IITA

R4D Review

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Market stall in Tanzania with local banana types. Photo by IITA

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R4D Review launched to exchange knowledge and develop solutions

For more than four decades, IITA and partners have been developing award-winning solutions to the severe and complex problems that plague agricultural systems in Africa. Our science is based on cutting-edge, authoritative thinking anchored on development needs of the hungry and poor. We focus on research for development (R4D) that reduces producer and consumer risks, improves productivity and production, and generates wealth.

Many promising solutions remain on shelves because participation in their development and access to such knowledge have been limited. We launch this 6-monthly R4D Review in print and interactive online versions based upon open source principles. The free flow of information and participation in knowledge development with partners, investors, beneficiaries, and others help to accelerate the development, dissemination, and continuous improvement of innovative solutions.

We encourage you to visit and participate in the online R4D Review at www.iita.org/r4dreview, which provides the essential interactive and collaborative environment to share views, ideas, and innovations. The print version does not help with dialogue as the online version does, but it provides access to some of the solutions which otherwise may be impossible to obtain online. We would like to encourage you to share your copy of the print version with others and try to give us feedback through other means, such as a letter to the editor.

Each R4D Review will have general information and a more particular focus. This maiden issue focuses on bananas, highlighting the important work done by our scientists and partners to address problems in banana growing and development. We also forward a perspective on how the current food crisis provides Africa with opportunities to turn agriculture around, and achieve food security and economic development. We present insider and outsider views about our R4D work and partnerships, and emphasize the breadth and depth of R4D work in developing solutions and its impact on natural resource management and sustainability, producer communities, and markets.

“IITA has focused on research for development that provides poor farmers and consumers with options and opportunities that would take them out of the poverty trap.”

A bustling marketplace in Ibadan, Nigeria. Photo by IITA

NEWS

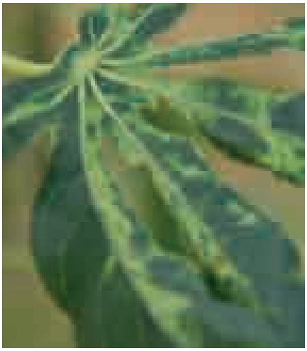
Cassava research

The United Nations Food and Agriculture Organization (FAO) has called for more research on the tropical root crop cassava to help poor countries cope with rising food and oil prices. Cassava is a staple food for millions of poor people in sub-Saharan Africa, Latin America, and Asia, providing as much as a third of daily calories.

Members of the FAO-facilitated Global Cassava Partnership for Genetic Improvement (GCP21) reviewed the current state of cassava production worldwide and future prospects at a conference held in Belgium in July.

Current average cassava yields are barely 20 percent of those obtained under optimum conditions. Despite growing demand and its production potential, the crop is grown mainly in areas that have little or no access to improved varieties, fertilizer and other production inputs, by small-scale farmers with no access to marketing channels and agroprocessing industries.

To help develop the crop's potential in addressing the global food and energy crisis, GCP21 will launch new projects such as establishing a cassava chain delivery system to channel technical advances to poor farmers, improving soil fertility, enhancing basic scientific



African cassava mosaic virus. Photo by IITA

knowledge of the crop, including genomics, and training the next generation of cassava researchers in developing countries.

Irish Aid

IITA was among eight CGIAR centers that will receive over €4 million in funding from Irish Aid.

Peter Power, Irish Minister of State for Overseas Development, said that the €4.4 million funding is a "central component" of Irish Aid's response to the global food crisis.

"More than 850 million people across the world today are hungry, while high food prices risk pushing 100 million additional people over the edge into hunger and poverty. Top quality agricultural research plays a crucial role in improving the performance and sustainability of agriculture. It will also help the poorest and most vulnerable farmers cope with the effects of climate change."

IITA will receive €640,000 in funding. Other research centers selected include Biodiversity International, International Livestock Research Institute (ILRI), and the World Potato Centre (CIP).

Ireland has provided more than €20 million to support the UN's World Food Programme (WFP) this year, which includes €3 million to help mitigate the effects of price rises on the WFP's existing food relief programs.

AGRA

Alliance for a Green Revolution in Africa (AGRA) Vice President for Policy and Partnerships Akin Adesina, was at IITA recently to talk about how agriculture could transform Nigeria from a food-deficit to a food-exporting country again.

"The answer to Nigeria's development problems lies in using agriculture to transform the country into a 'cohesive production system'," he said.

"Agriculture has changed from a way of life to a business. Market intelligence is required to make agriculture work. Hence, national governments in Africa have to change their mind sets and think of agriculture as a business."

Sub-Saharan Africa has a population of 781 million people, with 306 million or 39% living on less than US$1 a day. Of this number, 131 million live in Nigeria. Of the 131 million Nigerians, 101 million, equivalent to 77%, are poor.

"Africa is not a basket case," Adesina said. "With a distinctly African Green Revolution, we can turn the situation around. We can do this by building our competitive advantage in agriculture through research and infrastructure. Government support is crucial; political will is important. Africa cannot afford not to act."

"A new, efficient, dynamic, and competitive agricultural sector will unlock hope for millions of children, and will provide a better, more secure future for everyone," he concluded. Adesina was formerly a socioeconomist at IITA.

Banana 2008

Representatives from the banana research and industry from all over Africa will converge in Kenya this month to develop a 10-year strategic roadmap that would harmonize and guide efforts to promote the marketing and trade of the crop in the continent.

The conference on "Banana and plantain in Africa: Harnessing international partnerships to increase research impact" will take place at the Leisure Lodge Resort in Mombasa, Kenya on 5-9 October. This is the first Pan-African banana conference that links research to markets within the African context.

The event is organized and coordinated by IITA in cooperation with Bioversity International, Forum for Agricultural Research in Africa (FARA), Kenya Agricultural Research Institute (KARI), and the International Society for Horticultural Science (ISHS), and supported by the International Service for the Acquisition of Agri-Biotech Applications, the National Agricultural Research Organization of Uganda, Du Roi, and Bill and Melinda Gates Foundation.

The conference has three major themes: markets and trade, production, and innovation systems. The role of research and the importance of public-private sector partnerships will also be highlighted.

The strategy document will shape and change the way bananas are produced and marketed in Africa, linking state-of-the-art research to new markets and stimulating trade. In the long term, the impact will be to change commercial banana production from a donor aid-supported system to one which is sustained by an invigorated private sector that actively seeks technological interventions.

Selling bananas in the local market. Photo by IITA

Ticket out of poverty

Hartmann

A market in Nigeria. Photo by IITA

The world's food supply has for the last few decades worked well but now new dynamics, as reflected by the recent food crisis, call for change. The current system, based on large-scale production in the developed world, is efficient and responsive to market dictates though distorted by subsidies. It could be stabilized when complemented with a more significant system from the developing world. Such a two-tiered system would also protect poor regions of the world from extreme food scenarios.

Today's world food situation has been well aired in the media. But what is not fully appreciated is the opportunity it also brings for Africa. As the most food-deprived region of the world, Africa needs a more robust agricultural growth. This food crisis, albeit temporary, could be used to trigger an agricultural turn-around. African countries are food importers and thus affected by international prices of traded food commodities, but have untapped assets to exploit for the immediate and longer term.

The African food basket is, in many countries, complex and its commodities are affected differently by international food prices. For example, while maize prices in Tanzania were dragged up with the world prices, the effect on sorghum, cassava, and plantain was much less. This allows some immediate substitution and underscores the need for focusing on local production, helps reduce foreign currency needs that limit a country's purchasing power, and stimulates rural economies to benefit both the rural and urban poor.[1]

[1]Hartmann. 2004. An Approach to Hunger and Poverty. IITA.

Food commodities also allow for substitution in agroprocessing. If rice is used to produce starch, it can be replaced with other crops such as millet/ sorghum or roots and tubers. Bread does not have to be 100% wheat. Tef, banana, sweetpotato, millet, sorghum, and a mix can be used that includes cassava, and yam. This richness needs to be more appreciated and encouraged.[2]

For the less immediate term Africa just needs to produce more (see Figure 1). Its food output is extremely low. But its diversity of ecologies, altitudes, and cultures, is a powerful asset. Africa can produce more food by expanding acreage, unlike Asia. But other things need to happen before the potential of ample arable lands can be realized. Immediate needs would be rural feeder roads, access to credit and inputs, and a stimulated processing sector. The latter is increasingly important as the growing urban migration means more consumers are far from production zones and food shelf-life and convenience are major concerns.

For the medium term, Africa has to increase yields. For most food crops of sub-Saharan Africa[3] yields can be increased by 150-300% immediately, because varieties already exist with this potential[4].

To benefit more from what it grows, Africa also needs a parallel effort to reduce huge (postharvest) losses, ranging from 18 to 40% depending on the crop. Investments in food processing and transformation, energy, and roads are needed.

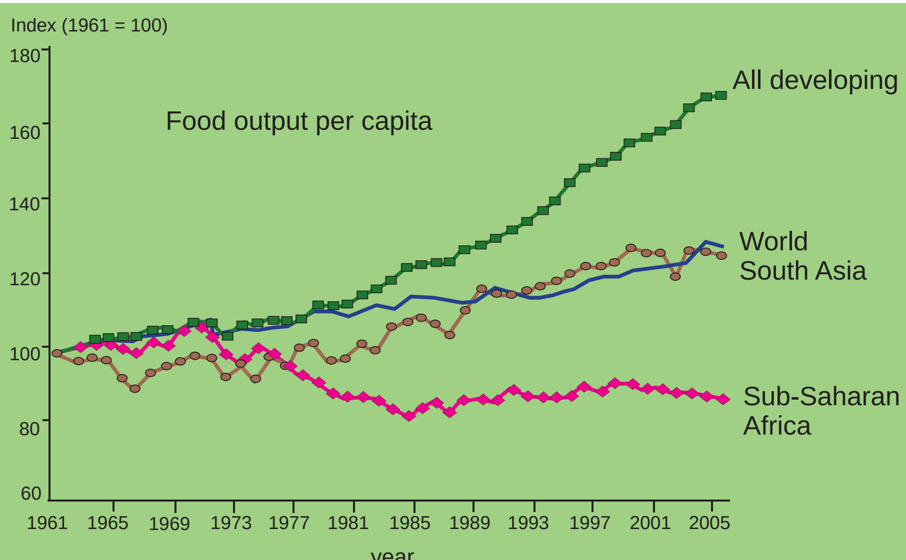


Figure 1. Index of total agricultural output per capita by region (index 1961–2005). Adapted from FAOSTAT (2006). Source: Hazel and Woods

[2]Cereal imports in the last couple of years have increased by a factor of three to five times.

[3]Rice is the exception where the yield gap is around 67%.

[4]For example, IITA varieties of these crops already have this potential built into their genetic codes.

"The full use of Africa's assets—arable land, different ecologies, altitudes, cultural differences, and eating habits—gives Africa resources more powerful than oil." – Hartmann

This processing and transformation capacity is also critical to address the rural-to-urban migration, which is itself a major challenge. Not long ago, 80-90% of Africans were rural; today most are urban. Wars have accelerated rural-to-urban migration. Africa must increase production even more, because it is not one to one in feeding the urban versus the rural poor. As production systems function today there is tremendous waste at all levels, rural and urban.

A holistic approach to the sector is essential and includes the now well-rehearsed list of needs and problems—infrastructure, finance, taxation, corruption, communication, soils, inputs, productivity, and numerous postharvest technologies and processes. As these elements are developed and constraints cleared away, the approach has to adjust. Underinvestment in infrastructure is costly in many ways. Transport difficulties, for example, give Malawi's (2007/8) maize surpluses few outlets so that farmers do not fully gain from favorable global prices.

Photo by IITA

It is not uncommon to have food shortages in one part of a country, when another has food surpluses. Poor information and transport systems, plus the short shelf-life of many commodities prevent Africa from benefiting fully from its harvest. In Ethiopia, widespread drought (2003) in some parts of the country put at risk over 12 million people, while in other parts, prices collapsed due to a bumper crop of cereals (Borlaug and Natios). Zambians (2004) were suffering from a shortage of cassava, when Nigeria had abundant surpluses.

Small producers are one group that needs special attention. While they are the key to Africa's food self-sufficiency, it is hard for them to respond effectively to increased food needs on their own. One way to support them is to encourage the movement of their produce into alternative uses within the food chain.[5] Again, this means investments in the agroprocessing sectors and a slew of processed food products. Farmers take all the risks but rarely benefit long from any gains.

Conclusion: The full use of Africa's assets—arable land, different ecologies, altitudes, cultural differences, and eating habits—gives Africa resources more powerful than oil. Emphasizing and then benefiting from the agricultural sector has positive repercussions that reach far into all segments of an economy, in particular in increasing employment at all levels and with it, purchasing power.

[5]Hartmann, 2004.

Banana + Coffee = More

What happens when banana and coffee are grown together? Farmers earn more, say IITA scientists and partners.

Growing coffee and banana forms the economic base for most of the small-scale farmers in much of Uganda and the surrounding highlands of Rwanda, Burundi, northwest Tanzania, and eastern Democratic Republic of Congo.

Banana is an important food staple in Uganda produced all year round; farmers sell surplus yield on a daily basis. Coffee, on the other hand, is a pure cash crop, cultivated on over half a million coffee farms, 98% owned by smallholders. It is a major foreign exchange earner for the Great Lakes countries. In Uganda, for example, it generates some 20% of the country's foreign exchange revenues. Robusta coffee is dominant below 1400 meters altitude, Arabica at higher altitudes.

In some densely populated areas, banana-coffee intercropping is practiced, but it is not common. Some countries even recommend that coffee be grown as a sole crop. Some farmers, however, report on the advantages of growing coffee under bananas, such as providing shade, mulch, nutrients, and moisture. For instance, farmers use coffee husks to replenish nutrients in banana and coffee fields, although this is discouraged by Robusta coffee growers to prevent the spread of coffee wilt disease. Meanwhile, some researchers also cite advantages such as reduced erosion in the highlands.

The crops complement one another in terms of socioeconomic benefits to growers and farm families. Bananas


Banana systems in Rwanda. Photo by IITA

provide permanent food and income security, doubling as a primary food and cash crop, and providing a modest but continuous cash flow throughout the year. Coffee gives a cash boom twice a year, helping farmers acquire funds for more expensive items such as infrastructure, farm inputs, transport equipment, and large social events.

So how effective is intercropping? R4D Review editors asked IITA agronomist Piet van Asten who works on banana-based systems in IITA-Uganda.

"Despite farmers' beliefs and practices, perceived benefits, and some positive indications, there are no official recommendations or advice about intercropping," he said. "There has been no research about this until now."

"Banana and coffee intercropping is much more profitable than either banana or coffee monocropping," reports van Asten and the team of scientists who conducted a diagnostic survey in seven districts in Uganda.

IITA collaborated with the Agricultural Productivity Enhancement Program (APEP-USAID) to study some 150 APEP demo plots of banana and coffee monocrop and intercrop fields, and 150 farmer control fields in the major banana-coffee growing areas from southwest to east Uganda. The demo plots were farmers' fields where APEP extension officers provided fertilizer and stimulated the adoption of best crop management practices, such as mulching, pruning (coffee), or desuckering (bananas).

Information on resource use, including external inputs, labor, land, and farmgate prices were obtained through structured farmer interviews in 2006-2007; data on crop production, soil fertility, pest and disease pressure, and management practices were quantified through field visits.

"Study results were beyond our expectations," van Asten pointed out. "In the Arabica-growing area around Mt. Elgon, coffee yields were similar in monocropped and intercropped coffee—even when the demo plots were fertilized. The number of coffee trees per hectare decreased slightly when intercropped, but yields per tree were higher."

In the Robusta-growing areas, intercropping reduced coffee yields slightly (by 13%) when the fields were not fertilized, but when they were fertilized coffee yields were the same in monocropped and intercropped fields. In general, banana yields suffered when intercropped with Robusta coffee but not from intercropping with Arabica coffee, (Table 1).

Because the coffee yields were not affected, the additional banana production increased the revenue of banana-coffee intercropped fields by 50-60% compared to monocropped coffee fields (Table 2). These figures show that banana-coffee intercropping is much more profitable than sole planting of either crop, van Asten and IITA and APEP colleagues concluded.

"For instance, in the Arabica coffee-growing region around Mt. Elgon, annual returns per hectare averaged US$4,441 for intercrop, $1,728 for banana monocrop, and $2,364 for coffee monocrop. In Robusta-growing areas in South and Southwest Uganda, annual returns per hectare averaged $1,827 (intercropping), $1,177 (banana monocrop), and $1,286 (coffee monocrop). These results are for the nondemo plots," he said.

Why did this happen? Coffee plants are shade loving and bananas are taller, so there is not much light competition. Potassium is an important nutrient for both crops, and the intercropped coffee seemed, on average, to be less

Table 1. Crop yields under different cropping systems with and without fertilizers

Cropping system	Mt. Elgon area		Masaka, Rakai, and Bushenyi	
	Coffee (t/ha/yr) green bean	Banana (t/ha/yr)	Coffee (kg/ha) green bean	Banana (kg/ha)
Coffee control	1.2		1.3	
Coffee-Banana control	1.2	19.2	1.1	8.9
Coffee demo	1.7		2.2	
Coffee-Banana demo	1.6	15.7	2.2	10.6
Banana control		18.3		15
Banana demo		32.6		22.6

Table 2. Partial budget analysis for the different systems: coffee monocrop, banana monocrop, and intercrop system

Returns and costs	Coffee mono system		Banana mono system		Intercrop system	
	Robusta	Arabica	Robusta area	Arabica area	Robusta area	Arabica area
Control yield value (US$/ha)	1.286	2.364	1.177	1.728	1.827 (696)[1]	4.441 (2.174)
Demo yield value (US$/ha)	2.314	3.272	1.773	3.374	3.094 (831)	4.942 (1.909)
Fertilizer costs demo (US$/ha)	246	507	213	201	204	415
Value yield increase (US$/ha)	1.028	909	596	1.646	1.267	501
Net benefits (US$/ha)	782	402	383	1.445	1.063	86
MRR (%)	318	79	180	719	521	21

[1]Number between brackets denotes value of banana yield.

Note: The geographic location of banana control plots differed from that of demonstration plots particularly in Arabica area. Hence, the high MRR in bananas in the Arabica region must be taken with caution.

Source: Van Asten P.V.A., J. Lorenzen, L. Wairegi, D. Mukasa, M. Batte, P. Muchunguzi, and M. Pillay. 2008. IITA/ APEP Banana Project Technical Report. IITA and APEP.

potassium deficient than sole coffee. This may be due to the very high biomass turnover in the banana system. The mulch may reduce the need for soil tillage, thereby keeping the shallow banana and coffee rooting systems intact. The high biomass turnover may also bring nutrients into forms more easily available for the plants. “There could be other reasons, but the findings thus far at least indicate that the intercrop system does have some strong advantages,” van Asten said.

“More research is needed. We have to understand how this works so we can apply the findings to other banana and coffee-growing areas.”

“We also need to come up with recommendations to help farmers exploit this opportunity to improve productivity and revenues, without purchasing additional inputs or increasing the area under cultivation. Land pressure and lack of credit or capital are two major constraints for African smallholder farmers.”

Drying coffee beans in Uganda. Photo by IITA

30 years R4D in soybean: what's next?

Forty years ago, only a handful of farmers in Benue State, middle belt of Nigeria were growing soybean. The crop was generally thought more suitable for large-scale commercial growing and industrial processing. But not anymore.

This *golden bean* is grown in the farms of resource-poor smallholders in the Guinea savannas of Nigeria and other parts of sub-Saharan Africa.

"In the 1970s, there was little interest and effort in Africa to grow and improve soybean because of extremely low yields and seed viability, poor nodulation, high shattering rate, and limited postharvest use," reported Dr Hailu Tefera, soybean breeder and OIC of IITA-Malawi, on 30 years of IITA soybean breeding work.

Breeding gains

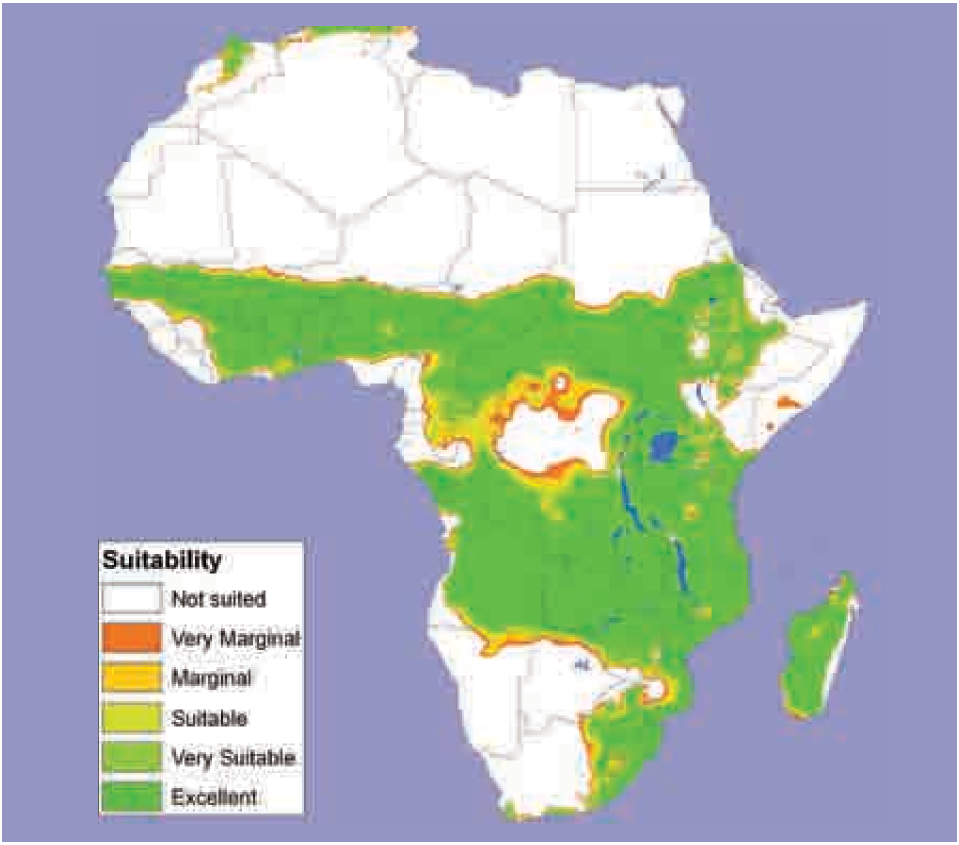
When IITA started improvement research in 1974, the average yield per hectare in Africa was 660 kg/ha. Total production was only 0.2 million tons. Thirty years later, using IITA-developed varieties, the average yield in West African countries increased by more than 50%, and 67% in the whole of Africa, equivalent to 1.1 t/ha over 20 years of breeding effort. That is a genetic gain of more than 2% per year in grain yield.

Twenty-one African countries now produce soybean. Nigeria has the highest 6-year (2000-05) average production of 486,000 tons on an area of 553,260 hectares, followed by South Africa with 205,270 tons from 122,870 hectares, and Uganda with 155,500 tons from 139,500 hectares.

Soybean production increased dramatically, Tefera said, as locally adapted tropical germplasm was developed and distributed to other African countries. In Nigeria, the soybean industry quickly advanced. Integrated processing, use, and marketing aspects followed efforts to develop improved cultivars. This is a testament to IITA's research for development (R4D) in soybean that produced high-yielding and stable varieties, tolerant or resistant to biotic and abiotic constraints, and promoted processing and use.

Community impact

In 1985, to improve nutrition and to create demand, IITA began the development of small-scale and home-level food processing technologies. A study funded by the International Development Research Centre (IDRC) Canada with the Institute for Agricultural Research and Training (IART), Ibadan, Nigeria, after 3 years found that soybean had been successfully used to increase the protein content of traditional foods. New products—flour, milk, baby food—had been developed and introduced. Small-scale processing machines were introduced. Over 25,000 people in the rural areas were trained, with training project sites increasing from 3 to 27. The



Soybean growing suitability map. IITA

number of farmers growing soybean in target villages increased by 35%. Sales of grain and flour soybean increased in Nigerian markets.

Phase 2 of the project covered all Nigeria with several national institutions such as IART; National Cereals Research Institute, Badeggi; National Agricultural Extension Research and Liaison Services, Zaria; and the University of Nigeria at Nsukka. An assessment of four states in 1992 showed wide commercialization.

Markets had increased from 2 in 1987 to 42 in 1993. The number of retailers ballooned from 4 in 1987 to 824 in 1993. In Benue State, more women were involved in soybean production. New IITA varieties were widely adopted and grown by 9% of farmers in 1989 to 75% in 1997 on 30% of the area planted to soybean in the state.

So far, Tefera reports, some 17 IITA-bred tropical soybean varieties have been released by national agricultural research and extension systems (NARES) of several West and Central African countries (Nigeria, Benin, Ghana, Democratic Republic of Congo, Togo), and Uganda. These show considerable increases in grain and fodder yields, improving soil fertility in the savannas and enhancing the yields of subsequent crops such as maize and sorghum.

Since 2000, however, support for soybean research among the NARES has declined. On-farm variety testing and releases is at a standstill, except for MAKSOY 1N, an early maturing variety resistant to rust, a destructive foliar disease, in Uganda.

Potential for expansion

IITA recently expanded breeding of its West Africa-bred varieties to Southern Africa, where cultivation by small-scale farmers is rising because of less susceptibility to pests and disease, better grain storage quality compared with other legumes, large leaf biomass, and a secure commercial market. Commercial soybean farms are now found in South Africa, Zimbabwe, and Zambia.

In South Africa, the Agricultural Research Council develops cultivars with better adaptation and seed quality, high yield, resistance to nematodes and rust, and tolerance to low night temperatures. It is also developing genetically modified drought-tolerant soybean—the first soybean GMO in South Africa. Twenty-one members of the South African National Seed Organization produced 2,879 tons of soybean seed in 2006-07.

SeedCo in Zimbabwe breeds varieties for the local market and other countries in the region; these are resistant to red leaf blotch and frogeye disease. It produces inoculants that go with the varieties. The Zambia Seed Company produces, processes, and markets seeds of various crops including soybean and is considering testing IITA-developed varieties under Zambian conditions.

“Soybean improvement efforts in the past focused on helping subsistence farming,” said Tefera. “Currently many African countries are practicing market-oriented agriculture to increase farmers’ income and reduce poverty. Soybean improvement work at IITA should consider technologies for use by farmers of different capacities.”

According to FAO, Africa spent US$1 billion in 2004 to import soybean and soy oil. Of this, US$752 million was for soybean oil and US$254 million was for soybean grain/meal. Countries such as South Africa, Malawi, Zimbabwe, and Zambia in aggregate produce 33.4% of Africa’s total production.

Producing enough in the region and adding value can save millions spent on imports for other development activities, he further added. There are also export possibilities to Europe and Japan as soybean grown in Africa is mostly non-GMO.

Favorable government policies are needed to develop the soybean industry in Africa. In Brazil and Argentina in the 1990s, economic reforms created favorable conditions for agricultural investment, production, and exports. Research alone was not the driving force for the soybean industry’s impressive growth there.

Market-oriented policy changes included elimination of export taxes, lifted restrictions on import of agricultural inputs, privatization of marketing and transportation infrastructure including state-owned grain elevators, port facilities, and railroads. Farmers also invested heavily in new technologies that improve yields, accelerate planting and harvesting, and facilitate delivery.

Achieving these targets requires the efforts of various players in research, production, and marketing, Tefera concluded, and should consider technological, institutional, and organizational interventions in both the supply and demand sides.

Transforming livelihoods in Borno State

In Borno State in the extreme northeast of Nigeria, 30 farming communities are reaping the benefits of adopting new and improved soybean and *Striga*-resistant maize and rice varieties and management practices. They also benefit from knowledge sharing, new products, availability of new markets, and investment in improved and sustainable agricultural practices.

These communities participate in an IITA project funded by the Canadian International Development Agency. The project, *Promoting Sustainable Agriculture Project in Borno State* or PROSAB, was launched in 2004, to improve the livelihoods of the rural communities in the State through improved food security, reduced environmental degradation, improved sustainable production using transfer of gender-responsive agricultural technologies and management practices, easier access to input and commodity markets, an enabling policy environment, and enhanced capacity of project stakeholders.

Farmer James Buba and wife. Photo by IITA

Success stories

Mrs. Bata Joshua is one of the leading members of the women's group in a community called Vinadam located in the Hawul Local Government area of Borno State. When asked how PROSAB has contributed to their livelihoods, she stated: "In the past, prior to the introduction of PROSAB in our community, our harvests couldn't feed us for the whole year. We had to supplement by buying grains from the market. Presently, our harvests are sufficient to feed our families and we even have surplus for sale in the market". She further said, pointing to a new building under construction. "This new building is being built from revenues realized from selling soybeans. The project is making a remarkable contribution to improving our livelihoods." (*a translation from Hausa*)

Similarly in 2007, James Buba and his wife, who are promising soybean farmers in Nggabu Village had a similar success story with soybeans. Narrating his story, James said "We harvested 4.2 tons of soybeans from my 2-ha farm last year and made a profit of Nigerian ₦184,000 (about US$1,500) on soybean sales….This year, we have doubled the soybean farm and we expect about 6 tons to make more money."

The project operates within a sustainable livelihoods framework, which emphasizes increasing livelihood assets and improving the capabilities of the rural poor. Partners include Borno State Agricultural Development Program (BOSADP), University of Maiduguri (UNIMAID), the State government, IITA's sister center—the International Livestock Research Institute (ILRI), and Community Research for Empowerment and Development (CRED).

"The project aims to increase farmer productivity through adoption of improved crop varieties and better management practices that ensure improved and viable agriculture-based economic livelihoods." says Dr Amare Tegbaru, PROSAB Project Manager. "Small farmers form 80% of the population, and agriculture and trading are their only major activities."

Problems for farmers include erratic rainfall, marginal soil fertility, and an underdeveloped market. Agriculture can no longer cope with the increasing population and greater demand for food. As in many other parts of Nigeria, farmers are diversifying their sources of livelihood outside agriculture, once the backbone of the country's economy. Subsistence farming is based on growing crops and livestock keeping.

A socioeconomic survey was conducted in 2004 in the target communities to gather benchmark data on demographics, socioeconomic conditions, resource use patterns, market opportunities, and their effects on land degradation and agricultural productivity. Major crops grown are maize, sorghum, cowpea, groundnut, and vegetables, mostly grown for home use; any surplus is sold locally. Cattle, sheep, goats, pigs, and poultry are the animals reared.

According to Tegbaru, the participatory research and extension approach used by the project was effective in undertaking the community analysis to identify livelihood opportunities, constraints, entry points, and plan interventions; participatory action planning to address priority problems; and deployment of best-bet technologies through male/female farmer-led participatory research and trials in pilot communities. More than 300 producer groups in 130 cluster villages, of which 50% comprise women, have also been targeted.

The 2004 survey identified *Striga hermonthica*, a parasitic weed, as the single biggest agronomic constraint in cereal production. Then 228 farmers from 193 farmer groups across the 30 communities tested integrated *Striga* control (ISC) options in 2004 and 2005. Soybean was planted as a trap crop in the first year followed by *Striga*-resistant or tolerant maize in the second year with the standard farmers' practice. These reduced numbers of emerged *Striga* by 12% and increased maize productivity by 41%. Partial budget analysis showed a 200% higher profitability for ISC over traditional practices.

Male and female farmers selected the technologies that suited their circumstances and environment from a basket of options. These included maize tolerant to *Striga* and drought-, dual-purpose soybean and cowpea, early maturing groundnut, dwarf sorghum, and new rice for Africa (NERICA). Improved crop management practices included maize-soybean rotation to reduce *Striga* and improve fertility, proper and timely application of fertilizer, environmentally friendly agrochemicals, and appropriate planting densities.

Community-based seed multiplication operations were established to provide improved crop seeds. A market information system and links to major food processors provided ready markets.

Threshing maize in Miringa, Biu, Borno State. Photo by IITA

Results in 2007 from farmers' test plots showed that new varieties of maize, sorghum, cowpeas, and groundnut yielded well even under poor weather conditions. The project has more than doubled agricultural productivity with the use of new crop varieties and management practices. Yields have increased, compared with baseline data (2004), by 220% (maize), 100% (cowpea), 50% (sorghum), and 70% (groundnuts).

Fifty percent of the farmers adopted cereal and legume rotation and made better use of agrochemicals. Adoption rates of maize (77%) and soybean (53%) by male and female farmers were high. Improved *Striga*-resistant maize produced, on average, 3 t/ha (against 1 t/ha in 2004). Soybean was popular among women because of their good processing opportunities. Adoption of new sorghum and groundnut showed mixed results. Training increased cowpea yields by over 50%.

Animal fodder demo plots showed how fodder production has been integrated into crop production. Two years of crop and livestock integration have improved land preparation, animal nutrition, and health care. Farmers' access to genuine veterinary drugs has been ensured.

On the whole, 76% of the farmers' groups that used some or all of the improved PROSAB recommendations reported yield increases of over 100%, better food availability (94%), improved nutrition among children (86%), improved livelihoods through increased sales, and additional income (86%). Other benefits included better household nutrition through soybean processing and use, improved health care through affordable medicines, and more money for housing and children's education.

During the review period, 291 seed producers were linked to seed markets, including Premier Seeds, a big seed producer; 21 processors sold 49 tons of improved seeds, yielding ₦2.4 million (US$18,462). Through improved market linkages, 485 farmers sold 811 tons of soybean, earning ₦46.8 million (US$414,159). Improved demand by industrial processors and attractive prices helped to motivate the farmers to grow the crop. "This development in the soybean market is likely to be sustained," said Tegbaru.

The conduct of policy workshops, gender awareness and mainstreaming in technology development and dissemination, and field days have increased awareness among community leaders, policymakers, farmers, and market agents about the benefits of PROSAB's technologies and management practices. Adoption rates among farmers continue to rise.

Outlying communities and neighboring states not directly involved in the project have started to benefit through the scaling out of technologies by project participants and others.

This shows how IITA R4D technologies—combined with farmers' endeavors—add greater value to research products.

BEST PRACTICE

SCIENCE meets INDUSTRY

In Uganda, the local word for food is *matooke*, which is what the Ugandans call the green banana, their staple food. Nowhere is banana eaten in such a scale as in this East African nation of 31 million.

Ugandans reportedly eat, on average, more than a quarter of a kilogram of banana in a day, or in some areas, 450 kilograms per year! That's a lot of bananas.

Bananas are as important to the Great Lakes region as rice is to East or Southeast Asia. They are a valuable source of vitamins, minerals, and carbohydrates or calories; they are the primary source of income for 16 million smallholder farmers in Uganda; and they play a central role in the sociocultural fabric of the country.

About one-third of the total global banana production comes from sub-Saharan Africa where millions of subsistence farmers and consumers depend on the crop as a staple food. Bananas are easy to grow especially in the Great Lakes region where growing conditions for the crop are ideal.

But banana production in the region is being threatened by a complex of pest and disease problems. including Fusarium wilt (*Fusarium oxysporum* f.sp *cubense*), black leaf streak or sigatoka (*Mycosphaerella fijiensis*), viruses, banana weevils (*Cosmopolites sordidus*), and nematodes (e.g., *Radopholus*

Enhancing small tissue culture plants with endophytes. Photo by IITA

Tissue-cultured banana plantlets. Photo by IITA

similis). The most serious threat at the moment is banana *Xanthomonas* wilt (BXW, *Xanthomonas vasicola* pv. *musacearum*), which could devastate the banana industry in East Africa. These pests and diseases damage the banana plants, cause yield loss, and eventually food insecurity and loss of livelihoods.

With the food security and livelihood of millions of farmers at stake, science and industry meet to save the crop and develop technologies to make production more sustainable. One technology involves the rapid, mass propagation of more robust bananas using endophyte-enhanced tissue culture," said Thomas Dubois, biocontrol specialist and nematologist based in Uganda, who leads the team of IITA scientists that helped develop the technology.

"Old" technology

Tissue culture is not a new technology. Tissue-cultured banana is the norm in the rest of the world. Commercial tissue culture laboratories are beginning to emerge across East Africa to satisfy the rapidly rising demand for healthy planting material.

Tissue culture banana plants made in specialized private-sector laboratories are healthy and can grow faster than traditional plants. They are also ideal for establishing large plantations, which are then uniform, enabling better planning for harvests and marketing.

Tissue culture produces clean plantlets without disease but also without a natural defense system. They are quite sensitive to the relatively harsh conditions in the East African fields, including attack by pests and diseases, and low soil fertility. The smallholder fields are burdened with biotic pest pressures and abiotic constraints, and the small-scale farmers do not practice essential high-input field maintenance. Thus, tissue culture adoption in Africa faces a "barrier".

This is where IITA came to the rescue. "Endophytes" is a general term for naturally occurring microorganisms inside the plant that protect it from pests and diseases, and that enhance plant growth. Every single individual plant species, including banana, contains endophytes. They can be used as a natural form of control. Introducing endophytes in plants during propagation is like immunizing them. Plants inoculated or "vaccinated" with endophytes become resistant to pests or diseases.

Army against pests and diseases

The endophytes become part of the planting material before the young tissue culture plants are sold to farmers. Once inside, the endophytes go to work, boosting the plant's immune system—so long as they get there first, before the pathogen.

Thus, farmers are provided with a weapon to fight the banana weevils and nematodes, which abound in the soil and which are transferred by farmer-to-farmer contact through exchange of infected planting material.

IITA, through its station in Kampala, Uganda, developed the endophyte technology to produce robust pest- and disease-free banana planting material, in collaboration with various national and international partners. Research on this technology started in 1997 with funding from the German Federal Ministry for Economic Cooperation and Development (BMZ).

IITA isolated nonpathogenic strains of endophytes belonging to the Fusarium family from healthy plants growing under high levels of pest and disease pressure. Institute scientists developed a rapid, easy, and low-cost laboratory screening protocol for testing the numerous endophyte strains obtained against the banana weevil and the burrowing nematode. They also devised a more efficient technique to mass produce the best strains, and introduce them into the tissue-cultured plantlets. The endophyte-enhanced plants are then grown in screenhouses and in farmers' fields to assess their performance against target pests.

Using endophytes as biological control agents offers several advantages. When endophytes enter the plants first, they get a head start over the other microorganisms, and once they are established, other microorganisms would offer less competition. Because the endophytes are already in the plantlets when they are transplanted, control can be targeted using low levels or doses, and performance is consistent. Using endophytes also makes it easier to control cryptic pests such as the banana weevil and the burrowing nematode, which are embedded within plant tissues.

As an off-shoot of work on endophytes, IITA-Uganda scientists realized that endophytes circumvent many of the barriers associated with conventional biopesticides. This has spurred novel research in using conventional biopesticides, such as *Beauveria bassiana*, as artifical endophytes in seed systems. *B. bassiana* worldwide is the most researched and commercialized fungal biopesticide against a variety of insect pests.

Laboratory and screenhouse studies have revealed the great potential of this entomopathogenic fungus for use against the banana weevil. However, impractical field delivery methods and high costs associated with its application prevent its use and commercialization in banana fields.

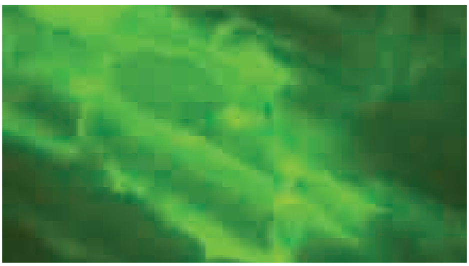
IITA's research also showed that *B. bassiana* can "colonize" the internal banana tissues for at least four months and that *B. bassiana*-enhanced plants reduced larval damage by more than 50%. It kills the damaging insect stages inside the plant; it is protected from adverse biotic and abiotic factors; little inoculum is required, greatly reducing cost. Farmers do not need to apply the biological control organism themselves, as the technology is easily transferable to a commercial tissue culture producer.

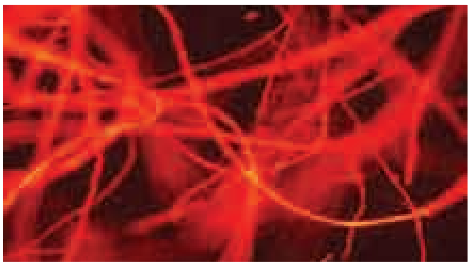
But IITA's research-for-development work does not end there. How does IITA make endophyte-treated plantlets available to farmers, the ultimate users of the technology, as a ready-to-plant product at low cost?

Confluence of science and industry

The Institute has established strategic alliances with several private and public sector entities to develop international public goods. It leads the research effort on endophyte-enhanced tissue culture technology, and a commercial tissue culture entity and a private biocontrol company handle the formulation, distribution, application, and storage of the plantlets. In the process, IITA and its

Genetically modified endophyte strains (with genes for fluorescent color). Photos by IITA





Researcher inspecting banana plantlets in a greenhouse, Democratic Republic of Congo. Photo by IITA

partners are helping commercialize the banana industry in East Africa.

Endophyte-enhanced banana tissue culture research is undertaken with research partners that include the University of Bonn, Germany; the National Agricultural Research Organization (NARO), Uganda; the University of Pretoria, South Africa; Makerere University, Uganda; Wageningen University, the Netherlands; the Catholic University of Leuven, Belgium; and the Biologische Bundesanstalt fűr Land-und Forstwirtschaft, Germany.

The work though is not confined to banana production in Africa. Bioversity International, in collaboration with IITA's German partners, is testing endophyte-enhanced tissue culture with large-scale banana producers in Costa Rica, using Latin American endophyte strains.

Since IITA does not have the in-house capability to undertake large-scale endophyte-based research in its facilities, the Institute partnered with several private and public organizations involved in tissue culture: Agro-Genetic Technologies (AGT), a commercial tissue culture laboratory in Uganda; Jomo Kenyatta University of Agriculture and Technology (JKUAT) and RealIPM, a biopesticide company in Kenya.

An exploratory and collaborative effort to produce more robust tissue culture plantlets as research material has developed into a synergistic partnership that bridged upstream research and downstream application. On the other hand, linking up with large-scale tissue culture producers in Uganda and Kenya have helped refine and move the technology from the lab to the farmers themselves.

Through collaboration, endophyte-enhanced technology is now being tested in farmers' fields in East and Central Africa. The technology enables the farmers to switch from subsistence to income generation, and more importantly to reach and create markets.

Following the research-for-development model, IITA and its partners realized that engaging and mobilizing the community of farmers is essential for the technology to succeed and gain wider adoption.

IITA saw the value of harmonizing public-private sector collaboration at the early stages of the project. It has adopted this approach in its R4D work in Africa, and is promoting its application in technology transfer work in other areas of research, mandate crops, and commodities.

The power of SMALL

Melba Davis-Mussagy

Photo by IITA

People tend to overlook the "small" and "insignificant", focusing more on the "big" and "obvious". In economic development, micro-businesses often receive less attention and access to growth-enhancing support facilities. Their contribution is also often undervalued.

Until recently in Nigeria, when people discussed economic development, they mainly talked about the oil and natural gas industries. These industries account for nearly 100% of earnings and more than 80% of government revenues[1] and they receive all the inputs and attention. Small-scale agriculture and agriculture-based enterprises are hardly ever talked about, as if they contribute very little to economic development. And yet agriculture still provides more than 60% of employment.

During the last 3-5 years, cassava has joined oil in the headlines. Because it is a highly important element in the Nigerian diet, growing cassava is embedded in the daily routine in many rural areas and city suburbs. For many years, it was considered a woman's subsistence crop. Things changed when the Presidential Initiative on Cassava was introduced early in 2002 by then President, Chief Olusegun Obasanjo. A directive of the Federal government followed instructing bakers to include 10% cassava flour in the production of bread and confectionery. Two years later, the directive urged flour millers to buy high quality cassava flour from local processors. This has encouraged both farmers and processors to produce large volumes of this good quality cassava flour.

In line with the Cassava Presidential Initiative, IITA implemented the Integrated Cassava Project (ICP). Through its two subprograms, the Preemptive Management of Cassava Mosaic Disease Project (CMDP) and the Cassava Enterprise Development Project (CEDP), ICP aims to reduce the impact of cassava mosaic disease (CMD) and increase productivity in 11 states in the south-south and southeast of Nigeria. The project benefits farmers, many of them smallholders, and small and medium cassava-processing enterprises (SMEs).

Through strong partnerships with the government, private sector, and farmers, the project deployed and tested 40 new cassava varieties to counter the threat of CMD and increase yield. Usually it takes 6-8 years to release a new variety in Nigeria, but in agreement with various partners, ICP adopted a participatory approach that led to the official release of 10 new varieties in just 2 years.

This had dramatic results. A disease monitoring field survey in 2006 found no severe forms of CMD, and 10-30% of fields were completely free. A similar survey in 2007 showed that disease incidence in fields with mixed virus infections on the same plants had dropped by 20%. The two variants of

[1]Economy of Nigeria. 2008. www.wikipedia.org

CMD can recombine to form the virulent Ugandan mosaic virus.[2]

The Project continues to distribute planting materials of these varieties. Recorded yields were impressive, averaging 25.6 t/ha, a significant increase over the 12 t/ha from traditional varieties. Some beneficiaries got even higher yields at 30-50 t/ha.

CEDP was implemented in 2004 to increase economic opportunities through sustainable and competitive cassava production, processing, marketing, and enterprise development. It links farmers to processors and facilitates processors' access to basic technologies and markets. It provides training on production and business development services, such as planning, record keeping, pricing, developing market linkages, sanitation and hygiene, and machine maintenance.

On the production side, nearly 250,000 farmers have benefited so far. They were trained on proper farm management and rapid multiplication techniques. Farmers succeeded in rapidly multiplying the planting materials and are gaining from increased income from greater production and sales and by selling cassava stems as well. In support and to provide a means of employment and income, a group of young people has been trained on proper weed control techniques to provide service whenever needed.

Other beneficiaries are the processors, including the mobile graters, microprocessing centers (MPCs), and the SMEs, which serve as market outlets to farmers.

Cassava is bulky and heavy. With the mobile grating service, women were able to save time and labor for other productive activities. The project created employment and income for the beneficiaries, mostly youths.

[2]Economy of Nigeria. 2008. www.wikipedia.org

The MPCs, which are equipped with more facilities, can produce 1 t/day with basic equipment such as a grater, press, sieve (manual or motorized), and fryers. Owned mostly by cooperatives and women's associations, the MPCs produce value-added cassava products for sale, and provide service—grating, pressing, or frying—to the public.

SMEs produce value-added cassava products. They have processing equipment similar to that in the MPCs but usually of higher capacity or more sophistication, such as flash and rotary driers. CEDP provided only a few of the machines for the MPCs and SMEs. The beneficiaries acquired most of them from more than 20 machine fabricators who had been trained by IITA and are now manufacturing machines of better quality and efficiency.

In collaboration with partners, especially the Agricultural Development Program in each beneficiary-state, CEDP provided intensive training for MPCs and SMEs on producing improved and high-quality flour, odorless *fufu*, *garri*, starch, chips, and their uses for industry as well as human consumption. A recipe book was also published.

Overall, the project introduced 22 technologies for beneficiaries, generating a total gross income of US$50 million, and creating 6,000 jobs. They gained knowledge and skills in farming and business development. The cooperatives and women's associations became stronger.

Through continuous collaboration with IITA, some of the SMEs have scaled up their farm production. Now Nigeria has factories producing glucose syrup, ethanol, adhesives, and starch, all using cassava raw material and assisted by ICP.

These enterprises may be small, but with assistance and opportunity, the small could become powerful instruments of economic development.

TOOLBOX

Increasing capacity
FOR PLANT HEALTHCARE

Bunchy top virus-affected banana in Ruzisi Valley, Democratic Republic of Congo, Rwanda, and Burundi. Photo by IITA

Plants, like people, need healthcare. But in Africa, where agriculture is dominated by smallholders, farmers do not have access to reliable plant health advice and management services. The first crucial step in controlling a disease is to identify the cause (disease diagnosis).

Many farmers rely on extension workers and researchers from national and international organizations for such needs. And such help is not always readily or quickly available.

This is why IITA and its partners are developing the capacity of national agricultural research and extension systems (NARES) in research, disease surveillance, diagnostics, and deployment of control options. A good example is in banana: when national partners at the L'Institut des Sciences Agronomiques du Burundi (ISABU) in Central Africa needed help in diagnosing and culturing the pathogen that was attacking banana, they turned to IITA for assistance. ISABU wanted to develop local capacity to independently make diagnoses, culture Banana *Xanthomonas* Wilt (BXW) from diseased banana plant samples, and provide treatment advice.

At that time, IITA was already working on BXW in Burundi under the Crop Crisis Control Project (C3P), managed by the Catholic Relief Service (CRS). IITA and CRS liaised closely to develop a regional training course, for national partners from Burundi, Rwanda, and Democratic Republic of Congo (DRC) to learn new techniques, while encouraging greater collaboration among scientists.

Thus, IITA and partners that include CABI UK, Central Science Laboratory (CSL), CRS, and the Consortium for Improving Agriculture-based Livelihoods in Central Africa (CIALCA) conducted a Training Course on Surveillance and Vigilance for Plant Diseases in Burundi early this year. It is a pilot effort to kick-start a series of capacity building initiatives in the banana-growing countries in the region.

The training was attended by participants from extension and research, universities, and a regional organization. Trainers came from IITA, CABI and Global Plant Clinic (GPC, see box), and Central Science Laboratory (CSL).

Training covered new methods for surveillance and vigilance of all banana diseases. Feedback from the participants highlighted the need for sustained training and the importance of introducing a system of mobile plant clinics to effectively link farmers and transfer knowledge.

The mobile plant clinics initiative was developed by CABI UK as part of GPC, led by Eric Boa and has been tried and tested across the world. Under the umbrella of Mobile Plant Clinics and GPC, IITA had collaborated on initiating clinics in Rwanda, Cameroon, Sierra Leone, and Benin and providing training in diagnostics and surveillance in Uganda, DRC, and Burundi.

“Training, however, is just the tip of the iceberg. It is important to consolidate capacity building in diagnostic techniques and to ensure that people adopt new methods with confidence and then use them regularly,” said Fen Beed, IITA's plant pathologist based in Uganda. “Isolating and identifying plant bacteria require practice as does the conduct of participatory disease surveys. When such methods are reliably deployed, the national programs could significantly improve

Training participants looking at banana *Xanthomonas* wilt chart. Photo by IITA the reliable detection of BXW and other disease outbreaks."

Knowing where a disease occurs allows extension staff to target particular areas and plan control programs. This requires careful organization and marshalling of resources. Although IITA already has effective recommendations for managing BXW, it lacks mechanisms for presenting them to farmers and monitoring their uptake. Further effort is needed to implement training that emphasizes direct action to help farmers.

In their after-training report, Beed and colleagues said that "Effective extension depends on sound intelligence about disease distribution and the damage it causes. National governments need to understand the risks posed to new areas and the actions required to control disease through sound research planning and identification of best management strategies."

Beed and colleagues forwarded this blueprint for managing risk and reducing banana disease losses to ensure success of a plant healthcare service managed by national programs.

Surveillance

It is important to undertake systematic and comprehensive surveys of banana growing areas to get an update on the distribution of BXW and control strategies being used by growers. The surveys provide the opportunity to determine spread and identify reasons why control strategies may not have been adopted. Where control methods have been deployed their socioeconomic impact can be quantified.

The extensive surveys will assess incidence and severity of BXW and other banana pests and diseases.

Systematic and quantitative surveillance of banana-growing areas begin with participatory surveys, a promising technique for assessing large numbers of growers quickly. Survey results can identify sites where permanent sample plots (PSP) would be established for more intensive assessments. PSP sites should be regularly monitored for disease incidence, severity, and efficacy of control methods. Data produced can determine disease spread and help to evaluate socioeconomic impact and deployment of control options.

The C3P project made huge strides towards developing databases on the spread of BXW and the influence of farmers' practices to control this disease. These databases can be further updated with information from the surveys and with data generated from pilot sites.

The databases could be linked to regional databases of climate, growing conditions, topography, farmer demographics, and agricultural practices (e.g., produced by the CIALCA project and many others). This allows use of the databases for predicting spread and risk due to disease at various geographic scales.

Vigilance

The next step is to establish and operate an extensive system of mobile plant clinics in targeted areas. Training courses for plant doctors are available and both DR Congo and Rwanda already have some experience in running clinics. The clinics concentrate on giving advice and gathering "intelligence" about banana problems, providing information on disease control, and offering services for other crops and diseases. This is important since farmers rarely grow bananas in isolation of other crops.

Once clinics are established and their benefits realized they can be self-sustaining and can provide a routine service to farmers and extension officers.

Upgrading facilities

There is a need to ensure that participating

Banana field trials in Rwanda. Photo by IITA

laboratories can isolate and confirm the presence of pathogens that cause BXW and other diseases of banana. Field staff should learn how to collect diseased plant samples for sending to diagnostic centers. Diagnostic centers will be established in the region and linkages developed with advanced research institutes (ARI) to provide technical backstopping for disease diagnostics using, for example, molecular techniques.

In addition, for BXW, rapid diagnostic field-based kits will be fully tested for accuracy to confirm the presence of the disease. Standard operating procedures for laboratory methods should be introduced to ensure consistent results and interpretation of results. The responsibilities of staff from national, regional, and ARI laboratories should be identified and links among them strengthened to create and nurture a network of expertise available to all.

Awareness raising

Data produced from the three activities can be used to publish new disease reports and develop pest risk analysis (PRA) documents for each banana disease in the region. PRA documents are crucial as they summarize all current information and increase awareness of disease recognition, distribution, control and risks. They must be routinely updated with new information and shared across the region to alert stakeholders of potential risks. This can lead to the deployment of preemptive disease control strategies before a disease epidemic breaks out.

Monitoring and evaluation

Detailed assessment of the progress and linkages should be undertaken. The increased capacity in laboratory and field techniques should be shared by project members through training. The support of IITA and the GPC in diagnostics, surveillance, and vigilance techniques encourages national and regional cooperation and use of new methodologies. Empowering scientists and extension staff and making them accountable for their actions is a powerful way to encourage sustainable development and to promote trade.

Linkages

The benefit of creating a knowledge network for banana diseases in the region is clear. This network can be expanded through linkages with scientists and the private sector and key extension, research, and government staff from Burundi, DRC, Rwanda, and regional organizations.

The International Plant Diagnostic Network (IPDN) was set up in response to NARES' surveys that highlighted the lack of diagnostic capacity in much of Africa and in recognition that this directly hindered the adoption of appropriate and effective integrated pest management programs and therefore international trade. IPDN has been established in collaboration with IITA in East and West Africa to increase communication and data sharing. Software for digital imaging and diagnosis, information management, and access to disease management recommendations provides a platform for enhanced diagnosis and communication between laboratory staff and experts across the world. Improved diagnostics tools and protocols have been developed and tested. This has been combined with training programs to enhance technical capacity and increase networking among diagnosticians in East and West Africa.

Initiatives such as IPDN can benefit by collaboration with similar internet-based initiatives in Africa such as the East Africa Phytosanitary Information Committee (EAPIC). EAPIC is linked to FAO's International Plant Portal to provide posting of plant pests for each respective country, which now includes Kenya, Tanzania, Uganda, and Zambia. The plant pest list helps in developing harmonized border inspection protocols, which support capacity building efforts in plant pest survey, identification, and communication systems, such as IPDN.

A follow-on project with these components that combines good science, effective surveillance, and proven advisory services could strengthen the contribution of extension and research to increase food security, income generation, and improved trade in Africa. It also highlights support required from national and regional organizations, governments, and donors. These include local training for diagnostic techniques and expansion of participatory disease surveys and strengthening of disease vigilance through the establishment of mobile plant clinics.

"Addressing all these considerations will contribute significantly towards providing a service to support farmers and trade that would move away from the current scenario of 'fire-fighting' diseases to providing preemptive control (see Figure 1)," concluded Beed.

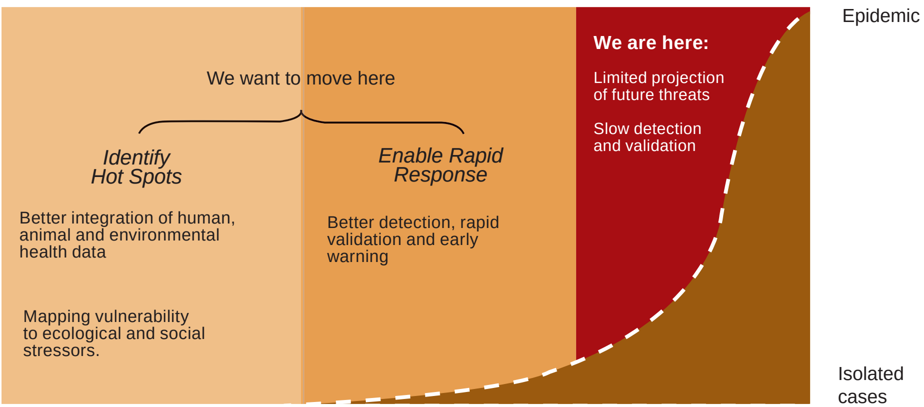


Figure 1. Scenario on managing diseases (fire fighting vs. preemptive control).

Global Plant Clinics

The CABI Bioscience Global Plant Clinic (GPC) provides a comprehensive diagnostic and advisory service for disease problems on all tropical crops. The Service is unique in its global operation and the range of plant diseases it handles. CABI Bioscience has been identifying plant diseases for over 90 years and other key partners in GPC include Rothamstead Research and Central Science Laboratories. The Global Plant Clinic gives expert advice on the interpretation and application of diagnostic results drawing on extensive international experience in a wide range of crops and information from CAB International's award-winning Crop Protection Compendium.

The GPC has initiated a series of mobile plant health clinics that offer regular and reliable advice on all plant health problems affecting any crop. These clinics are run by plant “doctors”, many of whom are agronomists or extension workers, who work for existing, grassroots organizations.

The clinics are not a technology but an advisory service. They link diagnostic labs with extension workers (plant doctors) and provide regulatory bodies in plant health with up-to-date information on current priorities by clinic ‘area of influence’. Such clinics have little direct expense. In the long term they need public investment and private support (from farmers or input suppliers such as those responsible for improved varieties or even fertilizer).

According to GPC head Dr Eric Boa, “Farmers benefit from advice at clinics: they preempt new problems and avert losses by quick action; reduce pesticide use; and reduce losses and save money by giving good or better recommendations for managing a problem. On vigilance/surveillance, clinics identify current problems affecting priority problems in an area.”

In banana, the most recent disease outbreak due to banana *Xanthomonas* wilt (BXW) was first reported to move from Ethiopia to Uganda by regional scientists and was subsequently confirmed by the GPC in Uganda in 2001. As the disease spread within Uganda and relentlessly across the region research programs led by CRS, IITA, and other national scientists tracked its movement into Burundi, DRC, Rwanda, Tanzania, Kenya, and the causal agent was confirmed by GPC.

Mobile plant clinic in Butembo, Democratic Republic of Congo. Photo by IITA

BXW is one of several damaging diseases in East Africa and the demand for better surveillance and vigilance through mobile plant clinics has been widely expressed. The deployment of control options through clinics was based upon methods used to control a similar disease of banana caused by another bacterium. These primarily consist of the use of disease-free planting material and farmers tools and the removal of male flower buds to prevent infection from insect vectors.

http://194.203.77.76/globalplantclinic/

growing bananas from "seeds"

Jim Lorenzen

Bananas are an important crop for global trade and nutrition where they are intensively cultivated, but few efforts exist to breed superior bananas. One of the reasons for this is that humans have intensively "selected" against seeded bananas and it is difficult or impossible to pollinate many banana varieties and successfully produce seeds.

Many of the most important banana varieties are triploid, which means that they carry an extra copy of each chromosome compared to the normal diploid. Being a triploid means that it is difficult for normal chromosome pairing and segregation to make fertile eggs or pollen, which results in most triploids being nearly sterile. Sterile bananas are great for people who don't like to crack their teeth on banana seeds, but mean that bananas have to be multiplied via vegetative propagation, similar to propagation of potatoes, sweet potatoes, cassava, and selected varieties of other fruit trees or ornamental species.

Gardeners are familiar with "seed potatoes," small potato tubers that are planted to produce a potato crop. Bananas do not form tubers; new plants derive from "suckers" that emerge from the lower banana stem (corm). These suckers can be uprooted and used to plant new banana plants. Similar to potato tubers, these suckers were a part of the original mother plant, which means that they potentially carry whatever disease pathogens or pests had infested the mother plant. Therefore, banana suckers are one of the main means of transport and spread of certain disease-causing agents, including important fungi, bacteria, and viruses.

Nematodes and pests can also hitchhike on banana suckers to infest the new crop. Not only does such hitchhiking result in early infection/infestation of new banana plants in a farmer's field, but transporting long distances may help introduce a new disease or pest problem in a new location. This dual hazard of reduced yield potential of already infected planting material that may introduce new pests and diseases emphasizes the need for superior disease-free

Finding seeds in breeding plots in Namulonge, Uganda. Photo by IITA

Macropropagated plants in chamber. Photo by IITA

planting material produced through a "seed system" designed to minimize the risks of spreading pathogens and pests.

The traditional means of obtaining banana planting material ("seed") is to acquire suckers from one's own banana garden, from a neighbor, or from a more distant source. This method served to spread common varieties around the world and to multiply them in their new locations. This system can be modified to produce more banana suckers or shoots by manipulating banana corms to allow more buds to sprout. One such method that is described here is called macropropagation. A higher tech procedure to rapidly produce many plants in just a few generations of propagation is called tissue culture. In tissue culture, plants are first surface sterilized and then grown in aseptic culture in test tubes using an artificial growth medium based on a gelling agent like agar. The tender tissue-cultured plants can then be planted in the field after rooting and hardening under protected conditions.

Seed systems for producing clean planting material can be operated at various levels of technology and efficiency. In some cases, plant health could be improved by merely raising the awareness of the negative impact of planting "sick" suckers. Where infected plants look visibly different from healthy plants, either because of reduced vigor or visual disease symptoms in infected plants, the propagator could practice negative selection against "sick" plants or positive selection for "healthy" plants (or both). Such plants could be multiplied faster by applying a rapid propagation method such as macropropagation. However, while low-tech and affordable for farmers, such a system does not eliminate problems that cannot be detected by visual observation. Unfortunately, many diseases and pests fall into this category for at least part of their infection cycle.

For crops such as cereals, seed certification systems were developed to assure varietal purity, and later expanded to include freedom from weed seeds and seed-transmitted pathogens. Since most pathogens are seed-transmissible for vegetatively-propagated crops like potato or banana, disease management is the major focus of most seed potato certification programs and banana multiplication programs. Modern technology has provided diagnostic tests to detect significant pathogens. These tests are similar to those used in modern laboratories to diagnose human diseases, and can be expensive. For this reason, it is more efficient to test a small number of plants and multiply those that were negative for all pathogens tested in the battery of diagnostic tests.

It is possible to use tissue culture to efficiently and rapidly multiply plants that tested "clean" in the pathogen testing. Most potatoes eaten in the Western world are just a few field generations removed from tissue-cultured plants used to produce "seed potatoes" in screened glasshouses to start the seed production cycle. Similarly, most dessert bananas in the global export trade are from plants originally propagated in tissue culture from plants that tested clean for known banana diseases. A modified form of tissue culture can also be used to eliminate pathogens from plants that did not test clean, after which they can be propagated to produce "seed" planting material. There is great potential to improve the health of banana plantations in the developing world through increased use of this technology.

Tissue culture is the process of growing plants that have been surface sterilized and planted in test tubes or similar containers in sterile medium that contains all the nutrients they need to grow. This is almost always done in indoor laboratory facilities and the medium also contains the sugars needed to grow, since there isn't enough light for photosynthesis.

Sanitation is extremely important, since a single mold spore is enough to contaminate a test tube. Tissue-cultured plants are generally tested for pathogens before commencing the multiplication cycle so that infected plants are not multiplied. The small banana plantlets produce small suckers that can be detached and planted as new plants, or an experienced technician can cut sections that contain buds that will grow. Extra shoots can sometimes be induced by cutting through the growing points so that multiple plants develop from single buds. This process can be repeated every 5-8 weeks so that a single plant can produce many new plantlets in a relatively short period of time.

Bananas are sometimes unstable in tissue culture and mutant versions can develop. For this reason, most multiplication labs try to limit the number of multiplication cycles before renewing their cultures from field plants observed to have all the correct traits for that variety.

When tissue-cultured plants are rooted in soil, hardened, and then planted back in the field, they can be more susceptible to some pests and diseases than the original plant was. To restore natural levels of resistance, these plants can be reinfected with the endophyte microorganisms that normally coexist with

Bicycle transport to Bujumbura, Burundi.
Photo by IITA

"A combination of new and old seed systems can improve the overall health of new plantings by providing healthy plants of preferred older varieties and resistant new varieties." - Jim Lorenzen

bananas, similar to the gut bacteria that are important for human intestinal health (see article on endophytes on page 19).

Macropropagation falls somewhere between tissue culture and traditional systems of distributing suckers. In macropropagation, large suckers from healthy banana plants are removed and the roots and soft stem portion (pseudostem) of the sucker are cut away to expose the buds of the corm (the hard stem portion at the base of the sucker). The bare corms are briefly dipped in boiling water to kill any nematodes (micro-worms) that were not removed when cutting off roots. Small cuts are made through the buds to encourage development of multiple sprouts from each bud. The apical (top) bud is often removed because it can suppress development of lower buds. The corm is then covered with moist wood shavings and incubated in a small plastic-covered chamber for a few weeks to encourage shoot development. Primary shoots can be rooted and used as planting material, or cut off and the growing point again cut to promote additional shooting. Shoots that develop are broken off with a bit of hard stem and roots attached, placed in small nursery bags in a similar high humidity chamber for a few days to allow root development, and finally moved to a nursery for hardening. Hardened plants can be planted in the field, similar to suckers or hardened plants from tissue culture.

A major drawback of macropropagation is that rustic or low-tech methods of detecting pathogens have not been developed, so this method can propagate infected plants if they were chosen as mother plants. Both macropropagated plants and tissue-cultured plants have less food reserves than suckers and require more care (compost/ manure, watering) after planting than suckers. Careful siting of "mother gardens" established from tissue-cultured plants in clean areas may be the best way to produce suckers for macropropagation.

Traditional seed systems have produced most of the nearly 6 billion banana and plantain plants in Africa currently spread over nearly 4 million hectares of farm and gardens. Many of these are in excellent condition; others have become infected with one or more banana diseases and need to be replaced. Since new banana diseases have been introduced to Africa in the last century, and many diseases have increased in distribution and prevalence, greater care needs to be practiced to multiply "healthy seed".

Breeding programs are nearly ready to release new varieties with resistance to some of the disease problems.

A combination of new and old seed systems can improve the overall health of new plantings by providing healthy plants of both preferred older varieties and resistant new varieties.

IITA's research on macropropagation is supported by the Directorate General for Development Cooperation (Belgium) and Agricultural Productivity Enhancement Program (APEP-USAID) Uganda Agricultural Productivity Enhancement Project.

Banana roadside market in rural southwest Uganda. Photo by IITA

Thomas Dubois:

Young scientist on the rise

Thomas Dubois joined IITA in 2003 to manage the German Federal Ministry for Economic Cooperation and Development (BMZ)-funded regional biocontrol project for banana, based in Uganda. This project has now made significant progress: banana infected with certain strains of endophytic fungi grow more vigorously and are better protected against pests and diseases. The development of this novel "bioprotection" is an exciting research theme that has the potential to revolutionize current thinking on biocontrol. Current focus of this project is to optimize inoculation techniques and scale up activities with commercial producers of tissue-cultured (TC) plants as part of a recently funded Eastern African Programme and Research Network for Biotechnology, Biosafety and Biotechnology Policy Development (BIO-EARN) project in Kenya and Uganda.

In 2006, Dr Dubois received the prestigious CGIAR Young Scientist Award. At present he is heading a BMZ project on improving market pathways for TC banana centered on commercial TC producers and nursery distribution centers. He is also spearheading the 2008 International Banana Conference in Mombasa, Kenya, as Chair of the Organizing Committee.

How did you come to IITA?

I studied bio-engineering first and then some foreign exchanges spurred my international ambitions. After my studies, in 1998, I was placed with IITA in Onne, southeast Nigeria. I absolutely fell in love with the then cowboy attitudes: nothing beats eating goat head, listening to Afropop in between oilrigs and blown up tankers! I liked the applied work, screening banana plants for nematode resistance, working under the supervision of Abdou Tenkouano and the late Paul Speijer. While I was at Onne, I was accepted at Cornell University to do my PhD studies in Insect Pathology. As I told Lukas Brader, the DG at that time, "I will be back."

After my PhD studies I was quickly involved in a fairly high-profile project with the United States Department of Agriculture, combating a devastating invasive insect species in the northern US; I traveled to China every year for prolonged periods of time. I toyed with the idea of entering Business School and tried to get into private industry. I settled with management consulting firms, using the Ivy League degree as leverage. I tried to get back into the CGIAR system and landed an 8-month stint with IITA in Uganda in 2003. This was a short project related to the use of endophytes, with no job security but ideal to get my foot in the door. I have been at IITA ever since.

What are some of your memorable experiences in research in the field or in the lab?

I like the applied and hands-on work. You can get much more done with a large dedicated team of staff, sometimes with less access to good infrastructure and facilities. I had to play farm manager for more than a year, doing activities from supplying water, fuel, and satellite dishes to keep the station running, to chasing away cows from encroaching the research fields in my spare time.

What are your realizations on the job?

I have come to appreciate several important realizations. First of all comes focus. It is easy to be carried away and drift into the development aspect of things. We are first and foremost scientists, on the applied side of science, publishing our work through peer-reviewed journals. It should be up to partner organizations to feed high-tech science upstream or to implement the work downstream. So choosing the right partners is essential. Secondly, teamwork is important. I started to fully appreciate this fairly late. Competition is natural in low quantities but, by definition, has no place in an institution that aims to do *Research to nourish Africa*. By working synergistically as a team and sometimes reaching out to other "competitor" organizations you would be surprised at what can be achieved in a short time and how the relationship can be swiftly turned into fruitful collaboration. Thirdly, at IITA, the sky seems to be the limit but sometimes you have to let go. One person simply cannot run two large international projects, write some more, fly to DR Congo to help with restructuring the agricultural sector, correct PhD theses, be a webmaster, and run a massive conference at the same time. My workload is insane but it is partly my fault.

What are your future plans?

In the immediate future, I would focus on my project on improving market pathways for TC banana centered on commercial TC producers and nursery distribution centers. Also, commercialization of the technology with private enterprises—this is what the BIO-EARN project is trying to do. At some point later, I hope to leave science and secure a managerial position with more job security as well. Deep down I know I am not a scientist "pure sang". Moving on to the bigger scheme of things can be anything, ranging from research management, policy, advocacy, consultancy to donor relations.

Any advice for IITA colleagues?

I am among the youngest at IITA so I should be receiving advice from others! A strong focus has been on mentoring students and I would hope that some colleagues would train more students. I have been supervising over 25 students in the last 5 years, both those from within Africa and European-based MSc students who do their research at IITA-Uganda. Benefits are manifold for them and IITA. Secondly, I think IITA folk could benefit if they "sell" themselves a bit more, through radio, TV, websites, and the popular press. Benefits include changing donor conceptions and misconceptions, putting science in the forefront, and ultimately benefiting farmers. Thirdly, it has helped me to think a lot out of the box and be a generalist. I came as an entomologist with a title of "biocontrol specialist". Now I am running a socioeconomic project entirely focused on market pathways for banana seed systems. One could look out of the box for good private sector players or partners. This is essential, in my opinion, for long-term sustainability.

What is your dream for Africa?

I hope Africa will, at some point, be weaned off the many donor agencies, volunteering organizations, and NGOs that seem to be becoming a sustainable big-bucket business rather than a means to an end. A conducive climate for private sector development, together with good governance, is what I wish for sub-Saharan Africa.

Photo by IITA

Leena Tripathi:

Looking after the welfare of smallholder banana growers

Photo by IITA

Leena Tripathi was born and grew up in India. She gained a PhD in Plant Molecular Biology from the National Botanical Institute, Lucknow, after completing an MSc in Molecular Biology and Biotechnology at G.B. Pant University of Agriculture and Technology, Pantnagar, India.

She joined IITA in 2000 and worked first in Nigeria and currently in Uganda where her primary research focuses on the development of transgenic Musa spp. with disease and pest resistance. She has established strong links with national and regional partners, and advanced labs. She is also Guest Faculty at the United Nations Industrial Development Organization (UNIDO) for biosafety courses.

Please describe your research work.
Since 2000, I have been developing transgenic banana and plantain resistant to pests and diseases. Currently, I am leading projects on producing bananas resistant to *Xanthomonas* wilt using the transgenic approach. I am also involved in capacity building in biotechnology and biosafety. I have trained several African scientists in genetic transformation and tissue culture. I have assisted in building capacity on genetically modified organism (GMO) detection and biosafety in East Africa by training students and national scientists on banana transformation and molecular biology. And I would like to acknowledge the strong financial support from donors such as Gatsby Charitable Foundation, African Agricultural Technology Foundation (AATF), US Agency for International Development, and the UK Department for International Development (DFID); and IITA of course.

Why did you choose to work in Africa?
Africa has missed the Green Revolution but should not miss the Gene Revolution. For this it needs human capacity in biotechnology that will help to accomplish things that conventional plant breeding could never do. The public needs to be better informed about the importance of biotechnology in food production.

What is the importance of transgenic technologies in banana improvement?
Many pests and diseases significantly affect banana cultivation and cause crop losses worldwide. Development of disease-resistant banana by conventional breeding remains difficult for various technical reasons. Transgenic technologies are the most cost-effective approach. There are enormous potentials for genetic manipulation using appropriate transgenes from other plants to achieve objectives in a far shorter time. It may also be possible to incorporate other characteristics such as drought tolerance, thus extending the geographical spread of production.

How do you demystify or explain a concept like biotechnology to lay audiences?
People think that biotechnology is just genetic modification (GM) technology. Contrary to its name, biotechnology is not a single technology; it is a group of technologies that

uses biological systems, living organisms, or their derivatives, to make or modify products or processes for specific use. This includes recombinant DNA technology, genetic engineering, GM foods, biopharmaceuticals, bioremediation, and more. Biotechnology is not new; it has flourished since prehistoric times. When the first human beings realized that they could plant their own crops and breed their own animals, they learned to use biotechnology. The discovery that fruit juices fermented into wine, or that milk could be converted into cheese or yogurt, or that beer could be made by fermenting solutions of malt and hops, started the study of biotechnology. When the first bakers found that they could make soft, spongy bread rather than a firm, thin cracker, they were acting as fledgling biotechnologists. "Modern" biotechnology derives from techniques discovered only in the last 20 years. These include the ability to cut and stitch DNA, to move DNA and genes from one organism to another, and to persuade the new gene in this new organism, that is to make new proteins. Genetic engineering technology is a branch of modern biotechnology and involves the transfer of gene(s) from one organism to another to create a new species of crops, animals, or microorganism. Modern biotechnology has offered opportunities to produce more nutritious and better tasting foods, higher crop yields, and plants that are naturally protected from disease and insects.

What have you learned on the job?

I joined IITA as a biotechnologist with plenty of experience in research but not in the field. Working at IITA has been overwhelmingly positive. I have gained experience in both research and administration. I have learned to appreciate the benefits of working in multidisciplinary and multicultural teams and of linking research to farmers in the field. I can now write successful project proposals, get funding, lead projects, and disseminate results to national partners and finally to farmers. Good communication skills are essential for successful research. One needs to be a good team worker and establish strong and successful partnerships as we are doing at IITA-Uganda. When I was relocated here, I realized the situation was very different. IITA in Ibadan has facilities but in Uganda, IITA facilities are based within a national partner, the National Agricultural Research Organization. I wanted to learn quickly from the experiences of others so I talked to colleagues about their work and successes and to national scientists about their expectations. I learned quickly.

Any advice for IITA colleagues?

IITA scientists should be committed to provide strong leadership in the key research areas to ensure scientific excellence and the quality of products. They should work applying "new science" to enhance food security and income generation for resource-poor farmers.

What are your future research plans?

I want to evaluate the disease resistance of banana varieties in the field, evaluate transgenic plants in the confined field for efficacy against *Xanthomonas* wilt disease, with the University of Leeds develop nematode-resistant plantains, and develop varieties with multiple disease resistance by integrating several genes with different targets or modes of action into the plant genome. I also want to train more national staff/students to build capacity in the region.

What is your formula for success?

The addition and sometimes multiplication of five key elements: vision, strategy, confidence, hard work, and learning. I am focused and have a clear vision for my research, based on project outputs. I frame strategy with clear goals. I follow the strategy with my group members and work hard to achieve the goals. At each step I identify problems and learn to solve or avoid them so that the group moves smoothly and fast to achieve the goals. I set the goals for my group at the start of each year. Everyone works extra hours to achieve group goals. I do not hesitate to seek advice and suggestions from experts, superiors, and collaborators to move things efficiently. Support is very important. I have benefited from support and encouragement from my superiors, higher IITA management, donors, collaborators, and from family. IITA nominated me for the CGIAR Young Scientist award in 2005 and gave me their Top Scientist award, based on my research achievements.

Erostus Njuki Nsubuga: Lessons on partnership

R4D Review interviewed Erostus Njuki Nsubuga, the chief executive officer and managing director of Agro-Genetic Technologies Ltd (AGT), to get his insights on the IITA-AGT partnership. AGT is the first and only private commercial tissue culture (TC) laboratory in Uganda and so far the biggest single supplier of banana TC planting material in East and Central Africa. It produces up to 8 million tissue culture plantlets per year, of which 1 million are banana plants.

Nsubuga wants to see AGT become well established and profitable by increasing its capacity to serve the whole region with quality TC planting material at affordable prices and introducing other services such as plant and soil analysis, and produce organic fertilizers. His dream is for AGT to become a one-stop shop that provides total solutions to farmers.

Nsubuga was born in Uganda and spent his early years there. Because of the war, he and his family had to move to other countries in Africa and Europe. He started living on his own at 16, studying in Europe and USA for 24 years to obtain an MSc (Agriculture) and MBA (International Marketing). He worked in international companies and managerial positions for over 20 years but his dream was always to come back, to help his mother who had survived all the wars, to sustain himself and his family, and to contribute to the development of his people and country.

What made you establish AGT?

I had completed one contract and was about to start a new job when I decided to start a TC laboratory at my house. I employed and trained two people to produce TC plants out of my kitchen while I was traveling. At that time (2001–02) banana and coffee wilt diseases were spreading like wildfire in Uganda. It was easy to start with these two crops as there was great demand for disease-free planting

CEO and Managing Director E. Nsubuga (left) in AGT's banana hardening nurseries, Uganda. Photo by AGT material to reduce the spread of diseases and restore healthy plantations. Over time, using my own finances, AGT built a state-of-the-art TC facility and we grew significantly. Our technical team now includes five university graduates and a retired professor. Degree students from Makerere University have been doing their internships at AGT's laboratory with their programs embedded in our production line.

How did the AGT and IITA partnership come about?

It started when Dr. Thomas Dubois called me out of the blue. IITA was looking for a commercial enterprise to start testing and producing its endophyte-enhanced plants. Under a mutual agreement, AGT and IITA have worked on fine-tuning the enhancement of TC plants with endophytes. We identified and established on-farm trials together, using the same farmers. In the short run, IITA assisted us with laboratory chemicals and AGT also benefited from publicity. In the longer run, production of endophyte-enhanced TC material would be greatly beneficial to AGT and other commercial producers in the region. Now that the original project has expired, we are trying to get this unique product commercialized to supply farmers facing high pest and disease pressure.

Please give some insights on public-private collaboration.

Collaboration can be very important in developing and disseminating research products. For IITA, it has forced them to think commercially from the onset. A good example has been the experimental protocol for endophyte inoculation. After piloting it in my lab, IITA quickly abandoned the use of a nutrient solution in favor of fertilizer-amended soil along the lines of the system used in commercial nurseries. Such partnerships should be developed as early as possible, especially for a technology such as this. This would help AGT to build up its technical, human, and financial capacity to take on the research products once they reach commercialization. Also a very clear agreement has to be drafted and this is sometimes a balancing act.

How could IITA improve its relationship with the private sector?

AGT indicated to IITA that it was open to other research products but wanted to be involved at an early stage. This is what we call a demand-driven research agenda where the consumer is sure of getting research products through private sector involvement. We are now backstopping a socioeconomic study looking at full commercialization of our nurseries in Uganda and Rwanda. At present AGT sells mainly through NGOs and institutions. Direct marketing to farmers would be better.

What lessons have you learned from the partnership with IITA and others?

It is great that research organizations such as IITA have realized the role of private sector involvement in agricultural research and in the product value chain. Such partnerships are relatively new and we still have much to accomplish. Personally, I feel many governments and international research institutions, even IITA, are working too much for the donors, not the farmers. We should tell the donors what needs to be funded. More impact assessment is needed on some research products.

Any suggestions for future collaboration or collaborators?

I hope IITA can do more demand-driven research by including the private sector in the development of research products as early as possible with specific roles for each partner clearly defined.

What do you think makes AGT successful?

I have a professional approach and commitment, with many years of experience in agriculture and entrepreneurship and good relationships, local and international. AGT started when diseases such as banana bacterial wilt and coffee were at their peak, so I was in the right place at the right time.

How else could development organizations and private entities such as AGT help farmers and consumers?

AGT is getting farmers involved in production, distribution, and training by establishing banana nurseries and demonstration gardens owned by local farmers. The farmer then becomes the AGT distributor for that community and the nursery the focal point for training others in modern agricultural practices.

What is your dream for Uganda?

Uganda is the second largest producer but seventy-fifth in banana exports. The Government and all development partners should industrialize this crop and thus lift many out of poverty.

Any thoughts about the world food crisis, food security, GMOs, or development in general?

African countries are the poorest in the world today with many problems. We urgently need biotechnology tools, including GMOs, to address problems. We should not waste time blaming others for creating poverty and hunger but make efforts ourselves to get out of the rut. I still have far to go but I am contributing to the well being of farmers in Uganda and the whole region.

Banana facts

In terms of production, bananas are the world's 4th most important food crop, mostly grown and consumed in the tropical and subtropical zones. The crop is grown in more than 120 countries, with an annual world production of around 104 million tons; around a third each is produced in the African, Asia-Pacific, and Latin American and Caribbean regions.

About 87% of all the bananas grown worldwide is produced by small-scale farmers for local consumption as a food security crop, and for local markets than for international trade. They provide a staple food for millions of people, particularly in Africa.

Approximately 13% of worldwide banana production is destined for the export market. The banana fruit is extremely important as an export commodity especially in Latin America and Caribbean, which contribute over 83% of the total banana in the international market. The banana export industry is also the backbone of the economies of many Caribbean countries, and the crop plays a vital role in the social and political fabrics of the islands.

In Africa, only five countries namely, Côte d'Ivoire, Cameroon, Somalia, Ghana, and Cape Verde, export approximately 427,000 tons of banana and plantain. There are more than 500 banana varieties in the world, but the Cavendish is the most exported banana cultivar.

The banana's ability to produce fruits all year round makes it an important food security crop and cash crop in the tropics.

Bananas and plantains supply more than 25% of the carbohydrate requirements for over 70 million people in Africa. East Africa is the largest banana-producing and consuming region in Africa with Uganda being the world's second leading producer after India, with a total production of about 10.5 million tons. In some African countries such as Uganda the daily consumption of banana may exceed 1.6 kilogram per person, which is the highest in the world.

Nutritionally, fresh bananas contain 35% carbohydrates, 6-7% fiber, 1-2% protein and fat, and major elements such as potassium, magnesium, phosphorus, calcium, iron, and vitamins A, B6, and C. Bananas are also used to manufacture beer, wine, and other products and form an important part of the cultural life of many people.

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Organic bananas from Africa?

Steffen Abele

Organic agriculture provides significant market opportunities for commercial agriculture globally.

Organic food markets grew at tremendous rates during the 1990s, encouraging organic food production throughout the world. Although this growth rate has slowed down a bit, and the niche market for organic food is less than 4% of the European or North American food markets, the prospects of high prices and a stable demand still make organic food markets attractive for producers.

Commercial and certified organic farming is not uncommon in Africa that has 19% of the world's organic farms. Main organic products include fruits and vegetables, cotton, coffee, tea, and herbs and spices.

Bananas are the most widely traded fruits worldwide. Recent trends in organic food demand in developed countries have made organic bananas an attractive crop in developing countries. In fact, trade in organic bananas increased during the late 1990s and early 2000s at a quite significant rate, from about 30,000 tons in 1998 to about 150,000 tons in 2003. Even so, organic bananas represent only a small share (1%) in the world banana trade.

About two-thirds of the organic bananas are traded to the European Union (EU), where they constitute about 2.5% of the banana market, a significantly larger percentage than on the world market. The other main target is North America, and, to a much lesser extent, Japan.

The entire trade in organic bananas comes from countries in Latin America. Africa and Asia are geographically closer to the EU and Japan but this does not seem to be relevant to organic banana trade.

Conventionally grown bananas are mainly traded from Latin America onto the world market, with minor shares coming from West and Central Africa (WCA) and Asia. North America sources its banana supply exclusively from Latin America. Europe imports bananas from Latin America, WCA (Côte d'Ivoire and Cameroon). Japan imports bananas from Latin America and Asia (Philippines and China).

East and Central Africa—in particular Uganda, Rwanda, and Burundi, as one of the largest banana-producing regions worldwide—does not feature to any significant extent in these statistics.

Suppliers of organic bananas are basically the same as those of conventional bananas, Latin American countries. Organic banana production and trade follow conventional production and trade, with suppliers such as the African or Asian producers lagging behind.

Although this is a large market, bananas, in particular conventionally grown bananas, seem to have had the peak of their market growth during the 1990s. Significant volume growth is expected to occur only in Eastern Europe and the Middle East. Elsewhere, volume growths are expected only to follow population developments, to a lesser extent increases in income and falling prices. While volume growths reached on average 4% in the 90s, they will reach only about 2.5% annually until 2010. Prices are expected to decline with increased liberalization of banana markets, in particular the EU. Overall, markets are considered saturated.

Africa has not been able to take up production and trade opportunities on the global banana market, with a few exceptions such as Cameroon and Côte d'Ivoire. However, more recently, there are efforts under way to try and enter the global banana markets in both the conventional and niche segments.

Conventionally grown banana production in Uganda, Rwanda, and Burundi is hardly competitive with that from other regions because of its small scale and low-input production. These lead to relatively low yields and consequently high production costs. Scattered small-scale production makes assembly and packaging a long and costly effort, with high postharvest losses as a consequence.

Transport routes are long and road and sea transport to possible final destinations often take longer than the shelf-life of bananas, so that the freight will decay before reaching markets in Europe or Asia. Consequently, the only exports of conventionally grown bananas from East Africa to Europe go by airfreight, often as by-cargo with higher value products. In Europe they supply only specialty markets, such as cooking bananas or plantain for African expatriates, who do not make up a significant market share. The problem can be quantified by comparing production and trade costs of conventionally grown bananas from Latin America and Uganda (Table 1).

The reasons for Uganda's disadvantages on the European market are obvious: High raw material costs. Land and labor-intensive small-scale production, losses from pests and diseases, and the lack of fertilizer already affect primary production adversely. Gathering, packaging, and transport from the small farms through many intermediaries impose a large amount of additional costs.

The transport of the material to the seaports (the nearest is Mombasa in Kenya) and the long distance to Europe add further disadvantages. Normally, the distance from production to market in terms of days would

Table 1. Competitiveness of conventional and organic bananas from Uganda vs. Ecuador, 2005

Cavendish, costs and revenues in US cents per kilogram	Uganda	Ecuador
Raw material, farmgate price	7.00	0.20
Transport, packaging and handling from farm to collection center	17.00	7.78
Transport and handling to seaport	5.93	2.56
Sea freight	80.00	27.06
Total costs at retail store, Europe	132.97	60.63
Retail price, Europe	135.92	135.92
Profit margin	2.95	75.29

Organic bananas, price in US cents	Uganda	Ecuador
Fresh bananas, farmgate price	11.10	27.00
Transport, packaging and handling from farm to collection center	17.00	7.78
Transport and handling to airport	1.48	2.56
Airfreight	170.00	40.00
Total costs cif Europe (Hamburg)	199.58	77.33
Transport to ripening chamber	10.67	10.67
Ripening	11.93	11.93
Delivery to retailer	0.44	0.44
Total costs retail store, Europe	222.63	100.38
Retail price, Europe	300.00	300.00
Profit margin	77.37	199.62

exceed even the 20-day shelf-life of fresh bananas.

Organic bananas from Uganda are cheaper at the farmgate than Ecuadorian bananas (Table 1), and although handling costs and airfreight are still high, and the final margins in retail are lower than those from Ecuadorian bananas, there is still a significant profit margin at the retail level. This makes the export of organic bananas from Uganda to the EU by airfreight far more attractive than the export of conventional bananas by sea—if the latter becomes technically possible.

This opportunity should be the same for more Central African countries, such as Rwanda and Burundi, but also for West African countries such as Cameroon and Côte d'Ivoire. What mainly contributes to this opportunity is the high value of organic bananas on the European markets, and the opportunities arising from this to export these high-value fruits to Europe by plane.

However, even if organic bananas (or any other organic fruit or agricultural product) represent an opportunity, some challenges exist which have to be considered. Poor quality and badly maintained roads, vehicles, rail links, and rolling stock all pose problems for transportation. Lack of refrigeration, erratic power supplies, poor communications, underdeveloped banking and credit systems, and, sometimes, political and economic instability, all raise serious and often insuperable problems.

In addition, the lack of local certification bodies imposes significant constraints and risks to organic agriculture in Africa. Certifiers have to be flown in and they increase the costs of organic production. So far, only Tunisia has its own European-standard certification bodies. The costs of certification have to be seen as investment costs and hence risks. If the investment costs are not amortized by the revenues, e.g., in the case of harvest failures or a sudden shortfall of market outlets, investments in certification are lost and hence, the farmers are liable to a significant

Photo by IITA

investment risk. Similar constraints apply to the establishment and sustainability of commercial organic agriculture elsewhere in Africa, and also to the production and trade in organic bananas.

In summary, these constraints are:

- Lack of experience in intensive organic production
- Lack of experience in handling and exporting fresh produce
- Lack of professional management
- Diseconomies of scale in exporting small quantities, e.g., for test exports
- Poor communication between foreign importers and exporters
- Poor negotiation skills and judgment of exporters
- Lack of familiarity with international markets, including knowledge of the organic market place overseas
- Lack of governmental support for exports

Organic banana production has its advantages, in particular for some Central and Eastern African producers, as markets are high value and stable in Europe and the US, while conventional banana markets are stagnating. Yet it is clear that there are a number of prerequisites for entry to the markets. Good marketing linkages and marketing skills for producers and marketers are at the top. Investments in certification have to be facilitated, in particular for small producers or producer groups.

Both physical infrastructure (roads) and political frameworks in Africa have to be favorable if organic production and exports are to be sustainable. Markets, although attractive at the moment, are competitive, probably limited, and probably highly income-elastic and thus sensitive to economic distortions on the demand side. This also means that oversupply has to be avoided and in the long run, cost reduction will be necessary to successfully compete in organic markets.

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The future of African bananas

Tripathi discusses work with staff at Namulonge, IITA-Uganda. Photo by IITA

The use of genetic engineering has transformed agriculture, and food production and development by providing options and solutions where none existed before—to the benefit of billions of the world’s inhabitants.

IITA and its partners have been using genetic transformation as a crop improvement tool to help produce more and better food staples. The Institute—with partners such as the National Agricultural Research Organization (NARO) of Uganda, Academia Sinica (Taiwan), and the African Agricultural Technology Foundation (AATF) in Kenya—is at the forefront of research “designing” a genetically modified banana that is resistant to the worst bacterial disease so far—Banana *Xanthomonas* Wilt (BXW). Entire banana fields can be destroyed, especially those planted to *Pisang awak*, a susceptible exotic variety widely grown to make banana beer.

Bananas are a major staple in East Africa produced mostly by smallholder subsistence farmers. Uganda is the world's second leading grower with a total annual production of about 10.5 million tons. It is Africa's biggest producer and consumer of bananas and plantains.

Most growers cannot afford costly chemicals to control the many pests and diseases that affect banana cultivation. As diseases continue to spread, demand grows for new improved varieties.

Bacterial wilt caused by *Xanthomonas campestris* pv. *musacearum* is threatening banana production and the livelihoods of these smallholder growers, and solutions have to be found fast before it could destabilize food security in the region.

Work on developing a GMO banana has been ongoing since BXW was first reported in 2001. The disease has been identified in the Eastern Democratic Republic of Congo, Rwanda, Kenya, and Tanzania, and is widespread in Uganda. It attacks almost all varieties of bananas, causing these countries an annual loss of over US$500 million. These can be reduced bunch weights or absolute yield loss or clean planting material is unobtainable for new plantations.

"Developing resistant varieties is a long-term but more sustainable way to control pests and diseases. Improving the plant's defense mechanism against BXW through genetic engineering is still the best line of defense because of its many advantages," commented molecular geneticist Leena Tripathi based in IITA-Uganda, Kampala. "Farmers are reluctant to employ labor-intensive disease control measures."

"Genetic engineering offers many opportunities for improving existing elite varieties not amenable to conventional cross-breeding, such as bananas. It allows breeders to develop new varieties quickly through the introduction of cloned genes into commercial varieties."

Transgenic bananas possess a gene or genes that have been transferred from another plant species. The term "transgenic plants" refers to plants created in a laboratory using recombinant DNA technology.

Tripathi said that the development of stable and reproducible transformation and regeneration technologies has opened new horizons in banana and plantain breeding. The development of transgenic banana and plantain has been reported by several groups, but a commercial transgenic banana variety is yet to be released.

There are no cross-fertile wild relatives in many banana-producing areas. Most edible bananas and plantains are male and female sterile. The clonal mode of propagation makes the risk of gene flow from banana to another crop species not an issue.

IITA's in vitro screening method for early evaluation of resistance to BXW uses small tissue culture-grown plantlets. This method can be used by breeders for screening *Musa* germplasm with larger numbers of cultivars for resistance to BXW and other bacterial diseases.

Currently, most transformation protocols for banana use cell suspensions, Tripathi said. Establishing cell suspensions is a lengthy process and cultivar dependent. At present, the major barrier in transforming East African Highland Bananas (EAHB), a cooking banana from Uganda, is the limited success in producing embryogenic cell suspension cultures from a wide range of cultivars. IITA scientists in collaboration with NARO have developed a rapid and efficient protocol using a cultivar-independent

"Developing resistant varieties is a long-term but more sustainable way to control pests and diseases." - Leena Tripathi

transformation system for improving *Musa* species including EAHB. This new technique has paved the way for the development of a transgenic banana using transgenes from sweet pepper that confer resistance against BXW.

Tripathi explains how the technology works: the ferredoxin-like amphipathic protein (*pflp*) and hypersensitive response-assisting protein (*hrap*), were isolated from the sweet pepper, *Capsicum annuum.* These are novel plant proteins that intensify the harpinPSS-mediated hypersensitive response (HR). These proteins have a dual function: iron depletion antibiotic action and harpin-triggered HR enhancement. The transgenes were shown to delay the hypersensitive response induced by various pathogens in nonhost plants through the release of the proteinaceous elicitor, harpinPss in various crops including dicots such as tobacco, potato, tomato, broccoli, orchids and monocots such as rice. Elicitor-induced resistance is not specific against particular pathogens, hence it is a very useful strategy.

Banana *Xanthomonas* wilt-infected plants. Photo by IITA

The *pflp* genes encode for ferrodoxin, which exists in all organisms, and is therefore common in human diets. This protein is safe for human consumption and the environment. The *pflp* and *hrap* genes are owned by Taiwan's Academia Sinica, the patent holder. IITA has negotiated a royalty free license through the AATF for access to the *pflp* and *hrap* genes for use in the production of BXW-resistant varieties in sub-Saharan Africa.

Hundreds of transformed lines of various banana cultivars have already been generated, and are under screening for disease resistance under laboratory conditions. The most promising will be evaluated for efficacy against BXW in confined field trials under different farming systems by national partners with IITA. The transgenic lines will be tested for environmental and food safety, in compliance with target country biosafety regulations, risk assessment and management, and seed registration and release procedures. The project will also study public perceptions, consumer preferences, and the acceptability of transgenic banana in Africa to guide commercialization and wide use.

"Wide-scale deployment of genetically modified, farmer-preferred banana varieties in African countries would succeed only with effective interinstitutional partnerships, particularly with advanced research institutions, AATF, national committees on biosafety, nongovernmental organizations, and private tissue culture companies," explained Tripathi. "This project will enhance the capacity of partners from the national agricultural research and extension systems in genetic transformation of banana, molecular biology, and biosafety. High-yielding BXW-resistant banana will bring greater productivity for smallholder farmers in East Africa and improved food security."

IITA R4D Review

The IITA R4D Review is published by IITA, Africa's leading research partner in finding solutions for hunger and poverty.

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The **IITA R4D Review** is a semiannual magazine intended to be a mechanism to help IITA provide the best new ideas for people creating, leading, and transforming tropical agriculture in sub-Saharan Africa.

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