Honduran Foundation for Agricultural Research (FHIA), which bred them to be resistant or tolerant to the main banana diseases. Their success in Tanzania is the result of a long-term vision and strategic collaboration by Bioversity International, the Catholic University of Leuven (KU Leuven), the FHIA and their Tanzanian partners.

The story began in the mid 1980s, when the FHIA was founded and what was to become Bioversity International’s research group on bananas began channeling financial support to it. This coincided with the creation of the Bioversity-managed International Transit Centre (ITC) at KU Leuven, which works to conserve banana diversity and distribute disease-free germplasm (five plantlets of any one accession upon request) around world. In 1988, the first of various FHIA hybrids were sent to the ITC, which eventually provided mother stock of FHIA-17 and FHIA-23 for distribution to farmers in the Kagera region as part of a package of 24 varieties to be disseminated by the Kagera Community Development Programme, in partnership with KU Leuven.

Multiplication of ITC germplasm is typically done in recipient countries, but given the absence of tissue-culture labs in the Kagera region, the FHIA germplasm was multiplied by KU Leuven’s Laboratory of Tropical Crop Improvement and some 71,000 plantlets were shipped to Tanzania in 2001. Those plantlets were further multiplied until an estimated 1 million suckers could be distributed in the region.

It wasn’t until 2009 that production began to reach levels that spurred demand for the hybrids, which was facilitated by capacity building for smallholders. The record harvests of 2012 were thus the fruit of a long-term vision and strategic cooperation among international and national partners. Bioversity International is currently helping Kagera farmers and businesses to upgrade local seed systems, in order to help smallholders supply the growing demand for the bananas in urban markets.
Harnessing the “Omics” Revolution to Accelerate Breeding and Better Yields

Yield increases over time for RTB crops, as reflected in national statistics, tend to be lower than those of the major cereals, largely due to aspects of their biology that make conventional breeding approaches for crop improvement cumbersome. Most RTB varieties carry more than two sets of chromosomes, and also have different alleles at each gene locus (high heterozygosity) limiting RTB breeders’ ability to identify the most elite germplasm (plant material with preferred traits of parents used in crosses). However, they also have breeding advantages, since clonal propagation makes it possible to fix and multiply favorable genetic combinations.

Breeders have traditionally based their work solely on phenotypes (physical and biochemical traits), making crosses among parents with desirable traits, and then planting out the seeds to see how they perform in the field. This breeding scheme is time consuming, labor intensive and expensive.

To improve efficiency and accelerate the breeding process, RTB is harnessing the potential of next-generation sequencing technologies and plant metabolite profiling. The goal is to create comprehensive maps of genes and metabolic processes underlying traits of interest in the main RTB crops. This “Omics” approach combines three strategic research areas – genomics (the use of DNA sequencing to uncover and map thousands of single nucleotide polymorphisms or SNP markers), metabolomics (the study of metabolites or the chemical fingerprints of cellular processes) and phenomics (evaluating how genes and the metabolic processes they control determine phenotypes). The convergence of these three resources sets the stage for the implementation of genome-wide association studies (GWAS) and genomic selection in RTB breeding schemes. The aim of GWAS is to uncover the genetic polymorphisms (inherited differences) underlying agriculturally important traits, by scanning the genomes of RTB crops for significant marker-trait associations. Useful markers can then be used to fast track the selection process through bypassing field phenotyping – a process referred to as marker-assisted selection.

RTB has established a collaborative platform to harness the “Omics” revolution for all major crops. Scientists from the sister CGIAR institutions, Cornell University and Royal Holloway, University of London – which are contributing to the genomic and metabolite profiling of RTB crops – met at IITA headquarters in October, 2012 to draft a roadmap for the next 18 months. An example of the collaborative nature of this effort is the work planned for cassava. CIAT and IITA are collaborating on the implementation of restriction site mediated DNA next generation sequencing – Restriction site Associated DNA (RAD) genotyping that uses Illumina next-generation sequencing – to simultaneously discover and score hundreds to thousands of SNP markers in hundreds or thousands of individuals for a minimal investment of resources. This collaborative effort aims to identify genome-wide SNPs (common genetic variations that can be associated with traits) in 1,200 cassava accessions from Africa, Asia and Latin America over the next two years. The results should significantly improve scientists’ understanding of cassava’s evolution and domestication and help them to identify useful genetic diversity for breeding. This effort will also contribute to efforts to map the cassava genome by helping geneticists to position and order the nearly 12,000 scaffolds, or pieces of the current cassava genome draft into full chromosomes; which remains a technical challenge for this crop.
The sequencing work with cassava includes Cornell University and the Beijing Genomics Institute (BGI), whereas Royal Holloway, University of London is concentrating on metabolite profiling. In order to carry out a joint assessment of global genetic structure of the crop from sequencing data generated by the labs at Cornell (for IITA accessions) and BGI (CIAT accessions), it was agreed that a subset of accessions from both CIAT and IITA (200 each) will be genotyped at both the BGI and Cornell facilities using a common restriction enzyme. This will not only ensure compatibility of SNP marker data between centres but also within centres (i.e with pre-existing data generated from previous sequencing efforts).

Augusto Becerra Lopez-Lavalle, a molecular geneticist at CIAT and the RTB leader for crop improvement said that approximately 70% of the accessions being sequenced are from an array of locations in Latin America, where cassava originated. This diversity could be quite beneficial for Africa, since it may contain traits lacking in African landraces. He observed that having the genetic data for 1,200 accessions and representative metabolite profiles just six years after the release of the first cassava genome sequence will be a major accomplishment, providing breeders with a vast amount of information about varieties planted in farmers’ fields.

Peter Kulakow, cassava breeder and RTB focal point at IITA, explained that this collaborative development of genomic and metabolomic information on cassava will accelerate the development of farmer preferred varieties for Africa with improved quality and sustainable production in the face of poor soil quality and increasing threats from pests and disease and stresses from climate change. Thanks to RTB and the commitment of donors, cassava and other RTB crops will have access to the same advanced breeding technologies as other crops.
Disease-Resistant Potato Variety Reaps Smallholders Savings in Nepal

The Janakdev potato variety, which CIP introduced to Nepal, has become quite popular in the Nala Valley, near Katmandu. Potato farmers switched from Cardinal to the Janakdev variety because it is resistant to viruses and the pathogen *Phytophthora infestans* – two of the biggest threats to the crop. Approximately 9,000 hectares in the Nala Valley are now planted with Janakdev, which was named after one of the researchers who developed the variety.

Whereas viruses progressively accumulate in potatoes leading to yield losses, *P. infestans* causes potato *late blight*, which can severely damage most of the plants in a field before the potatoes mature, so farmers have to apply fungicides regularly to keep the disease under control. CIP and the Swedish University of Agricultural Sciences have developed a simple scale for classifying potato varieties according to their resistance to *late blight*, in which a higher number indicates greater susceptibility to the pathogen that causes it. The Cardinal variety, for example, scores 8, indicating low resistance, whereas Janakdev has a value of 4, indicating medium-high resistance.

The lower a potato variety’s resistance, the more often farmers need to spray fungicide to control *late blight*. Farmers in the Nala Valley who switched to the Janakdev variety have reported that whereas they used to spray fungicide on their fields 10 times per growing season, they now get by with just 6 applications. For an area of 9000 hectares, that represents a seasonal savings of approximately US $1.4 million. The adoption of the new variety has thus increased the incomes of some very poor families, while reducing the negative impact of fungicide applications on the environment and farmers’ health.
Managing Priority Pests and Diseases
Managing Priority
Pests and Diseases

Pests and diseases are some of the biggest constraints for smallholders, and an array of pathogens and pests affect RTB crops, among them viruses, bacteria, fungi, oomycetes, nematodes and a wide range of insect pests. Annual losses due to the potato late blight disease in developing countries alone have been estimated at $12 billion.

Farmers worldwide employ an array of agrochemicals to control those threats, but few RTB smallholders can afford such inputs, and those who can often don’t know how to apply them properly, which can lead to the pathogen or insect-developing resistance, thus decreasing their effectiveness. The use of broad-spectrum insecticides also affects the natural enemies of pests, which can lead to serious outbreaks of secondary pests, not to mention the threat they pose to the health of farmers and their families.

Because RTB crops are vegetatively propagated, they share some similar disease issues. For example, viruses that significantly diminish yields are transmitted from one generation to the next via vegetative seed. This limits the exchange and dissemination of planting material of improved varieties, and reduces the quality of farmer-produced seed, resulting in a condition known as degeneration. Degeneration is a major cause of low yields in RTB crops, and is thus a priority for the research program.

Pests such as whiteflies and aphids, which are common across many crops, also act as vectors that spread viruses. The bacteria *Ralstonia solanacearum* attacks both banana and potato, among the RTB crops. At the same time, oomycetes (a class of organisms similar to fungi) of the genus *Phytophthora* are responsible for diseases that constitute major threats for several crops.

To create research synergies around such common threats, RTB promotes knowledge sharing and collaboration among research centers to build communities-of-practice, strengthen capacities, and develop products that will improve the ability of NARES and farmers to manage pests and diseases. The program’s comprehensive strategy for pests and disease includes the development of resistant varieties; new diagnostic tools for screening material to detect and identify diseases and pests; dissemination of techniques for propagating, selecting and cleaning planting materials; and an array of tools for Integrated Pest Management (IPM). IPM is central to the research program’s approach, combining effective use of disease- and pest-resistant varieties with biological, biophysical and biorational controls, cropping systems and other on-farm cultural practices to reduce crop losses in the most economically efficient manner and with the least possible threat to people and the environment.

To help farmers deal with the viruses and other diseases that are transmitted on planting material, RTB launched a crosscutting project on seed degeneration in 2012 that involves scientists at the four centers and several
other advanced research institutes. That project aims to study the main diseases that affect planting material in RTB crops and developing tools to control them that are appropriate for the regions where the research program is active, (see Controlling Seed Degeneration, page 45).

Greg Forbes, a plant pathologist at the CIP China Center for Asia and the Pacific and the leader of the seed degeneration project, observed that the project marks the first time that he has been involved in real collaboration among CGIAR centers. “I had sought opportunities to work with pathologists in the other centers in the past, but it didn’t work, not because of lack of goodwill, but because there was no funding to support joint activities,” he said, adding that, “RTB is also providing new opportunities to link with institutions outside the CGIAR.”

Effective management of crop diseases and pests requires tools to identify them early, which is a challenge in the countries RTB works in. The research centers are consequently collaborating in the development of diagnostic tools to identify pests and diseases, which could accelerate responses to outbreaks by NARES and other organizations with field extensionists. A tool for rapid diagnosis of the bacteria *Ralstonia solanacearum* has been developed and implemented in Colombia. CIAT and IITA have collaborated on a genetic analysis of white flies, that serve as vectors of cassava viruses, identifying DNA markers that can be used to differentiate between nearly identical whitefly species (see Using DNA Barcodes to Identify Whitefly, page 41).

A molecular tool for the fungus Fusarium tropical race 4 (Foc TR4) – a major threat to banana farms – is also being made available in Latin America to strengthen quarantine and detection efforts. The mapping of TR4 distribution in Asia is near completion, which will facilitate a more focused surveillance of that disease.

RTB is also supporting the development of a diagnostic tool for the bacterial disease Banana Xanthomonas Wilt (BXW), which has spread rapidly through East Africa and eastern DR Congo. The tool would contribute to quarantine and clean seed systems. Research has also shed light on the pathogen’s speed of movement, time to disease expression, root colonization and the influence of environmental factors. In collaboration with Uganda’s *National Agricultural Research Organisation* and other partners, Bioversity International developed an effective single-plant removal approach that has been promoted through Farmer Field Schools.

Another serious threat to banana and plantain is the Banana Bunchy Top Disease (BBTD), caused by an aphid-vectored virus that is spreading through Africa. Bioversity International and IITA are collaborating on the leadership of an alliance of international and local organizations working together on strategies to study, and halt the spread of that pathogen, which constitutes a major threat to banana and plantain production in Sub-Saharan Africa (see A Collaborative Response to a Threat, page 42).

Farmers in much of Colombia struggle to control Frog Skin Disease (FSD), a viral disease that significantly reduces cassava yields and can be spread by planting material. CIAT scientists have consequently developed a methodology to help small farmers produce their own disease-free planting material to renew their fields, and increase production (see Taking Cassava Seed Research to Small Farmers, page 50).

CIAT has been paying particular attention to the cassava mealybug (*Phenacoccus manihoti*), one of the most serious pests for that crop, which spread from South America to Africa in the 1970s and to Southeast Asia in recent years. CIAT Entomologist Soroush Parsa was the lead author of an article on the cassava mealybug’s presence in Asia and the risk it poses that was published by the online scientific journal *PLoS ONE* on October 15, 2012.

Climate change is likely to increase the intensity of an array of crop pests and diseases, which could significantly exacerbate other climate-driven challenges that farmers will face in the future. In an ambitious attempt to quantify and confront this threat, RTB and CCAFS are collaborating on a project to study the biology and life cycles of pests and their interaction with the environment, in order to predict how climate change will affect them, and provide advice to help NARES and farmers manage those threats.
As greenhouse gas emissions continue to grow, scientists who study crop pests and diseases are increasingly concerned about the degree to which climate change could exacerbate those threats. Approximately 30 such scientists participated in a workshop at CIP headquarters in Lima, Peru in December, 2012, to chart a course of action for monitoring and modeling the impacts of climate change on RTB pests and diseases.

The workshop marked the beginning of a collaboration between RTB and the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) to assess and predict how climate change will affect crop pests and diseases, identify which ones could grow more severe or expand their ranges, and help governments, international organizations and farmers to prepare for them.

The workshop’s results included a list of priority pests and diseases, the identification of modeling tools and system level frameworks to improve risk prediction, and plans for shared databanks to house data in appropriate formats for modeling. By the end of the week, participants had identified top research priorities and a pilot site for collaborating on that research – the Kivu region of East Africa – and they had outlined a plan for the next few years with specific products, milestones and outcomes.

“The most important outcome of the workshop was the fact that we completed a log frame that the participants endorsed as a group, which will serve as the basis for a project proposal that we will use to secure funding,” said Jürgen Kroschel, Science Leader for Agroecology and Integrated Pest Management at CIP and the workshop’s principal organizer.

The CCAFS-RTB collaboration will build upon the experience and tools developed under a three-year CIP project led by Kroschel to model climate change impact on critical insect pests in Africa, which was funded by the German Federal Ministry of Economic Cooperation and Development (BMZ), and ends in 2013. Kroschel and his team wrote and updated a software program called Insect Life Cycle Modeling, which researchers are using to develop models and conduct risk assessments.

Kroschel noted that participation by scientists from a wide range of disciplines and organizations bodes well for the project, since it will result in synergies and expand its impact. Workshop participants included scientists from seven CGIAR research centers (Bioversity International, CIAT, CIMMYT, CIP, ICRISAT, IITA and IRRI), advanced research institutions such as FERA, icipe, UC Davis, University of Leeds, Kansas State University and Ohio State University, and international organizations such as the Commonwealth Agricultural Bureau International (CABI) and the United Nations Food and Agriculture Organization (FAO).

FAO participation is especially important since the project will use the FAO framework for pest risk assessment, and FAO can serve as a link with national agricultural research and extension systems. “We can contribute to the FAO framework on the science side with the modeling tools we have developed,” Kroschel said.

He cited the potato tuber moth as an example of a pest that could become increasingly destructive as the climate warms. A CIP climate change impact study concluded that damage caused by the moth will increase progressively in regions where it now exists and its range will expand in Asia, North America, Europe and the Andes. Kroschel explained that possible responses to the threat include systems to ensure that planting material isn’t infected, the introduction of parasitoids for bio-control purposes and the use of attract-and-kill technologies.

Kroschel explained that the project’s results and tools will inform and support policy makers in the preparation of national and regional adaptation plans. Collaborating organizations will help to build capacity at national institutions for surveillance and integrated pest and disease management, in order to limit the spread and introduction of those threats in a changing world.

Assessing Climate Change’s Impact on Pests and Diseases
Whiteflies are major crop pests in the tropics and sub-tropics, attacking many crops, including some that play an important role in food security, such as cassava. Whereas most whiteflies are host-specific, meaning they lay their eggs on only one species of plant, some can lay their eggs on several plant species. Not only do whitefly pupae damage plants directly by tapping into their phloem in large numbers, they can also spread viral diseases that cause serious crop damage. Though economic losses due to whiteflies are difficult to measure, they are estimated to be in the hundreds of millions of dollars every year worldwide.

Efforts to combat this crop pest are complicated by the difficulty in identifying whitefly species, of which there are at least 1,556. Adult whiteflies are very similar, so biologists usually identify species based on morphological traits of the pupae. However, pupae bodies may change slightly according to the host plant, which can result in misidentification.

Molecular geneticist Augusto Becerra Lopez-Lavalle and his colleagues at CIAT and IITA are consequently trying to facilitate the identification process – and thereby efforts to control whiteflies – through the use of genetic information (DNA barcodes). They completed a study comparing morphologically based identification to genetic material extracted from 10 whitefly species that attack economically important crops in Latin America and the Caribbean.

The scientists sequenced Mitochondrial DNA, because it facilitates finding different markers in closely related species, to attain DNA barcodes for the COI gene. The results indicated that the COI gene has significant potential as a diagnostic tool for whitefly species identification. This is a first step toward developing a diagnostic kit for the rapid identification of whitefly species, which could even be used with pupae that are damaged during collection in the field.

Quick and accurate identification of whitefly species can facilitate research, or decisions about how to deal with the pest on a farm, or regional level. The RTB researchers’ identification of the COI gene’s potential and progress toward the development of a diagnostic kit could also help scientists working on crop pests at other advanced research centers. In the long run, it should help farmers across the tropics to avoid crop losses from whiteflies.
A Collaborative Response to a Threat to Africa’s Banana Farms

Banana Bunchy Top Disease (BBTD) is devastating banana and plantain farms across Sub-Saharan Africa, where it is present in at least 14 countries. A viral disease that stunts plants’ growth and prevents them from producing fruit, BBTD has the potential to cause major hardship in Central and Eastern Africa, where banana and plantain provided approximately 35% of the calories people consume. Its steady advance across the continent is a threat to the food security and livelihoods of approximately 100 million people.

To strengthen the response to BBTD in the region, scientists at two RTB centers – Bioversity International and IITA – have collaborated on research and the organization of a Global Alliance to control the disease. That multidisciplinary alliance – which includes African national and regional institutions, international organizations such as FAO and the private sector – is coordinating efforts to better understand BBTD and developing strategies to help the region’s small farmers deal with it.

BBTD is caused by a virus that is spread via infected planting material or by an aphid (*Pentalonia nigronervosa*) that is common in the region. The disease is initially hard to detect, which complicates timely eradication work and the prevention of new outbreaks. And because it is spreading across international borders and through extremely poor regions, halting its advance and reducing its impact is especially challenging.

IITA virologist Lava Kumar explained that scientists at Bioversity International and IITA have been working on BBTD for years, but before 2012, they concentrated on different regions and agroecologies. Thanks to RTB, they formed a partnership to identify and advance research priorities, and coordinate a regional response to the threat.

“This partnership has helped us to share our knowledge and experiences, and to set common goals,” observed Kumar. “We are more efficient as a combined force.”

The two centers collaborated on the organization of an RTB-supported workshop on BBTD held in Arusha, Tanzania in early 2013. Nearly 50 participants from 18 countries formalized the Global Alliance for BBTD Control in Africa, identified gaps in the region’s response to the disease, and formulated actions to improve surveillance, quarantine and awareness of the threat; promote crop improvement and the development of low-cost diagnostic tools; and devise strategies to help farmers manage the disease. This work will be complemented by products from RTB’s crosscutting project on seed degeneration (see Controlling Seed Degeneration, page 45).

One of the priorities is to understand how far BBTD has advanced in the region, so surveys were conducted to determine the disease’s distribution, incidence and severity. Research on the possibility of biological controls for the aphid that spreads the virus has also been launched, as well as the development of clean seed systems in Burundi, Cameroon, Democratic Republic of the Congo and Malawi.

Pascale Lepoint, a plant pathologist at Bioversity International, explained that in addition to facilitating exchange among scientists from different research
centers, RTB provided complementary funding for specific research on BBTD and workshops in 2012. She observed that RTB has contributed to the formulation of a holistic strategy for managing the disease.

According to Charles Staver, another Bioversity International scientist working on BBTD, the research synergies that RTB has facilitated are vital for mounting a coordinated response to the disease.

Studying a New Threat to Potato Farms in East Africa

When Anne Njoroge was growing up in the village of Kikuyu, in central Kenya, she would listen to her mother and friends complain that their potato crops had been “Waru Kuhla ni mbaa” – burnt by the wet, cold weather. Years later, when she began working at the Rwanda Agricultural Research Institute’s potato program, it occurred to her that the culprit behind those crop losses had been Phytophthora infestans – the pathogen responsible for late blight, a disease behind the world’s major potato famines – but her mother and neighbors didn’t know that it was a disease.

Njoroge now works as a plant pathologist at CIP, and is studying a new lineage of P. infestans called KE-1 that is spreading rapidly across East Africa. KE-1 is a more aggressive strain which appears to pose a more serious threat to the region’s potato production than the US-1 lineage that has been common there for the past half century. The KE-1 lineage was first detected in 2007 in two fields in western Kenya, but when Njoroge collected and analyzed late blight samples in 2011, she was surprised to find that all the samples she collected in Kenya were KE-1. Most of the samples she collected in eastern Uganda were also KE-1, whereas most of her samples from western Uganda were of the old US-1 lineage. This indicates that the new lineage has completely displaced the old one in Kenya and is spreading westward across Uganda.

Njoroge, who did the research for her Master’s thesis at Uganda’s Makerere University on a CIP scholarship, said that farmers who she spoke with in eastern Uganda, where the samples she collected were KE-1, complained that the disease was difficult to control with fungicides. She wonders if this means that KE-1 is more fit, or has higher levels of fungicide resistance than the US-1 lineage.

To answer such questions, she has started a new research project to study the two lineages’ population dynamics and impacts in the region, and to collect genetic data to be used in the development of resistant varieties. The research will be part of her doctoral dissertation for the Swedish University of Agricultural Sciences (SLU) in Uppsala, Sweden, under the supervision of Professor Jonathan Yuen, though it will be done in collaboration with Uganda’s National Agricultural Research Organization (NARO) and RTB.

“The ultimate goal is to generate potato varieties that are resistant to late blight in East Africa,” explained Njoroge. “This would allow local farmers to abandon the use of fungicides, which are expensive, pose a health risk, and are rarely applied with the proper frequency and dosage.”
Confronting a Disease that Threatens Taro Farming in Nigeria

Taro (*Colocasia esculenta*) is an important staple crop in West Africa – able to grow on swampy land and serving as a cheap source of carbohydrates and nutrients. It is commonly grown by women and men on marginal land, with little or no inputs, which makes the recent appearance of Taro Leaf Blight (TLB) in Nigeria and Ghana a serious threat to food security there. IITA is consequently collaborating with the NARES in those countries to study and respond to the disease.

TLB is caused by the oomycete *Phytophthora colocasiae*, which is similar to the pathogen that causes potato late blight. It spreads quickly during the rainy months, when it can defoliate and kill most of the plants in a field. It was first reported in Nigeria in 2009, and by 2010, it was quickly becoming an epidemic. In a 2011 assessment of farms in eight Nigerian states, Joseph Onyeka, a plant physiologist with Nigeria’s National Root Crop Research Institute (NRCRI), found that field incidence of TLB ranged from 65% to 90%, and that many farmers were abandoning their fields.

In 2012, scientists from IITA and two Ghanaian institutions confirmed the presence of TLB in Ghana in an article published by the American Phytopathological Society1. Onyeka noted that he has heard reports of TLB in Benin and Togo, which indicates the epidemic is spreading across the region.

IITA has helped Onyeka and his colleagues at NRCRI to identify the disease and pathogen and report its presence on Nigerian farms, with support from the International Plant Diagnostic Network. IITA was also influential in helping Onyeka to secure a professional development grant from the International Fund for Agricultural Research (IFAR), which supported his farm survey and work toward the development of TLB-resistant taro varieties.

Onyeka found that the Nigerian taro landraces maintained at NRCRI are highly susceptible to TLB. NRCRI subsequently solicited TLB-resistant germplasm from the Secretariat of the Pacific Community Center for Pacific Crops and Trees, in the Fiji Islands, which provided 50 accessions, 34 of which are considered resistant to TLB. According to Onyeka, NRCRI is testing those accessions, which are different from the taro grown and consumed in Nigeria, so the TLB-resistant germplasm will probably be used to improve local landraces.

Onyeka noted that his collaboration with his partners at IITA to study the TLB outbreak has marked a new chapter in his relationship with the organization, which he hopes will grow in the coming years, as they work together to develop TLB-resistant taro cultivars that will be distributed to farmers in Nigeria.


A farmer in Patuakhali, Bangladesh harvesting a variety of taro for his daily consumption.
Controlling Seed Degeneration to Improve Yields and Quality

During his years working in the Andes region, it became clear to plant pathologist Greg Forbes that the diseases transmitted by seed potatoes, a condition known as seed degeneration, are a pervasive problem for the region’s small farmers, reducing their production and/or the quality of their potatoes. Because seed degeneration is a major production constraint for all RTB crops, Forbes and colleagues designed a crosscutting project within RTB to develop tools to help researchers, extension workers and farmers to better manage seed degeneration in cassava, potato, sweetpotato, yams and bananas.

“It is evident to anyone who works in potato that seed degeneration is important,” said Forbes, who is now based at the International Potato Center (CIP) China Center for Asia and the Pacific. “On a global scale, it has got to be one of the biggest obstacles to productivity for smallholders.”

Forbes explained that because roots, tubers and bananas are vegetatively propagated, diseases are passed from one generation to the next more easily than in plants that produce seeds through sexual reproduction. He noted that industrialized nations have largely solved the problem through “clean seed systems,” in which pathogen-free planting material is multiplied under controlled conditions and then sold to farmers, however, attempts to establish clean seed systems in developing countries have had limited success.

Forbes and colleagues are consequently studying the diseases that affect planting material and developing tools to control them that are appropriate for the regions that RTB focuses on. He explained that they are looking for a balanced approach that combines the use of resistant varieties with the promotion of on-farm practices and clean seed systems that are appropriate for local conditions.

“CIP has done some research around teaching small farmers a very simple technique called positive selection, which just involves selecting clean looking mother plants to take seed from. It’s very simple, but the farmers that did it got, on average, a 20 percent yield increase. It’s an imperfect control technique, but it gives you an idea of the ubiquitous reduction of productivity that seed degeneration causes,” he said.

Forbes and two-dozen colleagues from the United States, Latin America, Europe and Africa met in Arusha, Tanzania in early February, 2013 to review the most recent research on seed degeneration and plan their collaboration over the next two years. Participants included specialists from the four research centers collaborating on RTB, the Swedish University of Agricultural Sciences (SLU), the University of Greenwich’s Natural Resources Institute and Kansas State University, among others.

Forbes noted that participants will work on the project at their own institutions, but will feed their data into one analysis. The project’s goals include identifying the main diseases that cause seed degeneration in the RTB crops and regions and modeling how factors such as resistance, on-farm management and local weather conditions affect them. The plan is to develop simple models to predict seed degeneration under different conditions and guidelines to manage the problem.

“The project will generate a clearer qualitative and quantitative understanding of plant resistance to degeneration. This will enable the NARES to better recommend one variety over another,” Forbes said. “We will also produce information on how well specific on-farm management activities work under specific biophysical conditions. We also want to identify the utility of additional on-farm activities, such as sanitation (being sure not to spread viruses and bacteria with agronomic activities), seed plots or net houses, removing the sources of pathogens, such as infected hedge rows, soil health management for pathogens with a strong soil-borne phase or more effective seed storage.”

Potatoes deformed by virus.

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

Ensuring that farmers have access to sufficient, quality seed (planting material) is essential to decreasing the yield gaps for RTB crops. While good seed is vital for all crops, the vegetative propagation that is common to RTB crops results in a series of challenges that require special attention. These include low multiplication rates, bulky, perishable planting material and a high risk of pests or diseases being passed from one field to another, or from one crop generation to the next.

Many of these obstacles have been largely overcome in industrialized nations, or on commercial plantations, through clean seed systems, which propagate, test, and distribute clean seed to farms, but such schemes have had only a marginal impact in the developing world, where less than five percent of RTB farmers get planting material from formal seed systems. Approximately 95% of smallholders get their RTB seed material from their own or neighboring farms, nearby communities, or the local market, which makes it difficult for them to expand production, or overcome endemic crops diseases and other biotic constraints.

The dearth of effective seed systems also holds back the rapid and wide-scale adoption of new varieties, making it difficult to translate the achievements of successful breeding programs into better harvests, diets, or incomes for the men, women and children that RTB aims to help.

Scientists at the four RTB centers have long worked on strategies to improve smallholder access to quality planting material, but their success has been mixed, and lessons learned in one crop or region are often ignored by scientists working with the same, or a comparable crop in another region. For this reason, the research program has brought together experts on seed issues from the four RTB centers and other interested institutions to share knowledge, identify commonalities, and work on innovative approaches and cross-crop strategies.

Creating a Community of Practice

“The program’s main accomplishment has been to connect people who have been working on these issues for years, but who haven’t been communicating,” said Oscar Ortiz, the Deputy Director of Research for Regional Programs at CIP and the theme leader for seed systems. “RTB has created an important opportunity to start discussing ways to improve seed systems for all these crops.”

Ortiz explained that experts from the four centers are now involved in a community of practice that is sharing lessons learned and exploring commonalities among the different RTB crops they work with. An important component of the knowledge-sharing process during RTB’s first year was the completion of literature reviews on seed systems and planting material constraints in banana, cassava potato, sweetpotato and yam by teams of scientists at the four centers. He noted that documentation of research and
experiences in seed systems is scattered and hard to find, and organizations have used such disparate criteria that it is difficult to compare their results.

The literature reviews were presented at a workshop in Wageningen, Holland in February 2013, where experts from the four RTB centers discussed commonalities among the crops and identified things that should definitely be avoided, or promoted. That meeting provided an opportunity to analyze and improve a multi-stakeholder framework for intervening in seed systems across RTB crops that experts from the four centers developed with a complementary grant from the research program. They are designing a project proposal to apply that framework to approximately 10 test cases covering different RTB crops on several continents.

“The principal challenge is to improve access to healthy planting materials for small producers. To achieve this, we need to work with networks of actors, which include farmers groups, government agencies, NGOs and the private sector,” said Ortiz.

He observed that one of the reasons seed systems in the developing world have had such limited success is that most are managed by government agencies with limited budgets, capacities and reach. He said that one thing that RTB will do is document existing public-private experiences in seed systems in order to get the dynamics of the private sector into seed systems, in coordination with government organizations.

“The challenge is to design a common framework for analysis and decision making that can be effective for various crops,” he said, adding that while there clearly isn’t going to be one solution for all crops in all countries, there is an undeniable opportunity to create synergies between research centers, or with other partners, for real improvements on the current state of RTB seed systems in the developing world.

Building on Experience

Ortiz explained that workshop participants shared examples of successful projects and strategies, and there are already some innovative strategies being applied and success stories worth sharing.

Scientists at CIAT reported their success in helping smallholders in several regions of Colombia to develop systems for produce their own cassava planting material using tissue culture, which has helped them to decrease the threat of Frog Skin Disease (FSD) – a major constraint for cassava farms in that country – while increasing the multiplication rate of planting material (See Taking Cassava Seed Research to Small Farmers, page 51).

CIP has undertaken a major effort to improve the production and handling of planting material for orange-fleshed sweetpotato in various regions of Africa under the Sweetpotato for Profit and Health Initiative (SPPHI). The work has included training in vine multiplication as a business, defining standards for producing healthy planting material, and the promotion of public-private seed enterprises.

RTB funded the publication of two training manuals that resulted from an IITA project to teach smallholders in East Africa to produce banana plantlets using tissue culture, and to help them turn the enterprise into a successful business. The project featured a train-the-trainer strategy that included approximately 350 workshops. (see Helping Banana Farmers Make the Transition, page 52).

In collaboration with Ecuador’s National Autonomous Institute for Agricultural Research (INIAP), CIP organized a regional meeting on non-conventional seed systems for potato in the Andes region. More than 100 participants from Bolivia, Ecuador and Peru attended the meeting, held in Quito Ecuador on April 26-27, 2012 to learn about alternative models for potato seed production.

Bioversity International is collaborating with local partners in Nicaragua, Panama and the Dominican Republic on a project to improve plantain bunch size, and thereby the per-hectare yield. They completed the first cycle of selection in 2012, with support from FONTAGRO. Only plants with more than 45 fingers per bunch were selected for multiplication in vitro. The bunches from vitro plants had 5-6 more fingers per bunch than bunches from plants derived from suckers taken at random. Plots are currently being monitored to determine bunch size from the ratoon harvest.

IITA scientists have widely promoted a seed system for yams in Western Africa that both decreases the transmission of diseases from one generation, or field, to the next and helps farmers to increase the multiplication rate of their planting material. Known as the yam mini set, the technique involves cutting seed yams into smaller pieces than farmers have traditionally planted and treating them with pesticides. It has helped some farmers to double their yam production.
With help from scientists at CIAT, small farmers in Pilamo, in Colombia’s Cauca department, are producing their own cassava planting material to renew their fields and decrease the risk of Frog Skin Disease (FSD), which significantly reduces cassava yields in the region.

Farmers traditionally cut up and store cassava stems to use as vegetative seed for the next planting season, but those stems sometimes spread FSD and other diseases, and they provide neither the quantity nor quality of seed needed to improve livelihoods. CIAT scientists have consequently developed a methodology for helping groups of small farmers to adopt tissue culture and other propagation techniques that allow them to produce large amounts of healthy, quality planting material with a minimal investment.

In 2012, the scientists gave workshops to more than 100 farmers in Pilamo and Morales, another Cauca community, with support from the Fondo Regional de Tecnología Agropecuaria (FONTAGRO), a Latin American fund for agriculture. The subjects they covered included recognizing FSD, controlling the disease, and new techniques for multiplying healthy planting material. Participating farmers built propagation chambers to produce clean planting material from hardy local plants and improved varieties from CIAT.

Pilamo and Morales are two of the eight Colombian communities that have benefited from the outreach program, which helps farmers’ groups to develop the capacity and infrastructure necessary to ensure the genetic quality of their planting material, minimize the effects of pests and diseases, and ensure adequate quantities of seed at planting time.

CIAT research associate Roosevelt Escobar explained that he and his colleagues developed the methodology several years ago with a group of women cassava growers in Santa Ana, Cauca, in collaboration with the Foundation for Agricultural Research and Development (FIDAR). They taught the women how to produce planting material with tissue culture, and helped them to design and equip a lab in their community using affordable equipment and inputs.

The team subsequently helped several other farmers’ groups create tissue culture labs, often in collaboration with NGOs or government programs. More recently, the team has begun establishing labs at secondary schools and working with teachers to incorporate biotechnology into the education system.

“We are now trying to use rural schools to promote new planting material in the communities,” said Escobar.

He said the plan is to start a lab and cassava propagation center at Pilamo’s secondary school in 2013. He hopes they can repeat their success in the municipality of Tuluújio, in Sucre department, where the government of Japan and other donors funded the creation of a biotechnology lab and tissue culture center at the Caracol Agricultural Technical Institute. Escobar explained that students there have based their senior theses on their work in the institute’s new lab. In 2012, the first group of 29 students graduated from the institute as technicians in biotechnology and planting material production.
Escobar explained that CIAT geneticists and plant virologists are studying FSD to contribute to the development of more resistant cassava varieties. He said they also plan to provide farmers in Pilamo and other communities with planting material from several varieties that can help them to access new markets.

While most of the region’s farmers sell their roots to processing centers for the starch industry, CIAT also has cassava varieties with excellent characteristics for the production of drinks or biodegradable plastics – markets that are growing. He added that his team also works with communities in the Llanos region of eastern Colombia that produce cassava for sale fresh to consumers.

“The idea is for the seed system to support the farmers in their efforts to produce the varieties that the market demands,” Escobar said.

Helping Banana Farmers Make the Transition from Subsistence to Income Generation

As part of its efforts to make low-cost, high-quality planting materials available to farmers and to promote market opportunities, RTB supported the publication of two training manuals to help smallholders, farmers groups and entrepreneurs in East Africa to produce tissue culture bananas, and use them to build profitable businesses. The manuals are the product of a four-year IITA project to promote the production of clean banana planting material in East Africa.

Producers of banana seed using tissue culture technology hold great promise for farmers in East Africa, where banana and plantain are essential staple crops. Plants produced through tissue culture are largely free from pests and diseases, and are more vigorous than the suckers traditionally used for banana propagation, which can translate into faster growth and higher yields. They are also more uniform, allowing for better marketing, and can be produced in large quantities in a short period of time, facilitating the distribution of both established and new cultivars.

Tissue culture technology can also help banana farmers to make the transition from subsistence to income generation, but there are many technical hurdles that limit its adoption or optimal use in East Africa. Tissue culture plantlets are fragile, especially in the early stages. For nursery operators, the correct handling of plantlets in humidity chambers and shade houses determines survival and quality. Farmers also need to handle and transport plantlets properly, and give them suitable water and fertilizer to fully reap full benefits.

“From our experience, addressing these technical issues alone will not suffice in making this technology available to smallholder farmers,” explained IITA’s Thomas Dubois, who coordinated the manuals’ production. “Switching to tissue culture technology from conventional suckers requires different skills and knowledge for both farmers and nursery operators.”

The manual consequently teaches tissue culture technology as part of a package that includes business and marketing skills, farmer group formation and credit access. During the project, hundreds of farmers and nursery operators in East Africa received training. In Burundi and Uganda, over 700 farmers were trained in more than 250 sessions, and 150 nursery operators in 20 sessions. In Kenya, farmers and nursery operators were trained together at 75 workshops.

In Uganda and Kenya, 11 new nursery businesses were established or strengthened as a result of the project, and entrepreneurs who participated in training sessions now earn thousands of dollars per year. An example is the group of women farmers in Mukono, Uganda who built a nursery that is now the principal plantlet supplier in their area. They even used their newly acquired business skills to start a catering service.

The RTB training manuals should facilitate more such success stories in East Africa, where the potential of tissue culture has barely been tapped, and the need for clean banana seed is vast and growing.
Developing tools for more productive, ecologically robust cropping systems
Developing tools for more productive, ecologically robust cropping systems

Subsistence farmers in developing countries often cultivate RTB crops with few inputs beyond their own labor, land and rainfall. Those who produce them for markets often opt for irrigation, fertilizers or other agrochemicals, which may increase yields, but require significant investment. Diversifying cropping systems can improve productivity without costly inputs, while contributing to environmental sustainability and adding resilience in the face of climate change or other stresses. RTB consequently seeks to develop innovative cropping systems, with farmer participation, that respond to the needs of different regions.

The goal is to identify best management practices, and develop decision support tools to improve cropping systems and enhance the productivity and resilience of small farms. Those tools need to target specific agroecologies, soils and yield gaps, and be based on current farm practices. This requires field research in the main RTB crops and regions, which was barely begun during the research program’s first year.

Examples of cropping system work in 2012 include research in East and Central Africa on systems in which banana is combined with annual food crops, such as beans, and on farms in Latin America and East Africa in which banana is combined with coffee, a perennial crop. Simple criteria for managing the banana canopy for understory beans or coffee were validated through both formal experiments and farmer experimentation.

Progress was also made in getting farmers in Sub-Saharan Africa to grow the South American root crop ahipa (*Pachyrhizus sp*), also known as yam bean. A legume with an edible root that is commonly grown with other crops in the Andes and Amazon Basin, ahipa adds nitrogen to the soil, which makes it an excellent addition to cropping systems.

Potatoes in dragon fruit orchard, Guangxi, China.
South American Root Crop Holds Potential for West Africa

CIP breeder Wolfgang Grüneberg reported progress in 2012 on getting farmers in the sub-Saharan regions of West Africa to grow the Andean root crop ahipa (*Pachyrhizus sp*.), also known as yam bean, the root of which can be eaten raw or processed. Ahipa is commonly grown with other crops in the Andes and the Amazon Basin, since it is a legume that adds nitrogen to the soil, so it is a good component for cropping systems. Ahipa roots are also good sources of protein, iron, and zinc, and recent research showed that ahipa can serve as a substitute for cassava in the production of the popular West African dish *gari*, or the Central African dish *fufu*, as well as porridge. The roots have also been used as feed for African giant snails, which are raised by smallholders in several African countries.
Promoting Postharvest Technologies, Value Chains and Market Opportunities
Promoting Postharvest Technologies, Value Chains and Market Opportunities

While RTB crops are staples that provide vital sustenance for some of the world’s poorest and most marginalized people, they are also commercial crops widely sold in urban areas, either fresh or as processed foods. Between those extremes lie varied value chains, some of which provide opportunities for smallholders to access markets and add value to their RTB crops. The options range from delivering crops to a local market to selling a processed product to becoming a supplier for a processed food industry. RTB is thus promoting research, partnerships and knowledge sharing to develop postharvest improvements that reduce food losses, and facilitate linkages to value chains and marketing options that can help smallholders move from subsistence to income generation.

While RTB crops hold untapped economic potential for small farmers, they also present many of the same postharvest challenges, due to their bulky, perishable nature, which can be especially problematic in remote areas where food security and income generation are weak. RTB biologists are developing improved varieties with greater shelf life and higher market value, whereas training projects and other interventions have helped smallholders to add value to their crops or access new markets, such as by propagating planting material for sale.

During its first year, RTB concentrated the bulk of its resources on the up-stream research products – advancing genetic and metabolic profiles, developing improved varieties, or exploiting synergies among centers for disease management and seed systems – but much of that research will have positive downstream impacts in areas such as the quality and robustness of smallholder harvests and the marketability of their crops.

An example of this is CIAT’s development of cassava varieties with characteristic demanded by the food industry, which in some cases purchases cassava from small and medium-sized farms. CIAT scientists discovered a natural mutant that resulted in the development of starchy (low-amylose) cassava varieties that are in high demand by the starch industry. CIAT also has cassava varieties with excellent potential for the production of biodegradable plastics or drinks – growing markets – which the institute is distributing to farmers groups in Colombia.

RTB researchers are also developing cassava varieties with longer shelf lives, which provide new opportunities for farmers to access value chains. Cassava suffers from a condition called postharvest physiological deterioration (PPD), which can leave roots unmarketable in a matter of days. CIAT and IITA are collaborating on the development of improved cassava varieties that resist PPD for a week or more, which opens the door to new market opportunities for countless smallholders (see Progress Toward Longer-Lasting Cassava, page 29).

The RTB centers have executed successful projects to help farmers access value chains and market opportunities, and the research program’s focus on knowledge sharing has helped experts at the four centers to learn from those experiences. There is a potential for transferring lessons learned in cassava and
sweetpotato to yam and banana, though in different contexts and at different scales. A postharvest technology workshop held at CIAT headquarters in Colombia in early 2013 provided an ideal forum for representatives of the four centers, other research and development organizations and the private sector to share success stories, analyze the most pressing postharvest challenges, and identify common tools and methods that could be applicable across RTB crops.

Efforts that have generated lessons worth learning include a project in the East African highlands promoting group banana marketing, and an IITA project that taught smallholders in East Africa how to produce and market banana plantlets using tissue culture. RTB funded the publication of two training manuals that resulted from the latter, which ensures that the lessons learned will widely disseminated (see Helping Banana Farmers, page 51).

CIP’s SASHA Project, which promotes the production, consumption and marketing of orange-fleshed sweetpotatoes – rich in pro-vitamin-A beta carotenes – includes a venture in Rwanda to produce and sell biscuits made from sweetpotato pulp. In November of 2012, the local company Urwibutso (SINA) Enterprises began producing and distributing Akarabo Golden Power Biscuits, eight or nine of which provide the daily vitamin A needs of a child under the age of nine. The factory purchases sweetpotato from various farmers’ groups, many of the members of which are women (see Rwanda Sweetpotato Products, page 60).

Bioversity International undertook several banana value chain studies in Uganda in 2012, including a study of beer-banana value chains that resulted in two papers that have been submitted for publication. Researchers identified a potential for growth in banana-based drinks, such as juice, beer and distilled alcohol, which are mainly processed on a small-scale, while the few factories that exist struggle due to a lack of access to credit and financing.

A study of farmers’ groups that engage in collective marketing in order to increase prices and market access was done in partnership with those groups. Bioversity International helped the groups to map local value chains for different types of banana, which their marketing committees are now using to draft marketing strategies. Researchers found that whereas banana value chains have always included many middlemen, there is trend toward more direct contact between farmers and large-scale traders thanks to mobile phones and associated money transfer systems.

To promote efforts to help small farmers in East Africa to market their crops, RTB sponsored a value chain proposal-planning workshop in Kampala, Uganda in June of 2012. The meeting brought together experts from three of the RTB centers and various national and international organizations to identify RTB products, a research agenda for testing technologies, key partners, potential pilot sites and strategies for incorporating gender into the work.
Rwanda Sweetpotato Products Benefit Women Farmers

Rwanda Sweetpotato Super Foods, a component of the CIP project Sweetpotato Action for Security and Health in Africa (SASHA), is promoting the production of some inventive food products made from sweetpotatoes grown by smallholders, most of whom are women. In November of 2012, Urwibutso (SINA) Enterprises, in Kigali, Rwanda, began producing Akarabo Golden Power Biscuits, a nutritious packaged snack made from orange-fleshed sweetpotatoes that are purchased from small farmer groups.

The biscuits are the first of a series of processed food products that Rwanda Sweetpotato Super Foods plans to promote to the country’s growing urban population as a way of adding value to, and creating demand for sweetpotatoes, which are predominantly grown by smallholders. The project has been helping groups of women to produce sweetpotatoes and it seeks to use sweetpotato food products to build gender-equitable value chains. Some of the farmer groups that the project works with are more than 80% female, and more than half the sweetpotatoes that Urwibutso Enterprises has purchased for biscuit production were grown by women farmers.

The value chain project has grown out of a larger effort to promote farming and consumption of orange-fleshed sweetpotato in East Africa. The orange-fleshed sweetpotato varieties that CIP is promoting in the region are rich in beta-carotene, which the body converts into vitamin A. Vitamin-A deficiency is a major health problem in Africa, where it causes childhood blindness and other health problems. Just four Akarabo Golden Power Biscuits provide 48% of the vitamin A that a nine-year-old child needs per day, 28% of a non-pregnant woman’s daily requirement, or 21% of an adult male’s needs.

Farmers who sell sweetpotatoes to Urwibutso Enterprises keep part of their harvest for home consumption, so their families benefit from improved diets as well as income. Rwanda has some of the highest per-capita sweet potato consumption in Africa, which is good for local diets, but depresses market prices, especially during the peak harvest season. By promoting the development of processed food products, the project seeks to create additional demand, while extending the sweetpotato’s nutritional benefits to more consumers.

Rwanda Super Foods has also taught women in the farmer groups it works with how to prepare breads, cakes and doughnuts called mandazi from sweetpotato puree, which they can sell locally for additional income. Those value-added options have inspired more farmers to plant sweetpotato, which in turn creates yet another market opportunity for project participants – selling vine cuttings to their neighbors.

Rwanda Sweetpotato Super Foods is a collaboration of CIP, the Rwanda Agricultural Board, Urwibutso (SINA) Enterprises, Catholic Relief Services, the Kigali Institute of Science and Technology and the local NGOs Imbaraga and the YWCA of Rwanda.
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Ruben Echevarría
Director General, CIAT

Emile Frison
Director General, Bioversity International

Nteranya Sanginga
Director General, IITA

Graham Thiele
Program Director, RTB

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Augusto Becerra Lopez-Lavalle, CIAT
Theme 2: Development of Varieties

Rachid Hanna, IITA
Theme 3: Managing Pests and Diseases

Oscar Ortiz, CIP
Theme 4: High-Quality Planting Material

Stefan Hauser, IITA
Theme 5: Ecologically-Robust Cropping Systems

Dominique Dufour, CIAT/Cirad
Theme 6: Postharvest and Markets

Inge Van den Bergh, Bioversity International
Theme 7: Communications, Knowledge Management and Capacity Strengthening

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Theme 7: Social Sciences

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Javier Madalengoitia, Grants & Contracts Specialist

Milagros Patiño, Budget and Planning Supervisor

Antonio Sánchez, Budget Analyst

Zandra Vásquez, Executive Administrative Assistant
RTB Partners

**A**
- Africa Innovations Institute, Uganda
- African Agricultural Technology Foundation (AATF), Kenya
- African Development Bank
- AGRICON International Inc, Canada
- Agricultural Genetics Institute, Vietnam
- Agricultural Research Council, South Africa
- Agricultural Research Institute Rwanda (ISAR)
- Agri-Food Canada
- Agro & Bio technologies, Burundi
- Alliance for a Green Revolution in Africa (AGRA)
- Almidones de Sucre, Colombia
- Appropriate Rural Development Agriculture Program, Kenya
- ARDI Ukiriguru, Tanzania
- Asociación para el Desarrollo Sostenible del Perú (ADERS)
- Association for Strengthening Agricultural Research in Eastern and Central Africa (ASARECA)
- Australian Centre for International Agricultural Research (ACIAR)

**B**
- Bangladesh Agricultural Research Institute
- Bath University, United Kingdom
- Bill and Melinda Gates Foundation
- BioAnalyt, Germany

**C**
- Cámara Paraguaya de Mandioca y Almidones (CAPAMA)
- Cambodian Agricultural Research and Development Institute
- Catholic Relief Services (CRS)
- Central Tuber Crop Research Institute, India
- Centre Africain de Recherche sur Bananiers et Plantains
- Centre for Agricultural Bioscience International (CABI)
- Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD)
- Centre for Coordination of Agricultural Research and Development for Southern Africa (CCARDESA)
- Centre National de Recherche Agronomique, Côte d’Ivoire
- Centre de Recherche Public Gabriel Lippmann, Luxembourg
- Centro de Investigación en Biología Celular y Molecular, Costa Rica
- Chinese Academy of Sciences
- Chinese Academy of Tropical Agricultural Sciences (CATAS)
- Community Research in Environment and Development Initiatives (CREADIS), Kenya
- Compañía de Desarrollo y de Industrialización de Productos Primarios S.A. (CODIPSA), Paraguay
- Consorcio Latinoamericano y del Caribe de Apoyo a la Investigación y al Desarrollo de la Yuca (CLAYUCA), Colombia
- Consorcio de Pequeños Productores de Papa (CONPAPA), Ecuador
Cornell University, USA
Corporación Bananera Nacional, Costa Rica
Corporación Colombiana de Investigación Agropecuaria (CORPOICA)
Council for Scientific and Industrial Research, Ghana
Crawford School of Public Policy, Australia
Crops Research Institute (CSIR), Ghana

Dalhousie University, Canada
Davao National Crop Research & Development Center, Philippines
Department of Agriculture, Fisheries and Forestry, Australia
Directorate-General for Development Cooperation (DGDC), Belgium
Directorate-General for International Cooperation (DGIS), Netherlands
Dole Fresh Fruit International
Donald Danforth Plant Science Center, USA
Dow Agrosciences LLC

EkoRural, Ecuador
EMBRAPA Fruits and Cassava, Brazil
Emory University, USA
Escuela Superior Politécnica de Chimborazo, Ecuador
ETH Zurich, Switzerland
European Commission

Faculté universitaire des sciences agronomiques de Gembloux, Belgium
Farmer’s Choice, Kenya

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Federal Ministry of Agriculture, Nigeria
Federal University of Agriculture, Abeokuta, Nigeria
Fondo para el Financiamiento del Sector Agropecuario (Finagro), Colombia
Fondo Regional de Tecnología Agropecuaria (FONTAGRO)
Food and Agriculture Organization of the United Nations (FAO)
Food and Environment Research Agency (FERA), United Kingdom
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

Generation Challenge Program (GCP)
Ghent University, Dept. of Molecular Biotechnology, Belgium
Global Alliance for Improved Nutrition (GAIN)
Global Crop Diversity Trust
Global Forum on Agricultural Research (GFAR)
Grupo GPC, Colombia
Grupo PCI Rojas, Costa Rica
Guangdong Academy of Agricultural Sciences, China
Guangxi Cassava Research Institute, China

Helen Keller International, Africa Region
Horticultural Crop Research and Development Institute, Sri Lanka
Huazhong Agricultural University, China
N
National Agricultural Crops Resources Research Institute (NaCRRI), Uganda
National Agricultural Research Institute, Papua New Guinea
National Agricultural Research Organisation, Uganda
National Agriculture and Forestry Research Institute, Lao PDR
National Crops Research Institute, Uganda
National Horticultural Research Institute, Nigeria
National Institute for Study and Agricultural Research (INERA), DR Congo
National Potato Research Program, DR Congo
National Research Centre for Banana, India
National Root Crops Research Institute (NRCCI), Nigeria
Natural Resources Institute (NRI), University of Greenwich, United Kingdom
Nestlé, Nigeria
Nong Lam University, Vietnam
Northern Agriculture and Forestry College, Lao PDR

P
PATH
PepsiCo Alimentos, Ecuador
Philippine Council for Agriculture, Aquatic and Natural Resources Research and Development
Plant & Food Research, New Zealand
Plant Protection Research Institute, Vietnam
Provincial Dept. of Agriculture, Kampong Cham, Cambodia

R
Regional Strategic Analysis and Knowledge Support System (ReSAKSS)
Rimisp - Centro Latinoamericano para el Desarrollo Rural
Royal Holloway University of London (RHUL), United Kingdom
Royal Tropical Institute, Netherlands
Royal University of Agriculture, Cambodia
Rwanda Agricultural Board
Sierra Leone Agricultural Research Institute
SINA Gerard Ese Urwibutso, Rwanda
South China Botanical Garden
Swiss Agency for Development and Cooperation (SDC/DEZA)
Syngenta Foundation
Taiwan Banana Research Institute
Thai Farm International Ltd, Nigeria

U
UC Davis (Dept Plan Pathology & Dept. Plant Biology), USA
United States Agency for International Development (USAID)
Universidad de la Salle, Colombia
Universidad Nacional Autónoma de Nicaragua
Universidad Nacional de Colombia
Universitat de Valencia, Spain
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University of Copenhagen, Denmark
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University of Goettingen, Germany
University of Hohenheim, Germany
University of Leeds, United Kingdom
University of Nairobi, Dept. of Animal Production, Kenya
University of Puerto Rico Mayaguez
University of Stellenbosch, South Africa
University of the Philippines at Los Baños

V
Venganza, Inc.
Virginia Polytechnic Institute and State University, USA

W
WACCI (West Africa Centre for Crop Improvement), Ghana
Wageningen University - Plant Research International, Netherlands
Waite Analytical Services, University of Adelaide, Australia
West African Seasoning Company Limited (WASCO), Nigeria
West and Central African Council for Agricultural Research and Development (CORAF/WECARD)
World Bank
The total budget approved for the CGIAR Research Program on Roots, Tubers and Bananas (RTB) was **US$76.9M**, US$33.65M (44%) of which was funded from Window 1 and Window 2, and US$43.2M (56%) of which came from Window 3 and bilateral donors. By the end of the year, total expenditures were **US$54.6M** (71% of the Budget), of which US$22.3M (66%) were from W1 and W2 and US$32.3M (74%) were from W3 and bilateral donors. Gender research accounted for 6% of total expenditures.

RTB had an accounting balance of US$11M corresponding to funds received from W1 and W2. Funds pending distribution (US$5.5M) correspond to additional complementary funding received late in the year.

### Funding Profile

RTB execution in 2012 came from CGIAR funds – US$22.3M (41%) from W1 & 2 and US$3.8M (7%) from W3 – and bilateral donors, providing US$28.5M (52%).

### Revenues

In 2012, total revenues were US$31.4M (93% of the budget). Receipt of US$2.2M was still pending in 2013.

At the end of the year, the RTB cash position amounted to US$9.1M.

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**Themes Overall Execution by Center**

![Themes Overall Execution by Center](chart)
Selected Publications

Banana and Plantain (Musa)

Manuals


Journal Articles


Cassava

Journal Articles


Proceedings


Potato

Journal Articles


Sweetpotato

Journal articles


Proceedings


Yam

Journal Articles


Proceedings


Tropical and Andean Roots and Tubers

Journal Articles


Teaming up for Greater Impact
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.

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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