IITA

Annual Report
2009/10

www.iita.org

International Mailing Address:
IITA
Carolyn House, 26 Dingwall Road
Croydon, CR9 3EE, UK

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Cover photos (from left to right): a researcher inspecting cassava *in vitro* culture plantlets; cowpeas for sale at a local market in Nigeria; selling yam tubers.

Photos by: Jeffrey Oliver and Jude Atalobhor

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Vision

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

Growing vegetables is hard work - from preparing the land to watering the plants twice daily. Photo by Arnstein Staverløkk, Bioforsk.

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.

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Introduction

Selling cowpea at a local market in Nigeria. Photo by J Atalobhor, IITA.

Opportunities from crises

In 2009, most of the world was still on unstable footing due to the lingering effects of the double-whammy–the global financial breakdown and the food price crisis–that hit the previous year. For millions of African farmers and their families, the negative impacts of these crises were still strongly felt. As if these were not enough, the third threat of climate change resulting in shifting weather patterns is making agricultural production much more unpredictable and volatile, making the lives of growers even harder.

However, these crises presented us with terrific opportunities to demonstrate the effectiveness of our research-for-development (R4D) strategy. Working closely with partners and with the support of our investors, we developed viable options to help African farmers mitigate and cope with the effects of these threats.

Below is a summary of our R4D highlights and achievements in sub-Saharan Africa for 2009. Details of these highlights and achievements are presented in the "Research Highlights" section of this annual report:

To address vitamin A deficiency especially among women and children in Africa, we gave tropical maize a boost of the nutrient by combining it with maize from the temperate zones containing high levels of beta-carotene and pro-vitamin A. The result was maize that is not only more nutritious but is also well-adapted to the tropical conditions of sub-Saharan Africa.

We were also able to produce a fungus-based biocontrol product against aflatoxin contamination in major African food crops. Called aflasafe™, the product has been proven to significantly reduce aflatoxin contamination in maize in our field trials in Nigeria. The product has been granted a provisional registration by the Nigerian government, allowing us to further test it in more areas. We are also trying to develop a similar product for application in Burkina Faso and Senegal.

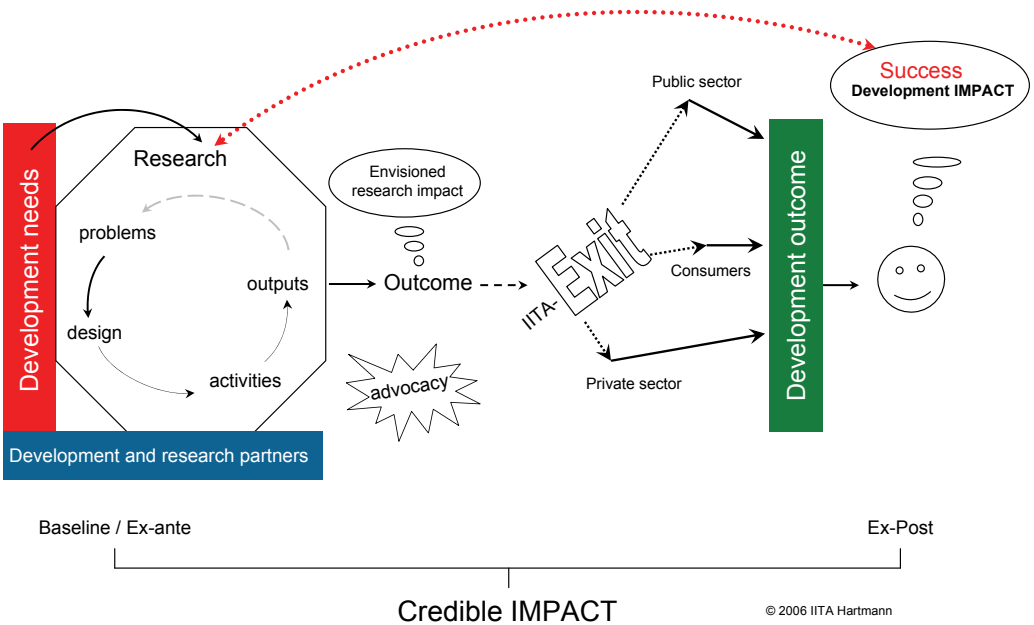
Mid-year, we sent our second shipment of seeds of African crops to the Svalbard Global Seed Vault. This comprised of about 5000 seed samples of soybean, maize, bambara nut, cowpea, and African yam bean. Through our Genetic Resources Unit, we are

continuing efforts to expand our germplasm collection to help ensure the security and future of Africa's agrobiodiversity.

We developed new diagnostic tools to help check the spread of crop disease-causing pathogens. Called 'DNA Barcoding', this new initiative could genetically characterize pathogen populations and recognize unique stretches of sequences. The DNA 'barcodes' could then be used as markers to diagnose pathogens and pests affecting African food crops.

In the face of the rapid onslaught of two deadly diseases of bananas and plantains in Africa – Banana *Xanthomonas* Wilt

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.

and Banana Bunchy Top Disease – that is threatening to wipe-out the crops from the continent, we engaged in a number of complementary disease-management research. These include conducting diagnostic assays, regional disease surveillance, developing management tools, and studying host-plant resistance.

We also undertook studies to delve deeper into the dynamics of Musa production in Africa. This included research that looked at relationships between and among pests and diseases, biotic and abiotic stresses, and farmers' preferences. All of these to establish the underlying causes of the present state of Musa production in Africa, and enable us to plot a more effective course for our R4D work on bananas and plantains in the continent.

Further to our work on developing a biocontrol product against aflatoxin contamination in food crops, we also developed six new aflatoxin-resistant maize inbred lines with our US-based partners. These maize lines, which have been released to farmers, are also well-adapted to the lowlands.

Our work on improved double-purpose cowpea has resulted in significant increases in the incomes of farmers in northern Nigeria. Cowpea growers in that part of the country have seen their farm profits jump by as much as 55 percent from using the improved varieties compared to local ones.

On soybeans, we developed a new variety that is resistant to the deadly Asian rust – a disease that causes as much as 80 percent crop loss in infested fields. Tagged TGx 1835-10E, the new rust-resistant variety is also high-yielding, bringing an average of 1655 kg/ha of grain and 2210 kg/ha of fodder. It also possesses other traits sought after by soybean farmers.

Our project on "Promoting Sustainable Agriculture in Borno State" (PROSAB), which ended it five-year run this year, showcased the effectiveness of our R4D approach. Our post-project socioeconomic analysis have shown that the poverty levels of about 17,000 households, or more than 100,000 participating farmers, have dropped by an average of 14 percent, while food security improved by about 17 percent – due mainly to PROSAB's R4D interventions.

Our Sustainable Tree Crops Program (STCP) was tapped as one of five technical partners of a global, multi-sector consortium

to implement the US$40 million, 5-year Cocoa Livelihoods Program (CLP). The program is funded by the Bill & Melinda Gates Foundation and 14 chocolate industry companies. STCP will lead the CLP's site selection, develop and validate training approaches for cocoa farm rehabilitation, produce appropriate training materials, establish a community-level distribution system for improved planting materials, conduct market opportunity and product diversification studies, and manage the program's Performance Coordination Unit.

A study on the impact of agricultural research on productivity and poverty in sub-Saharan Africa that we completed this year has shown that agricultural research has a direct positive impact on poverty, reducing the number of poor people in the region by as much as 2.3 million annually. In view of the long-term research investments and demonstrated successes in the region, our own R4D work is helping uplift the lives of about 500,000 to one million poor people in sub-Saharan Africa annually.

This year, we moved even closer to developing cassava that has dual resistance to two of the crop's deadliest diseases – Cassava Mosaic Disease and Cassava Brown Streak Disease. We are currently conducting further disease-stress tests and breeding on candidate cultivars that have shown promise. We are also ensuring that traits sought after by farmers – such as cooking taste, texture, and yield – are addressed.

Yam farmers in sub-Saharan Africa have been traditionally beset by high production costs. We developed a novel way of propagating yam that does away with using tubers as seeds, saving farmers as much as 25 to 30 percent in production expenses. The innovative technique involves using vine cuttings grown in inexpensive carbonized rice husks to produce mini-tubers, which are then used as the planting material in the fields. Aside from reducing costs, this new yam propagation technique could also address the need for faster and wider distribution of disease-free and improved varieties to farmers.

For years, cabbage farms in West Africa have been suffering from the damage inflicted by the Diamondback Moth (DBM), affecting farmers' incomes and market prices of the high-value crop. This year, we developed a biopesticide based on a fungus–

Beauveria bassiana – that effectively controls DBM. Used in integrated pest management, the biopesticide offers a cost-effective and ecologically-friendly alternative to inorganic pesticides, which are not only expensive but also poses health risks to humans and the environment. The *B. bassiana*-based biopesticide has been tested and proven effective in a number of field tests in the Benin Republic.

We carried out advanced studies in the biological control of the cowpea pod borer, *Maruca vitrata*. We further evaluated the effectiveness of a previously identified natural enemy of the pod borer, the parasitoid *Apanteles taragamae*. We also continued host-range studies of the Multi-Nucleopolyhedrosis Virus, another promising biocontrol against *Maruca vitrata*, which was found through collaborative studies with the World Vegetable Center.

To service more African farmers, we established our Southern Africa Administrative Hub in Zambia to backstop our R4D efforts in that part of the continent. The hub will cater to the agricultural research support needs of Zambia, Malawi, Mozambique, Zimbabwe, Lesotho, Swaziland, Botswana, Namibia, South Africa and, as needed, the DR Congo. With the establishment of our Southern Africa hub, our administrative support system now have three focal points: West Africa (covered by IITA-Nigeria), East Africa (serviced by IITA-Tanzania), and Southern Africa (covered by IITA-Zambia) (see map on p54).

Our 2009 audited financial statements reflect the institute's sustained financial health and stability, and the prudent management of resources. Our liquidity and reserve levels are above those recommended by the CGIAR, indicating our continued ability to meet short- and long-term obligations. Please see the "Financial Information" section of this report for details.

Research Highlights

A staff of the Genetic Resources Unit sorting seeds in preparation for shipping to the Svalbard Vault. Photo by JT Oliver, IITA.

Agriculture and Health

Poor food quality risks health, restricts trade, and reduces labor productivity of millions in Africa. We improve diets, health, and productivity through research on micronutrient content, food toxins, and nutrient patterns.

Giving tropical maize a vitamin-A boost

Nutrition studies have shown that over 100 million Africans who rely heavily on cereal-based diets such as maize have sub-optimal vitamin A intake. Due to vitamin A deficiency, these people have high risk of visual impairment and blindness, and increased susceptibility to diseases such as anemia, diarrhea, measles, malaria and respiratory infections. Young children, pregnant women and lactating mothers are especially vulnerable. In Africa, an estimated 33 million preschool-aged children are reported to be deficient in vitamin A.

To address this, we undertook research to develop tropical maize that is genetically fortified with increased levels of vitamin A. By introducing and crossing maize from the temperate zones that contain high levels of beta-carotene with tropical maize having intermediate pro-vitamin A content, we were able to produce inbred lines that contain high levels of both nutrients.

We further evaluated and crossed these improved lines with cultivars that are well-adapted to the prevailing diseases of maize. After repeated selection for desirable agronomic traits and resistance to diseases at the different stages of inbreeding, we were able to produce a large number of

Biofortified maize could effectively address vitamin A deficiency of people in Africa, especially women and children. Photo by O Adebayo, IITA.

promising lines that are not only rich in pro-vitamin A but are also resistant to most maize diseases. More than 300 of these lines have been assayed at Iowa State University and at IITA-Ibadan for pro-vitamin A carotenoids.

These adapted maize inbred lines have higher concentrations of pro-vitamin A ranging from 2.5 μg/g to 10.5 μg/g. From 2004, through extensive selection, we have been able to boost the pro-vitamin A content of our maize inbred lines by 1.8 μg/g per year.

We identified and used the best inbred lines to further develop hybrids, some of which showed 25% to 79% more pro-vitamin A content than Oba Super II, a commercial yellow hybrid in Nigeria. The best hybrids were also found to have grain yields and agronomic traits comparable to those of Oba Super II.

Our studies highlight the possibility of enhancing the pro-vitamin A content of tropical maize without adversely affecting its productivity and adaptation to production environments. Future work could be undertaken to intercross these improved maize cultivars to generate lines with even higher levels of pro-vitamin A and adapted to the savannas of West and Central Africa.

Making African food crops safer

Aflatoxins are chemical poisons produced mainly by the fungus *Aspergillus flavus* in maize, groundnuts, cassava, and yam chips. They undermine human health, are potent causes of cancer, suppress the immune system of humans and animals, and stunt children's growth.

In trade, about US$1.2 billion in global commerce is lost annually due to aflatoxin contamination, with African economies suffering some US$450 million in yearly trade losses. Aflatoxins are also non-tariff barriers to international trade since agricultural products that have more than the permissible levels of contamination are rejected.

To address this, we worked with partners to develop a safe and natural biocontrol method that drastically cuts aflatoxin contamination in African food crops. The resulting product is called aflasafe™.

Collaborating with the United States Department for Agriculture – Agriculture Research Service, Kenya, we demonstrated the ability of a natural fungus found in Nigeria to significantly reduce concentrations of aflatoxins in maize. On-station trials of aflasafe™ in Zaria, Ikenne, Mokwa and Ibadan showed a drop in aflatoxin contamination in maize by 50 to 99 percent.

With aflasafe™, native strains of *A. flavus* that do not produce aflatoxins (called atoxigenic strains) are applied to alter the fungal community on crops and throughout an area so that crops become less contaminated with aflatoxins. When properly done, these native atoxigenic strains competitively exclude aflatoxin producers.

This competitive exclusion principle of biological control will be used as a new type of intervention strategy to mitigate the negative effect of aflatoxins on human health and trade initially in Nigeria.

Competitive exclusion works by applying selected native atoxigenic strains to out-compete and exclude aflatoxin-producers during colonization of grains, thereby reducing levels of aflatoxin contamination.

We identified several atoxigenic strains native to Nigeria and Kenya that are useful for reducing aflatoxins. We are also identifying native atoxigenic strains for Burkina Faso and Senegal for similar aflatoxin biocontrol.

In 2009, Nigeria's National Agency for Food and Drug Administration and Control provisionally registered aflasafe™ and permitted treatment of up to 100 ha of farmers' fields.

Farmers participating in the field trials of aflasafe™ attest that the quality of their maize grains has significantly improved after the product's application in their fields. On average, the farmers who treated their maize field with aflasafe™ achieved nearly 80 percent aflatoxin reduction in grains at harvest. The trials were coordinated by the Kaduna State Agriculture Development Program, and funded by the African Agricultural Technology Foundation and European Union's MycoRed Project.

aflasafe™ is a trademark of IITA.

Maize farmers brodcasting aflasafe™ in the field. Photo by R Bandyopadhyay IITA.

Agrobiodiversity

Africa's biodiversity is rich but very vulnerable. Our genebank conserves this diversity for sustainable use now and in the future. We use biotechnology and new diagnostic tools for the efficient, long-term conservation and use of genetic resources of staple and under-utilized crops and non-plant organisms.

More African seeds locked in global seed vault

In June 2009, we shipped the second batch of African seeds to the Svalbard Global Seed Vault located on the Norwegian island of Spitsbergen in the remote Arctic Svalbard archipelago. The delivery is a follow up to our shipment of seeds last year at the commissioning of the "Doomsday Vault".

Our 2009 shipment included about 5000 seed samples of soybean, maize, bambara nut, cowpea, and African yam bean, packed in more than 10 seed boxes. The shipment was prepared by the Genetic Resources Center (GRC) located at headquarters in Ibadan, Nigeria.

We were the first international agricultural research institute to send seeds to the Vault. Our initial consignment sent on 30 January 2008 comprised of 21 boxes filled with 7000 unique seed samples of crops from more than 36 African nations.

Between 2008 and 2009, we have shipped 11,414 accessions of different African food crops to the seed vault, representing 54% of the conserved seed germplasm at the GRC. These shipments to Svalbard are part of our ongoing commitment to safeguard Africa's agrobiodiversity for the future of humanity.

According to the UN Environment Program's 4th Global Environment Outlook report, the ongoing loss of biodiversity will restrict future development options for rich and poor countries with negative impacts on food security.

Boxes containing seeds of African crops being loaded onto a van on the way to Svalbard. Photo by O Adebayo, IITA.

To help stem the loss of agrobiodiversity, the GRC has over the years conserved more than 28,000 accessions of key food crops in sub-Saharan Africa. The GRC also houses the world's largest collection of cowpea—a key staple in Africa and offering an inexpensive source of protein— with about 15,000 varieties from 88 countries, mostly from Africa.

We are also continuously working to expand our germplasm collection. This year, we acquired 402 accessions of yam from Benin, Togo, and Ghana. We have also collected 73 local cassava germplasm from Guinea Conakry, and acquired 48 accessions of coco yam from Ghana. These newly acquired germplasm are presently in screen houses and will be characterized in 2010.

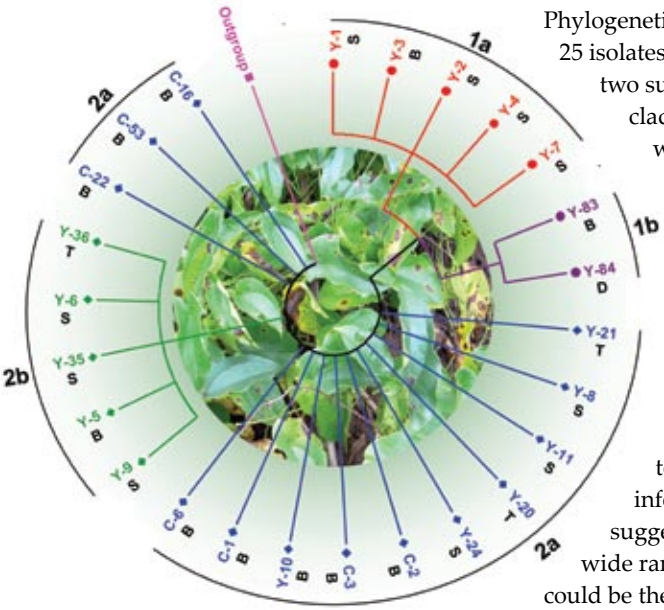
'DNA Barcoding': new initiative in determining the diversity and checking the spread of pathogens

Diagnostic tools is vital to disease surveillance, development of host plant resistance, quarantine monitoring, and supporting safe conservation and exchange of germplasm. Good knowledge on pathogen population structure and genetic diversity is a pre-requisite to developing unambiguous diagnostic tools and is critical in establishing disease management tactics. Increasingly, modern diagnostic tools are being based on the DNA characteristics of the pathogen.

We undertook a new initiative to genetically characterize pathogen populations and recognize unique stretches of sequences. Called 'DNA Barcodes', they can be used as markers for diagnosing pathogens and pests affecting African food crops.

For instance, we conducted molecular characterization of fungal pathogen(s) causing anthracnose – the most destructive disease of yam and cassava in West Africa. In yams, anthracnose appears as leaf spot that spreads rapidly, killing the leaves, shoots, and entire plant. In cassava, it appears as cankers on stems at the base of leaf petioles, and also kills the leaves, shoots, and whole plant. The disease causes severe yield losses in both crops.

The causal fungus, *Colletotrichum gloeosporioides* Penz., is widespread in West Africa. We identified various isolates of this fungi differing in morphology, growth characters, and pathogenicity, and investigated their genetic relatedness and diversity through molecular analysis using a set of 25 reference isolates (17 from yam and 8 from cassava). Based on the symptoms they induce, they were grouped into spot (S) and blight (B) isolates. Both isolates infect yam, but only B isolates infect cassava. We assessed the genetic diversity in these isolates by nucleotide sequencing and cluster analysis of the ~540 base pair (bp) nuclear ribosomal internal transcribed spacer region (ITS1, ITS2 and the 5.8S gene) and partial gene sequences of actin (~240 bp) and histone (~370 bp).



Clustering of 25 yam isolates based on rDNA sequences. Isolates from yam are indicated as 'Y', and cassava as 'C'. Isolates causing blight symptoms are indicated as 'B' and spot symptoms as 'S'. Gibberella moniliforme is the outgroup. Image provided by Lava Kumar, IITA.

Phylogenetic cluster analysis grouped the 25 isolates into two major clades and two sub-clades within the major clades. Both the S and B isolates were distributed between the two clades (see figure). All the isolates in clade 1 were unique to yam. Seven of these isolates (YA08-1, YA08-2, YA08-3, YA08-4, YA08-7, Y-83, Y-84) formed a genetically-distinct lineage indicating that they could be new strains unique to yam. Isolates in clade 2 infect both cassava and yam suggesting their capability to infect wide range of plants. Clade 2 isolates could be the most frequently occurring on yam and cassava because of their ability to survive on weeds and other crops. We recognized unique sequence motifs and designed diagnostic PCR primers for specific amplification of *C. gloeosporioides* infecting yam and cassava directly from infected plant tissues.

Using a similar approach, we characterized the fungal agent associated with grey leaf spot (GLS), the most destructive disease of maize. We found that GLS in Nigeria is caused by a distinct species of *Cercospora*, but not *C. zeae-maydis*. This work, in addition to confirming the GLS etiology, allowed us to establish a unique set of primers for specific identification of GLS pathogen prevalent in Nigeria.

Through comparative genomics, we identified common genome regions in cassava mosaic begomoviruses occurring in sub-Saharan Africa. We developed a simple multiplex PCR assay that can detect all the major viruses in cassava mosaic disease etiology. This test has been institutionalized for virus indexing of cassava propagated *in vitro*.

To aid in diagnostics research, we developed a simple and cost-effective procedure suitable for extraction of DNA from seeds, leaves, stems, tubers, and even roots. The resultant DNA is suitable for PCR-based diagnoses of fungi, bacteria, and viruses in the infected tissues in a wide range of plant species, and is handy for quarantine monitoring of germplasm. We are establishing a repository of diagnostic protocols in an approach we call 'Diagnostic Basket®' and make it available to users.

Banana and Plantain Systems

Banana and plantain are basic food- crops for over 70 million people in Africa, but yields have been declining. We use greater knowledge on the crops' agro-ecology to develop new varieties and better production practices. Our solutions improve production and productivity and increases profit from better quality and variety of banana-based food products.

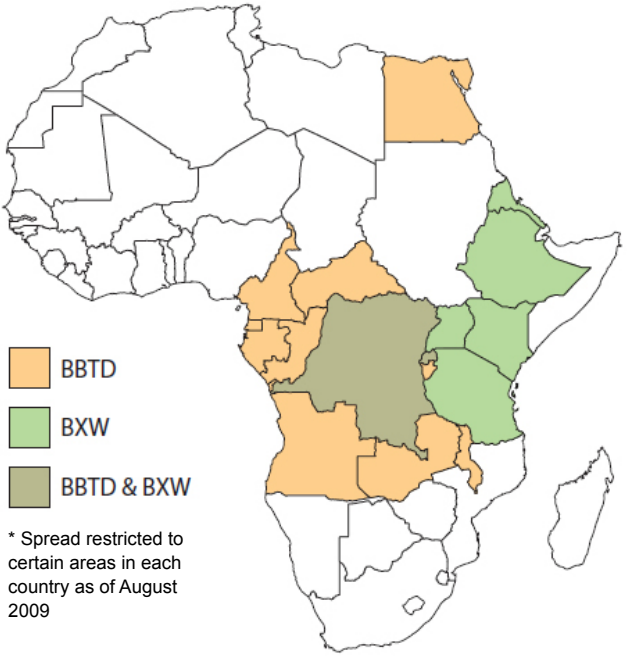
Fighting a two-pronged attack on African bananas

Among the many diseases that affect bananas and plantains in Africa, the two greatest threats are Banana *Xanthomonas* Wilt (BXW) and Banana Bunchy Top Disease (BBTD). Combined, these diseases have the potential to wipe out these economically- and food security-vital crops from the continent. Their rapid spread in recent years has alarm bells ringing in banana-producing countries across Africa.

BXW, which in the past had only been prevalent in Ethiopia, has been highly active in East Africa this past decade. On the other hand, BBTD, which was first reported in the 1920s and then the 1960s in Egypt and DR Congo, respectively, has been spreading rapidly in the East African highlands and in Central and Southern Africa.

In the face of this two-pronged threat, we have been actively engaged in a number of complementary disease-management research. These include developing specific diagnostic assays, initiating regional surveillance to map current disease distribution and future spread, developing

(Top) Flesh of BXW-infected banana fruit; (bottom) BBTD-infected banana plants. Photos by P van Asten and F Beed, IITA.



Distribution map of BBTD and BXW in Africa. Image provided by Fen Beed, IITA.

management tools to minimize establishment, spread, and impact, and working on host-plant resistance through germplasm screening and biotechnology approaches.

As the BXW pathogen is closely related to other *Xanthomonas* pathogens that affect maize, sorghum, and sugarcane, we, together with advanced laboratories in the USA, developed a highly specific assay to identify the banana variant using genomic tools. We also developed a sensitive assay for the banana bunchy top virus (BBTV), the causal agent of BBTD.

These two assays are now being used for verification of suspected BXW and BBTD cases in East and southern Africa in cooperation with national and private sector partners.

The development of sensitive diagnostics for BXW and BBTD permits epidemiological studies in plants that do not show symptoms during the latent period, rapid deployment of control measures, and effective detection of the pathogens by quarantine officers along borders.

We also conducted surveys with national partners in southern and Central Africa to map the extent of spread of BBTV, and to determine the abundance and distribution of the banana aphid, the only known insect vector of BBTV.

We recognize that insects play an important role in the spread of banana diseases, so we initiated studies on host-plant resistance to the banana aphid that spreads BBTV. We also plan to explore for natural enemies of the banana aphid in its putative area of origin in 2010. In Malawi, we established a field trial of various banana cultivars to study host reaction to BBTV and assess virus concentration.

Many insects have been implicated in the medium-distance, farm-to-farm spread of BXW. To help us develop management guidelines, we have been conducting studies in an isolated and controlled site in a forest reserve to further understand how insects spread the BXW pathogen.

Together with the Southern Africa Development Community, the Association for Strengthening Agricultural Research in Eastern and Central Africa, FAO, Bioversity International, and other partners, we co-organized an international workshop in Arusha, Tanzania in August to integrate recent information on these diseases and develop control strategies.

The workshop recommended measures to slow the spread of these diseases into new regions and offset their impact in already-affected areas. These included large-scale awareness and surveillance campaigns, community-level cooperative actions, establishment of reporting, communication, and monitoring systems, improved "seed" systems, development of national contingency plans, and long-term programs for eradication and/or management of BXW and BBTD.

A follow-up meeting in 2010 is being planned to establish the framework of a region-wide disease-management and production strategy.

Looking into the dynamics of *Musa* production in Africa

This year, we undertook research to further understand the dynamics of the relationships among factors affecting banana and plantain production in Africa such as pest and diseases, biotic and abiotic stresses, and farmers' preferences. This is to establish some of the underlying causes why bananas and plantains in Africa are as they are. More importantly, this would help us plot a more effective course for our *Musa* research-for-development efforts.

In East Africa, we conducted large-scale diagnostic surveys with our partners particularly in the major production areas of Uganda, Rwanda, Burundi, Eastern DRC, and central Kenya. We mapped yield levels, crop management practices, pest and disease pressure, nutrient deficiencies, and ecological parameters such as rainfall and altitude. Our surveys came up with some surprising facts:

- Yield levels (t/ha), taken from measurements of hundreds of farmers fields, were more than double the figures reported by national statistics and cited by FAO;

- Uganda, which has been traditionally regarded as the regional champion of banana production, actually had lower average yields (around 15 t/ha) than neighboring Rwanda, Burundi, and East DR Congo (more than 20 t/ha);
- Sigatoka disease pressure, which had been the primary focus of breeders, was generally low, especially in the higher altitudes;
- Nematode and weevil pressure was still important in the lower parts of the highlands (less than 1200m above sea level), but were not a primary yield constraint in most production areas;
- Nutrient deficiencies were widespread. With the exception of young and volcanic soils near the Albertine rift, the dominant Acricols and Ferralsols were low in nutrient stocks.; and
- Soil organic matter management is a key factor, and often explained the large production differences observed when moving 50 meters away from the relatively fertile soil adjacent to houses to banana plots farther away and less likely to receive discarded kitchen waste.

Transporting bananas in Uganda. The farther the farms are from the market, the lesser the incomes that growers get. Photo by P van Asten, IITA.

Our on-farm fertilizer trials across Uganda showed that modest fertilizer doses (average 71N, 8P, 32K kg ha^{-1} yr^{-1}) doubled yields from 10 to 20 t/ha per year in areas such as Central Uganda. Fertilizer use proved highly profitable near large urban centers such as Kampala, but at farther distances (>150km) from the market, the increased transport cost reduced farm gate prices to levels that would make fertilizer investments too risky (marginal rates of return <100%).

Besides soil fertility, regional production gradients seemed also strongly correlated to rainfall gradients. To prove this, we explored

data from past field trials, relating inter-annual yield variations to rainfall variations. Drought proved to be one of the biggest yield constraints, with an estimated 50% yield loss in large production areas in the highlands that received "only" 1000 mm of rainfall per year. Pot trials confirmed that even moderate drought stress (pF 2.8) resulted in strongly reduced growth (>63%) compared to plants that remained well watered (pF 1.8). Drought stress does not result in obvious visual stress symptoms, explaining why farmers and researchers in the East African highlands had not given it much attention.

We are planning to conduct similar diagnostic surveys for the plantain systems in West and Central Africa, as well as setting up irrigation trials in West and East Africa, in 2010.

Our plant health researchers are also conducting studies to probe deeper into the complex relationships between pest and disease resistance and abiotic and biotic stresses, and develop appropriate solutions to optimize *Musa* production in Africa.

Banana valley near Ruhengeri, Rwanda. Photo by P van Asten, IITA.

Cereals and Legumes Systems

Cereals and legumes such as maize, cowpea, and soybean are important food crops for most households in Africa, but production is very unstable. We develop and disseminate improved varieties, natural resource management approaches, and new production technologies to enhance and sustain productivity.

New aflatoxin-resistant maize

Aflatoxins, poisons produced by the fungus *Aspergillus flavus*, infect agricultural commodities such as groundnuts, cassava, yam, and maize. They pose serious potential health hazards to both humans and animals, and have far-reaching negative implications on the global trade contaminated crops (see related article "Towards safer African food crops" under Agriculture and Health).

Various solutions have been proposed to minimize aflatoxin contamination in food crops. Host resistance remains as the most widely explored strategy as *A. flavus* infects susceptible crops before harvest.

Our researchers in partnership with colleagues from the US Department of Agriculture - Agricultural Research Service (USDA-ARS-SRRC) have developed and released six new maize inbred lines with resistance to aflatoxin contamination and adapted to the lowlands. These lines, named TZAR101 through TZAR106, have also been registered in the United States. The research was co-funded by FAS-USDA-ARS, USAID, and IITA.

Improper and unhygienic postharvest practices, such as sun-drying maize on bare ground, usually lead to crop contamination. Photo by G Atser, IITA.

Collaborating for almost a decade, USDA-ARS plant pathologist Robert Brown and IITA maize breeder Abebe Menkir developed the new maize lines through conventional breeding by crossing the best aflatoxin-resistant lines found in the US (GT-MAS:gk, MI82 and Mp420) with

tropical elite lines found in Central and West Africa (1368, 4001 and KU1414-SR).

Aside from demonstrating good resistance against aflatoxin accumulation under laboratory and field tests, most of these new maize lines also possess other commercially-desirable traits and resistance to diseases such as leaf blight and southern corn rust.

A local partner holding a cob of aflatoxin-contaminated maize. Photo by G Atser, IITA.

As these inbred lines involve parents of both tropical and temperate origin, they are likely to contain new combinations of complimentary alleles imparting resistance to aflatoxin accumulation. These can be exploited by maize breeders as new sources of resistance for developing maize cultivars with higher levels of resistance to *A. flavus* infection/aflatoxin contamination.

They can also serve as sources of resistance to foliar diseases as well as desirable agronomic traits to expand the genetic base of adapted US and tropical maize germplasm to accelerate the development of productive new cultivars. The resistant lines with good agronomic traits could be used as parents to accelerate breeding efforts against aflatoxin contamination of national programs in West and Central Africa.

Better livelihoods from improved dual-purpose cowpea

Resource-poor cowpea farmers in northern Nigeria have seen their profits jump an average of 55 percent due to improved dual-purpose cowpea varieties that we and our partners developed and introduced.

Farmers who use traditional varieties earn about US$251 per hectare, while those who are growing the improved cowpea are getting US$390, or US$139 more, per hectare with proper crop management.

With improved dual-purpose cowpea, farmers now have more options to improve their lives. Photo by S Muranaka, IITA.

The improved varieties: IT89KD-288, IT89KD-391, IT97K-499-35, and IT93K-452-1 produce high-quality grains that are used by farmers for food and fodder. They are also resistant to *Striga*, a parasitic weed that reduces yields of susceptible local cowpeas by as much as 80 percent.

Over 100,000 farmers in Borno and Kano states in northern Nigeria and in the Niger Republic are currently using the improved varieties, where their adoption rate is conservatively estimated at 65 percent.

Farmers in the savannah region view cowpea as both food and cash crop. When the varieties were introduced, farmers took to them readily since they serve both ends well. Those who cultivate the dual-purpose cowpeas are basically better off than those who do not.

The improved cowpea varieties were developed and deployed in partnership with the Borno State Agricultural Development Project, Kano State Agricultural and Rural Development Authority, Kaduna State Agricultural Development Project, the Institute of Agricultural Research - Zaria and the University of Maiduguri.

Other local development partners are promoting the improved varieties by organizing farmers' field days, exchange visits, training and farmer-to-farmer diffusion.

Cowpea is a grain legume grown mainly in the savanna regions of the tropics and subtropics in Africa, Asia, and South America. Its grain contains about 25 percent protein, making it extremely valuable to those who cannot afford more expensive animal-derived protein sources such as meat and fish. It is tolerant to drought, fixes atmospheric nitrogen, and improves poor soils.

The FAO, about 7.56 million tons of cowpeas are produced worldwide annually, with sub-Saharan Africa accounting for 70%, or about 5.3 million tons, of global production.

New soybean offers respite from deadly Asian rust

The Asian soybean rust is a fungal disease that is capable of laying waste as much as 80 percent of infested crops. This year, a soybean variety resistant to the disease that we developed was approved for release by the Nigerian National Variety Release Committee (NNVRC). The rust-resistant soybean is the first of its kind to be made available for cultivation not only in Nigeria but also in West and Central Africa.

Tagged TGx 1835-10E, our scientists bred the variety and further developed it in collaboration with the National Cereal Research Institute. Its release for general cultivation was approved in December 2008 and notified in June 2009 by the NNVRC.

Field trials in Nigeria showed that aside from being resistant to the Asian rust, the variety is also high-yielding, averaging 1655 kg/ha grain and 2210 kg/ha fodder. It is also early-maturing, has good promiscuous nodulation character, and resists pod shattering and other prevalent diseases.

The variety can be used for direct cultivation in tropical Africa or as a source of resistance genes in soybean breeding programs. It was previously released in Uganda through the initiative of Makerere University, a local partner, and has already shown excellent performance in trials carried out in Southern Africa, suggesting that it is well-adapted.

Its resistance is effective against all currently known types of the rust fungus in Nigeria. We have bred several other lines with rust resistance genes from various sources, which can be deployed quickly if this variety succumbs to newer forms of the rust fungus.

Asian rust-resistant TGx 1835-10E (right) compared with a susceptible variety (left). Photo by IITA.

It was in 1996 that the Asian soybean rust first arrived in Africa, rapidly spreading through Uganda, Malawi, Mozambique, Rwanda, South Africa,

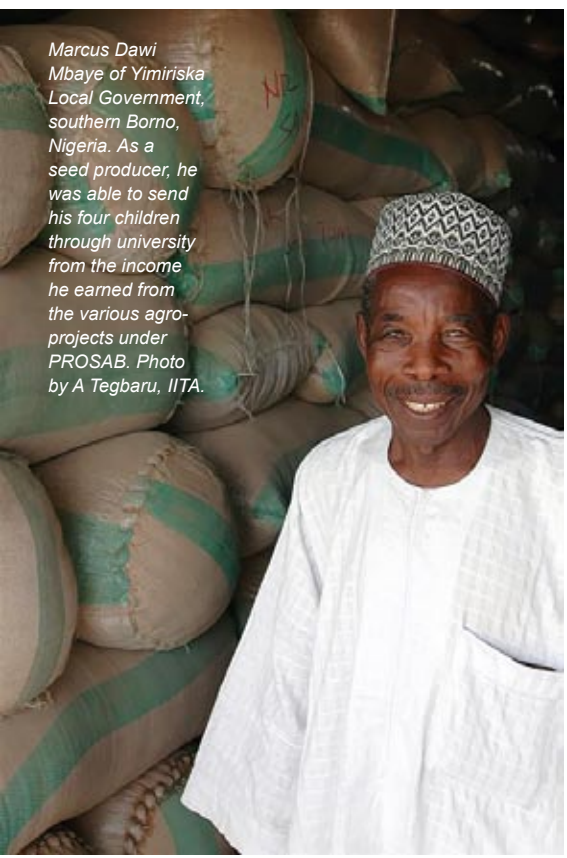
Zambia and Zimbabwe. The disease was first noted in Nigeria in 1999.

The causal fungus of the Asian soybean rust, *Phakopsora pachyrhizi*, is very aggressive and can produce billions of spores capable of turning lush green crops with healthy foliage into brown fields with bare stalks in 2-3 weeks.

For most African farmers, using resistant varieties is the most viable method to control the disease as applying fungicides proves very costly.

PROSAB: demonstrating the effectiveness of our R4D approach

The successes recorded by the five-year run of the "Promoting Sustainable Agriculture in Borno State" (PROSAB) project that we coordinated proved the effectiveness of our research-for-development (R4D) approach in tackling not only livelihoods and food security but also social empowerment and gender equality. PROSAB started in 2004 and ended this year.



Marcus Dawi Mbaye of Yimiriska Local Government, southern Borno, Nigeria. As a seed producer, he was able to send his four children through university from the income he earned from the various agro-projects under PROSAB. Photo by A Tegbaru, IITA.

Farmers in the project area who adopted the technologies and management practices espoused by the project experienced increased food availability and incomes. Considerable progress was also made in addressing the problems of declining soil fertility and *Striga* infestation.

Our socioeconomic analysis involving about 17,000 households, or more than 100,000 farmers, that participated in the project showed that poverty levels dropped by an average of 14 percent, while food security improved by 17 percent.

Farmers who participated in the project increased their average incomes by an average of 81 percent compared to what they were earning before PROSAB started. They attributed this mainly to the project's interventions.

More importantly, the knock-on effect on other non-participating farmers in the region has been tremendous.

PROSAB introduced improved crop varieties, trained farmers on improved agronomic practices and promoted gender equality in agricultural development.

Some members of the Women Farmers' Group organized under PROSAB. Photo by A Tegbaru, IITA.

Apart from reducing poverty in households from 63 percent to 49 percent, the project also made significant inroads in enhancing women's roles in agricultural activities.

Ruth Dasika Mshelia, a mother of five and a participant of the project, attested, "PROSAB has helped us freely interact with our male counterparts in development projects. We are not ashamed anymore,"

Borno state, where the project was centered, is predominantly Islamic, with social interaction between men and women largely restricted by religious norms.

Farmers, policy makers, nongovernment organizations, and other local partners hailed it as a major success story in northern Nigeria where climatic and cultural factors are major challenges to development.

Some local governments have signified interest in out-scaling PROSAB's approach to other states. It has also been touted as a model that could be adopted in agriculture-based communities in other African countries.

The CA$ 7 million (about US$6.33 million) project was funded by the Canadian International Development Agency. Our implementing partners included the International Livestock Research Institute, Borno State Agricultural Development Program, Community Research for Empowerment and Development, the Institute of Agricultural Research - Zaria, and the University of Maiduguri.

Horticulture and Tree Systems

Vegetables and tree crops such as cocoa support the income of Africa's rural poor. We develop and promote responsible production and post-harvest technologies, and influence enabling policy and marketing environments that sustain productivity and increase income.

STCP in the Cocoa Livelihoods Program

This year, our Sustainable Tree Crops Program (STCP) was tapped to be part of a multi-sector consortium to implement the US$40 million, 5-year Cocoa Livelihoods Program (CLP). The CLP, managed by the World Cocoa Foundation, aims to improve the livelihoods of approximately 200,000 cocoa farmers in Cote d'Ivoire, Ghana, Nigeria, Cameroon and Liberia by addressing marketing and production inefficiencies, income diversification, and farming technology/ innovations.

Cocoa farmers breaking pods. Photo by C Prah, IITA.

The program was first announced in February 2009. Activities began following intensive site selection that we led in consultation with public and private sector partners in the project countries. We would also be training cocoa farmers in production practices and quality management through innovative approaches such as Farmer Field School, Farmer-to-Farmer training, and Video Viewing Clubs.

Cocoa seedlings at a community nursery put up by STCP. Photo by R Asare, IITA.

We would develop and validates a new training approach that would help rehabilitate existing cocoa farms through the proper establishment of productive systems of high yielding, fertilizer-responsive varieties. We will also develop distribution systems for improved planting material in the five countries by facilitating the establishment of commercial and on-farm nurseries, and clonal budwood gardens for rehabilitation through grafting. These nurseries will serve as sources of high-yielding planting material for cocoa and other crops and trees.

To ensure that the nurseries are supplied with the best available cocoa, timber, plantain, and cassava planting materials, we would develop a community-level brokerage service that would link communities and commercial nurseries to various suppliers. We will also explore the Farmer Organization and the Business Service Center approaches to ensure the availability and accessibility of input supply for farmers.

We are currently conducting a market opportunity study in the five countries to analyze diversification opportunities in local, regional, and international markets using a common economic and financial analytical framework. The study covers cocoa, cassava, and plantain and their associated inputs, with other key country-specific commodities also to be considered. It would provide vital market information to reduce the risk of an income shock on the economies of these countries and its spillover impact on cocoa-growing communities.

We are also responsible for managing the Performance Monitoring Coordination Unit (PMCU) of the CLP. The PMCU coordinates the monitoring activities of the five technical partners to ensure consistency and accuracy of data collected. The PMCU will maintain a centralized information database, and provide data to partners as needed to promote informed decision-making within the program.

The CLP is funded by the Bill & Melinda Gates Foundation and 14 chocolate industry companies. Aside from IITA/STCP, the other four implementing partners include Agribusiness Services International - an ACDI/VOCA affiliate, Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH, Société de coopération pour le développement international (SOCODEVI), and TechnoServe. The program has been launched in Ghana, Cote d'Ivoire and Nigeria, and is expected to be launched in Cameroon and Liberia soon.

Guiding farmers toward profitable, eco-friendly and sustainable cocoa production

Covers of the PRD Manual (above) and accompanying guidebook (right).

Cocoa production in West and Central Africa is generally low. Average yields are about 200-700kg per hectare. Surveys conducted by STCP show that as much as 40 percent of farmers in the region are at the losing end of growing cocoa.

To enhance productivity, old and non-productive farms need to be rehabilitated, or new cocoa farms established using best agronomic practices. In 2007, we conceived the idea of developing a comprehensive and compact manual on ecologically-friendly, profitable, and sustainable cocoa production practices that could be used to build the capacity of farmers.

In consultation with growers and cocoa experts from national and regional partner institutions across West Africa, we developed the *Planting,*

Cocoa beans inside a cocoa pod. The PRD Manual and guidebook are designed to help growers produce better quality cocoa. Photo from Wikimedia Commons.

Replanting and Diversification (PRD) Manual – a cocoa production training document that is based on mutual participatory learning between farmers and experts.

The PRD Manual is designed to help sharpen the skills and knowledge of farmers in carrying out best practices to rehabilitate old farms and/or start new ones. The manual uses the Farmer Learning Group approach, which is a structured, group-based learning methodology that that focuses on practical demonstrations, hands-on field exercises, and discussions to hone farmers' skills.

To help farmers use the manual, we also developed an accompanying guidebook entitled *Implementing Guide for Planting, Replanting and Tree Diversification in Cocoa Systems*.

These resources are already being extensively used in farming communities in Ghana, Cote d'Ivoire, Nigeria, Cameroon, and Liberia. Hundreds of farmers in these countries have benefited from their use and the initial outcomes have been encouraging.

The manual and guide are expected to contribute towards the regeneration of cocoa farms across West Africa, and consequently improve the plight of farmers in the region. They are available online as downloadable PDFs from the STCP Web site at www.treecrops.org.

Opportunities and Threats

Food security and livelihoods in Africa face many risks. We examine and analyze the environmental, social and economic dynamics that impact food security and livelihoods. Our work serves as early warning system, strategic guide and assessor of all our research for development activities.

Agricultural research uplifts lives

A study on the impact of agricultural research on productivity and poverty in sub-Saharan Africa (SSA) that we completed this year has shown that agricultural research has a direct positive impact on poverty, reducing the number of poor people in the region by as much as 2.3 million annually.

Agricultural research has a direct positive impact on the lives of African farmers. Photo by IITA.

According to the study, in view of the long-term research investments and demonstrated successes in SSA, our own R4D work is helping uplift the lives of about 500,000 to one million poor people in the region per year.

The study, authored by Arega Alene, Impact Assessment Economist, and Ousmane Coulibaly, Agricultural Economist, also estimated that the aggregate rate of return to agricultural research in the region runs as high as 55 percent.

However, the study cautions that the actual impacts are not large enough to offset the poverty-increasing effects of population growth and environmental degradation in the region.

The study, which has been published in the journal *Food Policy*, further demonstrated that doubling investments in agricultural R&D in SSA from the

current US$650 million annually could reduce poverty in the region by two percentage points per year. However, the study adds that this projected drop in poverty would not be realized unless existing extension, credit, and input supply systems become more efficient.

The study also established that agricultural research had contributed significantly to productivity growth in SSA, with the highest payoffs noted in Ghana, Cameroon, Nigeria and Ethiopia. This is attributed to sustained investments in building national research capacity, long-term operations of the Consultative Group on International Agricultural Research (CGIAR), and regional technology spillovers. Work by the CGIAR contributed about 56% of the total poverty reduction impact in the sub-region.

Despite the contributions of agricultural research, the study notes that SSA faces several unique constraints outside the research realm that hinder the realization of potential benefits. It singled out weak extension systems, lack of efficient credit and input supply systems, and poor infrastructure development. The study recommended that concerned entities undertake efforts to improve these systems and related infrastructure, and increase investments in agricultural research, to further reduce poverty in SSA.

Africa can feed itself

Even while nearly a quarter of the world's one billion-plus hungry are in Africa, the continent can easily meet its food and income needs with additional investments in agriculture, particularly in research and capacity-building. This was the general sentiment aired by agricultural experts gathered at a World Food Day 2009 forum that we organized in Lusaka, Zambia in October.

By investing in research and training, simple but effective technologies that already exist can be easily made available to African farmers to improve their productivity, which is currently very low compared to global average.

If the gap between potential and actual yields can be reduced using existing science, Africa's production can increase three-fold. However, farmers must be able to generate wealth from the increased yields. This is not always the case as a lot of produce go to waste before and after harvesting.

In Africa, an increase in production usually results in a drop in prices, which consequently means lesser incomes for farmers. Produce must also be protected from pests and diseases and from losses during

Gari for sale at a wholesale market in Ihugh, Benue state, Nigeria. With proper infrastructure and policy support, Africa can indeed feed itself. Photo by IITA.

transportation and storage. Alternative markets are needed to prevent prices from spiraling down with increased production.

Other lessons floated during the forum included the need to develop mechanisms to help farmers cope with the lingering effects of the global financial and food crises, strengthening the agricultural research backbone of Africa, and creating an enabling environment for farmers.

Experts said research and training institutions must come together to produce a labor force that is knowledgeable and ready to face the challenges of climate change on agriculture, and quickly find and disseminate solutions. This becomes more apparent considering that over 60 percent of the continent's population depends heavily on agriculture for their livelihoods, with 70 percent of this comprising subsistence agriculture. Most also depend on the rains, which makes agriculture even more uncertain because of climate change.

They were also in agreement that in order to increase agricultural productivity in Africa, farmers should also start increasing their farm inputs. To achieve this, farmers need a lot of motivation through an agriculture-friendly policy environment and support for improved access to feed, fertilizer, irrigation, and other inputs.

They supported the call for more investment in agricultural research and training to fight food insecurity and poverty in Africa. However, they emphasized that farmers need to actively participate in research to ensure that the technologies produced are appropriate and acceptable to them.

Roots and Tubers Systems

Roots and tubers such as cassava and yam are Africa's main staple-food, but they face many threats. We reduce pre- and postharvest losses, increase productivity, and improve processing technologies, marketing and profitability.

Developing dual-resistance cassava

This year, we moved closer to developing cassava with dual resistance to Cassava Mosaic Disease (CMD) and Cassava Brown Streak Disease (CBSD) – the most devastating diseases of the crop in Eastern and Central Africa and the greatest threats to the food security and livelihoods of over 200 million people.

In Uganda, we selected eight clones with resistance to CMD and CBSD and other farmer-preferred traits. These clones, which are the first ones with dual resistance suitable to the mid-altitude areas of the Great Lakes regions, were sent to the Kenya Plant Health Inspectorate Services for cleaning and multiplication in preparation for regional distribution to national partners. An additional 41 yellow-fleshed clones, also with dual resistance to CMD and CBSD, are undergoing advanced evaluation.

This is the fourth year of trials for dual-resistance cassava for mid-altitudes in Uganda. The trials are being conducted in Mukono and Namulonge, considered hot spots of CBSD and CMD in the country. The breeding work started with over 5000 true seeds of parents with tolerance to CBSD from Tanzania that were sent to Uganda for crossing with IITA varieties that are resistant to CMD.

Cassava grown from the Tanzanian seeds were repeatedly subjected to high disease pressure along with susceptible varieties for comparison. From each growing season, only 10 percent of the crop was selected for the next stage.

Cassava root rot caused by CBSD. Photo by IITA.

After four growing seasons, the field has been narrowed down to eight very promising varieties.

Similar dual-resistance evaluation was carried out in Tanzania. Eight clones that have resistance to both CMD and CBSD were deliberately subjected to the diseases by grafting them with infected plants. Five of these clones are being evaluated on-farm, while 11 clones with dual resistance and high starch content – a preferred trait by farmers – are also being evaluated.

Cassava that survives these tests, thereby producing a true dual-resistant variety, can then be used for further disease-resistance breeding in other countries in the Great Lakes region such as Rwanda, Kenya, and DR Congo. Throughout the selection process, farmers were actively engaged to ensure that the varieties meet their preferences such as cooking taste, texture, and yield.

A novel way to propagate yams

Propagation by vine cuttings would make yam production faster, safer, and more profitable for farmers. Photo by O Adebayo, IITA.

In the traditional method of growing yam, farmers set aside 25 to 30 percent of the harvested tubers as seeds for the next planting season. This makes the crop expensive to produce. It is also inefficient: the multiplication rate is only about 1:5-10, which pales in comparison, for instance, to cereals that have a propagation ratio of about 1:300.

To address these constraints, we developed an innovative yam propagation technique using vine cuttings. In this method, cuttings, usually one to two nodes with leaves are taken from the lateral branches of immature healthy-looking vines before tuber enlargement, and planted into soil with carbonized rice husks (CRH).

Once the cuttings formed roots and shoots, they are transplanted to nursery beds where they are nurtured for 150 days. During this time they will produce mini tubers, which are then used as the planting material for the next crop.

We are testing this novel technique in a number of farmers' fields in Nigeria's north central Niger state. The technology has been extensively featured in a number of broadcast and print media in Nigeria, Japan and the UK, and some countries in sub-Saharan Africa and Oceania.

By reducing the use of ware tubers as seeds, more yams are made available to farmers for food or for sale. The technique also promotes faster multiplication and better and more uniform crop quality by introducing a break in the cycle of nematode infestation often associated with regular use of field-grown tubers as planting material.

Another advantage of this technology is that the rooting medium, CRH, could be obtained by farmers cheaply, even for free.

Previously, we developed another propagation method together with the National Root Crops Research Institute of Nigeria based on mini-setts: yam tubers are cut up into 20-25 g pieces and used to produce planting material for ware tuber production.

Compared to using whole tubers, mini-setts enable faster multiplication and lesser amount of planting material needed. The use of vine cuttings further improves on this pace of multiplication and reduces the amount of need planting material even more. The technology could address the need for faster and wider distribution of disease-free improved varieties to meet rising demand.

The research is funded by the Japanese government, the Sasakawa Africa Association, Tokyo University of Agriculture, and the International Cooperation Center for Agricultural Education, Nagoya University, Japan.

Workers loading yam tubers onto a truck for transport to markets. Photo by IITA.

Integrated Pest Management (CGIAR System-wide Program)

Pests cause high crop losses and reduce quality of agricultural produce. We coordinate and participate in the CGIAR System-wide Program on Integrated Pest Management (SP-IPM), which develops knowledge and technologies that responsibly tackle crop pests.

Beauveria bassiana: a golden opportunity for vegetable farmers

One of the biggest threats to cabbage farming in West Africa is *Plutella xylostella*, commonly known as the Diamondback Moth (DBM). For years, DBM has been devastating both smallholder and commercial cabbage farms in the region, affecting incomes and market prices of the crop.

To address this, we developed and field tested a biopesticide based on the fungus *Beauveria bassiana* 5653 against DBM. Aside from effectively controlling DBM, cabbage yield in plots treated with Bba5653 was almost three times higher compared to plots treated with the insecticide bifenthrin or to untreated plots.

Songhai Center—a Private Voluntary Organization for training, production, research and development of sustainable agricultural practices—have been involved in the testing and highly recommends the product.

Cabbage damaged by DBM. Photo by I Godonou, IITA; (inset) adult of Plutella xylostella. *Photo from Wikimedia Commons.*

Bba5653 can control DBM on cabbage and its cousin kale, regarded as high-value cash crops. Compared to other vegetables such as carrot and lettuce, farmers say returns are higher with cabbage cultivation.

For the past few years, thousands of

farmers in West Africa had to abandon cabbage production because of DBM. Consequently, market prices for African cabbage have jumped because of dwindling supplies.

The high costs of synthetic pesticides do not help either. The most common chemical pesticides—bifenthrin and deltamethrin—require about 19 applications within three months prior to harvest. The expense is prohibitive for most farmers.

Farmers, like Louis Awandjinou who has been cultivating the crop since 1986, have also observed that the chemical pesticides have been less and less effective against DBM over the years.

Alternatively, farmers have been using botanical pesticides, mostly extracts from the seed of the neem tree, against DBM and a wide range of other arthropod pests, but the approach has had limited success.

Used in integrated pest management, *B. bassiana*-based biopesticide offers a cost-effective and environmentally-friendly solution to DBM. The fungus has a narrow range of target pests and persists in the environment with the ability to remain active for several months after initial application, *B. bassiana* could end the frequent application, high costs, and risks associated with the use of chemical pesticides. It could also preserve beneficial insects, and, by extension, biodiversity.

Advances in the biological control of the cowpea pod borer

Ecological studies carried out at the World Vegetable Center (AVRDC) in Taiwan identified the parasitoid *Apanteles taragamae* as the most promising for controlling the legume pod borer *Maruca vitrata* in Africa. To test its effectiveness, our researchers in Benin imported *A. taragamae* under standard quarantine protocols and carried out experimental releases in Benin, Ghana, and Nigeria in 2007 on patches of wild vegetation including plants known to host the pod borer such as *Lonchocarpus sericeus*, *Pterocarpus santalinoides*, *Lonchocarpus cyanescens*, and *Tephrosia* spp.

Prior to these releases, we had studied the host searching capacity of *A. taragamae* using a 4 arm-olfactometer, and flowers of three different host plants: cowpea, *Pueraria phaseoloides* and the three *Lonchocarpus sericeus*. These studies revealed that *A. taragamae* uses kairomone-mediated host recognition at the short to medium range.

From as early as six months after the first releases and up until 2009, we conducted a series of surveys to monitor establishment of the parasitoid. Although we were not able to successfully recover the released parasitoid, we got indirect evidence of its establishment in the

Apanteles taragamae. *Photo by G Goergen, IITA.*

environment. We ruled out that interspecific competition with indigenous parasitoids exploiting *M. vitrata* larvae of the same age and on the same host plant could be the cause for this lack of evidence because we had conducted, just before the releases, elaborate competition studies which did not reveal any problems. Also, in its area of origin in Taiwan, *A. taragamae* coexists with similar parasitoid species found in Benin e.g. *Phanerotoma* sp. and *Dolichogenidaea* sp.

In Taiwan, however, *A. taragamae* is found prevalently on the cover crop *Sesbania cannabina*, which is difficult to grow in West Africa because of foliage beetles, particularly *Mesoplatys* sp. that completely defoliates the plant. We recently intensified our studies on African indigenous species of *Sesbania* that suffer less beetle damage, but so far there have been no signs of direct establishment. This is despite screenhouse experiments confirming the suitability of *Sesbania* species as feeding substrate for the pod borers and also as host for foraging parasitoids.

From 2007 onwards, we also started testing the newly-discovered *Maruca vitrata* Multi-Nucleopolyhedrosis Virus (*Mavi*MNPV) found in Taiwan through collaborative studies with AVRDC. After a series of laboratory tests which confirmed the Taiwan results, we carried out host range studies to ascertain its specificity. Of the seven lepidopteran species tested (four *Pyralids*, two *Noctuids*, and one *Crambid*), none got infected by *Mavi*MNPV applied on artificial diet. We then tested the virus in semi-natural condition using field cages with artificial infestations of *M. vitrata* larvae. Results showed a very high mortality of pod borer larvae (>95%) using standard concentrations comparable to those found in commercial formulation of entomopathogenic viruses (e.g. against the cotton bollworm *Helicoverpa armigera*).

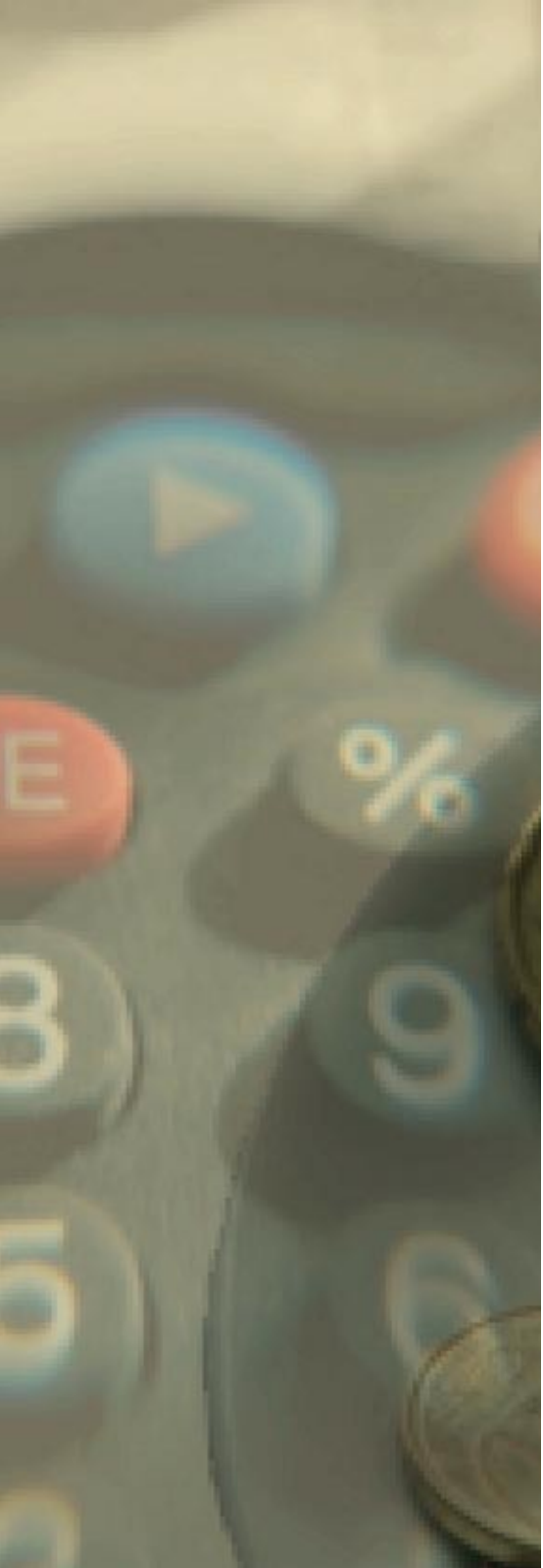
In the Mono region of Benin, we discovered a few pod borer larvae with apparent signs of *Mavi*MNPV close to the release sites of the

parasitoids. This observation was important since we did not carry out open field experiments nor has *Mavi*MNPV been found in West Africa prior to its introduction in 2007. We hypothesized that the parasitoid *A. taragamae* could have transmitted *Mavi*MNPV to pod borer larvae.

To verify this, we deliberately infected pod borer larvae using three methods: ovipositor only, whole body without ovipositor, and through artificial diet. The parasitoid was able to transmit the virus to the larvae through all of the infection methods.

This finding was significant as the parasitoid could spread the virus without further intervention. This is also indirect evidence that *A. taragamae* is present in the environment, albeit in low levels, which cannot be detected by current sampling methods, or on yet unknown secondary host plants for *M. vitrata*. We are currently conducting collaborative studies in our virology lab in Ibadan to identify and ascertain the mechanisms of transmission, and duration of virus retention and transfer.

Characteristic symptoms of pod borer attck on cowpea; (inset) close-up of Maruca vitrata *larva. Photos by IITA.*



Financial Information

Funding overview

Funding for 2009 was US$52.202 million, of which 92.7% came from CGIAR investors and 7.3% from other sources. Expenditure was US$50.821 million (net of indirect costs recovery of US$5.535 million), of which 81.2% was used for program expenses and 18.8% for management and general expenses.

The governments and agencies that provided the largest share of our funding in 2008 and 2009 are shown in Figure 1 (top 10 donors). Our 2008 and 2009 expenditures by CGIAR system priorities and program portfolio are shown in Figures 2 and 3, respectively; while the performance indicators, as prescribed by CGIAR, are reflected in Figure 4.

Figure 1. Funding: Top 10 donors, 2008 and 2009

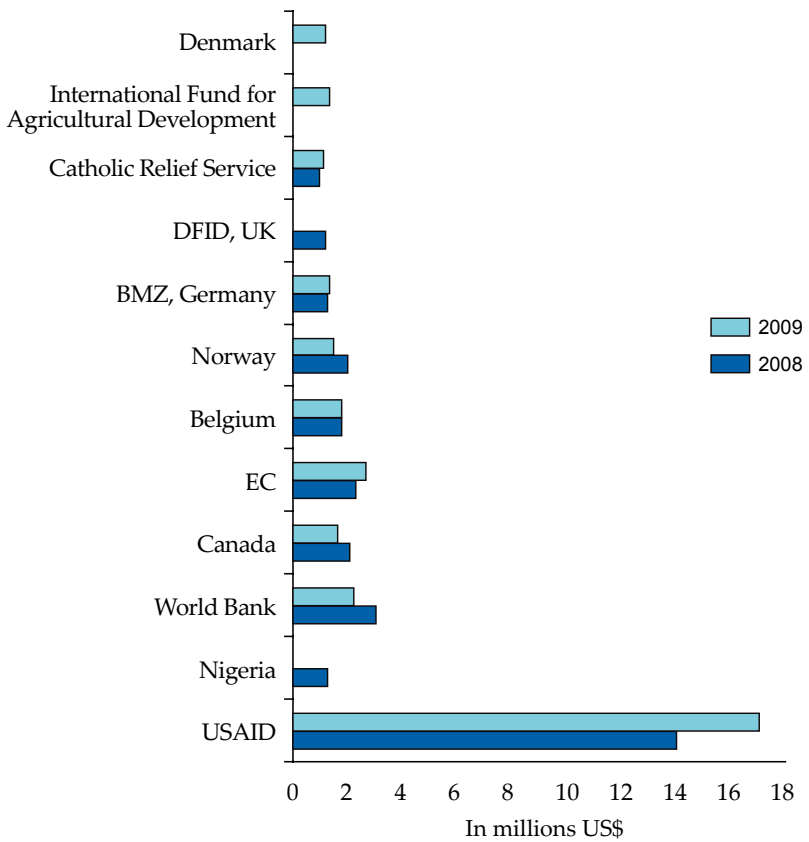
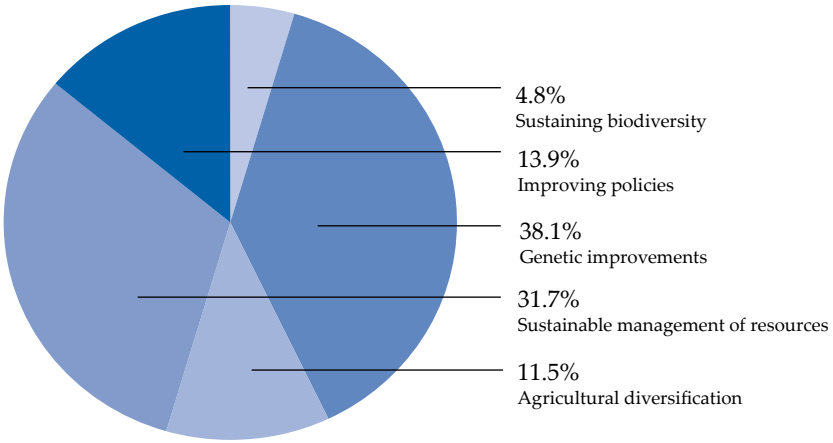
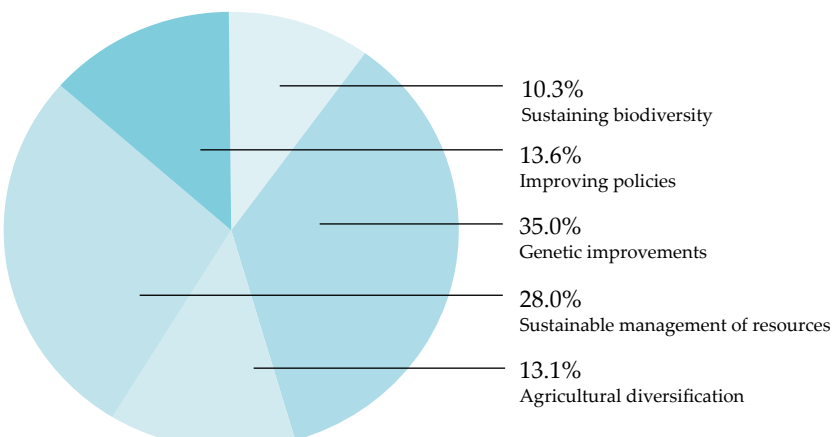


Figure 2. Expenditure by CGIAR System Priorities, 2008



Expenditure by CGIAR System Priorities, 2009



IITA Investors	2008 (expressed in US$ Thousands)	2009
African Agricultural Technology Foundation	223	147
Austria	259	460
Belgium	1,767	1,740
BMZ, Germany	1,267	1,334
Cadbury Schweppes	374	0
Canada	2,092	1,623
Catholic Relief Services	944	1,083
Centro Internacional de Mejoramiento de Maiz y Trigo	1,325	2,177
Chemonics International	114	637
Commission of the European Communities	2,251	2,664
Common Fund for Commodities	350	364
Denmark	777	1,160
Department for International Development, UK	1,174	1,034
Food and Agriculture Organization	519	810
France	175	330
Gatsby Charitable Foundation	283	196
Global Crop Diversity Trust	165	244
icipe - African Insect Science for Food and Health	0	130
International Food Policy Research Institute	0	519
International Fund for Agricultural Development	827	1,362
Ireland	765	681
Italy	379	10
Japan	411	390
Korea, Republic of	50	40
Netherlands	833	892
Nigeria	1,255	610
Norway	1,984	1,491
PLAN International	145	0
Rockefeller Foundation	392	117
Shell Petroleum Development Company of Nigeria Ltd	274	146
South Africa	40	0
Sweden	486	476
Switzerland	393	501
United Nations Development Program	152	0
United States Agency for International Development	13,981	17,060
W K Kellogg Foundation	266	153
World Bank	3,000	2,221
Miscellaneous Projects	4,233	4,459
Challenge Programs	4,225	1,149
GRAND TOTAL	**48,150**	**48,410**

Figure 3. Expenditure by IITA Program Portfolio: 2008 and 2009

	2008		2009	
Project	Cost ($`000)	%	Cost ($`000)	%
Agriculture and Health	2,299	4.5	1,870	3.7
Agrobiodiversity	2,765	5.4	6,073	11.9
Banana and Plantain Systems	5,054	10.0	5,254	10.3
Cereal and Legume Systems	13,673	26.9	8,619	17.0
Opportunities and Threats	2,834	5.6	3,273	6.4
Horticulture and Tree Systems	8,512	16.8	9,055	17.8
Root and Tuber Systems	14,644	28.9	16,312	32.1
System-wide Program on Integrated Pest Management	966	1.9	365	0.7
Total	**50,747**	**100**	**50,821**	**100**

Figure 4. Performance Indicators: Financial Health

	2008	2009
Short-term Solvency (or Liquidity)	158 days	161 days
Long-term Financial Stability (Adequacy of Reserves)	158 days	161 days
Indirect Cost Rates	20.4%	19.67%
Cash Management on Restricted Operations	0.24	0.10
Audit Opinion	Unqualified / Clean Bill of Financial Health	

Grains and legumes section of a farmers' market in Nigeria. Photo by O Adebayo, IITA.


BORN

Publications and Graduate Research

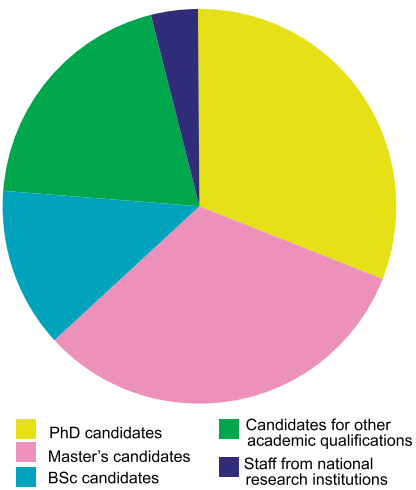
A researcher inspecting cassava in vitro *culture plantlets at the Genetic Resources Unit. Photo by JT Oliver, IITA.*

Publications

In 2009, we produced 299 publications, which comprised of 181 journal articles, 17 books, 5 in-books, 20 conference proceedings, 12 technical reports, and 64 other publications. A total of 118 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



This year, 99 new trainees (29% female, 71% male) registered for our various programs; 92 came from sub-Saharan countries, while the rest were from countries outside of Africa.

A total of 118 students (46% female, 54% male) had ongoing research training, with 31% conducting studies for their PhD's, 32% working towards their MSc's (or equivalent), 13% working towards their BSc's, and 20% for other academic certificates and diplomas. The rest are staff of national research institutions that came for short-term training or to work alongside our scientists. One hundred and seven students came from 20 countries in sub-Saharan Africa, while 11 came from 7 countries in Europe, Central America, North America, and Asia.

Group training

We delivered over 195 group training courses in more than 300 locations in 13 countries across sub-Saharan Africa. Over 21,701 individuals (27% female, 73% male) participated in these courses. More than 50 of these activities were Training-of-Trainers involving NGOs, government extension, and farmer cooperative partners. These focused on crop management practices including IPM, agronomic management, and macro-propagation techniques.

Our other training activities covered extension, field/lab research skills, pest risk assessments, pest/pathogen diagnostics, collective marketing, agronomic practices, processing and utilization, statistical computing, vegetative propagation, lab safety, agribusiness, managing cooperatives, and participatory variety selection.

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A woman trader selling yam tubers. Photo by O Adebayo, IITA.

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Nigeria

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Searching for insect vectors of plant diseases in the field. Photo by JT Oliver, IITA.

Abass, Adebayo Busura
Coordinator, Cassava Value Chain
Abdoulaye, Tahirou
Outcome/Impact Socio-Economist
Ajala, Oyewole S
Maize Breeder
Akwah, George Neba
CIALCA Associate Scientist
Alene, Arega D
Impact Economist
Asare, Richard
Cocoa Agroforester
Asiedu, Robert
R4D Director
Badu-Apraku, Baffour
Maize Breed, DTMA Project
Bandyopadhyay, Ranajit
Pathologist
Beed, Fen Douglas
Plant Pathologist
Biemond, Pieter Chris
Seed System Specialist
Boahen, Stephen
Legume Specialist
Boukar, Ousmane
Cowpea Breeder
Bouwmeester, Hein
GIS Specialist
Casey, John H
Manager, STCP
Chikoye, David
R4D Director
Cornet, Denis D
Agronomist
Coulibaly, Ousmane
Agricultural Economist
Coyne, Daniel Leigh
Nematologist
David, Soniia
Technology Transfer Specialist, STCP
Davis-Mussagy, Melba
Agro-enterprise Development Specialist
Dubois, Thomas L M
Seed Systems Specialist
Dumet, Dominique Juliette
Head, Genetic Resources Center
Franco, Jorge
Biometrician/Statistician
Gedil, Melaku A
Cassava Molecular Geneticist
Gockowski, Jim J
Agricultural Economist
Godonou, Ignace
Entomologist
Gyamfi, Isaac Kwadwo
Country Manager, STCP-Ghana
Hanna, Rachid
Entomologist/Biocontrol Specialist
Hauser, Stefan
Agronomist/Soil Physicist
Hearne, Sarah Jane
Plant Molecular Geneticist
Hoeschle-Zeledon, Irmgard
Coordinator, SP-IPM
Ihedioha, Onyema Damia
Agri-Processing Specialist
Ingelbrecht, Ivan
Head, Biotechnology Lab
Iyangbe, Charles
Agribusiness Development Coordinator
James, Braima D
Entomologist/Project Manager, UPoCA
Jonas, Mva Mva
Country Manager, STCP-Cameroon
Kamara, Alpha Yaya
Savannah Systems Agronomist

Kanju, Edward Eneah
Cassava Breeder/Pathologist
Kikuno, Hidehiko
Yam Physiologist
Kim, Dong-Jin D
Biotechnologist
Kulakow, Peter
Cassava Breeder/Geneticist
Kumar, Lava
Virologist (West and Central Africa)
Legg, James
Virologist
Lorenzen, James H
Banana Breeder
Mahungu, Nzola-Meso
Coordinator, NPACI & IITA Cassava Project
Manyong, Victor A W
R4D Director
May-Guri, Seathre S
Senior Researcher
Maziya-Dixon, Busie
Crop Utilization Specialist
Menkir, Abebe
Maize Breeder
Muoki, Penina Ngusye
Food Technologist
Muranaka, Satoru
Crop Physiologist
Neuenschwander, Peter
Scientist Emeritus
Ngeve, Jacob Mbua
Cassava Breeder/Geneticist
Ntawuruhunga, Pheneas
Coordinator, SARRNET
Okafor, Christopher
Country Manager, STCP-Nigeria









Okechukwu, Richardson
Deputy Proj Manager, UPoCA
Olaopa, Yewande S
Association Development Specialist
Onzo, Alexis
Entomologist
Ouma, Emily Awuor
Socio-Economist
Pay-Bayee, Macarthur M
Country Manager, STCP-Liberia
Rabbi, Ismail Yusuf
Molecular Genetics Postdoctoral Fellow
Rusike, Joseph J
Outcome/Impact Socio-Economist
Sartie, Alieu Mortuwah
Yam Molecular Geneticist
Sharma, Kamal
Researcher in Plant Pathogen Diagnostics
Sonder, Kai
GIS/Data Management Specialist
Tamo, Manuele
Legume Entomologist
Tarawali, Gbassay
Manager, IITA-MARKETS and CEDP
Tefera, Hailu
Soyabean Breeder
Tegbaru, Amare
Manager, PROSAB
Toko, Muaka
Acarologist
Tripathi, Leena
Biotechnologist
Van Asten, Petrus J A
Systems Agronomist
van Vugt, Daniel
Legume Agronomist
Vayssieres, Jean-Francois J
Entomologist
Vroh, Bi Irie B I
Breeder
Yade, Mbaye
Regional Coordinator, SAKSS
Yapo, Robert Assamoi
Country Manager, STCP-Cote d'Ivoire
Yusuf, Ado Adamu
Soil Microbiologist
zum Felde, Alexandra
Banana/Plantain Agronomist

Our scientists in action during the Communication Workshop of R4D Week 2009. Photos by O Adebayo, IITA.

IITA locations

IITA-Nigeria

IITA Headquarters
PMB 5320
Oyo Road, Idi-Oshe
Oyo State, Ibadan
Tel: +234 2 2412626; +234 2 7517472; 1 201 6336094
Mobile: +234 2 8034035281-3
Fax: +234 2 2412221
Email: iita@cgiar.org

Abuja
Experimental and Outreach Station
Phase 4, Kubwa
Near Old Water Board (behind Government Secondary School)
PMB 82
Garki GPO, Abuja

Akure
STCP Office
c/o Federal University of Technology
PO Box 1803, Akure
Ondo State

Kano
Sabo Bakin Zuwo Road
PMB 3112
Kano
Email: iita-kano@cgiar.org

Lagos
IITA International Guest House
Plots 531 and 532 WEMPCO Road
Ogba Estate
PO Box 145, Ikeja, Lagos
Mobile: +234 803 4023913

Maiduguri
PROSAB Office
Kwajaffa Road, Old GRA, Off Giwa Barracks Road,
PO Box 935, Maiduguri
Nigeria
Tel: +234 076231732
Mobile: +234 8034475430; +234 8024092270
Email: iitaprosab@cgiar.org

Onne
Onne High Rainfall Station
PMB 008 Nachia Eleme
Onne, near Port Harcourt
Rivers State
Mobile: +234 8037001497; +234 8039784016

IITA-Bénin
08 BP 0932 Tri Postal
Cotonou
Republic of Benin
E-mail**:** iita-benin@cgiar.org

IITA-Cameroon
IITA Humid Forest Ecoregional Center
BP 2008 (Messa), Yaounde
Cameroon
Tel: +237 2 2237434; 22237522;
Fax: +237 2 2237437
Mobile: +237 99880832
E-mail: iita-cameroon@cgiar.org

IITA-Cote d'Ivoire
2pltx, 7ème Tranche,
Rue L54-27
BP 696 Abidjan 27
Cote d'Ivoire
Tel/Fax: +225 22 523732
Mobile: +225 05000441

IITA-Democratic Republic of Congo
INERA Headquarters
Avenue des Cliniques 13,
Gombe, Kinshasa
Democratic Republic of Congo
Tel: +243 815 216368; 995 386236
Email: iita_dr_congo@airpost.net

IITA-Ghana
HH/No.Z-75, Volta Street
Airport Residential
PO Box GP 135, Accra
Ghana
Tel: +233 21 773873/75
Fax: +233 21 772789
Email: iita-ghana@cgiar.org

IITA-Kenya
Plant Biodiversity and Genomics Facility
c/o International Livestock Research Institute (ILRI)
PO Box 30709, Nairobi
Kenya
Tel: +254 20 4223000
Fax: + 254 20 4223001
Mobile: +254 724 201918
E-mail: iita-kenya@cgiar.org

IITA-Malawi
Chitedze Research Station
Box 30258, Lilongwe 3
Malawi
Tel: +265 1 707014
Fax: +265 1 707026
Email: iita@iitamw.org

IITA-Mozambique
PO Box 709, Nampula
Mozambique
Tel: +258 2 6216381
Fax: +258 2 6216272
Mobile: +258 825678730
Email: iita-mozambique@cgiar.org

Maputo
PO Box 2100, Maputo
Mozambique
Tel: +258 21 462613
Fax: +258 21 462454

IITA-Tanzania
Plot 331, Kambarage Road
Mikocheni A
PO Box 34441, Dar-es-Salaam
Tanzania
Tel: +255 22 2700092
Fax: +255 22 2775021
Mobile: +255 764 580 866
Email: iita-tanzania@cgiar.org

Kibaha Office
Sugarcane Research Institute (SRI) Complex
Kibaha, Tanzania
Tel: +255 23 2402370/1
Fax: +255 23 2402372

IITA-Uganda
Plot 15 East Naguru Road
Upper Naguru, Kampala
PO Box 7878, Kampala
Uganda
Tel: +256 041 4285060/4
Fax: +256 041 4285079
Mobile: +256 075 2787802; 075 2787801
Email: iita-uganda@iita-uganda.org

International Mailing Address
IITA
Carolyn House, 26 Dingwall Road
Croydon, CR9 3EE, UK
Tel: +44 020 86869031
Fax: +44 020 86818

Where we work

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

Sifting dried powdered cassava. Photo by J Atalobhor, IITA.

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Coordination & editing: Jeffrey Oliver
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