IITA
Research to Nourish Africa

Annual Report
2010

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Cover photo: A woman-farmer happily walking home after receiving planting materials of improved cassava varieties through IITA's "Unleashing the Power of Cassava in Africa" Project.

Photo by: Godwin Atser, IITA.

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Vision

To be Africa's leading research partner in finding solutions to hunger and poverty.

Cassava, anyone? Photo by JT Oliver, IITA.

Who we are

Africa has complex problems that plague agriculture and people's lives. We develop agricultural solutions with our partners to tackle hunger and poverty. Our award winning research for development (R4D) is based on focused, authoritative thinking anchored on the development needs of sub-Saharan Africa. We work with partners in Africa and beyond to reduce producer and consumer risks, enhance crop quality and productivity, and generate wealth from agriculture. IITA is an international non-profit R4D organization established in 1967, governed by a Board of Trustees, and supported primarily by the CGIAR.

Contents

Introduction

A researcher inspecting a cowpea plant for aphids. Photo by JT Oliver, IITA.

Options and solutions

For more than four decades, we have been in the forefront of agricultural research to improve food security, enhance human health and nutrition, foster social and gender equity, and spur economic growth in Africa. We have been working towards these goals to benefit the poor and the underprivileged while reducing our environmental footprint. Whereas our work has mostly focused on Africa, its applications and impacts reach beyond the continent's boundaries particularly in countries with similar tropical environments.

We deliver the products and benefits of agricultural research to the people through our tried and tested research-for-development (R4D) approach that incorporates scientific knowledge, technologies, leadership, partnerships, and processes. Through our R4D model, we work closely with our partners and investors to develop and deploy agriculture-based options and solutions that help farmers face new challenges such as changing food and nutrition needs, increasingly competitive markets, intensifying biotic and abiotic stresses, and shifting climatic conditions.

Below is a summary of our work and achievements in 2010, details of which are presented in the "Research Highlights" section of this report:

To address vitamin A deficiency among Africans, we worked to identify and develop molecular markers for pro-vitamin A carotenoid genes in cassava. We envision that this effort will lead towards marker-assisted breeding of vitamin A-fortified cassava that could serve as an effective delivery mechanism of this important nutrient to millions of people who consume this root crop daily.

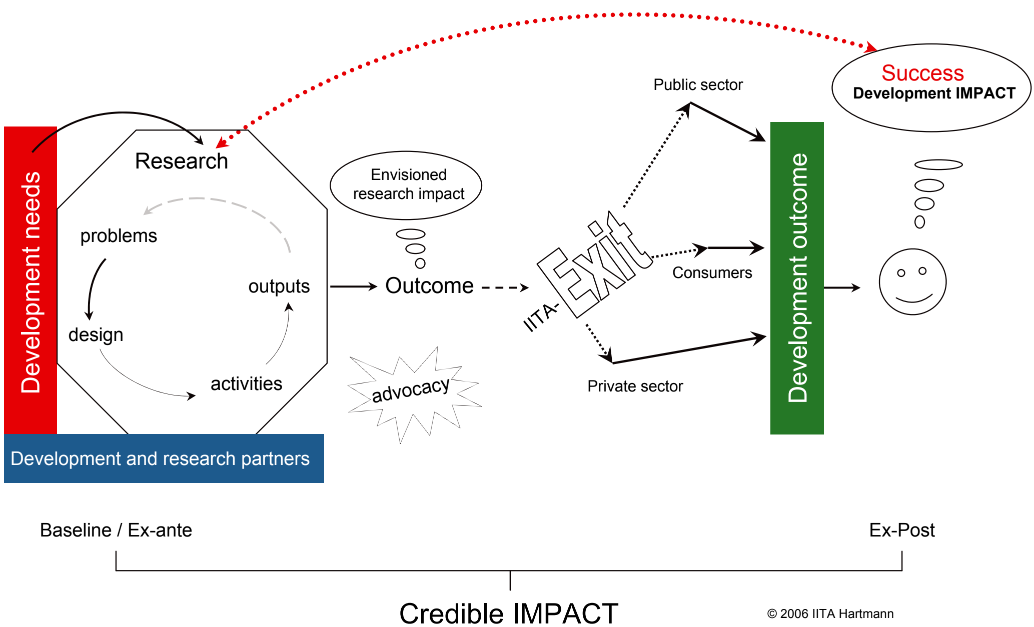
We continued to catalogue, characterize, update, and streamline the inventory of the African crops currently conserved in our Genetic Resources Center (GRC). We also undertook efforts to make relevant information available in online plant genetic resources databases to make them more widely accessible.

As part of an international undertaking to provide the ultimate rescue for African yam diversity, we partnered with national programs and the Global Crop Diversity Trust in an ambitious new effort to add 3000 yam samples to our international collection maintained in the GRC. Yam varieties gathered from all over the world through this initiative are being sent to the GRC at IITA-Ibadan in Nigeria for *in vitro* conservation and cryopreservation.

In Uganda, we completed a study that proved that banana-coffee intercropping is the way to go if farmers are to maximize profits. Our findings showed that fields that grew coffee and banana together generated over 50 percent more revenue that either coffee or banana growing alone. We have also initiated efforts to take the study to a regional level, covering Burundi and Rwanda, to promote the intercropping technology.

With funding from the USAID, we conducted research that showed that the systematic and moderate use of mineral fertilizers could double the production of East African Highland bananas. In Central Uganda, for example, yields almost doubled from 10 tons per

Our research-for-development model



1. Development needs: Identifies societal, producer and consumer needs that require addressing. Guarantees research relevance.
2. Research design: Specifies research problems that can be addressed by IITA with advanced research institutes and national partners. The design demands envisioning the potential impact.
3. Outcome: Defines scalable research outcomes and any advocacy activities required. A successful outcome entices partners to adoption.
4. Exit: Once the outcome is embraced by national/regional partners IITA exits implementation and changes role to monitoring the research outcomes.
5. Success/Development impact: Ex-post evaluations are carried and compared to baseline information to measure the impact on the ultimate beneficiaries.
6. Further work: Development impact creates new challenges which are referred back to development needs.

hectare to about 20 tons per hectare with modest fertilizer application. Additionally, the study also debunked some common myths about the unwanted side effects of fertilizers that hindered adoption by farmers, particularly on the soil quality and the taste of bananas.

In a major breakthrough, we successfully transferred genes from green pepper to bananas that conferred to the popular fruit the means to resist the banana *Xanthomonas* wilt, one of the most devastating diseases of bananas in the Great Lakes region of Africa. We have begun evaluation of the transgenic bananas in October 2010 under confined field trials in Uganda approved by the Ugandan National Biosafety Committee.

On cereals and legumes, we developed varieties that mature earlier, produce more grains, and resistant/tolerant to biotic and abiotic stresses through both biotechnology-assisted and conventional breeding techniques. Most of these varieties have been officially released to farmers, with the hope that these will help boost production in sub-Saharan Africa. We also conducted studies to identify the factors that influence the adoption of improved varieties by farmers in the region.

We co-organized the Fifth World Cowpea Research Conference held in Senegal in September-October in which more than 130 scientists gathered to discuss issues related to the black-eyed pea, one of the world's oldest crops and one of the most important in Africa. During the conference, researchers discussed a wide range of topics: from genetic improvement and use of molecular tools to improve the crop, to its uses in human nutrition, animal feed, processing, and enterprise development.

Through our Sustainable Tree Crops Program (STCP), we helped the government of Liberia develop an industry master plan for its rubber sector. Endorsed by in January 2010 by Her Excellency Ellen Johnson Sirleaf, Liberia's President, the "Liberian Rubber Industry Master Plan" is envisioned to resuscitate and reverse the declining production trend of the country's traditional rubber subsector to increase national production and export volume.

To guide prospective investors and partners in scaling up the Farmer Field School and Video Viewing Club as training methodologies, IITA/STCP completed a cocoa sector-based study that determined the costs of running these methodologies as well as presented options to increase cost-effectiveness. The results of the study can help donors and policymakers make informed decisions to institutionalize such farmer training approaches within national programs.

In another study, we determined that the systematic use of fertilizers can actually reduce the need to clear forests for agriculture and, consequently, prevent the release of massive amounts of carbon dioxide into the atmosphere that contributes to global warming. The study, which looked into land use change scenarios in four West African countries over a period of 10 years, presented empirical data that the significant increases in production in the region during the period would have been possible without the negative side effects of loss of biodiversity and enormous carbon emission and with little or no increase in the land area if smallholder growers used improved varieties and followed seed-fertilizer use recommendations that have been formulated and espoused by agricultural researchers as early as the 1960's.

In southern Africa, we led a multidisciplinary team to survey and catalogue existing pests and diseases of legume crops. The study was aimed at forming the basis to develop a sustainable crop protection strategy for the subregion where legume crops, specifically soybean and cowpea, are being grown in more areas because of their increasing importance in economy and food security.

During the year, we rounded up our "Unleashing the Power of Cassava in Africa" project – an initiative designed and implemented in response to the global food price crisis of 2008. Over just two years, the project was able to increase the production of cassava – an important staple – in the participating communities in the seven countries in which UPoCA was implemented by at least 30 percent and enhancing the competitiveness of cassava value chain actors through capacity building and by mobilizing, facilitating access to, and applying field-proven agricultural technologies.

We conducted a re-assessment of the Systemwide Program on Integrated Pest Management (SP-IPM) that we coordinate in order to anticipate and counter future challenges to IPM in the areas of food security and food safety. Related to this, we gathered forward-looking researchers at an expert workshop in Germany in March where researchers presented benchmark IPM technologies and discussed their suitability for different target farmers. New approaches in developing innovative technologies, their adaptability, and methods for delivery were also explored and discussed. During the year, three new projects were initiated that were borne out of close collaboration among the SP-IPM member centers, partners, and investors.

In 2010, we continued to enjoy sound financial health and stability through efficient management of financial resources. Our liquidity and reserve levels remain above the CGIAR-recommended benchmarks, and reflect our continued ability to meet both long- and short-term obligations. Our audited financial statements reflect balanced operating results due largely to increased investor support, continuing implementation of leaner cost structure, and frugal spending. Our auditors have given us a clean bill of financial health for the year. For details, please refer to the "Financial Information" section of this annual report.

Research Highlights

A cowpea farmer proudly showing his produce. Photo by T Abdoulaye, IITA.

Agriculture and Health

Developing biofortified cassava for improved health and nutrition

In Africa, over 100 million people suffer from sub-optimal vitamin A intake, with about 33 million under the age of 5. Vitamin A deficiency is a leading cause of visual impairment and blindness, and increases the susceptibility of affected people to diseases such as anemia, diarrhea, measles, malaria, and respiratory infections.

Cassava, being one of the most important staples in sub-Saharan Africa and consumed by more than 200 million people daily, could serve as an effective medium in delivering and increasing the intake of vitamin A. We continue to work with our partners to develop cassava that is enriched with this vital nutrient and contribute towards improving the wellbeing of consumers.

We are working to identify and develop molecular marker for pro-vitamin A Carotenoid (pVAC) genes in cassava. We envision improving the carotenoid content (beta-carotene, a precursor of vitamin A) of this root crop at the genetic level by identifying Single Nucleotide Polymorphism (SNP) – a kind of molecular marker or signpost in

Women cooking 'gari', a popular cassava-based food product. Cassava could serve as an effective medium to enhance the intake of vitamin A among Africans. Photo by JT Oliver, IITA.

A yellow-fleshed, beta-carotene enriched cassava root. Photo by IITA.

the crop's DNA – that attributes variation in carotenoid concentration among various cassava varieties.

Phytoene synthase (PSY1), β-carotene Hydroxylase (HYD1), Lycopene β, and ε cyclase (LYCB and LYCE) have been found to contribute to increasing the levels of beta-carotene in crops. We drew 32 cassava lines from the Uniform Yield Trial (UYT) stage of our cassava breeding program. These consist of lines with high carotenoid (concentration of 6ug-15ug) and low carotenoid (concentration of 0ug-5ug), as well as white root advanced clones. We then used primers for HYD1, LYCB, LYCE, and PSY1 genes designed from cassava ESTs to genotype these lines, and purified and sequenced amplified PCR products. From this process, we generated 228 sequences across all genes comprised of 49 HYD1, 62 LYCB, 59 PSY1, and 58 LYCE.

A search in the NCBI database of the sequences that we generated showed similarity with pVAC genes in *Ricinus communis, Zea mays, Arabidopsis thaliana, Carica papaya,* and *Daucus carota*, among others. Comparison of these sequences after multiple sequence alignment also revealed regions of conserved histidine cluster motifs that contain histidine residues: HXXX(X)H, HXX(X)HH, and HXXHH, a characteristic domain of the β-carotene hydroxylase superfamily. Other similarity searches in the phytozome cassava online database site (www.phytozome.net/cassava) matched full gene sequences of the carotenoid genes from which primers have been designed. These primers have been used to genotype a larger selection of 40 carotenoid variable lines (including the previous 32 lines).

We are currently sequencing the PCR products for analysis. We would then validate and convert the discovered nucleotide variants into user-friendly assay for marker-assisted breeding of vitamin A-fortified cassava.

Agrobiodiversity

Global initiative underway to preserve yam biodiversity

Farmers and crop scientists worldwide are engaged in an ambitious new effort to add 3000 yam samples to the international collection maintained at our Genetic Resources Center (GRC) with the aim of saving the diversity of a crop that is consumed daily by 60 million people in Africa alone.

The majority of the world's crops can be conserved over long periods simply by drying the seeds and storing them under cold, dry conditions.

However, a significant number of crops, including yams, cannot be stored so easily and must be conserved as vegetative material in tissue culture. Eventually, the international yam collection maintained at the GRC in IITA-Ibadan, Nigeria would provide the ultimate rescue for African yam diversity as part of an initiative to conserve critical crop collections backed by the Global Crop Diversity Trust.

Farmers in West Africa's "yam belt," which includes the countries of Nigeria, Côte d'Ivoire, Ghana, Benin and Togo, produce more than 90 percent of the world's yams. The project, however, will also include yam species/varieties collected in the Philippines, Vietnam, Costa Rica, the Caribbean and several Pacific nations. It is the first worldwide effort to conserve yam species and cultivars. The project is funded with support from the UN Foundation and the Bill & Melinda Gates Foundation.

Thousands of years of cultivation have resulted in a wide diversity of yam varieties existing in farmers' fields, particularly in West Africa. In some parts of Africa (mainly Benin and

An IITA genebank technician inspecting the condition of some of the in vitro conserved yam seedlings. Photo by JT Oliver, IITA.

Nigeria), yams are still being domesticated from wild tubers found in the forest. The crop is very popular with consumers, and sellers get a high price in urban markets. However, yams remain relatively under-researched despite their potential to bring farmers out of poverty in one of the world's poorest regions.

Yam varieties gathered from all over the world through the project are being sent to IITA in Ibadan, Nigeria, for sanitation and *in vitro* introduction. All samples will eventually be frozen at ultra-low temperatures (-196^{o}C) i.e. cryopreserved for long term storage.

While samples are received from all over the world, their DNA is collected for molecular fingerprinting to reveal sample uniqueness and avoid maintenance of duplicate in the collection. It will also provide information on overall collection diversity and help identify valuable traits to fight diseases, adapt to climate change, and provide higher yields for farmers.

"We would like to deploy the best tools science has to offer to secure centuries of yam cultivation" according to Dominique Dumet, head of the GRC.

"We will also be offering a stable and safe haven for yam collections that are sometimes at risk. For example, Cote d'Ivoire will be sending 500 yam samples for conservation from a collection that, after the civil war in 2002, had to be moved from Bouaké in the north to Abidjan," she adds.

Yams for sale. In some parts of Africa, yams are still being domesticated from wild tubers found in the forest. Photo by JT Oliver, IITA.

"This opportunity to protect an incredibly wide variety of yams allows us to feel more reassured that the unique diversity of yam will be safely secured and available to future generations," according to Alexandre Dansi, a yam expert at the University of Abomey-Calavi in Benin.

For Benin, which sits squarely in the buckle of the yam belt, yam is an integral part of the culture and community life. The large tubers weighing up to 70 kilos are a common sight on roadside markets. Dansi has worked with producers to catalogue about 250 discrete types of yams and more than 1000 named yam varieties. He is collaborating with farmers to document additional varieties. According to farmers' reports, many traditional varieties are disappearing in their production zones because of high susceptibility to pests and diseases, poor soil, soil moisture content, weeds and drought, which make them less productive or more costly to grow compared to other crops such as cassava. Through Dansi's work, Benin already has sent 847 yam samples to IITA.

A village royalty about to break 'new yam' during a yam festival in Ukpo, Anambra state, Nigeria. For many Africans, yams are an integral part of the culture and community life. Photo by JT Oliver, IITA.

"The security we now have is reassuring and allows us to focus on other things, like working with farmers to improve yields," Dansi says. "And on top of that we can now ask IITA for interesting yams from other parts of the world that we may never have seen before in Benin."

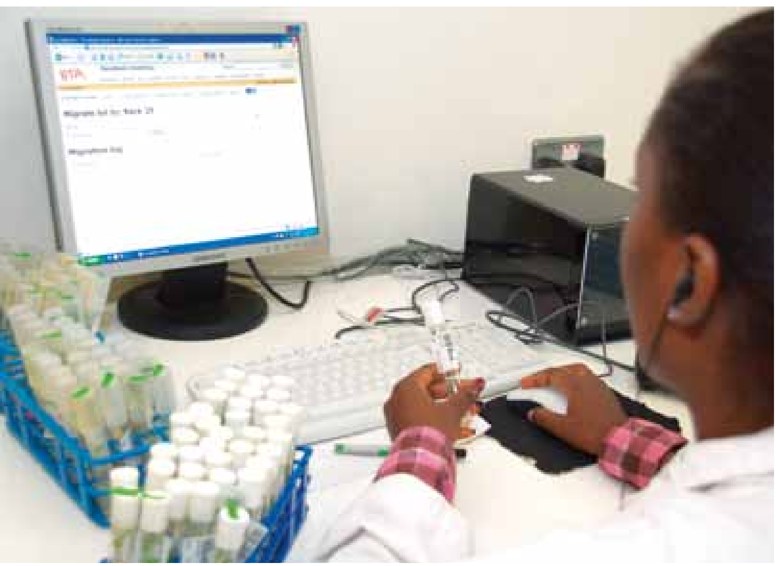
"It's really like putting money in the bank," says Cary Fowler, executive director of the Trust. "All crops routinely face threats from plant pests, disease, or shifting weather patterns, and a country's ability to breed new varieties to overcome these challenges is directly tied to what they have in the bank, not just in terms of financial resources but in terms of the diversity in their crop collections."

The yam project is part of a broader effort involving major crop species worldwide in which the Trust is helping partners in 68 countries—including 38 in Africa alone—rescue and regenerate more than 80,000 endangered accessions in crop collections and send duplicates to international genebanks and the Svalbard Global Seed Vault in the Arctic Circle.

Keeping track of Africa's crop genetic heritage

Our Genetic Resources Center (GRC) holds six international collections comprised of 28,000 accessions of major African food crops, namely cowpea and other *Vigna* species (which includes Bambara and wild relatives), cassava, yam, soybean, maize, and banana. In addition, the GRC holds about 600 accessions of miscellaneous legumes, including 147 accessions of African yam bean. Through our Agrobiodiversity Program, we keep track of and conserve these precious crop genetic resources, making them available for research to improve food security in Africa and beyond.

Between 2007 and 2010, we undertook efforts to improve the quality of the data associated with our germplasm and facilitate its use. We reviewed records in the original collecting books and refined the accession passport data accordingly. Overall, we checked 27,893 records documented in 118 collecting books. All passport data were cleaned and harmonized to fit the the CGIAR Systemwide Information Network for Genetic Resources (SINGER) and GENESYS Web-based global information portals. In addition, we scanned 15,504 pages of these historical records for security and posterity. We forwarded the electronic files (PDFs) of these records to SINGER for wider dissemination. We also reviewed characterization data for two collections (maize and cowpea) and uploaded them in our own online database as well as in GENESYS. We have also made further enhancements to our own database. Users can now easily browse and upload their selection as MS Excel files. Additionally, we initiated the deployment of the barcode inventory system for our yam and banana field collections.



A GRC staff entering information into the Genebank Inventory Database. Photo by JT Oliver, IITA.

In 2010, we completed the characterization of our cassava collection. This allowed us to define a core collection based on agro-morphological descriptors and passport data. During the characterization, we photographed the main descriptors for most of the accessions. The photographs will be compiled in an online catalogue for visual selection. Programming to complete the online catalogue is on-going.

During the year, we also conducted a cowpea wild relative collecting mission in Nigeria. With climate change, increased pest and disease pressures, cultural shifts, and increasing adoption of improved cowpea lines, including the recent introduction of Bt-cowpea, Nigeria's wild cowpea diversity is in danger of being lost forever. During the mission covering 26,000 km, we collected 261 samples comprising of 18 and 243 accessions, respectively, of *V. unguiculata* subspecies *baoulensis* (secondary genepool) and *V. unguiculata var spontanea* (genepool 1, progenitor).

Additionally, we completed the fingerprinting of the 2700 cassava accessions of the international collection using microsatellite markers. The aim was to identify duplicates for better genebank management and maintenance, and to standardize a protocol for easy identification of accessions when new cassava acquisitions are made.

Microsatellites have been proven as the most suitable marker for genotype identification. These markers are not influenced by environment, are co-dominant in nature, reproducible, hyper-variable, and are abundant in eukaryotes.

Following an identification criterion based on genetic distance (GD) between accessions, we conducted genotyping of the cassava collection using 25 SSR markers. We developed a high-throughput DNA extraction protocol and estimated the quality and quantity of DNA using advanced technology, NanoDrop. We carried out the genotyping initially using 10 SSR markers and polyacrylamide gel electrophoresis (PAGE) system, scoring the amplified products as either 1 (indicating presence) or 0 (indicating absence). Based on GD=0 and GD<0.15 range, we identified 895 identical and potential duplicates, which we further genotyped using additional 15 SSR markers following capillary electrophoresis in ABI 3130.

The genotyping data is being compared with available passport and characterization data to substantially identify absolute and potential duplicates. We are conducting a similar study to rationalize our international yam collection and those of national programs.

Banana and Plantain Systems

Banana and coffee: a match made in crop heaven

When two entities of seemingly diverse but complementary qualities come together, the result is usually a relationship typified by harmony and synergy. This holds true for people and crops. In a study that we concluded in 2010 in Uganda, banana and coffee, we discovered, make a perfect "couple" if managed well.

Uganda is the second largest banana producer in the world (after India), producing well over 10 million tons annually, almost equivalent to the volume of dessert bananas traded on the international market. The country is also Africa's second largest coffee producer, producing over 3 million 60 kg-bags in the 2008-2009 coffee cropping year.

A newly established banana-coffee intercrop in Uganda. Photo by P van Asten, IITA.

Coffee is Uganda's leading export crop but mostly produced on smallholder farms, yet most Ugandan farmers say that banana is their main cash crop. Unlike coffee, however, only a very small fraction of the banana produced is exported.

Banana and coffee yields in Uganda are only at 10 to 30 percent of their potential compared to similar ecologies in Asia and Latin-America. Uganda is also among the lowest mineral fertilizer users in the world, with less than 5 percent of farmers using mineral fertilizer. With modern farming methods and inputs, the scope for improving productivity of the crops is huge.

With a population growing at 3.4 percent yearly, Uganda is the third fastest growing population in the world. The country will have nearly 100 million people by 2050. Presently, over 80 percent of the population lives in the rural areas. These statistics point to an expected dramatic increase in land pressure in Uganda in the coming years.

To feed its growing population and maintain sufficient income, the country will need to up its agricultural production dramatically. It is therefore not surprising that the government has set its sights at increasing banana and coffee production in the next four years by 60-100 percent.

Most small-scale farmers in Uganda have grown both coffee and banana for years. At the socioeconomic level, both crops were already known to play a complementary role: coffee provides households with a cash boom twice a year, while banana provides a continuous source of food, as well as cash throughout the year. However, an evaluation of the USAID-funded Agricultural Productivity Enhancement Program (APEP) showed that the benefits of growing coffee and banana together were even greater than previously thought.

Detrashing banana interplanted with coffee. Photo by P van Asten, IITA.

APEP aimed at improving the productivity of coffee by setting up hundreds of demonstration plots in Uganda's major coffee-growing areas. Farmers received training on good crop management and improved postharvest handling. More importantly, the APEP farmers also received urea fertilizer.

In 2005, we received a research grant to evaluate the yield increases and profitability of the technologies demonstrated by APEP. We observed the performance of coffee and banana grown on their own (monocropped), and coffee and banana grown together (intercropped). We monitored 300 fields, half of them in the Southwest Robusta districts of Masaka, Rakai, and Bushenyi, and the other half in the Mt. Elgon Arabica districts of Bududa, Manafa, Mbale, and Sironko. We also compared APEP demonstration plots and local farmers' fields that served as controls plots.

Our findings were surprising: fields with coffee and banana growing together generated over 50% more revenue than either coffee or banana growing alone. For instance, in the Arabica coffee-growing region around Mt. Elgon, annual returns per hectare averaged US$ 4441 for intercrop, US$ 1728 for banana monocrop, and US$ 2364 for coffee monocrop. In the Robusta-growing areas in South and Southwest Uganda, annual returns per hectare averaged US$ 1827 (banana-coffee intercrop), US$ 1177 (banana monocrop), and US$ 1286 (coffee monocrop). These results were obtained from the non-demo plots.

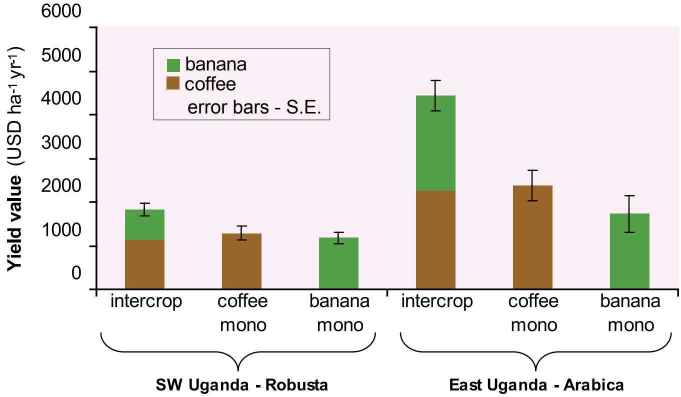


Table 1. *Yield value of mono and intercropped coffee and banana in two regions of Uganda.*

We also found that coffee yields did not decline (<13%) when intercropped with banana compared to when grown alone; therefore, all revenues generated by banana was a "bonus" to the farmers (Figure 1). The fertilized APEP demo plots showed the same trends as the control fields: the intercropped fields were much more profitable than the monocropped coffee or banana.

The demonstration plots had much higher yields than the farmer control plots due to increased fertilizer application, which was maintained at 200 grams per tree per rainy season incorporated in the topsoil in a 45-60 cm ring around the stem. Other factors such as pruning and mulching were not significantly different between demo and control plots.

The yields in the Robusta fields nearly doubled. In the Arabica fields around Mt. Elgon the yields increased by only 30% with high fertilizer applications due to high plant density. Consequently, marginal rates of returns to fertilizer investments in Robusta were between 300% and 500%, whereas those for Arabica varied between 20% and 80%. The differences were attributed to the nutrient concentrations in the leaves of the flowering coffee plants. Robusta coffee was dominantly nitrogen deficient so the urea-N application suited it well. Arabica coffee, on the other hand, was dominantly potassium and magnesium deficient and only moderately N deficient. Hence, the applying nitrogen increased yields by around 30% only.

Additionally, coffee is a shade-tolerant plant. The taller banana plant provides shade and its leaves enhance soil fertility through surface mulching. The best performing fields were those that had a plant ratio of 1 banana tree to 2 coffee trees.

For now, it is possible to double farmer revenues through intercropping and improved nutrient management. However, more research is needed to determine other factors to maximize this banana-coffee relationship, such as optimal plant densities and fertilizer recommendations.

This study proved that coffee and banana make a perfect match, and holds much promise not only for the Ugandan coffee sector but also for other countries in the region as well. With national partners, we have taken the study to a regional level. In Burundi, we have initiated four banana-coffee intercrop trials in young and mature coffee plantations in the framework of a project under the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA). The trials are being led by an *Institut des Sciences Agronomiques du Burundi* PhD student at *Université catholique de Louvain-Belgium*. In Rwanda, the coffee authority OCIR-Café and the Rwanda Agriculture Research Institute (ISAR) have funded and established a banana-coffee intercrop trial in the eastern part of the country. Traditionally, Burundi and Rwanda have recommended, and at times imposed, monocrop coffee.

Rational use of fertilizer could double African banana yields

A fertilizer-use study on East African highland bananas that we completed in 2010 has shown that moderate application of mineral fertilizers could double the production of the crop. However, the study also found that a vast majority of banana growers in the region do not use fertilizers, missing out on the opportunity to maximize the crop's food security and economic potentials. Over 70 million people in the East African highlands depend on banana as their primary source of food and income.

The USAID-funded study covering nearly 200 farmer fields in Uganda – the second largest producer and consumer of bananas in the world – indicated that modest fertilizer use can significantly increase the crop's yield. In Central Uganda, for example, annual yields doubled from 10 to 20 tons per hectare with modest fertilizer application.

The research was led by Piet van Asten, one of our agronomists based in Uganda, and Lydia Wairegi, an IITA-Makerere PhD student who successfully defended at Wageningen University in October 2010.

"The application of fertilizers not only increases bunch weight but also shortens the crop cycle so the plants produce more bunches in a year", says van Asten.

However, the study also found that less than 5 percent of the farmers apply fertilizer on their banana crop. The farmers cited high costs, erratic supply, and inconvenient packaging as the main reasons for not using fertilizers. They also indicated the lack of access to credit facilities, limited knowledge on fertilizer use, and the perceived negative effect on soil quality and on the taste of the bananas.

To debunk the latter, a related farmer sensory evaluation that we conducted with Uganda's National Agricultural Research Organization showed that fertilizer use not only increased yields, but also improved the quality of the fruit to make 'matooke' – a popular local delicacy made from steamed bananas.

The results of the evaluation indicated that fertilizer treatment actually improved the appearance, odor, texture, and overall acceptability of the steamed bananas.

Although the study showed proof of the positive effect of fertilizers on banana production, van Asten cautions that fertilizer use has to be very strategic. For example, the practice only becomes more profitable when it is specific to a crop and a region, and targeted at only those nutrients that are most deficient.

With the proper use of fertilizer coupled with modern farming techniques, it is possible to double the yields of African bananas. Photo by JT Oliver, IITA.

“Most farmers follow blanket fertilizer recommendations which can be very inefficient and therefore expensive. Farmers should apply only as much nutrient as needed for a realistic yield increase for their specific locality,” he says.

He adds that another consideration is distance to the markets. “Bananas are perishable and costly to transport because of their bulk. One needs to be close to the market to fetch a really good price,” he says. “Uganda’s production zones are too far from markets, some more than 150 kilometers away. This leads to low banana prices at the farm gate. Fertilizer use in such cases becomes risky and, therefore, may not be recommended.”

Fertilizers also help replace lost soil nutrients. For example, the study estimated that more than 1.5 million tons of potassium are removed from where the bananas are grown and transported to Kampala where most of the markets are. These nutrients are mined by farmers, but not immediately replaced. Over time, this could diminish the soil’s ability to profitably sustain banana production.

To guide East African highland banana farmers, we, with our partners, have developed several site-specific recommendations for the application of fertilizer based on the region and the distance to markets. We are also encouraging the private and public sectors to address fertilizer packaging to suit the specific needs of farmers.

Genes from sweet pepper fortify African banana against devastating wilt disease

In a major breakthrough in 2010, we successfully transferred genes from green pepper to bananas, conferring on the popular fruit the means to resist one of the most devastating diseases of bananas in the Great Lakes region of Africa.

The Banana *Xanthomonas* Wilt (BXW) costs banana farmers about half a billion dollars in damages every year across East and Central Africa. The leaves of affected crops turn yellow and then wilt, and the fruit ripens unevenly and before its time. Eventually the entire plant withers and rots.

Leena Tripathi, lead scientist of the study and author of the paper, says there is still a long way to go before the transgenic bananas find their way onto farmers’ fields, but she called the breakthrough “a significant step in the fight against the deadly banana disease.”

Banana bunches infected with BXW. Photo by SP-IPM.

The transformed bananas, newly-infused with one of two proteins from the green pepper, have shown strong resistance to *Xanthomonas* wilt in the laboratory and in screen houses. Confined field trials have been initiated in Uganda with the permission of the national government.

Some of the findings on the protective impact of the two proteins -- plant ferredoxin-like amphipathic protein (Pflp) and hypersensitive response-assisting protein (Hrap) – were published recently in the Molecular Plant Pathology Journal.

"The *Hrap* and *Pflp* genes work by rapidly killing the cells that come into contact with the disease-spreading bacteria, essentially blocking it from spreading any further," Tripathi says. "Hopefully, this will boost the arsenal available to fight BXW and help save millions of farmers' livelihoods in the Great Lakes region."

The novel green pepper proteins that give crops enhanced resistance against deadly pathogens can also provide effective control against other BXW-like bacterial diseases in other parts of the world. Tripathi adds that the mechanism known as Hypersensitivity Response also activates the defenses of surrounding and even distant uninfected banana plants leading to a systemic acquired resistance.

Together with scientists from the National Agricultural Research Organization (NARO) of Uganda and in partnership with the African Agricultural Technology Foundation (AATF), we have begun evaluation of these promising new banana lines in October 2010 under confined field trials at NARO in Kawanda. The Ugandan National Biosafety Committee approved the tests.

The genes used in this research were acquired under an agreement from the Academia Sinica in Taiwan.

The highly destructive BXW affects all varieties including the East African Highland bananas and exotic dessert, roasting, and beer bananas. The crop is also under threat from another deadly disease, the banana bunchy top.

Tripathi says that there are presently no commercial chemicals, biocontrol agents or resistant varieties that can control the spread of BXW. "Even if a source of resistance is identified today," Tripathi said, "developing a truly resistant banana through conventional breeding would be extremely difficult and would take years, even decades, given the crop's sterility and its long gestation period."

BXW was first reported in Ethiopia 40 years ago on Ensete, a crop relative of banana, before it moved on to bananas. Outside of Ethiopia, it was first reported in Uganda in 2001, then rapidly spread to the Democratic Republic of Congo, Rwanda, Kenya, Tanzania, and Burundi, leaving behind a trail of destruction in Africa's largest banana producing and consuming region.

BXW can be managed by de-budding, or removing the male bud as soon as the last hand of the female bunch is revealed, the banana plant and sterilizing farm implements used. However, the adoption of these practices has been inconsistent at best as farmers believe that de-budding affects the quality of the fruit and sterilizing farm tools is a tedious task.

We started the research to fortify banana against BXW using genes from sweet pepper in 2006.

The transgenic banana confined field trials site in Uganda. Photo by L Tripathi, IITA.

Cereals and Legumes Systems

Keeping a close eye on black eyed peas

Cowpea is an important food grain legume grown mainly in the drought-prone regions of the tropics and sub-tropics, with sub-Saharan Africa accounting for 80% of global production. However, several factors impede the realization of the crop's full potential for income generation, food security, and nutrition. Cowpea yields are generally low due to pests, diseases, drought, and low soil fertility. Confounding this, consumers and producers in different areas of the region have correspondingly diverse tastes and preferences in plant growth habit, seed type, maturity, and use. In 2010, we continued to focus on breeding efforts to develop a range of cowpea varieties that suit regional preferences combined with high-yield potential and resistance/tolerance to major biotic and abiotic stresses.

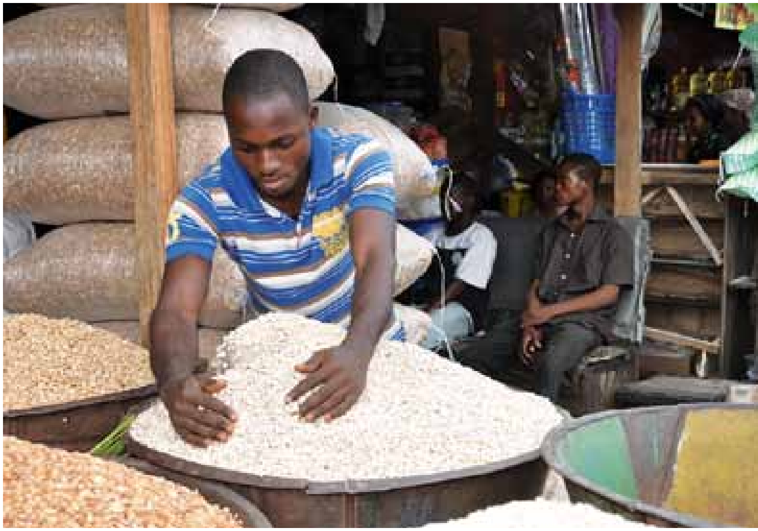
Breeding early maturing and high performing varieties

During the year, we developed varieties that matured in only 65 days (as opposed to about 120 days normal harvest time) and produced up to 2.0 tons of grain per ha. These varieties also exhibited resistance to some common cowpea diseases and pests such as brown blotch, *sclerotium, septoria*, viruses, and aphids. These high-performing lines are IT07K-243-1-2, IT07K-202-2-10, IT07K-243-1-5, IT07K-222-2, IT07K-298-15, IT07K-299-6, and IT07K-243-1-10. Three of the varieties – IT07K-298-15, IT07K-243-1-2, and IT07K-202-2-10 – also produced more than 3.5 tons of fodder per hectare.

In addition to these extra-early maturing lines, we also developed 13 different-maturing and dual-purpose lines that have high grain and fodder yields and are resistant to major diseases. These include IT07K-318-33, IT07K-322-40, and IT07K-273-2-1 (early-maturing at 70 days); IT07K-292-10, IT07K-297-13, IT07K-291-69, IT06K-147-1, and IT07K-318-2 (medium-maturing at 80 days); and IT06K-275, IT07K-187-55, IT06K-270, IT07K-241-1-2, and IT07K-252-1-9 (dual-purpose, medium-late maturing at 90-100 days).

Under the Tropical Legumes II Phase 1 Project, we identified cowpea lines with enhanced tolerance to drought and preferred by farmers in the five participating countries. In Mali, two varieties have been registered: CZ1-94-23-1 (Gana Shoba) and CZ1-94-23-2 (Gana Shoni), while two were released (see cowpea section in "Giving cereals and legumes production in sub-Saharan Africa a boost").

In Mozambique, we identified seven lines that perform well under drought conditions: IT00K-1263, IT97K-1069-6, IT98K-131-2, IT98K-128-3, IT97K-499-35, IT97K-390-2, and IT98K-205-8, with the first two being eyed for release in 2011. In Niger, IT96D-610, IT99K-573-1-1, IT97K-499-35, IT97K-499-38, and IT90K-372-1-2 are being tested in different localities to confirm their adaptability and suitability for release. In Nigeria, we identified 13 lines that performed well in drought conditions: IT99K-573-1-1, IT98K-491-4, IT98K-506-1, IT99K-377-1, IT98K-131-2, IT03K-378-4, IT03K-316-1, IT00K-901-5, IT98D-1399, IT98K-412-13, IT97K-568-18, IT99K-7-21-2-2, and IT04-227-4. These will be incorporated in the All-Nigeria Coordinated Trials for possible release. In Tanzania, two promising lines – IT00K-1263 and IT99K-1122 – have been selected following farmer-participatory selection in 2009/2010 and entered into the national performance trial of 2010/2011. Information on DUS has also been submitted to the Tanzania Seed Certifying Institute for verification.



Better cowpea means more yield and higher income. Photo by IITA.

Marker development and verification

Working with partners under the Tropical Legumes I Project, we screened and identified drought-tolerant genotypes and QTLs contributing to drought tolerance and thrips resistance. We also developed and validated associated markers.

Additionally, in collaboration with the University of Wageningen - The Netherlands and the University of California, Riverside, USA, we identified molecular markers associated with resistance to the bacterial blight disease using a set of recombinant inbred lines that we also developed. These markers would be useful in incorporating resistance to the disease in cowpea through marker-assisted selection.

Variety adoption study

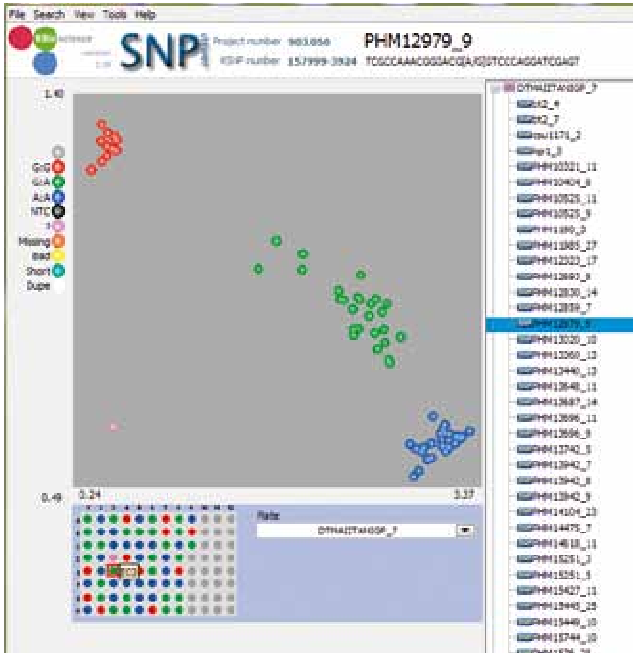
After more than three years of implementing the Tropical Legumes II Project, we conducted an assessment of the adoption of our improved cowpea technologies in Borno and Kano States located in the savannas of northern Nigeria. We found that more than three-quarters of the participating farmers adopted our improved cowpea varieties, with IT97K-499-35 being the most adopted followed by IT90K-277-2. We also found that access to extension services was the most significant factor influencing the improved varieties' adoption by farmers. Other factors are collaboration with projects that promote the improved varieties and frequency of visits by extension agents. In the two states, more male farmers (75%) adopted the improved technology than female farmers (25%). It is our hope that the findings of this study will help in the development of policies that would fast track the dissemination of improved cowpea technologies to smallholder farmers.

Maize: MARS and beyond

"Maize on Mars; on another planet?" you ask. Not quite! MARS means marker-assisted recurrent selection. It is an approach adopted by crop breeders to accelerate the rate of development and discovery of 'lines' (something like animal breeds) that possess certain valuable traits. We use MARS to address a key problem of maize growers in Africa: of getting good yields despite unpredictable rainfall and periods of drought.

Drought has always been a bane for farmers; however, climate change has exacerbated the problem, making droughts more unpredictable and intense. We endeavor to improve drought tolerance in maize by selecting those lines with good tolerance and use them in our breeding programs. While very successful these efforts take a long time as materials have to be grown in drought conditions, a process called "drought phenotyping", in order to identify the best ones. After many years of selecting and testing parental lines and their offspring through drought phenotyping, we are able to develop new drought-tolerant varieties that can be used in farmers' fields. This process is called "recurrent selection" – season-to-season selection and recombination to produce the best material possible.

Modern molecular tools can be used to speed up this process. Single nucleotide polymorphisms (SNP) – a kind of molecular marker or signpost in the DNA of the maize lines – can be used in recurrent selection to get new varieties much faster. MARS defines this process. In MARS we phenotype materials under drought stress and then ‘genotype’ them – that is we determine the status of their SNP markers. We combine this data and identify the markers that are linked with yield under drought. After the initial phenotyping, we then use the SNP markers as molecular signposts to infer the best materials. We do this in both drought and non-drought seasons. There is usually only one drought season a year but up to 4 growing seasons if land is irrigated so we can select the best materials four times faster than using standard recurrent selection with the use of the SNP markers, replacing the need for as much drought phenotyping.



Graphical representation of the SNP genotyping results for one SNP of a maize population that we are studying. Image provided by S Hearne, IITA.

Just as technology moves forward so does the application of tools to breeding. We now use a technique called genome wide selection (GWS), which is similar to MARS and uses the same SNP markers and initial drought phenotyping. But unlike MARS it enables breeders to capture small contributions to drought tolerance that may otherwise be missed. We currently have a number of maize populations in various stages of GWS, using the most advanced population as a pilot to validate the approach and to test and develop better systems to fully utilize markers to expedite the development of drought-tolerant varieties.

The pilot population is a cross between two elite drought-tolerant and adapted maize inbred lines with diverse ancestry. This population was specifically formed in 2008 to be the source of superior lines with much higher levels of tolerance to drought, resistance to prevalent diseases in the lowlands, and desirable agronomic traits. Inbred progeny from this cross were pre-screened for tolerance to a common African problem, maize streak virus (MSV) disease and for desirable agronomic traits. The best materials were bred with a common tester

Chipped maize kernel with seed chip in extraction tube. Through biotechnology, this single grain could give birth to a whole new generation of improved maize. Photo by JT Oliver, IITA.

line to make something breeders call a testcross hybrid.

We have to evaluate hybrids to assess the value of a line. Farmers grow hybrids – they are much more vigorous and higher yielding than lines. This is the nature of maize. As such, we have to evaluate the contribution of any line to a hybrid and assess the performance of that hybrid. We evaluated the testcross hybrids under controlled drought stress conditions in Kenya and Zimbabwe in 2009, and under both drought and full irrigation conditions in Nigeria. At the same time we genotyped the parents of the lines using SNP markers and identified all SNPs that were polymorphic, that is each parent had a different version of the SNP.

We then genotyped the lines used to develop the testcross hybrids using all the polymorphic SNP markers. This enabled us to see which parts from each parent a particular line got, a bit like paternity testing in humans.

We combined the phenotypic data obtained from testcross hybrid phenotyping with the SNP genotype data from the lines. Analysis allowed us to define a breeding value for each variant of each SNP marker (say how important it is for yield). With the genotype data we can add up all the values for any particular line and get a total, called the genomic estimate of breeding value or GEBV. We calculated the GEBVs for all the lines and ranked them from highest (the most valuable materials) to lowest (the least valuable materials). We then selected 5% and 10% of the lines with the highest GEBVs. We planted and crossed these lines with each other to develop new materials with all the best SNP variants mixed together in random patterns. We have harvested the seeds from these crosses and are presently genotyping the materials again with the same SNP markers in order to identify individuals with even higher GEBVs. We would go through the same process again until we maximize the value of GEBV. At this point, we would phenotype the resulting materials to assess progress made and then move the materials into the variety development stage. Following this process we are able to accelerate the generation of new, high value materials for variety development, and shorten the time it takes to get good, adapted, drought-tolerant varieties into the hands of farmers. From MARS to GWS we are perhaps – taking a cue from astronaut Neil Armstrong – taking "one small step for maize breeders, one giant leap for farmers".

Giving cereals and legumes production in sub-Saharan Africa a boost

The production of cereals and legumes in sub-Saharan Africa, particularly maize, cowpea, and soybean, got a much-needed boost with the release of improved varieties that we developed with partners in the region. The varieties address many of the major constraints to the production of the crops such as drought, low soil fertility, pests, diseases, and parasitic weed, and were developed through conventional plant breeding by tapping naturally-available traits. Every year, we distribute improved varieties and hybrids to national partners and the private sector through regional trials. We use these trials to select promising varieties and hybrids adapted to specific conditions in the different countries for extensive testing and later release.

Improved maize

In Nigeria, the Nigeria National Variety Release Committee released 13 new open-pollinated maize varieties of extra-early-, early-, intermediate-, and late-maturity with improved resistance to *Striga* and stem borers, tolerance to drought, and well adapted to suboptimal soil nitrogen. We developed the varieties in partnership with the Institute for Agricultural Research (IAR) of the Ahmadu Bello University in Zaria

With the release of new maize varieties, farmers and consumers have more and better options. Photo by IITA.

and the Institute of Agricultural Research and Training (IAR&T) of Obafemi Awolowo University in Ile Ife, Nigeria.

The committee also approved the release of four drought-tolerant hybrids, two *Striga*-resistant hybrids, and two white and two yellow productive hybrids that we developed in collaboration with Premier Seeds Nigeria Limited. The company will commercially produce and market these hybrids.

In Ghana, four Quality Protein Maize (QPM) varieties tolerant to drought, resistant to *Striga*, and have high levels of the nutrients lysine and tryptophan have been released to farmers to boost maize production in the drought-prone and *Striga*-endemic areas of the country. The varieties, which are early and extra-early maturing, were approved by the Ghanaian Crops Research Institute (CRI) in collaboration with the Savanna Agricultural Research Institute (SARI) of the Council for Scientific and Industrial Research (CSIR) of Ghana.

Of the four varieties, we bred three under the Earlies Program and have been designated EV DT-W 99 STR QPM Co, TZE-W Pop STR QPM C0, and TZEE-W Pop STR QPM C0 (an extra-early maturing variety). The fourth, an intermediate maturing drought-tolerant QPM hybrid, was developed under the National Maize Program of Ghana.

The breeding work for the IITA varieties was funded through the Nippon Foundation QPM Project in 2003-2006. They were extensively tested in on-station and on-farm trials in Ghana by SARI and CRI between 2008 and 2009 through the funding support of the Drought-Tolerant Maize for Africa (DTMA) Project.

New cowpea

In 2010, the *Institut d'Economie Rurale* (IER) of Mali released four new cowpea varieties in 2010, two of which we developed. The four varieties and their given local names are CZ1-94-23-1 (Gana Shoba), CZ1-94-23-2 (Gana Shoni), IT97K-499-35 (Jiguiya), and IT93K-876-30 (Fakson). Farmers named one of the IITA varieties 'Jiguiya' – meaning 'hope' in the local language – because of its resistance to *Striga*, exceptional drought tolerance, and good grain size, color, and yield.

In Nigeria, two new varieties – IT89KD-288 and IT89KD-391 – that we developed in collaboration with the IAR- Ahmadu Bello University, Zaria; the University of Maiduguri, Borno; and the Agricultural Development Programs of Borno, Kaduna, Kano, and Katsina States have been released.

IT89KD-288 (now SAMPEA-11) is a dual-purpose cowpea variety with large white seeds and a rough seed coat. It has combined resistance to major diseases such as septoria leaf spot, scab, and bacterial blight, as well as to nematodes. It is also tolerant to Nigeria's strain of *Striga gesnerioides*. The variety produces at least 80% more grain than the local varieties and is a good candidate for sowing in cereals or as a relay crop with maize in the moist and dry savanna zones.

Cowpea being readied for storage. Photo by T Abdoulaye, IITA.

IT89KD-391 (now SAMPEA-12) is also a dual-purpose cowpea variety that has medium-to-large brown seeds with a rough seed coat. These are preferred seed characteristics for commercial production in northeast Nigeria. Researchers say that IT89KD-391 is a welcome improvement over SAMPEA 7, Ife brown, IT90K-76, and IT90K-82-2, which are the main improved brown-seeded varieties available. It has been tested extensively in this area and is well accepted by the farmers. The variety performs well either as a monocrop or an intercrop, and could also be planted as a relay crop with maize in the Guinea savannas. On-station and on-farm trials have shown that IT89KD-391 produces twice the yields of local cultivars.

Better soybean

We continue to work with our partners in the soybean-producing countries of sub-Saharan Africa to develop and disseminate varieties that address production constraints while taking into account local suitability and farmers' preferences. In 2010, six of our soybean varieties have either been released or are in the final stages of being released to farmers in Nigeria and Mozambique. These varieties have valuable traits such as high grain and fodder yields, short planting-to-harvest duration, tolerance to drought, and resistance to common pests and diseases such as weeds and soybean rust.

Rust-resistant soybean varieties (green) being tested alongside susceptible ones (brown). Photo by R Bandyopadhyay, IITA.

In Nigeria the early- to medium-maturing varieties TGx 1987-10F and TGx 1987-62F were released by the Nigerian Variety Release Committee in December 2010. These varieties gave an average grain yield of 1670 and 1630 kg per hectare, respectively, in a two-year multi-location, on-station trials. They also mature in just 96-97 days on the average (compared to 100-150 days by local varieties) and are capable of producing 2.6 tons of fodder per hectare. They have also been proven to be highly resistant to rust, bacterial blight, and *Cercospora* leaf spot, and are preferred by farmers because they smother weeds and reduce the cost of weeding. Farmers that participated in the on-farm trials also indicated that they especially like the golden color of the grains at maturity. The trials of these new varieties were supported by our Tropical Legumes II Project.

In Mozambique, five varieties that we developed have been pre-released to expedite access by farmers while the country's Variety Registration and Release Committee continue their assessment for full release. The varieties were evaluated across four agro-ecological zones of Mozambique in on-station and on-farm trials for three years. Results showed that yields for the varieties TGx 1485-1D, TGx 1740-2F, TGx 1904-6F, TGx 1908-8F, and TGx 1937-1F in the major soybean producing regions of Zambesia and Tete provinces were 3527, 3748, 4096, 3963, and 3614 kg per hectare, respectively, compared with 2830 kg per hectare of 'Storm', the most popular and highest yielding existing variety. The new varieties mature in 93-113 days.

Farmers prefer the varieties because of their high yields, profuse nodulation, moderate drought tolerance, and resistance to *Cercospora* leaf spot, frog eye, and pod shattering. The varieties grow vigorously and their canopy closes early effectively controlling the growth of weeds and reducing the need for frequent weeding.

Scientists gather to give hunger a black eye

A long neglected crop with the potential to halt hunger for millions in Africa, sustain the livestock revolution underway in developing countries, rejuvenate nutrient-sapped soils, and even feed astronauts on extended space missions, attracted more than 130 scientists from around the world to Senegal from 27 September to 1 October for the Fifth World Cowpea Research Conference.

Logo of the World Cowpea Research Conference.

"It's hard to imagine a more perfect crop, particularly for Africa, where food production lags behind population growth, demand for livestock products is soaring, and climate change is bringing new stresses to already challenging growing conditions," says Christian Fatokun, cowpea breeder and one of the driving forces behind the conference.

We co-organized the conference with the Institut Senegalais de Recherches Agricoles (ISRA), Dry Grain Pulses Collaborative Research Support Program, and Purdue University, and supported by the West and Central African Council for Agricultural Development (CORAF/WECARD), African Agricultural Technology Foundation, Japan International Research Center for Agricultural Sciences, and Kirkhouse Trust.

"But fulfilling the promise of this marvelous legume requires intensive efforts to deal with threats that inhibit production and long-term storage," he added. "The good news in Senegal is that researchers revealed new and innovative approaches to dealing with the pests and weeds that attack cowpeas at every stage of their lifecycle and with the voracious weevils that devour dried cowpeas."

The cowpea, which is also known as the black-eyed pea, is one of the world's oldest crops. It is currently cultivated on 10 million

Participants of the 5th World Cowpea Research Conference pose for a group photo. Photo by G Atser, IITA.

Some Nigerian dishes made from cowpea. Photos by S Muranaka, IITA.

hectares, mainly in Central and West Africa, but also in India, Australia, North America, Brazil and parts of Europe. It was brought to the Americas on slave ships and became a favorite of President George Washington, who was looking for a variety of peas—he called them "pease"—that could withstand the warm climates of the southern United States.

Cowpeas are treasured for their high protein content (grains contain about 25 percent protein), leaves and stalks that serve as especially nutritious fodder for cows (hence the name cowpea) and other farm animals, and the fact that their roots provide nitrogen to depleted soils. For many in Africa, the crop is a critical source of food during the "lean period"–- the end of the wet season when food can become extremely scarce in semi-arid regions of sub-Saharan Africa.

The many qualities of the cowpea are being discovered anew for a number of reasons. One is the potential of the cowpea's high protein content to help satisfy dietary requirements in food-challenged developing countries, particularly in Africa, where over 200 million people remain undernourished.

Cowpeas provide strong yields, even in hot and dry conditions, and scientists are developing ever more resilient varieties. And as climate change turns up the heat in sub-Saharan Africa, there is growing concern that production of current staples such as maize and rice may fall or even collapse in some areas, requiring so-called "climate-ready crops" like cowpeas to fill the void.

In addition, cowpeas can be used as cheap, high-quality animal feed. Today, livestock experts are drawn to the cowpea as they search for sustainable approaches to satisfying the fast-growing demand for meat and milk in developing countries. Scientists at IITA and the International Livestock Research Institute (ILRI) say new "dual use" cowpea varieties bred to satisfy both human and animal nutrition needs could be generating US$ 299 million to US$ 1.1 billion by 2020, given their potential to boost livestock production and reduce hunger.

Cowpea could also significantly contribute to human health. Studies presented at the conference have shown that cowpea could be a significant source of various antioxidants contained in the grain's cotyledon and seed coat. In food, the cowpea's seed coat could be used as a natural colorant.

The cowpea is also well-known for its ability to infuse soils with nitrogen, which again makes it a crop that could be enormously valuable to Africa, where many farmers struggle with nutrient-poor soils that is among the most challenging in the world.

Even the National Aeronautics and Space Administration (NASA) is on the cowpea bandwagon. With the plant's ability to produce nutritious leaves in only about 20 days, NASA scientists are considering sending cowpeas to the international space station, where they could be cultivated to provide food for astronauts.

This widely ranging and rapidly intensifying interest were highlighted at the World Cowpea Conference, where ground-breaking work in all aspects of cowpea production was showcased.

For example, new research by IITA and the University of California-Riverside presented at the conference focuses on the successful use of cutting-edge genome analysis tools and techniques to probe cowpea DNA for genetic traits associated with prized qualities like drought and disease resistance.

"When we can zero in on a particular place in the genome and essentially point to the DNA that is associated with the traits we want, the time it takes to breed improved cowpea varieties can be shortened from a decade or more to three years or less," said Fatokun, who specializes in cowpea genomics.

Scientists also reported on the latest developments in efforts to use biotechnology to borrow a gene from a soil bacteria, *Bacillus thuringiensis* or Bt, to create a transgenic cowpea variety. The goal is to provide farmers with cowpeas that can fend off assaults

Senegalese women packing cowpea flour. Value-added cowpea products could provide viable sources of additional income for many Africans. Photo by K Lopez, IITA.

from a caterpillar known as the *Maruca* or bean pod borer that routinely ruins entire fields. Researchers also discussed endowing cowpea varieties with a gene from a common bean plant to provide protection against weevil infestations during storage.

Related discussions focused on fresh research probing the risk of transgenic Bt cowpea spontaneously mating or "crossing" with wild relatives—wild cowpea is common in West Africa, which is a "center or origin" for the crop—and possibly creating a super weed that would be difficult to control.

Extracting cowpea grains from newly-harvested pods. Photo by S Muranaka, IITA.

Scientists from Purdue University in the United States and Niger's Institute of National Agriculture Research also reported on an effort to disseminate a simple storage technology to African farmers, which comprises a three-layer plastic bag that shuts off the oxygen required to fuel a weevil population explosion.

Other research results discussed at the conference focused on the challenges of translating cowpea production into income and how to encourage wider adoption of improved cowpea varieties along with better approaches to cultivation and storage.

For example, researchers discussed a new study analyzing the economic fortunes of hundreds of street vendors in Ghana and Niger who sell a popular, deep-fat fried fritter made from cowpea batter called kossai or akara. Most of the vendors are women, and the researchers found that they tend to earn 4 to 16 times more than the prevailing minimum wage in their countries.

Meanwhile, in another study, researchers reported on an innovative effort that brings together scientists, linguists, and 3-D animators to provide cowpea educational materials and training programs for rural farmers.

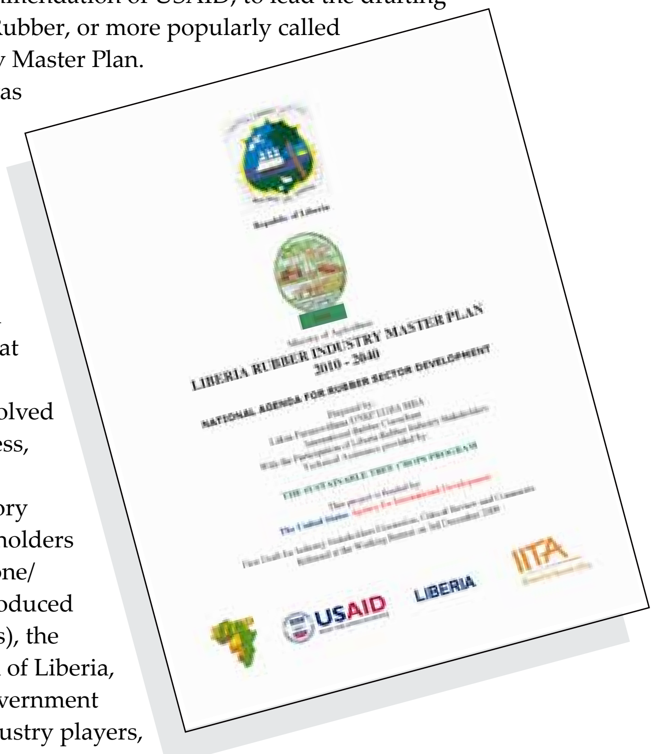
Horticulture and Tree Systems

Shaping a Master Plan for Liberia's rubber sector

Up until the crisis in the early 1990s that devastated Liberia's economy, rubber was the country's top income-producing tree crop. It had the potential to create a major manufacturing industry in West Africa and provide regular employment and huge export earnings. Today, national rubber production has dropped considerably as trees are old, plantations abandoned, infrastructure destroyed, and processing units operating at less than half of capacity. Compounding the situation, the country did not have a well-crafted long-term plan for rejuvenating the industry.

In 2008, the government of Liberia requested our assistance through the Sustainable Tree Crops Program (STCP) to develop a master plan to revive and uplift the country's rubber sector. Responding to the call, IITA/STCP contracted an international rubber industry expert, Lakna Paranawithana, on the recommendation of USAID, to lead the drafting of the National Agenda for Rubber, or more popularly called the Liberian Rubber Industry Master Plan.

Paranawithana's work was supervised by a national steering committee set up and chaired by the Minister of Agriculture and assisted by Franklin W Phillips, a senior Liberian agronomist. IITA/STCP also established a special Master Plan Secretariat in Monrovia to facilitate the planning process, which involved creating and raising awareness, and conducting extensive consultations and participatory deliberations with key stakeholders such as multinational Firestone/ Bridgestone (which first introduced rubber in Liberia in the 1920s), the Rubber Planters' Association of Liberia, farmers' groups, relevant government ministries, private sector industry players,



The multisector group that finalized the draft of the rubber master plan for Liberia. Seated third from left is Lakna Paranawithana. Photo by C Prah, IITA/ STCP.

donors, and NGOs. The consultant also conducted a series of field visits to get a firm grasp of the practical aspects of Liberia's unique industry operations.

Four multisector workgroups were formed to collect information, analyze and document specific needs and challenges of the industry and develop possible solutions based on the information gathered. The workgroups were comprised of the country's best minds and leading industry specialists. The Governance and Resources workgroup was chaired by the Ministry of Agriculture; the Supply Chain Development workgroup was chaired by the Rubber Planters Association of Liberia, the private sector apex body; the Value Addition and Marketing workgroup was chaired by the National Investment Commission, a quasi-governmental body; and the Human and Physical Capacity Building workgroup was chaired by the University of Liberia.

During the planning period, the IITA/STCP Rubber Secretariat was a beehive of action and became the de facto industry nerve center that galvanized and propelled stakeholders to think innovatively. This strategizing and planning culminated in December 2009 in the first-ever roundtable discussion for Liberian rubber stakeholders to discuss the way forward. The draft master plan presented during the two-day retreat specified national targets and highlighted issues concerning policy environment. These included the introduction of the Rubber Development Fund Act, new plantings, replanting and extension services, enhancing technological capabilities and manpower needs, opportunities for value addition, industry infrastructure needs, meeting international quality standards in production, funding requirements, and timelines.

Participants at the roundtable extensively reviewed, debated, and revised the draft document. But more importantly the Plan garnered wide support and consensus. A case study developed by the consultant that described the vision of a young dynamic Liberian created lot of enthusiasm among the participants. Slowly but steadily, a Liberian Rubber Cluster took shape. As one industry leader put it: "the task was enormous and daunting but the results were incredible". The work was considered "trailblazing and admirable" by James Logan, Deputy Minister of Agriculture and a former member of the IITA/STCP Executive Committee.

By 2010, a significantly improved version of the Liberian Rubber Sector Master Plan had been produced and was circulated among key stakeholders, industry players, and international development partners for final review, endorsement, and approval. IITA/STCP has formally handed over the plan to the Government of Liberia to be taken forward and hopefully signed into law very soon. Expectations are high that the plan would serve as a beacon in the agricultural sector of the country. Prevailing high prices for rubber provide further impetus to implement the plan as soon as possible. Already, the Liberian Oil Palm sector is contemplating a master plan of its own.

The Rubber Master Plan was validated by Her Excellency Ellen Johnson Sirleaf, President of the Republic of Liberia, in her annual message to the 52nd National Legislature on 25 January 2010 stating that "…the revitalization of the industry will be guided by the Liberia Rubber Industry Master Plan 2010-2040: A National Agenda for Rubber Sector Development, which was prepared and validated by the Ministry of Agriculture in collaboration with stakeholders. The plan emphasizes the need to resuscitate and reverse the declining production trend of our traditional rubber subsector to increase production and export volume."

Costing the IITA/STCP cocoa Farmer Field School approach

The Farmer Field School (FFS) is one of several capacity-building methodologies that IITA/STCP developed, validated, and implemented with much success since 2003. For the past 10 years, we have trained more than 150,000 farmers through FFS on integrated crop and pest management (ICPM) in the five countries in which we operate—Ghana, Cote d'Ivoire, Nigeria, Cameroon, and Liberia. Since 2006, together with national partners in these countries, we have undertaken efforts to scale up and institutionalise the approach. However, to guide investors and partners in scaling up, we needed to know how much it costs to run such methodologies.

Farmer-trainees discussing during a Farmer Field School. Photo by S Muilerman, IITA.

In 2010, we completed a study to determine the cost of conducting FFS in four of the countries (except Nigeria as it follows a different model), with the goal of providing vital financial information to prospective partners who may be interested in investing in such interventions. We also included a cost analysis of the Video Viewing Club (VVC), another innovative training approach that we developed and implemented, in Cote d'Ivoire and Ghana. The study covered the cost of all activities directly implemented by IITA/STCP, or by partners who worked closely with IITA/STCP.

Based on expenditure data gathered in 2009 and projected for three training cycles in Cameroon, Cote d'Ivoire, Ghana and Liberia, the study showed that it costs on average US$ 1917 to implement an FFS, or US$ 71 to train one farmer. Costs and number of farmers enrolled varied significantly among the countries (Table 1). In comparison, it costs US$ 1853 to run a whole VVC, or US$ 78 to train one farmer using this methodology.

The study showed that one FFS, when implemented over three training cycles, costs an average of US$ 1678, while one VVC costs US$ 1306 to operationalize. Many factors influence these costs such as the level of supervision needed, the size of the operational area, and the number of participants. In fact, the average FFS implementation costs across the four countries goes down from US$ 2040 per FFS cycle run by new facilitators, to US$ 1474 per FFS cycle run by experienced facilitators.

Our analysis also revealed that the facilitation cost of a 5-6 week residential ToT for FFS varied between US$ 520-905 per facilitator, which is 18 to 36 percent of the total cost to train one farmer. However, this goes down significantly when the same facilitator covers more

Table 1. Farmer Field School and video viewing club costs over three training cycles[a] (in US$).

	FFS (2009)				VVC (2010)
	CAM[b]	RCI	GHA	LIB	GHA
ToT costs for one facilitator[a]	291	189	302	173	182
Equipment costs[c]	-	-	-	-	305
Implementation costs[d] per school/club (materials, supervision, facilitator)	1385	1377	1949	2001	1001
Total cost per school/club (facilitator ToT, implementation, equipment)	1676	1566	2251	2174	1853
Average number of participants per school/club	20	32	30	29	25
Cost per farmer (facilitator training, implementation, materials)	84	49	75	75	78
Additional cost of training two secondary knowledge recipients	16	16	16	16	-

[a] *Assumes that the programme starts with new facilitators who are trained and supervised intensively during the first training cycle and run two more cycles as experienced facilitators*
[b] *Includes ToT and implementation costs borne by the cooperative partners*
[c] *Assumes straight line depreciation for television sets, video players and generators over a two year life and a salvage value of zero*
[d] *Assumes a conservative 20% cost reduction for supervision costs in the second and third year in Cameroon and Ghana (in italic)*

training cycles. When a facilitator covers three training cycles, the facilitation cost decreases to just 8 to 17 percent of the overall ToT cost to train one farmer. For the shorter VVC ToT, the per-farmer facilitation cost decreases from 29 percent of the total cost for one training cycle to just 10 percent for three training cycles.

To reduce the cost of implementing the FFS and VVC methodologies, the study suggests the following:

- Using the same facilitators in multiple training cycles;
- Applying national partners' own cost structure for staff, transport and other operational costs;
- Testing new arrangements for partnering farmer and extension facilitators and for compensating them;
- Broadening training activities to cover other enterprises;
- Doing away with superfluous elements of the FFS methodology such as farmer graduation ceremonies;
- Conducting VVC in centralised and/or existing video viewing locations, thereby reducing equipment costs; and
- Centralising procurement of FFS materials thereby optimising economies of scale.

Worldwide, interactive training methods such as FFS and VVC require high human and financial investments when compared to

Farmers listening intently to a lecture being delivered under the canopy of cocoa trees. Photo by S Muilerman, IITA.

other training approaches for technology transfer. There are three key justifications for the relatively higher costs of implementing these methodologies, FFS in particular. The first is sustainability. With FFS, there is a higher probability that farmers will use their acquired improved decision-making capacity and experimentation skills to adapt crop and pest management strategies to changing circumstances. The second is human and social capital strengthening. This includes improved knowledge, skills, leadership abilities, increased membership in groups and networks, and improved social interactions and relationships. Third, facilitators trained by FFS programs – whether extension agents or farmers – can be used for other development and research activities. While the costs associated with FFS and VVC might be considered to be on the high side, this should be viewed as a disadvantage and should not deter organisations from adopting them. These costs must be rated against the potential benefits of these training approaches and how they contribute towards a program's development goals and impacts.

The study recommends that further cost-benefit research of FFS and VVC be carried out to take into account productivity, and social and developmental impacts. The results of such research will guide and contribute towards the scaling up of IITA/STCP's and institutionalising farmer training approaches within national programs.

The cost analysis study can be accessed from IITA/STCP's Web site at http://www.treecrops.org.

Opportunities and Threats

‘Fertilizers for Forests’: systematic use of fertilizers can mitigate deforestation in West Africa and help fight global warming

As the world grapples with the challenge of feeding an ever growing population in the face of dwindling natural resources confounded by climate change, findings from a recent research that we conducted show that science-based farming methods integrating the systematic use of fertilizer by farmers can significantly reduce the need to clear forests for agriculture, one of the identified culprits of global warming.

Findings of the research, published in the latest issue of Environmental Management Journal, shows that the use of fertilizers and improved cocoa varieties by smallholder farmers could have averted the destruction of some 2.1 million ha of the Guinean rainforest of West Africa and the subsequent release of 1.4 billion tons of carbon dioxide into the atmosphere valued at over US$ 1.6 billion.

At the beginning of the 21st century, only 18 percent – or about 113,000 sq km – of the original rainforest that once stretched from Guinea to Cameroon remained. This forest is one of the 25 UN-identified global biodiversity hotspots that collectively contain 60

Ducks fly across a lake toward a patch of the remaining Guinean rainforest in Nigeria. Photo by O Adebayo, IITA.

percent of all animal and plant species on the planet. The principal cause of this environmental change has been the expansion of extensive smallholder agriculture dependent on traditional slash and burn technology systems. Cassava, cocoa, oil palm and plantain have expanded the most rapidly, with the area harvested of these commodities increasing by 72,000 sq km since 1988.

The study, which looked into the land use change scenarios in Cote d'Ivoire, Ghana, Nigeria, and Cameroon from 1998 to 2007, found that although cocoa production more than doubled in West Africa during the period it came at huge costs – the irreversible loss of biodiversity and enormous carbon emission. Researchers say that the same output would have been possible with little or no increase in the land area by using improved varieties and following seed-fertilizer use recommendations developed as early as the 1960's.

Jim Gockowski, IITA Agricultural Economist and one of the authors of the study, indicates that smallholder farmers cannot continue to expand their enterprises with low input extensive agriculture.

"With the reduction of the Guinean rainforests to less than 20% of its original size and the tripling of populations in these countries, there is absolutely no more room for expansion. Strategies to reduce deforestation and conserve biodiversity must focus on reforming agricultural practices and weaning farmers from traditional to modern science-based methods," he says.

"The 'Fertilizer-for-Forests' has proven that it is possible to increase crop production with little or no harmful effect on the environment," he adds.

The study further recommended that Reducing Emissions from Deforestation and Forest Degradation (REDD) climate change mitigation programs immediately address low agricultural productivity by investing in intensification of agriculture. By doing this, farmers would not only have better incomes but also produce more food while reducing carbon emissions.

The study also called for solutions to lack of credit facilities, an underdeveloped agrochemical/fertilizer sector, inadequate seed multiplication, poor roads, and weak extension that are preventing smallholder farmers from adopting these innovations. It said that these challenges have been waiting for solutions for the past 30 years. Addressing the low productivity of West African agriculture should be one of the principal objectives of West and Central African REDD+ climate mitigation programs that are rapidly evolving since the recently concluded Cancun climate meetings.

Cataloguing pest and diseases of legumes in southern Africa

Soybean and cowpea are increasingly gaining importance in southern Africa due to agricultural diversification and intensification, with more and more areas being dedicated to their cultivation. However, knowledge on existing pests and diseases plaguing these crops in this region are limited. To address this, we led a multidisciplinary team to conduct a survey in 2010 to assess important pests and diseases on cowpea and soybean in Zambia, Malawi and Mozambique.

The survey identified occurrence of bacterial pustule (*Xanthomonas axonopodis, pv. glycinea*), rust (*Phakopsora pachyrhizi*), and mosaic disease caused by viruses on soybean in most locations. However, only rust appears to be causing economically significant damage. A new soybean disease – witches' broom – that causes the crop's flowers to turn into a leaf-like structure and which leads to total yield loss was observed in several locations in Malawi and Mozambique, with incidences as high as 15 percent in the latter. Characterization revealed that this disease is caused by '16SrII-C group *Candidatus* phytoplasma' – the first to be recorded in Africa. Identification of alternative hosts and vector species would improve our understanding of the disease's epidemiology and help us develop appropriate management tactics.

Soybean witches' broom. Photo by L Kumar, IITA.

Among insect pests, the most visible symptoms of attack were caused by defoliators mainly caterpillars of *Spodoptera* sp. and *Helicoverpa armigera*, together with a conspicuous armored ground cricket, *Acanthoplus speiseri*. Also, the invasive groundnut leaf miner *Aproaerema modicella* was observed attacking leaves of both soybean and groundnut in Mozambique. However, the extent of yield loss

Juvenile of the armored ground cricket Acanthoplus speiseri. *Photo by D Coyne, IITA.*

and economic impact attributed to these pests are not yet clear and will be the subject of further investigations. But since the symptoms of attack are highly visible, farmers resort to spraying insecticides indiscriminately. Therefore, yield loss data will be crucial in determining appropriate crop protection measures against these defoliators.

Additionally, the entomopathogenic fungi found on cadavers of caterpillars presenting sporulation symptoms were identified as belonging to *Beauveria bassiana* and *Metarhizium anisopliae*, and might be developed into biopesticides as alternatives to chemical insecticides. A stem-tunneling coleopteran identified as *Mecysolobus arcuatus* was observed causing damage at locations in Malawi. Termites also appeared to be a consistent pest across the region, often causing plant toppling.

Visible severe symptoms of root knot nematodes (*Meloidogyne* spp.) were observed in Malawi, especially at Bvumbwe, and in Mozambique at one site. Extraction identifications confirmed *M. incognita* and *M. javanica* plus possible other *Meloidogyne* species causing the galling damage. Damage in general was limited, probably because most sites were newly cultivated (1-2 years). Other nematode species identified mostly included species of *Pratylenchus, Scutellonema, Rotylenchulus*, and *Helicotlylenchus*, which were all recovered in relatively low densities. *Meloidogyne* species were by far the most prevalent.

On cowpea, major problems were caused by different viruses, with high incidence particularly in southern Malawi and northern Mozambique. Several of these could be transmitted through seed, which poses a serious risk to the safe distribution of cowpea seed material. It is important to characterize these viruses and establish control measures. Of the major insect vector groups, Chrysomelids were observed at several locations, aphids were absent (too late in the season), and *Bemisia tabaci* whiteflies were infrequent. Whiteflies were more common in Mozambique, where incidence of virus infection and symptom diversity were greatest.

A caterpillar of Spodoptera *sp. killed by the entomopathogenic fungus* Metarhizium anisopliae. *Photo by D Coyne, IITA.*

The incidence of the pod borer *Maruca vitrata* was surprisingly high around Lusaka, Zambia and in Nampula, Mozambique. Occasionally, mixed flower infestations with the bollworm *Helicoverpa armigera* were observed. Other major pests included the pod weevil *Piezotrachelus varium*, from whose pupae the parasitoid *Entedon apionidis* was also collected. Samples of cowpea flowers taken from all fields revealed the general presence of the flower bud thrips *Megalurothrips sjostedti*. However, thrips populations were generally below the damage threshold. The thrips parasitoid *Ceranisus femoratus* was also observed in Zambia and Mozambique. Termites, again, were consistently observed across the region, while nematode damage was limited for similar reasons described for soybean.

Although the survey covered only 22 locations in 3 countries, valuable information on pest and disease situation was gathered, which identified targets for intensive studies towards developing a sustainable crop protection strategy in this subregion.

Roots and Tubers System

Cassava power unleashed

In 2008, the world was rocked by a global food price crisis. Many African countries were heavily affected. Heeding the call for assistance, we partnered with USAID and national entities to implement a two-year project – dubbed "Unleashing the Power of Cassava in Africa" or UPoCA – to maximize the utilization of cassava to mitigate the effects of the food crisis in Nigeria, DR Congo, Ghana, Malawi, Mozambique, Sierra Leone, and Tanzania. We sought to increase cassava production in these countries by at least 30% as well as to enhance the competitiveness of cassava value chain actors by mobilizing, facilitating beneficiary access to, and applying available and field-proven technologies.

Every now and then, women beneficiaries of UPoCA in the DR Congo break out in songs in praise of the project and their bountiful harvest. Photo by IITA.

To expand productivity of cassava across the seven countries, UPoCA introduced 58 improved varieties and facilitated their spread by establishing 399 community-based stem multiplication sites covering 777 hectares. These improved varieties have been planted on about 13,590 hectares of smallholder farms in the seven countries. GIS projections, based on a 5 km per year diffusion from each introduction site, indicate that these varieties would spread to around 79,500 km^2 and 107,500 km^2 in 2010 and 2011, respectively. The seed and root production farms will help ensure the steady supply of healthy planting materials to farmers and reduce per unit cost of production.

Higher yields could boost cassava-based rural enterprises. Under UPoCA, farmers learned modern production techniques to increase yields. We used the experience gained from the numerous farmer training to develop a user-friendly protocol to measure root yields, estimate plant population (to guide farmers on appropriate plant spacing), and root rot incidence (to promote techniques to sustain yields). By the end of 2010, using the protocol, we found that the average root yield of the UPoCA-introduced improved varieties in DRC and Sierra Leone were 18.9 tons per hectare and 13.3 tons per hectare, respectively, which are higher than the countries' 2007 national average of 5-8 tons per hectare.

An IITA/UPoCA staff distributing planting materials of improved cassava varieties to project beneficiaries. Photo by G Atser, IITA.

To build a critical mass of skilled people in the countries, UPoCA trained almost 2000 farmer-beneficiaries (1043 men and 884 women) on improved cassava production techniques and value-added processing through experiential learning using training of trainers' (ToT) approach. The training participants produced a wide variety of cassava products such as odorless fufu flour, high quality cassava flour (HQCF), soya-fortified gari, starch, tapioca granules, HQCF/wheat flour composite bread, and different cassava snacks. Most of these products were either known but crudely prepared, or are new introductions in the communities.

To further strengthen the capacity of its trainees, the project developed and disseminated a number of technical and learning materials such as a cassava variety handbook describing 59 improved cassava varieties, cassava processor's guidebook on HQCF production and quality management, Swahili version of the IITA Cassava Recipe Book, and guidelines on agribusiness training and managing small cassava businesses.

Also through training, the project introduced IITA's "Green Muscle" biopesticide to national crop protection services of Ghana and Sierra Leone to manage the variegated grasshopper *Zonocerus variegatus* on cassava. UPoCA also introduced low-cost and user-

friendly cassava processing equipment (motorized graters, hydraulic press, hammer mill, mechanical sieves, and gari roasting bays), improved sun-drying shed, a specially-designed steam dryer for year-round drying of cassava flour, and upgraded equipment (graters and hammer mills with the cutting and grinding edges made of stainless steel instead of mild steel).

The project provided expert advice on issues related to cassava processing, quality management and compliance, and market assessment to support emerging cassava businesses. We also linked farmers to processors by using GIS maps that showed raw material supply sources for incorporation in potential contract farming arrangements, as well as linking equipment fabricators to processors. In Nigeria, for example, UPoCA linked the Niger State Cassava Growers' Association to Ekha Agro Company which guaranteed to buy, through a purchase order, 200 tons of fresh roots per day for one year at an agreed farm gate price. This required the association to cultivate 5000 hectares of cassava in the 2009/2010 season using improved varieties provided by UPoCA.

In Ghana and Mozambique, the project provided technical advice on quality and safety management of small-scale private sector cassava initiatives, particularly on good manufacturing practices (GMP) and good hygienic practices (GHP) such as drainage systems, handling of liquid and solid by-products, basic hygiene requirement for staff, equipment maintenance, and factory design. In Sierra Leone, we assisted the National Standards Bureau in drafting and updating

(Above) Members of the Tongea Women Farmers' Group in Sandeyalu, Sierra Leone demonstrating the use of improved gari roasting bay. (Below) Wambato group members in Tongwe village, Tanzania drying grated cassava before milling into high quality cassava flour. Photos by IITA.

quality standards for key cassava products currently marketed in the country.

The project conducted market perception surveys on the opportunities and constraints faced by cassava value chain actors in Mozambique and Sierra Leone. The sales data collection guidelines are yet to be fully implemented in the countries; however, preliminary observations showed that, except in Nigeria, concerted efforts to commercialize cassava products were uncommon.

Awareness about the project was promoted through online, print, and broadcast media, and through field days and site visits across the countries. In Ghana, information on the rapid multiplication of cassava, product development, and quality compliance was broadcast on six radio stations and information centers in 13 municipalities. In Sierra Leone, project beneficiaries and partners engaged in "Farmers' Talk", a 15 to 30-minute daily program of the community radio network Cotton Tree News. The project also developed an "UPoCA People" story series highlighting the experiences of selected project beneficiaries. In the last quarter of 2010, UPoCA researchers presented seven oral papers at the 11th ISTRC-AB symposium held in the DR Congo that highlighted the project's achievements.

Some of the public awareness materials produced by UPoCA: a poster on the steam cassava dryer introduced by the project, and one of the 'UPoCA People' stories.

The project was successful in fulfilling its mission of promoting and guiding collaborative efforts to mitigate the negative impacts of the food price crisis on cassava smallholders and their households. The participating countries are looking to scale-up the interventions of the project; however, such an effort will require a strategic shift towards market-oriented production and processing. Expectedly, this shift will have its share of challenges and will require long-term engagement with stakeholders and beneficiary groups. But if successful, this will enable countries to fully embed the cassava subsector in their national agricultural frameworks and expand the crop's role in food, feed, and industry applications. UPoCA has laid the foundation upon which cassava-producing countries in Africa must actively build upon to realize this vision.

Adding value to cassava in East and Southern Africa

Manually processing cassava in Zambia. We aim to move farmers and processors in East and southern Africa from labor-intensive processing...

In 2010, we launched a four-year initiative that aims to add value and raise the economic profile of cassava in East and Southern Africa from being a "poor man's crop" to a profitable and sustainable source of income for resource-poor farmers in the region.

Funded by the Common Fund for Commodities (CFC) and supervised by the FAO, the project is promoting the production, use, and marketing of High Quality Cassava Flour (HQCF) from fresh cassava roots in three countries: Zambia, Madagascar, and Tanzania.

HQCF is simple unfermented cassava flour. Under the project, we are introducing and deploying production processes and technologies that would improve the quality of flour produced and minimize the capital investment required for HQCF production by making use of simple equipment, most of which are already being used for processing gari – another popular African food product derived from cassava. Through this, we would be able to increase production efficiency and lower associated costs, which translates to higher profits for the participating farmer-processors. We would also be improving the farmers' access to markets by linking them to HQCF distributors and buyers.

A number of private bread and pastry companies in southern Africa have met mixed successes in using cassava flour to supplement wheat-based flour in their baking processes. Ralaivoa Solange, R&D Manager with Biscuiterie JB, a biscuit-making factory in Madagascar, said her company had previously used blended flour containing 25-30 percent cassava flour to make biscuits and wafers.

"They were accepted by the consumers and the company was saving money," she said. "We get our cassava flour from smallscale processors and farmers who use sun-drying. However, we stopped after a year as supply was irregular and the quality inconsistent."

Adebayo Abass, IITA cassava value chain specialist and the project's regional coordinator, explained that the project is introducing appropriate and low cost mechanical drying systems that will solve the problems associated with sun drying. The project will involve about 9000 small-scale farmers and processors in the three countries to sustainably produce and market HQCF.

Nicholas Cromme, CFC project manager, added that the project intends to attract the private sector to take over the commercial production of HQCF and make it competitive, sustainable, and beneficial to resource-poor farmers. Aside from providing farmers with improved high-yielding cassava varieties, the project will also train them on modern agricultural practices and processing technologies.

Watson Mwale, former Director of the Zambia Agricultural Research Institute (ZARI), says that "in many countries, cassava is perceived as a subsistence crop. This project hopes to change this by maximizing its income-generating potential."

"Cassava is a highly dependable food security crop that can help ease future turmoil in world food supply as it is thinly traded in the global markets. It can also foster economic development through processing," said Adam Prakash from the FAO.

According to the regional project coordinator, 'The project is a follow-up to a similar one that we implemented from 2003 to 2007. During that phase, we introduced to smallholder farmers and farmer groups simple, market-oriented technologies to transform the highly-perishable fresh cassava into stable, high value products such as chips and HQCF'.

In this current project, we would be partnering with ZARI, the Tanzania Food and Nutrition Centre, and Madagascar's National Center for Applied Research on Rural Development.

...to mechanized methods that are safer, hygienic, and more efficient. Photos by IITA.

Nigerian farmers get new cassava varieties

In December 2010, the Nigerian government released four improved cassava varieties intended to boost production and keep the country in the lead as the world's largest producer of the root crop. The varieties, which are products of almost 10 years of conventional breeding, have been dubbed NR 01/0004, CR 41-10, TMS 00/0203, and TMS 01/0040. Two of the new varieties – TMS 00/0203 and TMS 01/0040 – were bred by our scientists at our Ibadan station, while NR 01/0004 and CR 41-10 were bred by the National Root Crops Research Institute (NRCRI) and the International Center for Tropical Agriculture (CIAT), respectively.

On-farm trials involving local farmers in eight states of the country showed that the newly-released varieties outperformed local ones with an average yield of about 31 tons per hectare as opposed to 26 tons per hectare from traditional varieties. Farmers who have tested the new varieties also indicated that they like their excellent culinary qualities, high yield, and resistance to various pest and diseases.

Bigger, better cassava. The new varieties will help secure Nigeria's position as the world's top producer of cassava. Photo by G Atser, IITA.

"The release of the varieties is good news for Nigerian farmers in particular and African farmers in general," says Peter Kulakow, IITA cassava breeder. "We expect to see more cassava produced in Nigeria".

Over the last decade, cassava has evolved from being a food security crop to a cash and industrial crop. Annual production has increased from 32 million tons in 1998 to 45 million tons in 2008.

Although cassava is a hardy crop and can survive where most others cannot, it performs even better in good environments.

Researchers say the key to mitigating changes in environmental conditions and pest and diseases, among many other stresses, depends on the deployment of suitable and adapted varieties.

Integrated Pest Management (CGIAR Systemwide Program)

Evolving roles, anticipating future challenges

Meeting the ever-growing demand for more food in the face of dwindling resources and changing climatic conditions is a top priority for agricultural researchers. Aside from increasing the yield potential of crops, scientists look at ways to reduce crop losses by managing crop pests and contamination. In doing so, they not only address food security but also food safety and quality, areas increasingly being tasked to IPM and crop protection researchers.

Managing crop pests and contamination is important as it impacts on people's health and global trade. Everyone, regardless of economic status, has the right to healthy and safe food, but not all can afford this "luxury". Additionally, to enter and survive in today's highly competitive global market producers must be able to meet the strictest standards of food safety and quality. IPM addresses these issues.

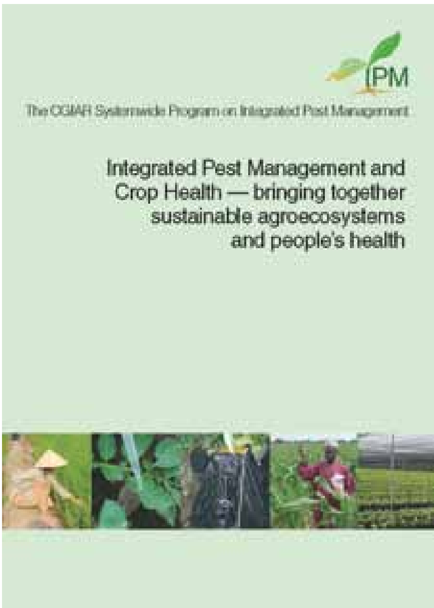
There is also increasing pressure on IPM to provide other benefits such as ecosystem services. Healthy and biodiversity-rich environments, culturally diverse landscapes, clean waterways, and robust watersheds are but some of the vital services and public goods that IPM is expected to deliver in the near future.

Changing mindsets

To anticipate and counter future challenges to IPM in the areas of food security and food safety, SP-IPM gathered forward-looking researchers at an expert workshop themed "Plant Health Management

Participants of the expert workshop on plant health management held in Bonn, Germany in March 2010. Photo by SP-IPM.

in a changing world: Innovative pathways towards food security and food safety" in Bonn, Germany on 3-5 March 2010. Participants presented benchmark IPM technologies and discussed their suitability for different target farmers. They also explored new approaches in developing innovative technologies, their adaptability, and methods for delivery.



Cover of the the White Paper on "Integrated Pest Management and Crop Health - bringing together sustainable agroecosystems and people's health"

The results of the workshop formed the basis of a White Paper titled "Integrated Pest Management and Crop Health – bringing together sustainable agroecosystems and people's health". The White Paper calls for a change in mindset. Addressing crop production, crop protection, and sustainable agriculture separately and delivering component technologies should be supplanted by integrated multidisciplinary approaches. This approach, which includes IPM, should aim at Crop Health Management (CHM) across crops in a particular ecozone. This movement away from isolated management of single pests on one crop towards CHM and agricultural system performance is in line with farmers' concerns and the broader pest situation in the field. This change requires working more closely with institutions and scientists who have comparative advantages along the chain from development, adaptation, and delivery to adoption of CHM technologies.

The paper also points out the lack of available human capacity to develop, understand, and apply CHM. The paper suggests measures to build CHM-related capacities at various levels and targeting different groups specifically those who are in a position to make an impact on sustainable food production. The need for reforms in policies and extension systems in support of CHM is also tackled.

The document, which outlines the requirements to fully deploy modern CHM, is addressed to the CGIAR Consortium and its research partners, donor agencies, and organizations that work on reducing poverty and hunger, improving human health, and fostering agricultural ecosystems.

The workshop report and the White Paper can be accessed from the publications section of the SP-IPM Web site at www.spipm.cgiar.org.

Implementing a program-wide research framework

In early 2008, the SP-IPM team agreed on a research framework with the following three research thrusts that are underpinned by capacity building:

- Adaptation of IPM to climate variability and change;
- Improving agroecosystem resilience for soil, root, and plant health; and
- Managing contaminants in foods, feeds, and the environment.

To implement this framework, multicenter project proposals were developed and submitted to relevant investors. SP-IPM proposals are developed by multiple member centers but submitted by one on behalf of the others to encourage and enhance intercenter collaboration. SP-IPM intercenter projects complement on-going research at individual member centers. In 2010, three projects have been initiated (see box), all funded by the German Government through the Federal Ministry of Economic Cooperation and Development (BMZ). Each project will run for three years.

New projects on the ground

Expanding the rational and biological control of invasive *Liriomyza* leafminer flies to major horticultural production systems in East Africa

This project takes off from a previous intercenter regional biocontrol effort to stop the spread of invasive leafminer flies (LMF), reduce the associated losses in horticultural and food crops production, and lessen pesticide use and environmental contamination in Africa and Latin America.

The project aims to improve the natural control of vegetables and potato leafminers in East Africa by building on existing experience in international agricultural research centers and to address jointly the identified research gaps towards environmentally friendly management approaches of LMF. Its activities include country-specific collection of baseline data of the status of the pest and its natural enemies, introduction and release of exotic biocontrol agents, and the development and implementation of biocontrol-compatible augmentative management strategies involving entomopathogens (fungi, nematodes) and the rational use of insecticides.

The project is expected to improve the biological control of LMF in major horticultural and food crops. Specifically, it would reduce pesticide use and decrease the incidence of LMF through the introduction of exotic parasitoids and other environment-friendly control methods in Kenya, Tanzania, and Uganda.

Funding: BMZ (€1.2M); Implementing SP-IPM members: icipe, CIP

Predicting climate change-induced vulnerability of African agricultural systems to major insect pests through advanced insect phenology modeling, and decision aid development for adaptation planning

Through innovative phenology modeling and risk mapping the project seeks to understand the effects of rising air temperatures caused by climate change on the future distribution and severity of major insect pests in important food crops in Africa. The Insect Life Cycle Modeling (ILCYM) software developed by CIP will also be further improved and adapted to a wide range of insect pests.

It addresses: (i) the current knowledge gap of climate change effects on economically important insect herbivores and related natural enemies (parasitoids), especially in the tropics, (ii) the ability of African agriculture (farmers, national agricultural research institutions, policy makers, etc.) to cope with the risk of exacerbating and expanding insect pests due to climate change, and (iii) adaptation strategies to minimize crop losses caused by major pests.

The project is expected to: (i) determine climate change-induced vulnerability of crops to pests through phenology modeling; (ii) develop a database on temperature-driven phenology models; (iii) improve and provide computer-aided tools for pest risk mapping and adaptation; and (iv) train scientists and IPM practitioners on the use of project tools for country-specific pest risk assessments, adaptation planning, improving their pest management strategies, and providing information to policy makers to improve national pest management and quarantine programs. Participating countries are Bénin, Cameroon, Kenya, Tanzania, and Uganda.

Funding: BMZ (€1.2M); Implementing SP-IPM members: CIP, icipe, IITA

Less loss, more profit, better health: reducing the losses caused by the pod borer (*Maruca vitrata*) on vegetable legumes in Southeast Asia and sub-Saharan Africa by refining component technologies of a sustainable management strategy

Damage caused by Maruca vitrata *on a cowpea pod. Photo by D Coyne, IITA.*

The goal of this research is to improve the livelihoods and income-generating capacity of small-scale vegetable legume farmers by developing a simple, economical, and environmentally sound IPM strategy for the control of the legume pod borer (LPB).

The project addresses: (i) refining sex pheromones; (ii) developing newly identified entomopathogens into biopesticide formulations; (iii) evaluating the efficacy alone and in combination with other biopesticides and botanical pesticides which will act synergistically; and (iii) identifying species-specific natural enemies (parasitoids) of *M. vitrata* in Southeast Asia, believed to be its center of origin.

An IPM strategy based on pheromones, natural enemies, and biopesticides will be developed and validated in pilot sites in Southeast Asia and sub-Saharan Africa. Molecular markers developed for characterizing the LPB populations will be made available to entomologists working on LPB worldwide to help them characterize local *Maruca* species and/or populations. Newly developed mass production techniques for natural enemies and entomopathogens will enable NARES, NGOs, and the private sector to enhance their capacities to produce component technologies in sufficient quantities for wide distribution.

At the end of the project, farmers, consumers, and livestock will benefit from increased availability of safer vegetable legumes for food and fodder with reduced pesticide residues. The target countries are Thailand and Vietnam in Southeast Asia, and Bénin and Kenya in sub-Saharan Africa.

Funding: BMZ (€1.2M); Implementing SP-IPM members: AVRDC, IITA, icipe

Financial Information

Funding overview

Our funding for 2010 was US$ 53.227 million, of which 98.5% came from CGIAR investors and 1.5% from other sources. Expenditure was US$52.959 million (net of indirect costs recovery of US$ 4.506 million), of which 83.7% was used for program expenses and 16.3% for management and general expenses.

The governments and agencies that provided the largest share of our funding in 2009 and 2010 are shown in Figure 1 (top 10 donors). Our 2009 and 2010 expenditures by MTP projects and CGIAR system priority are shown in Figures 2 and 3, respectively; while the performance indicators, as prescribed by the CGIAR, are reflected in Figure 4.

Figure 1. Funding: Top 10 donors, 2009 and 2010

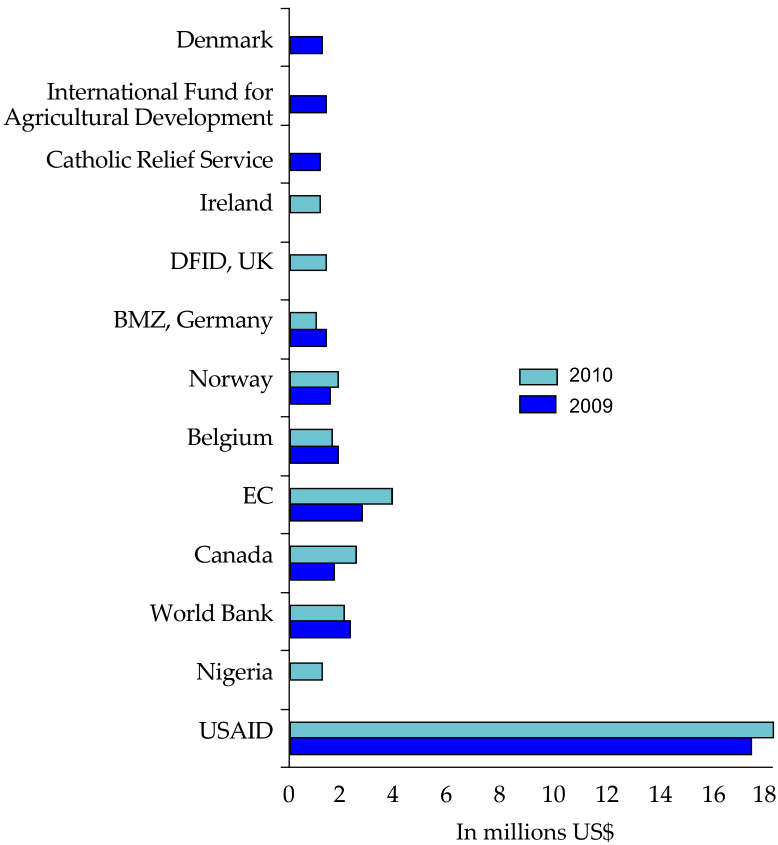
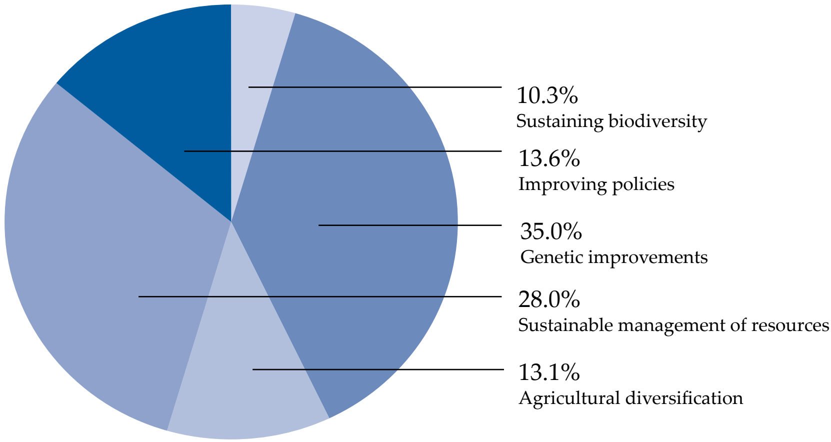
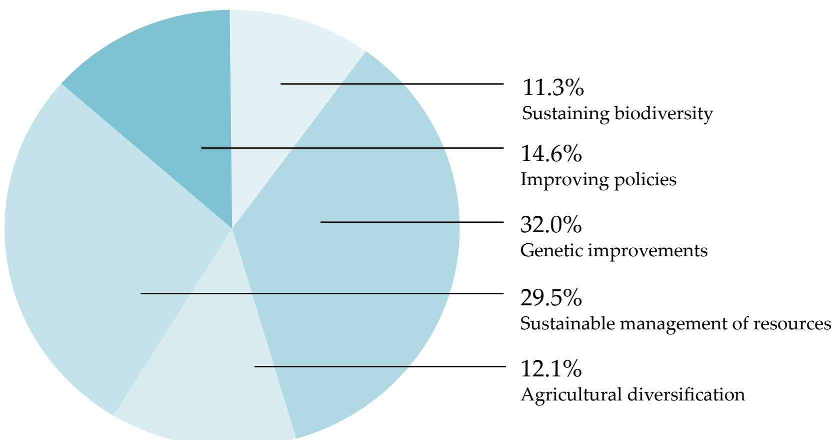


Figure 2. Expenditure by CGIAR System Priorities, 2009



Expenditure by CGIAR System Priorities, 2010



IITA Investors	2009	2010
	(expressed in US$ Thousands)	
African Agricultural Technology Foundation	147	246
Austria	460	119
Belgium	1,740	1,544
BMZ, Germany	1,334	985
Canada	1,623	2,422
Catholic Relief Service	1,083	756
Chemonics International	637	619
CIMMYT	2,177	2,320
Commission of the European Communities	2,664	3,770
Common Fund for Commodities	364	586
Denmark	1,160	803
Department for International Development, UK	1,034	1,296
ECOWAS	0	248
Food and Agriculture Organization	810	361
France	330	330
Gatsby Charitable Foundation	196	109
Global Crop Diversity Trust	244	528
icipe - African Insect Science for Food and Health	130	193
ICRISAT	1,091	986
IFPRI	519	135
International Fund for Agricultural Development	1,362	686
Ireland	681	1,114
Italy	10	0
Japan	390	602
Korea, Republic of	40	40
Netherlands	892	766
Nigeria	610	1,207
Norway	1,491	1,750
Rockefeller Foundation	117	0
Shell Petroleum Development Company of Nigeria Ltd.	146	567
Sweden	476	512
Switzerland	501	478
United States Agency for International Development	17,060	17,818
WK Kellogg Foundation	153	47
World Bank	2,221	2,026
Miscellaneous Projects	3,368	4,368
Challenge Programs	1,149	2,111
GRAND TOTAL	**48,410**	**52,448**

Figure 3. Expenditure by IITA Program Portfolio: 2009 and 2010

	2009		2010	
Project	Cost ($`000)	%	Cost ($`000)	%
Agriculture and Health	1,870	3.7	1,658	3.1
Agrobiodiversity	6,073	11.9	6,978	13.2
Banana and Plantain Systems	5,254	10.3	4,780	9.0
Cereals and Legumes Systems	8,619	17.0	10,021	18.9
Opportunities and Threats	3,273	6.4	4,565	8.6
Horticulture and Tree Systems	9,055	17.8	9,390	17.7
Roots and Tubers Systems	16,312	32.1	15,063	28.4
Systemwide Program on Integrated Pest Management	365	0.7	504	1.0
Total	**50,821**	**100**	**52,959**	**100**

Figure 4. Performance Indicators: Financial Health

	2009	2010
Short-term Solvency (or Liquidity)	161 days	135 days
Long-term Financial Stability (Adequacy of Reserves)	161 days	135 days
Indirect Cost Rates	19.7%	19.3%
Cash Management on Restricted Operations	0.09	0.06
Audit Opinion	Unqualified/ Clean Bill of Financial Health	

Trading cassava at a roadside market in Nigeria Photo by JT Oliver, IITA.

Publications and Graduate Research

A graduate student searching for information in the IITA Library. Photo by JT Oliver, IITA.

Publications

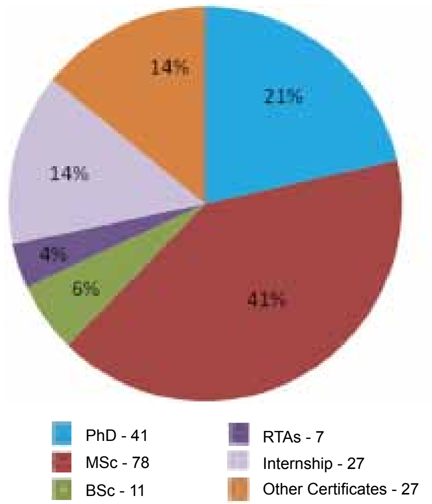
In 2010, we produced 446 publications comprised of 154 journal articles, 10 books, 8 chapters in books, 58 conference proceedings, 14 technical reports and 202 other publications (including abstracts). A total of 102 of the journal articles appeared in peer-reviewed journals that are listed in Thomson Scientific/ISI. The complete listing and details of these publications can be found in our online bibliography at http://biblio.iita.org/.

Graduate research

Individual training

In 2010, we offered more training opportunities than in the previous year. By the end of the year, some 191 students, of which 53% were female, were in various levels of completion of their respective degree programs. The continuing 132 trainees came from 21 different countries in sub-Saharan Africa and 9 countries outside of Africa.

All training topics were tailored to address identified gaps in research capabilities of participating national entities, and also in response to needs required to build human resource capacity of the countries.



Group training

A total of 193 group training activities were conducted in 2010 in which 10,334 men and 3749 women participated. Several training of trainers activities were conducted under CIALCA projects, while a number of farmers' participatory activities involving NGOs, universities, and private enterprises were held during the year mostly related to our ongoing cassava projects. Highlights are:

- A six-week Geographic Information System (GIS) training course for three scientists of the Epidemiological Unit of the Nigerian Federal Ministry of Agriculture, in collaboration with ILRI. The course aimed to strengthen capacity on the use of GIS in the early detection, reporting and surveillance of avian influenza in the country;
- Training of farmers in Cameroon to promote the adoption of *Pueraria phaseoloides* cover cropping to improve and maintain soil fertility. IITA-Cameroon organized the training to raise awareness among farmers of the benefits and management aspects of *P. phaseoloides* cover cropping; and
- A one-week workshop in Accra, Ghana involving scientists from six West African countries to sharpen their technical and statistical skills on collecting and generating data from yam field activities.

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A woman trader selling plantains. Photo by IITA.

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Looking for banana insect pests. Photo by JT Oliver, IITA.

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Our scientists in action during the 'Race4Distinction' , R4D Week 2010. Photos by JT Oliver, IITA.

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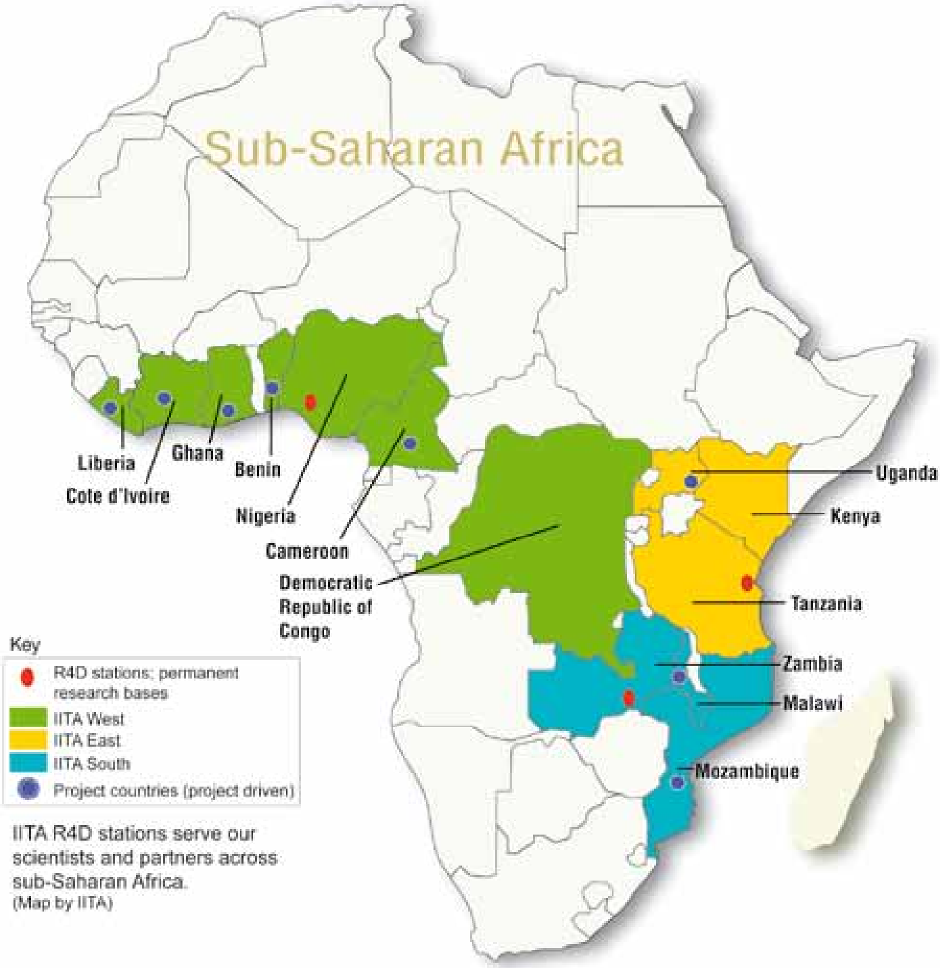

IITA R4D stations serve our scientists and partners across sub-Saharan Africa. (Map by IITA)

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2010

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http://annualreport.iita.org

A processor cooking gari, a high value food product made from cassava.
Photo by JT Oliver, IITA.

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