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Photo from Wikimedia Commons



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The **IITA R4D Review** is a six-monthly magazine intended to help IITA and research and development partners, investors, collaborators, and beneficiaries discuss and develop the best new ideas for people creating, leading, and transforming tropical agriculture in sub-Saharan Africa and beyond.

The R4D Review has six sections:

Features provides an in-depth, rigorous presentation of a significant advance in research-for-development thinking and its application to real world needs that help establish an intellectual agenda for discussion—and change—within the organizations and for society at large.

Best Practice describes the how and why behind a successful research for development achievement.

Tool Box provides a nuts-and-bolts explanation of a useful research-for-development tool that can be translated into action in many different situations.

Who's Who recounts a personal story of an IITA staff that contains lessons for colleagues.

Looking In features people from outside IITA whose ideas hold salient lessons for those within IITA.

Frontiers is a forum for forward-looking articles that explore new science and technology trends affecting development needs (i.e., starting projects or technologies in the pipeline).

CONTRIBUTIONS needed

The R4D Review is looking for new sources of solid, useful ideas that can improve research-for-development practice. Please submit your contributions or participate in the R4D Review interactive site at www.iita.org/r4dreview. The general guidelines for contributions are also available at this site. Prospective authors can also send submissions, communications, comments, and suggestions to: The Editor, R4D Review.

Headquarters: IITA, PMB 5320, Ibadan, Nigeria
Mailing address: IITA, Carolyn House,
26 Dingwall Road, Croydon CR9 3EE, UK
Telephone: (234 2) 7517472, (1 201) 6336094
Fax: (234 2) 241 2221
www.iita.org

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This commentary by Rachid Hanna, IITA entomologist and biocontrol specialist, presents a comprehensive review of IITA's past and present efforts, and future initiatives on biocontrol. It also forwards some insights on how biocontrol efforts could be more successful.

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Last August, the international community came together in Tanzania to establish a framework—presented here—for combating the worst enemies of African banana in years—banana *Xanthomonas* wilt and banana bunchy top disease.



The power of biocontrol

Farmers and scientists have, time and time again, turned back to nature to find solutions to pest problems in crop fields.

When several exotic pests were accidentally introduced into Africa from South America through infected planting materials in the early 1970s, ravaging economically important crops, such as cassava, scientists turned to the origins of the pests to solve the problem.

A lot has been said about the benefits of biological control or biocontrol. It is natural and safe to the environment and humans, and rigorous tests ensure that it is effective only on the target pests.

And almost three decades of research and development at IITA have shown the continuing effectiveness and sustainability of biological control in combination with other approaches for managing insect pests.

These biocontrol practices and technologies provide the subsistence farmers in sub-Saharan Africa with solutions that are sometimes their only safety net.

This issue on biocontrol celebrates the success of solutions to problems in tropical agriculture that IITA and its partners have developed for millions of African farmers.

A commentary on IITA's biocontrol activities shows the diverse range of work that the Institute is doing in this area. A series of features describes the many successes and widespread impact of IITA's biocontrol work, and focuses on best practices in managing *Striga* and fruit flies. The interviews with IITA scientists and collaborators highlight ongoing efforts and constraints in battling agricultural pests to help secure food supplies in Africa. IITA continues efforts to manage the problem of disease pandemics caused by viruses with the help of their vectors.

Thanks to continuing efforts of the national agricultural research systems and the international community, farmers in sub-Saharan Africa are now enjoying the benefits of biological control work.

“*Biological control...cannot be a substitute for mismanaged plant production, in short, for bad farming. To have access to the full power and potential of biological control, the crop production system needs to be fully integrated in the larger agroecosystem, fulfilling the principles of agroecology.*”

- Hans Herren, World Food Prize recipient and former IITA scientist



Male of the variegated grasshopper (Zonocerus variegatus) feeding on cassava, IITA–Benin.
Photo by Christiaan Kooyman, Wikimedia Commons

PROSAB ends

An 81% increase in farmers' incomes over the past 5 years from improved yields, better access to farm inputs, and social empowerment are the key results of the US\$6.33 million PROSAB project in northern Nigeria.

PROSAB is Promoting Sustainable Agriculture in Borno State, a project started in 2004 by IITA with Canadian International Development Agency (CIDA) funding.

In a conference held last September in the state capital of Maiduguri, government officials, farmers, participants, local partners, and other stakeholders said that PROSAB has "helped significantly increase agricultural productivity and build the capacity of thousands of farmers and farmers' associations in the northern Nigerian state."

Key project interventions included the introduction of improved crop varieties from IITA, training of farmers on improved agronomic practices, and promotion of gender equality, especially empowerment of women, in agricultural development.

The local government plans to upscale the project to further reduce poverty by promoting greater farmer education on best agricultural practices through the Agricultural Development Program; and encouraging more women to participate in the program.

Amare Tegbaru, PROSAB Manager, says the program has also improved the nutrition of farmers, especially children. "Farmers who adopted improved technologies and management practices experienced increased food availability and improved livelihood. Also, considerable progress has been made in addressing the problems of declining soil fertility and witchweed (*Striga hermonthica*)," he says.

Google books

Enhanced knowledge availability

IITA is promoting greater access to R4D knowledge by making use of knowledge resource access, video-sharing, and online social networking services.

Last year, in partnership with Google Books, IITA started digitizing and uploading more than 200 publications, which are now available via Google Book Search (GBS). It also uploaded videos in SciVee and YouTube. Now, IITA has accounts with Twitter and Facebook too.

Increasing its online presence is an initiative aimed at "getting the word out" to a wider audience and driving more traffic to the Institute's Web sites. With these free and popular online services, IITA is potentially tapping into a 300 million-plus combined user-base. Even with just a 1% bite, potentially some 3 million people will get to know more about IITA and what we do.

Dual-resistance cassava

IITA scientists are a step closer to making a breakthrough in developing cassava that is resistant to both the cassava brown streak disease (CBSD) and the cassava mosaic disease (CMD) in Eastern and Central Africa. The two diseases



Farmer tending soybean field, Borno State. Photo by IITA

are the biggest threats to cassava production in the region putting at risk the food security and livelihoods of over 200 million people.

According to Edward Kanju, IITA cassava breeder, 14 types of the crop under research are very promising. Kanju's team had just harvested an advanced trial of such cassava in Uganda.

This is the fourth year of trials for dual-resistance cassava for the mid-altitudes in Uganda. The trials are being conducted at Mukono, near Kampala, an area regarded as a hot spot for CBSD and CMD. The breeding work started with over 5,000 true seeds of parents with tolerance to CBSD from Tanzania for crossing with IITA varieties that are resistant to CMD.

Farmers have also been involved in the selection process to ensure that the varieties meet their preferences on cooking, taste, texture, and yield. Breeding for dual-resistance cassava is also being conducted in Tanzania and DR Congo.

Drought-tolerant maize

Drought-tolerant maize developed and disseminated by IITA, other international agricultural research centers, and national partners are helping farmers make a profit despite droughts in northern Nigeria. Drought remains one of the major limiting factors to profitable maize production in Africa.



Boy selling maize.

Photo by IITA

"The drought-tolerant maize varieties have mitigated the effects of drought on maize production and farmers are having better incomes," says Olumide Ibikunle, Research and Development Manager, Premier Seeds. "The seed industry is also better off because demand for maize has actually increased."

Over the years IITA, CIMMYT, and partners have released several drought-tolerant varieties including Samaz 16, ZM309, and ZM523, in sub-Saharan Africa to cushion the effects of drought on the crop and, ultimately, on farmers and their households.

Researchers and other stakeholders said that developing such varieties will boost maize production, enhancing not only incomes but more importantly food security.

Rust-resistant soybean

A new soybean variety that is resistant to the deadly Asian soybean rust—a fungal disease that could wipe out as much as 80% of infested

crops—has been released. The rust-resistant soybean is the first of its kind to be made available for cultivation in West and Central Africa and has the potential of increasing soybean production in rust-prone areas of the region.

Tagged TGx 1835-10E, the variety was bred by scientists at IITA and further developed in collaboration with Nigeria's National Cereal Research Institute (NCRI).

"The variety is high yielding, averaging 1.6 t/ha grain and 2.2 t/ha fodder in field trials in Nigeria," says Olumide Shokalu, NCRI pathologist who conducted the trials. It is also early maturing, has good promiscuous nodulation, and resists pod shattering and other prevalent diseases.

"The variety can be used for direct cultivation in tropical Africa or as a source of resistance genes. It was previously released in Uganda through Makerere University, and has already shown excellent performance in trials carried out in Southern Africa, suggesting that it is a well-adapted variety," says Hailu Tefera, IITA soybean breeder.



Farmers keen on GM crops

The debate rages about the role of genetically modified (GM) crops in ensuring food security in sub-Saharan Africa, yet the level of awareness and basic understanding of GM crops remains low among small-scale farmers in Tanzania, a study reveals.

The study, conducted recently by IITA with the Africa College of the University of Leeds, assessed the understanding and attitudes of local farmers towards GM crops, using disease-resistant cassava as an example. It was carried out in three districts in Tanzania where cassava is an important staple crop with the Mikocheni Agricultural Research Institute and the Tanzanian Commission for Science and Technology.

The study team had to overcome difficulties of explaining GM crops in Swahili to Tanzanian farmers. They reported that the majority of the farmers interviewed said that they had never heard of GM crops. The farmers asked if these new crops were similar to hybrids and whether or

not they would look and taste like current crops, or grow differently from them.

The study also found that the level of awareness was equally low among the district agricultural extension officers and relevant local district employees. Farmers look up to these officials for information and guidance.

However, the majority of the farmers were keen to increase their knowledge. They were also more interested in the potential of these crops to increase their productivity than concerned about any potential middle- to long-term risks associated with GM crop use.

Dr Caroline Herron, former IITA virologist involved in the research, said that it was clear from the study that there is a need to increase the knowledge of farmers on the pros and cons of GM crops to enable them to participate fully in the debate.

“It is important for the scientific community to raise the awareness levels of farmers by providing accurate and objective information so that they can make informed and autonomous decisions on the potential of GM crops in their agricultural practice,” she said. “The tendency of farmers to focus on short-term gains in productivity should not prevent the potential middle- and long-term risks being fully explained to them to allow them to make a clear judgment.”

According to the study, one barrier to raising awareness about GM crops in the country is the lack of a specialized vocabulary in Swahili for GM. The study recommends that appropriate Swahili terminology to facilitate better understanding should be developed before any campaign is launched to create awareness about GM crops.



Researcher in cassava field. Photo by IITA

The study further recommends that any potential trial for GM crops should be conducted in close consultation with government bodies, backed by a biosafety framework that aims at preventing any potential harm resulting from their use.

Tanzania has made good progress in developing such a framework. The country is a signatory to the Cartagena protocol that outlines the minimum standards of biosafety regulations that must be adopted by all the signatories. More significantly, the country's biosafety framework was recently approved by the Cabinet after a lengthy consultation process.

Tanzanian scientists and IITA are working on developing GM cassava varieties that are resistant to both cassava mosaic disease and cassava brown streak disease. If they are successful, these crops could, in the future, be used to enhance the resistance of existing local varieties to increase the country's food security.

When the issue of safety was raised, many of the participants placed their confidence on the government's rules and regulations, which, they felt, would have been followed prior to the development of any GM crop.

The survey also identified concerns that farmers wanted addressed before participating in any GM crop trial. Farmers need unbiased information about the crops, preferably from scientists who developed them. The involvement of scientists in all stages of the trials—from ground preparation to planting to harvesting—was also very important.

The farmers also had confidence that the government would put in place strict rules and regulations that would be followed by both government entities and scientists in the development and trial of these crops. Some of the respondents stated that they would be seriously concerned if there were no such regulations in place and that this would prevent them from taking part in any trial.



Cassava harvest. Photo by IITA

During the trials, the farmers said that they would look not only at the crop yields but also their growth pattern, resistance to pests and diseases, and the labor required to care for the new varieties during the growing season. The taste of the new variety was also considered important by farmers who sold their surplus crop.

When asked whether they would eat the GM crops, they said that the involvement of scientists and the government in GM crop development would greatly increase their confidence to do so. According to one respondent in Bagamoyo: "...because of the way these crops are made, I would be worried about eating them unless scientists were involved in the trials and they ate the crops with me. This would show me that they believed they were safe."

Editor's note: The work on GM crops in Tanzania is at a very early stage and no GM cassava has been developed yet. So far, all the disease-resistant cassava varieties under trial have been developed through conventional breeding.

Unraveling the diversity of African insects

“A problem identified is half-solved.”
— Anonymous

The IITA insect center in Bénin houses one of the largest reference collections of arthropods and microorganisms in West Africa. An insect identification hub, it plays the role of a “gatekeeper” by facilitating the discovery and monitoring of invasive pests in the region. The resulting information helps to locate the probable area of origin where promising natural antagonists may be found.

Several invasive insect pests have recently been identified by the center, among which are fruit flies, whiteflies, and moths. An example was when a myriad of caterpillars and moths invaded Liberian farms early this year, providing entomologists a puzzle. The identity of this pest that devastated crops and contaminated water supply in northern Liberia had been established through the joint efforts of FAO, IITA, and CABI. It was later identified as *Achaea catocaloides* by Dr Georg Goergen, IITA entomologist and biosystematist. The insect is a member of the Lepidoptera group and known as a fruit-sucking moth.

Goergen says that proper identification is a starting point for any basic or applied research and a prerequisite for any successful biocontrol program. “Any biocontrol approach without proper identification of the insect pests will fail,” he says.

Rapidly accelerating human trade, transport, travel, tourism, and porous borders have dramatically contributed to the introduction, ease of movement, and spread of invasive pests thereby overwhelming the capacities of quarantine services in West Africa.



Entomologist Georg Goergen working in his lab, IITA-Benin. Photo by IITA

IITA works with national and international partners to control the spread of these invasive species. In addition to its role of identifying insects, the center is also helping scientists to unravel and conserve the rich diversity of African insects.

Through the identification of insect specimens, scientists get more insight on the species richness of the African insect diversity in various ecosystems, the structure of their populations, their interrelationships, and interactions with their habitats.

Insects represent the majority of living organisms, accounting for about two-thirds of all living animals on earth and filling many niches in both terrestrial and aquatic ecosystems. They thus play an important regulatory role in all ecosystems including agricultural environments. Many of them can become notorious pests of agricultural, medical, and veterinary importance.

However, existing knowledge on insect diversity is still inadequate for large parts of the globe and no one knows exactly how many species of insects exist. The situation is worse in Africa where much of the planet’s biodiversity occurs, but where traditionally the scarcity of biosystematists is the strongest.



A small part of the insect collection, IITA–Benin. Photo by IITA

Goergen says, “Biosystematics is important in all phases of a control program starting from a reliable pest identification, assessment of native antagonists, monitoring faunal changes following the use of exotic beneficials, and detection of eventual nontarget effects. To do that, you need to have a reference collection such as the one we have here in Cotonou.”

IITA has developed a strong regional capacity in biosystematics through the West

African Network for Taxonomy, BioNET-INTERNATIONAL.

The center continues to attract students from different parts of the world while offering capacity building and ensuring a requisite contribution to countries seeking to comply with the sanitary and phytosanitary agreement of the World Trade Organization and to fulfill the objectives anchored in the Convention on Biological Diversity.

Biological Control 101



Chemical pesticides have become a mainstay in pest management because of their “quick-fix” effects and their ease and convenience of use. Their use over time, however, has some negative effects on human health and the environment.

Biological control or biocontrol is an alternative to the use of chemical pesticides. It uses natural “enemies” to reduce pest populations and their damage to crops and food products. These enemies include predators, parasitoids, or pathogens.

Biocontrol approaches build on the natural control already existing within an ecosystem by strengthening a naturally occurring enemy or by importing and introducing a natural enemy into that ecosystem.

IPM toolbox

Biocontrol is just one of the many components in the integrated pest management (IPM) toolbox that includes, among others, the use of cultural practices, planting of resistant or tolerant crop varieties, and the application of inorganic (or chemical) pesticides.

Biological alternatives involve the use of biological control, biological pesticides,

botanicals, semiochemicals, and transgenic organisms.

Biocontrol

Biocontrol is the use of natural enemies, also called biological control agents, such as predators or parasitoids that attack the pest to reduce pest damage. In an undisturbed ecosystem, insects, mites, or microorganisms, and other species that prey on or parasitize different species are part of the natural control or balancing mechanisms.

Biocontrol approaches include conservation biocontrol, augmentation biocontrol, and classical biocontrol.

Conservation biocontrol enhances the effectiveness of natural enemies already present in the ecosystem through, for example, the application of cultural practices. Examples include planting food sources for natural enemy pests or reducing the amount of chemicals in the system to allow natural enemy numbers to increase.

Augmentation biocontrol means the addition of a predator or parasitoid to an ecosystem to increase numbers or begin a new population when the natural enemy has disappeared. Inoculation is adding



small numbers of the species, which increase naturally over time, whereas inundation means adding large numbers of the natural enemy for a rapid effect on the pests.

Classical biological control involves importing natural enemies to a location where they have not been present before, especially, when a pest has been accidentally introduced. Classical biocontrol has been applied successfully to control hundreds of pests in horticultural and field crops and in forestry. Despite the initial high investment, it is the most economical form of pest control.

Biopesticides

Biopesticides involve the use of pathogens—microorganisms that cause disease—to kill pests. Also called microbial pesticides, they contain pathogenic microorganisms as their active ingredient, e.g., bacterium, virus, fungus, nematode, or protozoa. They are applied in a manner similar to chemical pesticides, but their "live" ingredient gives them a potentially greater advantage over chemicals since this is able to reproduce and provide continuing pest control.

Some popular examples include the use of *Bacillus thuringiensis* (*Bt*), which naturally occurs in the soil and in plants, or mycopesticides (insect-killing fungi) such as *Beauveria bassiana* and *Metarhizium anisopliae*, which attack a relatively wide

range of insects. IITA has been using these fungi for its biocontrol work.

Botanicals

Also called botanical pesticides, these contain plant extracts that have biocidal properties. The best example is the use of the extracts from the popular neem tree (*Azadiracta indica*) (active ingredient: azadirachtin), which can be used to disrupt molting in a wide range of insect pests. Such botanicals can be grown alongside agricultural crops.

Semiochemicals

These are chemicals produced by insects and other species that stimulate behavior or interactions, and are used to manipulate behavior to control pests. Well-known examples are pheromones, which stimulate behavior between individuals of the same species, and allelochemicals, which mediate interaction between different species.

Transgenic crops

Transgenics contain protectants produced by the plants themselves, following the introduction of genetic material coding for that substance, as in *Bt* transgenic plants, e.g., *Bt* maize, potato, and cotton. The gene coding for the *Bt* toxin is inserted into the chromosome of the crop plant so that the plants themselves become toxic to the pest.

Source: SP-IPM. 2006. Biological alternatives to harmful chemical pesticides. IPM Research Brief no. 4. SP-IPM Secretariat, IITA.



Biological control at IITA – past, present, and future

Rachid Hanna, r.hanna@cgiar.org



Biological control is one of the oldest and most useful and eco-friendly approaches to pest management.

IITA has had an excellent tradition in biological control which has given it some of its greatest successes. These were captured by Peter Neuenschwander in his 2004 commentary in *Nature*.

The past and the present

The invasion of Africa by the cassava mealybug and the initial failure to find a solution to this devastating pest marked the start of a series of highly successful biological control efforts led by IITA in collaboration with partners from Africa and from around the globe. The mealybug invasion was shortly followed by the cassava green mite, also originating from South America. The duo devastated production throughout the cassava belt. Finding a natural enemy—a tiny parasitic insect (renamed several times) *Anagyris* (= *Apoanagyris* = *Epidinocarsis*) *lopezi*—for the control of the mealybug was relatively quick. Once it was released, the parasitoid quickly established. Aided by over 150 additional releases and within a span of

12 years the parasitoid covered nearly all of SSA, in the process leading up to 90% reduction in cassava losses and up to US\$29 billion in estimated value of crop recovery.

The campaign for green mite biological control followed an approach similar to that of the mealybug, but it took much longer to find appropriate predators that would eventually provide the control needed for cassava recovery from the two South American invaders. Three promising predators (tiny phytoseiid mites) were established, one became extinct, another was restricted to humid regions, and a third species (*Typhlodromalus aripo*) became nearly the equivalent of *A. lopezi* (without the many name changes!).

Within a span of 11 years and over 450 additional releases, *T. aripo* has been established in at least 22 countries. Where it has been present for 2 or more years (and where cassava varieties have at least partly hairy apices that are favorable for *T. aripo* colonization and persistence), it brought down losses to the mite from an average of 35% to below 10% (after



Banana bunchy top and banana aphid survey, DR Congo. Photo by IITA

mealybug control), resulting also in billions of dollars in crop recovery.

The mealybug and green mite campaigns have been credited for bringing the capacity of biological control to SSA and spreading its science and practice as no other on any continent has done. Several successful projects followed, including that of the mango mealybug (an invader from India) and the spiraling whitefly (a polyphagous pest from the Caribbean), and extended to control of the water weeds. These successful efforts added another billion US\$ in estimated savings.

These campaigns provided the stimulus and the capacity to build on successes with the continuation of biological control efforts at IITA. Presently, cowpea thrips and cowpea pod borer are being fought with the tiniest of known parasitoids (for thrips) and with a combination of a parasitic wasp and a virus (for cowpea pod borer). Programs are under way to tackle several other devastating pests: the coconut mite (from South America), the banana aphid (an invader from Southeast Asia and the only vector of the devastating banana bunchy top virus), the Sri Lanka fruit fly (now present in 24 countries and on more than 50 host fruits in Africa), and a variety of indigenous pests including the African root and tuber scale (in the Congo Basin), the sweet potato whitefly (vector of cassava mosaic viruses throughout Africa), cotton worms, several pests of cashew, and several fruit fly pests of fruits and vegetables.

However, biological control of indigenous pests is much more challenging than the control of exotic pests and tends to be insufficient alone. It often requires integration with one or more approaches, such as host plant resistance and cultural controls, among others. A prime example of this challenge is the control of the whitefly *Bemisia tabaci*, the vector of the viruses that cause the devastating cassava mosaic and cassava brown streak virus diseases in cassava fields in Africa (J. Legg, this issue). *B. tabaci* can be controlled with inundative releases of parasitoids and



Release of Fopius arisanus in a mango orchard in Parakou, Benin. Photo by IITA

predators in protected and high-value agricultural systems. However, biological control alone has not been sufficient. Other complementary tactics, particularly host plant resistance, are necessary if we are to rein in this pest.

IITA in partnership with the *Centre de cooperation internationale en recherche agronomique pour le developpement* and Africa Rice Center has recently demonstrated the usefulness of the weaver ant in fighting off pests of mango and other tree crop pests. A sister species has been used in pest control by the Chinese for thousands of years. The article by Vayssieres et al. (this issue) shows that this native predator works principally by repelling the damaging fruit flies. The effectiveness of this ally has been demonstrated. Now its full potential is being exploited through a campaign to inform farmers how to manage this ant to promote its abundance and provide an additional weapon in the sustainable control of fruit fly pests.

Nearly parallel to the development of biological control with parasites and predators in Africa is IITA and its partners' pioneering work on the development of microbial agents for the control of a variety of pests and pathogens.

The first pioneering success was the development of the biopesticide Green Muscle®. Based on a naturally occurring fungus *Metarhizium anisopliae* var. *acidum*, this natural and now commercial



Aflatoxin-contaminated groundnut kernels from Mozambique. Photo by IITA

product has proved to be the weapon of choice against a variety of devastating pests, such as the red and desert locusts.

The successes of biocontrol of the mealybug with parasitoids and green mite with predators opened the gate for numerous other programs that relied on arthropod biocontrol agents. The success of Green Muscle® has also given substantial impetus to a variety of other efforts aimed at harnessing the power of naturally occurring microbes to fight harmful pests.

Microbial agents are being developed for pests that are very difficult to control, such as parasitic weeds. IITA's efforts to rein in the parasitic weed *Striga hermonthica* or witchweed is paying dividends. *Striga* attacks maize, sorghum, and millet, often the sole staple crops in many areas of the Sahel of West Africa. Biocontrol agents—host-specific strains of the common pathogen *Fusarium oxysporum* f. sp. *striga*—in combination with *Striga*-resistant/tolerant varieties are giving farmers in SSA hope for controlling a scourge that causes some \$7 billion in annual crop losses.

Similarly, IITA and its partners have found strains of the fungus *Beauveria bassiana* that can serve as a full replacement to toxic pesticides used to control the diamondback moth, a pest that can cause complete loss of cabbage crops if unchecked. This pest has developed resistance to many

pesticides and has forced farmers to rely on the excessive application of pesticides that are not even meant for use on food crops, such as cabbage. That treadmill can end with the new microbial agent.

More recently microbial control has taken another innovative and pioneering direction at several IITA locations in SSA. In a twist on the concept of using beneficial arthropods to fight off harmful arthropods, fungi that do not produce mycotoxins were identified and used to exclude toxogenic strains that contaminate stored grains. Similarly, endophytic fungi that grow harmlessly inside the banana plants have been used to impart resistance to pests such as weevils and nematodes that have, in some places, resulted in farmers abandoning banana and plantain production.

The list goes on. Last but not least, entomopathogenic nematodes are being explored for the control of an indigenous pest—the African root and tuber scale—and an exotic pest—the banana weevil.

For as long as there are problems and experienced scientists and staff to deal with emerging problems, IITA will continue to strive to be a leader in the field of biological pest control.

Key to successes

At the heart of these efforts and as the key to this success were fruitful partnerships and sustained donor support. The message: complementary capacity—be it geographic, scientific, or political—is essential for the development and implementation of successful technologies on a continental scale. (IITA's partners and donors can be found on our Web site at www.iita.org). IITA's partners are from all corners of the globe and run the spectrum of all research and development institutions. The core are CGIAR sister centers, universities, government (including NARS) and UN agencies, and (more recently) the private sector.

The sustainability of biological control has numerous requirements. Chief among them is donor and institutional commitment

followed by the recruitment and retention of highly experienced scientists to lead the development of innovative pest control. All require long-term commitment, because the goal can take a long time to achieve but the payoff is often handsome.

While the mealybug and green mite programs brought biological control to Africa, training of African scientists has been the key to the successful dissemination of the capacity to do biological control. IITA has led this effort in Africa. The continuity and scope of such training will be necessary if we are to emulate past successes.

Of particular significance and another central element in the success has been the correct identification of pests and natural enemies; this is fundamental because it provides knowledge not only on identity but also about origin and distribution, biology, association with other organisms, evolutionary relationships, and other important topics. Without the proper naming and organization of organisms, biological control would be haphazard and chaotic, and can lead to failure and considerable waste in time and resources.

Lessons

The scientific lessons learned from past and present efforts are numerous.

Anagyrus lopezi, the parasitoid responsible for the control of the cassava mealybug, is host specific and has an incredible capacity for dispersal (about 350 km per year) and for finding its host, which had been key to its ability to keep mealybug populations

at low levels. The parasitoid originated from the LaPlata Valley (Paraguay) where conditions are not like those common in Africa. Nevertheless, *A. lopezi* proved to be highly adaptable. It quickly established and efficiently controlled the mealybug from the Sahel to the Congo Basin and to the East African Highlands. This example highlights some difficulties in predicting the outcome of biological control introductions that otherwise would eventually prove effective in controlling the target pests while relying on classical criteria for selecting natural enemy candidates.

A similar lesson was drawn from the green mite biocontrol program. Eleven species of predatory mites were introduced into Africa during the exploration phase of the program. *T. aripo* was the least efficient in terms of predation and efficiency in turning energy from consumed prey into the production of its own offspring. However, it turned out to be best at becoming established and dispersing (> 200 km per year), and in controlling green mite. The key was not its voracity but its ability to use the apical growing point of cassava as a shelter, to be so tuned to cues from its plant and prey to locate them, to use plant-based food for sustenance during periods of low prey abundance, and to have a phenomenal dispersal capacity. This is a landmark lesson: voracity and rate of population growth need not be always the top criteria in selecting effective natural enemies, as by these criteria, *T. aripo* would not have been selected for introduction into Africa.

Impact of IITA's integrated pest management projects

Pest and year of appearance	Biocontrol agent	Area under analysis	Reduction in loss (%)	Estimated savings (US\$ million)
Cassava mealybug (1973)	Encyrtid wasp <i>Anagyrus lopezi</i>	27 African nations	90–95	7,971–20,226
Cassava green mite (1971)	Phytoseiid mite <i>Typhlodromalus aripo</i>	Nigeria, Ghana, Bénin	80–95	2,157
Mango mealybug (1980s)	Encyrtid wasp <i>Gyranusoidea tebygi</i>	Bénin	90	531
Water hyacinth (1980)	Weevil <i>Neochetina eichhorniae</i>	Bénin	36	260

Source: Adapted from Neuenschwander P. Harnessing nature in Africa: Biological pest control can benefit the pocket, health, and the environment. *Nature*. 432:801-802.

The future

Invasive weeds and arthropods continue to hamper development and ravage and disrupt agricultural and natural ecosystems, and doubtless many will continue to make it through porous borders. IITA has been a leader in developing options for controlling the invaders and restoring that balance. While classical biological control will likely continue to be the preferred way to deal with invaders, greater intensification of agricultural production, with its associated reliance on external inputs, necessitates an integrated approach. Biological control will be a component of a package that may include selective pesticides, varietal resistance, attractants and behavioral disruptants, as well as appropriate agronomic practices.

Hans Herren—former IITA scientist and recipient of the World Food Prize—in his foreword to the book *Biological control in IPM Systems in Africa* (Neuenschwander et al. 2003, editors) wrote: “Biological control, however, cannot be a substitute for mismanaged plant production, in short, for bad farming. To have access to the full power and potential of biological control, the crop production system needs to be fully integrated in the larger agroecosystem, fulfilling the principles of agroecology. Under such a system, the powers of biological control can best be unleashed, and its synergistic effects with host plant tolerance/resistance, habitat management, and agronomic practices brought to bear maximum impact.”

The old and timeless adage—an ounce of prevention is worth a pound of cure—captures the essence of the need and

value of preventing the invasion of new species. Key to effective prevention is the development and maintenance of the capacity for quarantine, surveillance and readiness to develop appropriate options to deal with the invaders and limit their impact on African agriculture and the rest of the African ecosystems.

We also need more modeling for predicting the distribution and abundance of pests and their potential natural enemies to guide the development of experimental approaches to pest problems. Climate change can affect pests and their natural enemies in many ways. Modeling, along with long-term monitoring and demographic studies can be useful approaches to determining the effects of climate change on pests and their natural enemies.

Greater emphasis is needed on the use of the modern tools of molecular biology to trace the origin of invaders and use that knowledge to search for natural enemies where the invaders originated. Taxonomic services (and their associated collections) have been and will continue to be one of the essential tools in successful programs. In addition—and among their many uses—biodiversity collections can often serve as the first stop for foreign exploration against pests and weeds on other continents.

The targets will doubtless change. Highly trained and experienced staff will always be necessary to address the new targets. We also need to continue to strengthen existing links and develop new complementary partnerships. Training of local staff and African scientists is essential for them to become leaders in biological control in their countries, capable of running their own programs.

The younger generation is the one to find the solutions to future threats to the continent’s food security and livelihoods of its inhabitants. Improvements in the health of ecosystems will go a long way in protecting and promoting biodiversity. Biological control, if carefully developed and implemented, is the greenest approach to saving farmlands, waterways, savannas, and forests from the ravages of pests.



Farmers field school on IPM in Mali.

Photo by IITA

BEST PRACTICE

Hope for cabbage farmers

African cabbage farms ravaged by the Diamondback moth (DBM), *Plutella xylostella*, are set to recover with the help of a biopesticide (*Beauveria bassiana*) developed by IITA scientists to kill the pest.

Resource-poor farmers, who have tried the fungal pesticide, said the biocontrol method has proved effective in controlling the insect pest that has devastated both smallholder and large-scale cabbage farms in Africa. DBM had earlier forced thousands of farmers in West Africa to abandon cabbage production for other crops.

“We now have the hope of promising results obtained using *B. bassiana*,” says Raymond Ahinon, who heads the Crop Department at the Songhai Center. Songhai is a commercial farm center in Porto Novo, Republic of Bénin. “The product is effective, and has helped in eradicating DBM on our cabbage farms.”

Cabbages are among the most important vegetables in Africa in general and particularly in Bénin, especially for lower income groups. It serves as an income source among groups most affected by poverty, including small farmers, youths, and most especially women who play an important role in agricultural production.

Eaten daily, either raw in salads, steamed, boiled or fried, cabbages and their cousin, kale, serve as important cash-generating crops.

Why biological control

In recent years, chemical control of DBM is proving ineffective, according to farmer Louis, who has been cultivating the crop since 1986 in his farm in Porto Novo.

Dr Ignace Godonou, IITA entomologist based in Cotonou, Republic of Bénin, says the pest has developed resistance to a wide range of insecticides, including *Bacillus thuringiensis*, a biological agent used against the pest. The situation is made worse by the high costs of inorganic or chemical pesticides.

“The most common chemical pesticides used by farmers are bifenthrin and deltamethrin,” says Godonou.

“These chemicals need to be applied about 19 times within three months of the crop’s growth prior to harvest. Also, acquiring these chemicals comes with a cost that is sometimes prohibitive.”



Cabbage ravaged by DBM.
Photo by IITA



Plutella xylostella. Photo from Wikimedia Commons

On a global scale, chemical control is estimated to cost about US\$1 billion annually. The accompanying package of health and environmental risks include pollution, destruction/death of nontarget but sometimes useful insects, and the reduction of biodiversity.

But there is good news. Biological options in an integrated pest management approach could offer a solution to sustainable control of DBM, according to Godonou.

So far resource-poor farmers use botanical pesticides, mostly aqueous seed extracts of the neem tree, against DBM and a wide range of other arthropod pests. The success of this approach, however, has been limited.

B. bassiana to the rescue

In search of sustainable biological agents to control the pest, Godonou says eight isolates of the entomopathogenic fungi *B. bassiana* and *Metarhizium anisopliae* indigenous to Bénin were screened for virulence against larvae of the insect. Two isolates showed promise.

One, Bba5653, caused 94% mortality of DBM larvae, and mortality was significantly higher than that caused by any other isolate. Cabbage yield was approximately three-fold higher than the yield in plots treated with the insecticide bifenthrin or in untreated plots.

In a study published in the journal *Crop Protection* in 2008, Godonou and his colleagues said that fungi, such as *B. bassiana* and *M. anisopliae*, are ubiquitous

in nature and are specific to target pests. They persist in the environment and are easy to mass produce.

Co-author C. Atcha-Ahowe says field trials of the *B. bassiana* biopesticide have sparked demand for the commodity.

“The majority of farmers who abandoned cabbage cultivation for other crops are now requesting the biopesticide so they can go back to growing the crop, but not enough of the product is available,” he says.

When compared to the production of other vegetable crops, such as carrots and lettuce, cabbage cultivation results in higher returns, say resource-poor farmers. The gap is exacerbated by the increasing demand and the dwindling supply of cabbage.

An opportunity for the private sector

Like the highly successful Green Muscle®, which was picked up by the private sector, Godonou says the *B. bassiana* technology is another opportunity waiting for the private sector.

He says farmers are willing to patronize the product to control the cabbage enemy and increase farm yield, but there should be enough supply to meet the demand.

“With the ability to remain active on the field for several months after initial application, *B. bassiana* will end the rigor of repetitions and costs associated with the application of synthetic chemical pesticides,” he adds.



Larva of DBM killed by Bba5653 (externally covered with whitish mycelia and spores of Bba5653). Photo by IITA

Safeguarding against locust invasion

Fourteen years after the introduction of the fungal biopesticide—Green Muscle®—developed by IITA's scientists with their partners, the product is gaining more prominence as a control option against invasive locusts that threaten African farmlands.

Recently, the biopesticide, which had been picked up by a South African firm for commercialization, averted the devastation of farmlands from an invasion of red locusts in Tanzania.

The rapid intervention by the Food and Agriculture Organization (FAO) using the biopesticide drastically reduced locust infestations in Tanzania and prevented a full-blown invasion that could have affected the food crops of around 15 million people in the region.

Dr Ignace Godonou, entomologist based in IITA-Bénin, was part of the team that developed the biopesticide more than a decade ago. He said that, if left uncontrolled, a full-blown invasion would have caused a major setback to food security in the region.

“We are happy that Green Muscle® has proved effective in controlling locusts and is now widely used.”

If not restrained, large swarms of red locusts will fly over vast areas of farmland, traveling daily more than 20 or 30 km and feeding on cereals, sugarcane, citrus and other fruit trees, cotton, legumes, and vegetables cultivated by poor farmers. A red locust adult consumes roughly its own weight in fresh food, about 2 g, in 24 hours. A very small part of an average swarm (about 1 t of locusts) eats the same amount of food in one day as around 2,500 people.

The biopesticide was developed by an IITA technical team under the LUBILOSA project (*Lutte Biologique contre les LOCustes et les SAuteriaux* – Biological Control of Locusts and Grasshoppers). It has proved effective in controlling locusts in the Sahelian region, including the Republic of Niger and Mauritania.

This environment-friendly alternative to synthetic chemical pesticides uses a natural fungus, *Metarhizium anisopliae* var. *acidum*, to kill the locusts and is therefore more effective as a control agent.

Green Muscle® is a fungal biopesticide that was developed in response to a locust plague in the 1980s. It is effective against most locust and grasshopper species; it is safe, does not affect other species, and can be sprayed in the same way as chemical pesticides.

A fungus, *Metarhizium anisopliae*, which is common in the tropics and subtropics, is used to kill the pests. It weakens and kills the locusts in 10 to 14 days and can persist in the ground for several weeks after spraying, continuing to attack and kill the grasshoppers. This environment-friendly alternative remains effective under prolonged dry conditions. The fungal spores are suspended in an oil solution, giving the product its green color.

Currently, a South African company is licensed to produce this mycopesticide.



Healthy and Metarhizium anisopliae var. acidum-infested desert locust.
Photo by IITA.



Nomadacris septemfasciata hopper band. Photo from Wikimedia Commons

Godonou said that initial field trials of the product were conducted in the Republic of Bénin under the close watch of IITA scientists, based in Cotonou. The subsequent large-scale field trials were held in Niger and Mauritania.

“Mass production of the fungus for small- to large-scale field trials also started at IITA-Bénin,” he added.

“Moreover, it can persist in the ground for several weeks or for up to a year after spraying, continuing to attack and kill

healthy locusts and grasshoppers. The fungus is very safe and has a narrow range of hosts,” said Godonou.

Apart from IITA, other leading institutions in the LUBILOSA project were the Commonwealth Agricultural Bureau International in the UK, and the Département de Formation en Protection des Végétaux in Niger, with many partners drawn from donors, several research institutes, national agricultural research and extension systems, nongovernmental organizations, FAO, private sector companies, and farmers.

A tale of an African farmer

Sixty-year old farmer Alphonse Ogoule-Okpe of Ogoukpaté Village, about 40 km from Porto Novo in northern Bénin, had all but abandoned cassava and maize farming.

Many years ago, insects (mealybug and cassava green mite) and diseases (such as blight) had attacked his cassava crops and “Baba” Alphonse and many like him in his village were hit hard because of the low yields and loss of a food and cash crop. The problem was compounded by the poor soil conditions in the fields.

During a visit to the small village by IITA scientists who distributed planting materials of improved IITA cassava varieties, Baba Alphonse said, “I would be happy if the problem with these insects and diseases will be over. Thanks to IITA, I can plant a new variety that is resistant to the problem pests.”

Unknown to farmer Alphonse, a few kilometers away from his farm was where the predator of the cassava green mite, *T. aripo*, was first released in Benin by IITA—way back in 1993. That—and his use of the



Baba Alphonse. Photo by IITA

new varieties from IITA would help ensure better cassava harvests for his family and the community.

Recipe for African farmlands



A natural enemy, capable of tackling the green mite menace, has been helping millions of Africans whose livelihoods depend on cassava.

The natural enemy, *Typhlodromalus aripo*, has proven to be an ideal candidate in controlling the cassava green mite (*Mononychellus tanajoa*) after 7 years of studies, says Dr Alexis Onzo, IITA entomologist based in Cotonou.

Back in the 1970s when the pest entered Africa, cassava green mite wreaked havoc on African cassava farms, depleting yields, in some cases, up to 80%.

Onzo says the neotropical spider mite attacks cassava—a major crop in Africa—by damaging the photosynthetically active leaf surface area of the plant.

The good news, however, is that the biocontrol option which saw the introduction of *T. aripo* in Africa has substantially reduced the population of green mites, as evident in studies carried out by scientists in southwestern Bénin and in many other countries in the African cassava belt. The results indicate that the introduction of *T. aripo* has helped in ensuring farms with healthier cassava plantations in Africa.

The predatory mite, *T. aripo*, was introduced by IITA and partners from Brazil, South America for the control of the cassava green mite. It resides primarily in the apices of the cassava plant, feeding on and reducing the populations of green mites not only in the apices but also in the upper part of cassava foliage.

Onzo says *T. aripo* was released in Africa by IITA and partners in the 1990s to contain the devastation caused by green mites. Since then the natural enemy has, on its own, been spreading to different parts of the continent, playing its role as a natural control agent against that cassava pest.

Unlike chemical control which wipes out the pests and other benevolent species, the biocontrol option reduces the population of the pest to a level that makes the pest's impact on the crop economically insignificant. Besides, the pollution associated with chemical control is also avoided.

Onzo described the continuing success of green mite control in Africa as a welcome development and a victory for resource-poor farmers who will have the opportunity of cultivating healthier cassava farms.

With the prevention of the devastation by green mites and other pests, cassava has now become a cash crop in Africa, generating wealth and improving the food security of many Africans.

“Today we see cassava serving as a raw material in the flour, ethanol, and glucose industries. Even the governments are benefiting from these benefits,” he says.

As cassava green mite becomes less of a problem, Onzo says he intends to take up the fight against mites that are ravaging and depleting the production of coconuts and vegetables in Africa.



Alexis Onzo examines cassava leaves for pests. Photo by IITA

Biocontrol: saving the environment, saving farmers' incomes

Biological control of water hyacinth is not only restoring the balance of nature in Africa but also putting savings in the pockets of resource-poor farmers whose livelihoods depend on fishing, thanks to IITA.

Using natural enemies, scientists have been able to control the purple-flowered water weed in southern Bénin, for instance, showing that annual incomes in that region increased by US\$30.5 million.

The result of the studies, which was published in the *Journal of Agriculture, Ecosystems & Environment*, estimated the total cost of the biocontrol program at \$2.09 million.

“Assuming that the benefits are to stay constant over the next 20 years—a most conservative assumption—the accumulated

present value would be \$260 million, yielding a respectable benefit-cost ratio of 124:1,” say Drs Hugo de Groote and Peter Neuenschwander.

Water bodies, such as lakes, rivers, and dams are important for agriculture and as water sources for domestic needs.

However, floating aquatic weed species mostly originating from South America, such as water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), giant salvinia (*Salvinia molesta*), and the red water fern (*Azolla filiculoides*) were deliberately or accidentally introduced from their native home into these water bodies as ornamental plants or for use in the aquarium trade. Because of their rapid reproduction by vegetative means and through seeds, these plants have attained a pest status.



Water hyacinth grows fast and can clog water bodies. Photo by IITA

Obinna Ajuonu, IITA entomologist, says the damage caused by water hyacinth, for instance, on the fishing community alone was devastating.

“It accumulates a large biomass that enables the plants to block waterways,” he explains, “thus impeding fishing and transport by boat or canoe, leading to increased transport costs and loss of revenue. They can also increase the incidence of diseases, such as bilharzia, and provide refuge for reptiles, such as snakes.”

A survey by IITA in southern Republic of Bénin in 1999 revealed that at the peak of the infestation, water hyacinth had reduced the yearly income of a community of about 200,000 people by approximately \$84 million. Men lost revenue mostly in fishing, while women experienced loss of income in trade, primarily in food crops and fish.

The intervention by IITA and partners through the release of three natural enemies, two weevil species and one moth that feed exclusively on water hyacinth, however, brought succor to the West African region where the devastation was most extensive.

IITA implemented the first biological control of floating weed in West Africa (Bénin) way back in 1991 with the release of the weevil *Neochetina eichhorniae* that ate nothing but the water hyacinth at immature and adult stages. Biological control of water lettuce, giant salvinia, and the red water fern using their specific agents, followed thereafter.

From IITA-Bénin, a starter colony of biocontrol agents against aquatic weeds and expertise in implementing weed biological control were provided to other countries, such as Burkina Faso, Côte d'Ivoire, Ghana, Kenya, Nigeria, Republic of Congo, Senegal, Tanzania, Uganda, and Zimbabwe.

Other benefits brought by IITA's intervention included an improvement in water quality and human health. Before the biological



Obinna Ajuonu explains how water hyacinth invasion was brought under control using a weevil, *Neochetina eichhorniae* (inset).

Photo by IITA

option was used, national governments in the subregion applied herbicides and mechanical/manual removal to control water hyacinth—options that were neither environmentally friendly nor cost-effective.

Ajuonu says an additional biological control agent for the water hyacinth is being planned. “The new ideal candidate is the mite *Orthogalumna terebranti*,” he explains. This has been discussed in several Economic Community of West African States (ECOWAS) meetings on aquatic weed control, where IITA was represented.

He explained that IITA provided many of the ECOWAS countries with starter colonies of agents and would continue to do so by importing the mite in 2009/2010 and maintaining a laboratory culture for supply to individual countries.

Save African bananas!

A high-level international effort is needed to save African banana and plantain, currently under threat from two deadly diseases— banana *Xanthomonas* wilt (BXW) and banana bunchy top (BBTD).

Xanthomonas wilt started in Uganda and is spreading to neighboring countries in eastern Africa. Meanwhile, the banana bunchy top disease is creeping across southern and central Africa. Currently, all bananas are susceptible to the two diseases.

If these diseases are not checked, they will affect the food security and livelihoods of 30 million farmers in 15 countries in sub-Saharan Africa (SSA), who cultivate banana and plantain in 4.5 million ha. They can spread to neighboring countries and further worsen the regional situation.

Looming crisis

BBTD is characterized by stunted growth and leaves in tight whorls sprouting from the top of the plant. It is present in Angola, Burundi, Cameroon, Central African Republic, Congo, Democratic Republic of Congo (DRC), Equatorial Guinea, Gabon, Malawi, Rwanda, and Zambia. The disease is transmitted by aphids, and once

established, it spreads rapidly and is almost impossible to eradicate.

Banana bacterial wilt disease was first identified in Ethiopia and is now ravaging production in the Great Lakes Region of DRC, Kenya, Rwanda, Tanzania, and Uganda.

Both diseases can rapidly kill banana plants and eliminate production, causing losses worth hundreds of millions of US dollars each year. At the moment, no disease-

resistant varieties are available, and pesticides for controlling insect vectors are ineffective against disease spread.

For both diseases, the only way to prevent further spread in the field is to uproot, chop, and sun-dry infected plants, and to replace them with clean planting material.

Experts respond to crisis

Due to increasing concerns about the two diseases, the international community came together



BBTD (orange) and BXW (green)-affected countries in Africa. Yellow indicates countries (DRC and Rwanda) with both diseases.

in a meeting held in Arusha, Tanzania, in August this year. Experts from 15 banana and plantain-growing countries in SSA (Burundi, Cameroon, Central African Republic, Congo, DRC, Kenya, Malawi, Mozambique, Nigeria, Rwanda, South Africa, Tanzania, Uganda, Zambia, and Zimbabwe) and also from Australia, India, and United Kingdom evaluated the current status and scientific knowledge on BBTD and BXW.

The meeting was convened by the Southern Africa Development Cooperation (SADC), with support from the UN Food and Agriculture Organization (FAO), IITA, and Bioversity International.

Participants recognized the need to plan strategies to manage the diseases in countries where they are already established and to prevent spread to those that are not yet affected. A recently issued joint statement said that “urgent action by national research organizations and governments in SSA, international research organizations, and development partners is necessary to avert or reduce the impact of the looming crisis.”

Framework for disease management

Building on ongoing regional efforts, FAO, IITA, and Bioversity International will work with relevant regional



Left: BBTD-affected banana. Right: BXW-affected banana.
Photos by IITA

organizations, such as SADC and the Association for Strengthening Agricultural Research in East and Southern Africa, to develop a banana disease management framework for SSA.

The framework aims to support effective networking and coordination for information gathering and sharing, and to identify national needs and gaps in funding. It will support efforts to increase awareness and raise funds so that disease eradication and management activities contribute to a common goal (see box on next page).

The participants further called on relevant research and development organizations, partners, and national authorities to

affirm their commitment to collaborate on regional responses to banana diseases, ensure coordination of activities and optimal use of resources to provide technical advice, develop sustainable new technologies, and deploy eradication and management practices across SSA.

A concerted effort among various stakeholders would ensure the success of measures to eradicate or prevent these diseases from further ravaging the livelihoods of banana and plantain farmers in Africa.

A high-level meeting will be convened in early 2010 to endorse the framework and take steps towards putting it into effect.

Participants' recommendations

- Urgently support active management and control programs in countries where production systems are already affected to mitigate the impact of the two diseases.
 - Make arrangements to provide safe and sufficient replanting material to encourage farmers to destroy diseased plants so as to safeguard and sustain production.
 - To prevent infection and further spread of these diseases, unaffected countries need to increase vigilance to take preemptive action to destroy infected plants as soon as they appear. Monitoring strategies and the capacity to recognize the diseases and to deploy rapid eradication responses are vital.
 - Educate and advise farmers on the importance of these diseases and mobilize them to report and combat them at the first sign of appearance. Large-scale, community-level action will be needed, supported by local and national governments and subregional organizations.
- Allocate funds for the following measures in countries with banana and plantain production—whether at commercial or subsistence level:
 - **large-scale campaigns** for disease awareness, surveillance, training of sufficient staff in sampling, field disease recognition, and laboratory diagnosis, and the production and distribution of clean planting material to respond to any disease outbreaks.
 - **community-level measures** to support actions in response to the diseases, helping to ensure local adherence to recommended practices.
 - **reporting and communication systems** to ensure an early and appropriate reaction once the diseases have been recognized at field level, and to monitor the success of eradication and management practices.
 - **improved arrangements for production of *clean* planting materials** through training and facilities to improve the quality of materials, and to ensure that enough are made available to farmers.
 - **national contingency plans** developed with the involvement of all concerned with banana disease management, including the creation or strengthening of national task forces to ensure country preparedness to implement disease eradication campaigns and monitor the impact of these efforts.
 - **other longer term programs** to improve field practices for disease eradication (for countries where invasion is recent) and management (where diseases are already established); and also to include review, information sharing, and update of policy frameworks, such as plant health/quarantine legislation.



Banana and plantain are important staples in East Africa. Photo by IITA

Paraleyrodes minei is a whitefly species that was accidentally introduced into West Africa some years ago and that was discovered as a new invasive pest by IITA's insect center. Photo by Georg Goergen, IITA



The witch menace



Left: Angry farmer showing *Striga*. Right: Maize field attacked by the parasitic weed. Photos by IITA

The witch's spell on millions of hectares of cereal crops in sub-Saharan Africa (SSA) will soon be broken. A deadly "potion" using natural enemies is being developed by IITA and its partners to manage the menace.

Striga hermonthica or witchweed, the parasitic weed that attacks cereal crops, such as maize, sorghum, and millet, has caused devastating annual production losses estimated at US\$7 billion among small-scale farmers, contributing to hunger, malnutrition, and poverty in SSA.

The sight of the deceptively beautiful pink flowers of *Striga* spells doom for farmers. The weed grows on the roots of host plants absorbing the plant's water, photosynthates, and minerals. When the flowers are in bloom, it is already firmly established. Thus, the use of aboveground herbicides is ineffective, since the damage has occurred long before the weed is visible to farmers. Each plant can produce tens of thousands of seeds that are dispersed far and wide by man and nature, and which lie dormant but still potentially active for many years.

Loss of millions of tons of food

Dr Fen Beed, an IITA plant pathologist, explains that production losses from *Striga* routinely range from 15 to 90% depending on the crop cultivar, degree of infestation, rainfall pattern, and degree of soil degradation.

Striga infests about 50 million hectares of land in SSA resulting in the loss of over 8 million tons of food annually. The larger areas affected are in Nigeria, Niger, Mali, and Burkina Faso.

Unfortunately, measures developed to control the weed in the developed world, such as soil fumigation, are too costly for the poor subsistence farmers who make up 70 to 80% of farmers in SSA. New management options are thus urgently needed.

One promising, sustainable, and environmentally friendly technology under development is biocontrol using indigenous fungi that are natural enemies of the weed.



Poisoning the witch

A team led by Beed with partners from the University of McGill (Canada) and University of Hohenheim (Germany), and national agricultural research systems (NARS) and universities in West Africa, have identified isolates of a fungus that attacks *Striga* for use as a bioherbicide.

By studying over hundreds of diseased shoots of *Striga* in Bénin, Burkina Faso, Ghana, Mali, Niger, and Nigeria, scientists discovered isolates of *Fusarium oxysporum* f. sp. *striga* that controlled the weed.

A series of controlled laboratory studies identified the most effective of these as M12-4A, an isolate from Mali, Foxy 2 from Ghana, and PSM-197 from the Nigerian savanna. The isolates attacked *Striga* in all its growth stages—from seed to germination, from seedling to flowering shoot. They significantly lessened the number of attachments and flowering *Striga* plants, thus reducing the number of seeds deposited in the soils and limiting the future reappearance of the weed. Furthermore, the isolates were specific to *S. hermonthica*, had no impact on cereal hosts or any other plants, and did not produce any toxins that harm man or livestock.

Repeated field trials were performed for the first time under West African conditions using *Striga*-resistant and *Striga*-susceptible varieties of sorghum and maize in Nigeria, Burkina Faso, and Bénin in partnership with various NARS and universities. The efficacy of the three isolates selected from laboratory studies were compared with other isolates originating from Bénin and Burkina Faso. Amino acids found to disrupt germination of *Striga* under laboratory conditions were also included but failed to produce significant improvements in weed control under field conditions.

Results showed that PSM-197 and Foxy 2 were the most effective in repressing witchweed, whereas isolate M12-4A was

less effective under the range of field conditions tested. Also, there was a 90% reduction in *Striga* emergence when the biocontrol technology was used in combination with a *Striga*-resistant maize line.

Two methods were used to apply the fungi: either directly coating the seed using locally available gum arabic or directly adding the fungus in powder formulations of kaolin-based PESTA granules into planting holes. The granular formulation was found to be more efficient, especially for sorghum which has much smaller seeds than maize, where the larger seeds receive more fungal inoculum when applied as a seed coating. However, it is more costly and difficult to distribute to farmers.

Therefore, the seed-coating method offers the most cost-effective method, especially when combined with *Striga*-resistant germplasm.

Another important finding is that the biocontrol agent works most efficiently when the soil is rich in beneficial (friendly) and not antagonist (nuisance) microorganisms. Container trials at IITA Ibadan showed that the profile of both bacterial and fungal microorganisms was changed when different species of cereals were grown in the same soil—this is because each plant type produces different exudates that are excreted around



Container trial, Ibadan, Nigeria. Photo by IITA



Drying seed-coated sorghum and maize.

Photo by IITA

roots that promote or inhibit the growth of different microorganisms.

Furthermore the profile was changed when different cultivars of the same species of cereal crop (maize or sorghum) were grown. Different fertilizer combinations had similar impacts on microorganism profiles—all of these changes in profiles affect the success of introduced biocontrol agents. This study was done using state of the art PCR-DGGE technology in collaboration with the University of Purdue.

Making the potion available and affordable

Supplying fungal-coated seeds of improved varieties to farmers requires a delivery pathway. Researchers face the challenge of mass producing the biocontrol agents and encouraging farmers to use them. The models being tested for mass production of the *F. oxysporum* inoculum include on-farm, cottage-industry, small entrepreneur industry, and government initiatives, such as that in Senegal initiated by *Foundation Agir pour l'Education et la Santé*.

Under the small entrepreneur industry models, one company in Kenya, Real-IPM, has secured funding to register PSM-197 before mass production using large-scale commercial tanks for liquid culture of the fungus. Another company, Western Seed

Company Ltd., has carried out preliminary field tests with support from the Kenya Plant Health Inspectorate Services.

Finding a way to curtail the negative impact of witchweed has been a long journey, but the biocontrol option can provide an important component in an integrated package of strategies for managing this pest.

“There will never be a silver bullet solution to alleviate the problems faced by farmers from witchweed. It is important to recognize that efficacy and persistence of the biocontrol agent is improved when steps are taken to prevent the soil from being degraded and to enrich it with organic matter,” says Beed.

New techniques are also needed for measuring the extent of losses caused by witchweed and their economic impact. Likewise, control technologies need to be developed and implemented, and their efficacy assessed across the different environments scoured by the pest, he added.

Biocontrol combined with the use of improved cereal cultivars that have increased tolerance/resistance to *Striga*, and the use of seed-coated herbicides such as imazapyr, in addition to the regular use of trap crops, at last offers small-scale farmers real hope against the “witch”.



PESTA granules. Photo by IITA

Allies in nature

Jean-François Vayssières (j.vayssières@cgiar.org), Appolinaire Adandonon (adanappo@yahoo.fr), Antonio Sinzogan (a.sinzogan@cgiar.org), and Paul van Mele (p.vanmele@cgiar.org)

Biocontrol has been around for over 2000 years. The most ancient example of biocontrol use recorded was that of Chinese and Southeast Asian fruit growers, who used weaver ants to protect their citrus crops. Farmers in Asia continue to practice this until today.

Weaver ants (one colony of *Oecophylla* = several nests) live on trees and defend their territories using chemicals or “pheromones” that they leave on leaves, branches, and fruit. Pheromones are chemicals secreted by insects that strongly influence, in the case of ants, the behavior of others of the same species. The release of these pheromones, which is a form of nonverbal communication, can effectively recruit ants to new food sources or trigger warnings as a protection against intruders.

There are two *Oecophylla* (Hymenoptera Formicidae) species in the world—the Asian species, *Oecophylla smaragdina* Fabricius, and the African species, *O. longinoda* Latreille.

Their successful application as an endemic natural enemy is rising in tropical countries. New research started exploring the mechanisms underlying ant protection of plants against arthropods. Apart from direct control mechanisms, including the predation on or deterrence of insect pests during direct encounters, indirect mechanisms have recently been discovered involving the detection of the territories of enemy ants.

Researchers have demonstrated that the Asian *Oecophylla* species can deter insect herbivores or plant eaters through info-chemical action. A laboratory test showed that a beetle which this ant preys on was more reluctant to feed on leaves sampled

within ant territories than on leaves sampled outside.

In Africa, *O. longinoda* is being used as a biocontrol agent against agricultural pests. This species defends chemically marked territories at both levels, the intraspecific (within species) and interspecific (between species). Due to their pronounced territoriality, permanent surveillance (all year round, day and night), and very efficient recruitment, *O. longinoda* respond quickly to any increase in prey numbers.

The use of *O. longinoda* colonies is suitable for perennial cropping systems in sub-Saharan Africa because they are efficient against fruit fly pests, one of the widespread threats, constantly present in tropical agricultural systems.

Two fruit fly (Diptera Tephritidae) species—*Bactrocera invadens* Drew Tsuruta & White and *Ceratitidis cosyra* (Walker), were found



Bactrocera invadens (4 adults) on a mango.
Photo by IITA

to be the most important species in terms of fly abundance and fruit damage in Bénin during the 2005 and 2006 seasons. The first is an exotic species from Asia, only recently recorded in West Africa, where it has become a huge threat in main fruit crops, such as mango (*Mangifera indica*) and citrus. The second species is indigenous.

To control fruit flies, growers sometimes resort to pesticides that are registered for cotton production. This control method is not convenient or effective at all.

Because of the economic importance of fruit flies and the lack of appropriate control methods especially in SSA, research efforts on alternative fruit fly control strategies have received greater attention, including the use of endemic biological control agents.

Making more efficient use of natural means of pest control can greatly benefit planters.

At the beginning of 2008, a Regional Control Program of Mango Fruit Flies called “West African Fruit Fly Initiative”

(WAFFI) was launched in West Africa by IITA-CIRAD, with World Bank funding. The program was based in IITA-Bénin. Seven West African countries took part in 2008, and another eight in 2009. A part of the WAFFI research focused mostly on the behavior of economically significant fruit flies and their control with biological control agents, such as weaver ants.

In Bénin, we studied the behavior of fruit flies in both laboratory and field tests over several months. These experiments revealed the fundamental role of info-chemicals of ants in repelling females of two fruit fly species during their oviposition or egg-laying period in mango. Interactions were studied on mango between two frugivorous or fruit-eating fly species (*B. invadens* and *C. cosyra*) and the African weaver ant (*O. longinoda*).

Results showed that: (1) female flies are strongly attracted to the mango fruit at ripening stages for egg laying; (2) without previous passage of ants on the fruit, the oviposition of tephritids (flies) is very important in mango; (3) once weaver ants have “patrolled” on mango fruit, female oviposition is significantly reduced; (4) *C. cosyra* seemed twice as sensitive as *B. invadens* about landing on treated fruit vs. untreated fruit; (5) similar results were found for the time spent on mango fruit; (6) ant-treated fruit had six times less damage from *B. invadens* and four times less damage from *C. cosyra* than untreated fruits; (7) *B. invadens* had significantly more pupae per kilogram fruit than *C. cosyra* in ant-free mango fruit, whereas no significant difference in ant-treated fruit was detected between the native *C. cosyra* and the exotic *B. invadens*.

The presence of weaver ants in mango trees reduced the damage caused by the fruit fly family Tephritidae through predation of adult fruit flies (rare), predation of third-stage larvae (quite frequent) and, especially, the effect of pheromones left by the ants on the fruit so that flies are



Nest of *Oecophylla longinoda* on a mango tree. Photo by IITA



Predation of fruit fly larvae (third larval instar) by weaver ants. Photo by IITA

repelled and are discouraged from egg-laying. Weaver ant presence resulted in a marked reduction in fruit damage.

The influence of info-chemicals from predators such as ants on the foraging behavior of fruit insects and more generally on pests could have crucial consequences for future observations and applications on host selection and consequently in host protection against these pests.

Practical information about the use of weaver ants in fruit fly pest control should be made available to all those involved in the fruit industry at every level, particularly local official producers, pickers, and rural advisors.

This work is also a good example of collaboration among IITA, Africa Rice Center, and CIRAD on a very important issue about high-value products in West Africa.

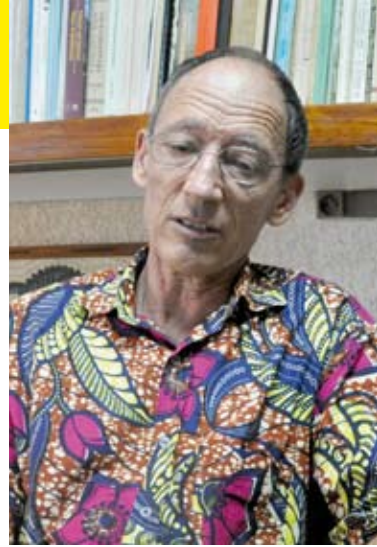
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WHO'S WHO

Peter Neuenschwander: How Africa can control invasive pests

The “father of biocontrol”, Dr Peter Neuenschwander, joined IITA's biocontrol project against the cassava mealybug in 1983. The project was later expanded to include biological control and integrated pest management of mango mealybug, spiraling whitefly, and floating water weeds. He retired in 2003. Last year, the International Organization for Biological Control recognized his life-long contributions to biological control by giving him Honorary Membership. In this interview with Godwin Atser, he bares his mind on the contribution of biocontrol and strategies on how Africa can check invasive pests.



Please explain the concept of biocontrol.

Biological control is a technique whereby we use natural enemies to combat pests. The pests can be insects, mites, pathogens, or even plants. Most times we apply biocontrol against invading pests. The beauty is that once something works, it spreads on its own and it carries on its business without difficulties.

Please give an overview of your work on biocontrol in Africa.

The cassava mealybug was actually one of the things that brought me to Africa. The mealybug was introduced in Africa in the 1970s. Eventually parasitoids were found in South America and transported here. With national partners, we made about 150 releases in most sub-Saharan African countries. From there we went on to other projects such as the mango mealybug, and water hyacinth control.

How can biocontrol check the spread of invasive pests in Africa?

Biocontrol is good; it slows the pests but it would have been best not to have introduced those exotic organisms in the first place. So, we need to strengthen and train the quarantine people.

We also need to tighten quarantine services in all African countries, not just on land borders but also the seaports and the airports so such invasions which cost so much can be reduced.

What has been the impact of biocontrol?

For the cassava mealybug alone, the project resulted in money directly going to the farmers

with the entire cassava improvement project in Africa.

What are the challenges you faced in the biocontrol projects?

Our main challenge is the uptake or adoption by the countries. Countries are autonomous in their decisions to import or not to import.

So, we have to convince some 30 quarantine authorities that they should give us quarantine permits, that they should help us, and that they should allow the insect to come in, and so on.

The challenges also include unsatisfied expectations from colleagues from different disciplines who expect us to extinguish the pest. We don't really extinguish anything.

What is the perception of people towards biocontrol?

The public in most cases is more afraid of biocontrol (insects) than the invasion itself. This is because they don't understand how it works.

Does biocontrol break down?

In technical terms, yes, it can break down—when biocontrol is working and you forget about it and suddenly start spraying the field with pesticides. That is, you kill the natural enemies and the pest.

What is the future of biocontrol?

The demand for biocontrol is already there and there will always be invasive pests. We also have to maintain the human capital in biocontrol. Unfortunately, the capacity in biocontrol worldwide is declining, not only in IITA.



Your colleague referred to you as the father of biocontrol. Can you comment on this.

I am the last surviving biocontrol specialist at IITA. That was what was written about me when I retired 6 years ago. I am still helping out.

What were the most exciting moments in your work on biocontrol?

The excitement was going out in the field and also the fact that I had a “privileged” job. It also

includes getting recognition. In the scientific world, the cassava mealybug project was seen as a success.

You have been retired for several years now. What’s next?

I have a request to go to Asia, because after 20–30 years, the cassava mealy bug turned up in Asia, and it is spreading. They want us to introduce biocontrol to curtail the spread.

Manuele Tamò:

Biocontrol should be the first option

Dr Manuele Tamò is the Officer-in-Charge of IITA-Bénin. In this interview, he talks about the outlook regarding invasive pests in Africa and the role of biocontrol.

Africa seems to be witnessing a lot of invasive pests. What are the factors responsible for this?

That observation may be a bit of an exaggeration at the moment. However, we have been experiencing some invasive species in the past years and, unfortunately, that might increase in the future. This is mainly due to the increase in people’s travels—people travel but do not know that they are carrying pests in their suitcases. Trade is also another contributing factor to the spread of invasive pest species in Africa.

What control measures have governments put in place to check this trend?

We have Plant Quarantine officers all over Africa. They are doing their best but, unfortunately, in West Africa, for instance, the borders are porous so people can pass through from one country to the other without much control. Also some of the invasive species spread freely and once they land on the continent the quarantine officers have no control over them.

How does biocontrol help in this instance?

Biocontrol is a natural response to controlling invasive pest species. It simply means reuniting the invasive species and its natural enemies found in its area of origin. This is what is called classical biological control.

How has your work on biocontrol helped in the control of, for instance, cowpea pests?

Let me start with the project on flower thrips (*Megalurothrips sjostedti*) that may be the oldest one—we have found a new natural enemy and we are spreading it all over West Africa. We are

monitoring the situation in Bénin, Ghana, and also in Nigeria where we made the releases.

For the cowpea pod borer (*Maruca vitrata*), we have just introduced a new natural enemy from Asia. Our aim is to release it and establish it on wild occurring host plants so that the *M. vitrata* population that is able to invade cowpea farms will be much reduced.

What is the damage caused by these pests on cowpea?

The damage can be devastating. If you take a susceptible variety in an uncontrolled situation, you might get about 80% yield loss, at least.



Some people worry that results from biocontrol never come early. What is your reaction to this statement?

Biocontrol is both a science and an art. As scientists, we know that experiments can take several years before results are achievable and thus conclusions are made. Just as it takes several years to develop a new crop variety, so it is for biocontrol.

The cassava mealybug biocontrol project gave results already after 2 to 3 years. This has raised stakeholders' expectations. Now, every time we embark on a biocontrol project, farmers and also politicians expect us to have the same level of success within 2 to 3 years.

In certain cases, results are obtained quite rapidly, but at other times, it might take 5 to 10 years. Results vary because we work on various types of insects that live in different environments.

On the other hand, biocontrol is an art because sometimes you need luck to get quick results.

Why biocontrol and not pesticides?

I am not against pesticides if they are used correctly to save crops from pest attacks. But biocontrol is an option that controls pests by reestablishing the natural balance (in nature)

and should be considered first, particularly in the case of alien invasive species.

What are your future plans?

Continue the work on flower thrips and *Maruca vitrata* and measure the impact. I am also working on a feasibility study on cotton. Cotton is the biggest consumer of insecticides in the whole of West Africa, and a source of concern with regard to environmental and human health.

We also want to start a new project investigating insects attacking cashew. The project is important because cashew nuts exported to Europe and the United States must be pesticide free.

How do you work with the government in achieving your results?

We collaborate with the government, starting with the Plant Protection Services. For instance, we need to comply with country quarantine regulations for the introduction of new biocontrol agents. Plant protection officers are with us in the field—from experimental releases of natural enemies to measuring establishment and impact. We also work with the NARS, which include research institutes and universities, by offering training to students and collaborators.

Ranjit Bandyopadhyay:

Ending aflatoxin contamination in Africa

Developing countries lose billions of dollars in trade annually to aflatoxin contamination in foods. Worst still, the contamination endangers the health of millions of people in the region. But the good news is that IITA has developed a biocontrol product (aflasafe) to tackle this problem.

Dr Ranjit Bandyopadhyay speaks to Godwin Atser on the journey that led to the development of aflasafe and other issues.

aflasafe™



Ranjit explains how aflasafe™ works. Photo by IITA

Tell us about your work at IITA

I am a plant pathologist, and one of my main responsibilities is how to manage plant disease. The other is to ensure food safety.

What about your work on biocontrol?

This is one of the most exciting projects that I have ever had. The work on biocontrol is on a toxin found on maize and peanuts called aflatoxins. The toxin causes a lot of harm to people's health and also makes farmers sell their products at lower prices. So, the losses are both in terms of health and trade. What I am trying to do is to manage the aflatoxins using a holistic approach, such as using resistant varieties, better crop management practices, and also the biological control method.

What is unique about your biocontrol work?

One thing that is unique is that we are using the natural resources from Nigeria to manage an economic and medical problem. We are making use of nontoxic fungi to eliminate the harmful fungi (aflatoxins).

Why are aflatoxins important?

Aflatoxins are harmful chemicals that are produced by a fungus called *Aspergillus flavus*.

The fungi produce toxins in maize, peanuts, and generally grains. When people eat them, it harms them and causes diseases such as liver cancer and kwashiorkor, among others. Worst still, farmers cannot sell their products at the premium price.

What makes you keen about biocontrol?

It is one of the strongest components of the holistic approach. If we can have the biocontrol approach adopted by farmers, most of the problems concerning aflatoxins which they face during postharvest will be greatly reduced.

Do you see IITA in the position to offer the biocontrol option to farmers?

Absolutely yes. The reason is that we actually started with good science and that science has given birth to a new product which the farmers are willing to use.

What is this product?

The product is "aflasafe". We coined the name aflasafe; when farmers use the product on their farms, they would produce grains that are free from aflatoxins.



Happy farmer receives aflasafe™ from IITA.

Photo by IITA

Did you face any challenge in developing the product?

The first challenge was developing the product itself. The fresh challenge now is how to get a large manufacturing firm to begin massive production, advocacy, and awareness so that it gets to the farmers.

Any interest so far?

We made a presentation to the Minister of Health, Prof. Babatunde Osotimehin, and he was so excited about the product. We also did a field deployment and the farmers were also very happy about it.

Who were your partners in this work?

Many organizations and people were involved in this work. They include the National Agency for Food and Drug Administration and Control, farmers, United States Department of Agriculture, US Agency for International Development, Prof Peter Cotty, Dr Joseph Atehnkeng, and several others.

How were you able to handle these partners?

Every partner is a unique entity but one thing important is to build trust. Once that is done, the partnership gets smooth.

Research wise, what are your future plans?

My future plan is to get this product used on at least one million hectares. I intend to put all my efforts to see that this product is used for the benefit of the farmers in general and women and children who are more vulnerable to aflatoxins.

Rachid Hanna:

Balance strategic research with development initiatives

Rachid Hanna is an entomologist by training with a diverse academic background (BSc in Horticulture, MSc in Plant Protection and Pest Management, PhD in Entomology). He joined IITA-Bénin in 1998 to lead the cassava green mite (CGM) biological control program. In Bénin, he initiated several other programs on biocontrol and IPM of other crop pests. He recently relocated to IITA-Cameroon and has been entrusted in helping to rebuild the research program with a new focus.



What were the differences in research priorities when you first started working for IITA and now?

When I joined IITA, there were several ongoing or recently concluded and highly successful biocontrol programs. We now need to give more attention to developing biological control options for insect vectors of the causal agents of serious crop diseases. There is still considerable appreciation within IITA and among our partners for the potential for biological control to solve many pest problems in agriculture, with numerous invasive pests lurking outside African borders. We need to maintain the capacity to provide a rapid response to these alien species. Biological control is often the only viable and sustainable solution.

IITA went through a period when scientists were pulled more toward the development side as core funding declined. It seems we now have a good balance in the R4D continuum. At present there is increased emphasis on biotechnology—molecular biology in particular—but natural resources management has suffered. IITA has also put greater emphasis on the commercialization of agricultural products as a means of reducing farmers' risks and increasing farm income. It has also given increasing attention to food safety and human health.

What are your current projects?

We have spent a lot of time and resources figuring out how CGM biocontrol works through predators and acaropathogens, and determining its socioeconomic impact. I have

also been involved in classical biological control of the coconut mite, which is present in the Americas, Africa, and the Indian subcontinent.

IITA and *icipe* have been collaborating for the last 3 years on a BMZ-funded project to develop IPM for several mango pests. At the core of this project is biological control of the invasive fruit fly, *Bactrocera invadens*, or Sri Lanka fly that is now present in at least 34 countries in Africa where it has caused huge losses in fruit production. With *icipe* we have explored natural enemies of this pest in Sri Lanka, its putative origin, and imported from Hawaii, tested, and initiated field releases of *Fopius arisanus*, a parasitoid known to be an excellent biocontrol agent of several fruit fly species closely related to the Sri Lanka fly. We have already released nearly 95,000 individuals of *F. arisanus* in Bénin and Togo, with encouraging recovery rates.

More recently, I began research on the banana aphid, also an exotic pest in SSA, and the only known vector of banana bunchy top virus that causes a very serious disease of banana and plantain. This disease is presently found in 12 countries in Africa and continues to move to others. IITA, in collaboration with partners, has initiated efforts to develop integrated options to control the banana aphid with emphasis on biological control.

For some years, I have been developing with several partners IPM for the African root and tuber scale, a pest of cassava in Central Africa. This pest is indigenous to



Central Africa where it has evolved on native hosts in association with an indigenous ant on which it depends for its survival and dispersal. We figured out how to deal with the scale using 'less scale-suitable' varieties, cultural practices that reduce the frequency of hosts that serve as a reservoir for the scale, and ecofriendly baits to kill the ants. To complicate matters even further, we recently discovered—using molecular biology tools—that the scale is a complex of species and not one species as has been suggested based on morphology. This work is part of a larger IFAD-supported project to develop integrated management approaches to high-profile cassava pests and diseases in SSA. Swiss funding is supporting a PhD student to elucidate the ecological factors that promote ant abundance and the nature of ant/scale interactions.

What is unique about biocontrol research?

We seek to develop sustainable solutions to major pest problems that limit agricultural productivity. Nearly all this research has unique scientific aspects. Biological control is not really new. It is a useful approach, but the process of discovery of natural enemies, understanding how they work, and promoting their abundance and persistence has many innovative and unique aspects.

What are your challenges at work? What are the rewards?

There are many challenges. One is farmers' acceptance of the technologies. Farmers like simple solutions to their problems. With biological control, the natural enemies work on their own, mostly without the farmers' intervention. In contrast, the success of a crop-variety pest control approach will largely depend on the farmers' acceptance of the varieties.

The breadth of our geographic coverage is also challenging and at times daunting. There is considerable restriction now on the exchange of biological materials and it is becoming increasingly difficult to export, import, and test natural enemies.

The rewards are equally many. Chief among these is the satisfaction of getting farmers to adopt a new practice and so achieving a noticeable impact in our work. The satisfaction of discovering a new natural enemy and

figuring out how it goes about its business of consuming and suppressing its prey is immense.

Discovering and describing a new species is equally satisfying. So are seeing students successfully complete their training and becoming full-fledged members of the scientific community, and farmers' glowing and wide eyes when they see through a hand-held magnifying lens the little mites that cause the damage to their crop, or the equally small predator that kills those pests and protects their crop.

We also get rewards through the recognition we receive from our employer and peers.

What is the impact of your work on African farmers, producers, and consumers?

The return on investment from biocontrol can be very high and the results are permanent. Except on rare occasions, farmers need not intervene at all.

All the work we are doing on biological control is important for agriculture. Take for example the work on cassava mealybug and CGM biocontrol. These pests devastated cassava production across the cassava belt in SSA. Their control has resulted in preventing billions of dollars worth of losses to African agriculture and translates to more food



Harvesting leaves in cassava field. Photo by IITA

security and income. The cassava mealybug has already invaded Thailand, and its farmers stand to reap the benefits from our work. The same is true for the other pests for which we are trying to develop sustainable solutions. This underscores the fact that biocontrol benefits can be obtained independent of the location where it was developed.

We are now trying to do the same with disseminating control measures for the African root and tuber scale in the Congo basin, coconut mite in Bénin, Tanzania, and Sri Lanka, the highly destructive Sri Lanka fly, and the banana aphid. Each of these achievements will have considerable positive impact on the productivity of targeted crops, in turn enhancing food security and people's livelihoods.

Who are your collaborators?

We have an excellent network of collaborators both in Africa and abroad, and a cadre of superb students and support staff. My main collaborators on strategic research have been IITA scientists and those from universities and government institutions in Europe, United States, Brazil, and Kenya. In Africa, I have worked closely with *icipe* and more than 14 NARS—government and university—partners in adaptive research and technology transfer. While not all collaborations were equally

successful, the best were those when all partners had ownership, trusted one another, had common interests, and were fully engaged.

Any insights for colleagues or partners?

Keep an open mind. Strive to be a scientist in search of new knowledge that can be translated to ways of improving people's livelihoods. For crop protection specialists, give biological control a chance. It is permanent, the safest, and most ecologically—and in most cases most economically—sound means of pest control.

Start thinking of the next project (or phase) or research topic as soon as you start one. Think big and act with humility.

To our partners, I would say that IITA is with you. Let's keep working together for we can achieve a great deal more together than alone.

How could IITA be more effective?

IITA is a very effective R4D organization; this is largely due to an appropriate balance between strategic research and development activities at present. However, we may be presently too spread out. Expansion often happens at the expense of existing posts. Some posts that have been very effective in R4D should be strengthened. Plant health and crop improvement research have led to huge impact; let's continue to give them priority and support.

Biodiversity should be everyone's business. We are well placed to work on biodiversity and conservation while enhancing crop productivity and livelihoods. We need to recruit topnotch scientists and keep them. We should promote a healthy work environment. We should also reestablish and restore the student training program to its previous prominence; the large majority of our NARS collaborators were trained through this program. Many are now older or retired. IITA has recently increased investment in specialized training of its entire staff. This is a good move.



Hanna interacting with farmers and extension agents. Photo by IITA

LOOKING IN

O.A. Adenola: More awareness needed on the dangers of aflatoxins

The president of one of the strongest crop networks in Nigeria, Pastor O.A. Adenola, talks about the need for stakeholders to join forces against aflatoxin spread and other issues. This is an excerpt from his interview with Godwin Atser.

Do farmers understand what aflatoxins are?

They may see the fungus on the maize cob but really many Nigerian farmers do not know the danger in what they see: what it is... what effects it has on people as a result of eating grain that is already contaminated... I think we need a lot of awareness, a lot of teaching to get our farmers to know the dangers of aflatoxins in our foods. The problem is that you don't see them and their effect physically. If you look at the cassava mealybug, for instance, the farmer sees the plant die. In the case of aflatoxins, you don't see them causing anything bad to maize; it is the after-effect that damages people's health.

What can be done to bring the message to the people?

It has to involve a collective effort from all of us: the research institutes, the Agricultural Development Programs, the Maize Association of Nigeria, and the media. We won't make any progress if we don't collaborate to get the farmers to know the importance of the effect of aflatoxins on human beings and on animals.

You participated in the Doubling Maize Project. What were your observations?

At the time the project was initiated in 2006, the maize production level on average was 1.5 t/ha. The project target was to double production—from 1.5 to 3 t/ha. A farmer who could not combine production inputs to give us 3 t/ha was not qualified to be involved in the scheme because we did not want to increase the area planted. We wanted to increase production per unit area. The intention was to intensify production so that we could double what was on the ground.



So what happened?

I tell you, farmers made more than 3 t/ha! Also if the technology is properly applied, Nigeria can easily double maize production.

What effort is your association making to disseminate some of the findings of that research to increase maize production?

The maize network is stronger than the networks of other crops in Nigeria, maybe, because of the facilities we have at IITA that are linking us up properly with research and also with Ministries of Agriculture all over the country. And since we were the beneficiaries of the research findings, it was easier for us and for our members to adopt the improved technologies.

All that the researchers were telling us was "You can be better farmers if you take the technology." I must tell you that every farmer is out there in the field because he wants to make more money. So the benefit is good enough to propel the technology.

How is the collaboration between MAAN and IITA?

Excellent! I have been relating with IITA since 1984 and when this Association was formed in 1992, it was formed in IITA. Since then we have had very good collaboration.

What can IITA do to make this partnership grow?

Whenever there is a need and we call on IITA, they have always answered. The Director General and the maize "chief", Dr Sam Ajala and his team, have been very cooperative. That collaboration is what is important. If you have a problem and you call your friend and he answers, then you are okay.

Sunday Ekesi:

Partnership is about respect

Sunday Ekesi is a research entomologist from Nigeria working at the International Centre of Insect Physiology and Ecology (*icipe*). He is currently leading a continent-wide initiative on the African fruit flies that threaten the production and export of fruits and vegetables. Its aim is to develop a cost-effective and sustainable technology for controlling the pest.

What are your research interests and focus?

I have a lot of curiosity for all aspects of reducing damage to crops by arthropod pests to raise productivity, increase income, and improve the livelihood of smallholder growers across Africa. I am interested in integrated pest management (IPM), the development and application of entomopathogens and baiting techniques for managing arthropod pests and their integration into habitat management and other IPM approaches. The goal is to develop effective, economical, and environmentally sound approaches for managing arthropod pests and to reduce dependence on chemical pesticides.

My research center on the development of an IPM package that encompasses baiting techniques, classical biological control, application of augmentorium¹, entomopathogens, and postharvest treatment for quarantine fruit flies².

Tell us about the project on fruit flies

icipe and IITA are the pioneering institutions that address the fruit fly menace in Africa.

The project, funded by the German Federal Ministry for Economic Cooperation and

Development (BMZ), involves developing and implementing an IPM program for three major mango pests—tephritid fruit flies (e.g., *Bactrocera invadens* and *Ceratitis cosyra*), mango seed weevil (*Sternochetus mangiferae*), and mealybugs (*Rastrococcus iceryoides*). These tree pests ravage mango, causing losses ranging from 30 to 80%, depending on locality, variety, and season. Fruit flies and mango seed weevil are also quarantine pests and quarantine restrictions limit the export of fruits to lucrative markets abroad.

In the project, *icipe*, IITA, and the University of Bremen, together with national agricultural research system (NARS) and advanced research institute (ARI) partners in Africa, Asia, Europe, and the USA are developing and implementing IPM programs in Kenya, Tanzania, and Bénin. The project aims to minimize the use of pesticides that lead to unwanted residues, and so to facilitate compliance with the standards required for domestic urban and export markets.

Any insights about partnership?

Partnership is about having common and complementary interests. Capacity and expertise can be strengthened only through partnerships and shared commitments. Partners have to believe that their work will make a difference. The scale and scope of work are usually amplified by the collaboration and it is in the interest of all scientists and centers to work with one another to solve pertinent problems to benefit the growers.

Above all, partnership is about respect for opinion and one another, affection, trust, and generosity. There is a lot that *icipe* and IITA can do together—projects that take a holistic approach to crop problems in which IPM is only one component.

More than just insects

icipe was established in Kenya in 1970 to improve the well-being of the peoples of the tropics through research and capacity building in insect science and its application. *icipe* believes that the incidence of pests and vectors of disease is invariably linked to the cycle of poverty and underdevelopment. It therefore works to find solutions for food insecurity and malnutrition, disease, poverty, and environmental degradation.

¹ a tent-like structure used in field sanitation and conservation of natural enemies of fruit flies.

² used to disinfect host tropical fruits (e.g., mango, citrus, etc.) to ensure quarantine security before the fruits are shipped to importing countries.



Sunday Ekesi (right) and a PhD student discuss fruit fly control methods with a mango grower.

Photo from S. Ekesi

Who are your other collaborators?

We work with the World Vegetable Center largely on managing red spider mite; also with the International Atomic Energy Agency in developing attractants for fruit fly management and rearing methods in support of the sterile insect technique and with the SP-IPM and other CGIAR centers that are interested in applying IPM for pest suppression.

I work with farmers with established orchards and involve them in formulating any research agenda from day one. Our national partners in all the target countries are the key to identifying farmers and farmer groups. They work with us from project planning to implementation and are vital to the success of the project.

What are your challenges?

I work mostly with alien invasive species where the first choice of management is classical biological control. This involves exploration for natural enemies in their aboriginal home. There are enormous challenges arising from the movement of biological control agents because of restrictions related to the Convention on Biological Diversity. No country is willing to allow any living organism to be taken from their environment for use in another country. Classical biological control is all about

international public good yet it is becoming increasingly difficult to take natural enemies from one place to help in another country facing a devastating pest problem. We have not been able to bring in parasitoids of *B. invadens* to Africa from its putative aboriginal home of Sri Lanka. Similarly, it has been extremely difficult to obtain parasitoids of *R. iceryoides* from India for managing the pest in Kenya and Tanzania.

Another challenge is working on three complex insect pests at the same time. None of these pests is easy to deal with but by prioritizing the activities, sharing the tasks among partners, and ensuring that the milestones are achievable, we have been able to address the challenges. Coordination has been challenging but the partnership has been wonderful.

There are rewards as well. Being able to find affordable solutions to pest problems and seeing farmers apply the technologies—those make me happy. For example, in one of our project benchmark sites in Kenya, farmers previously could not sell mangoes to urban markets or export to lucrative markets in the Middle East because of the *B. invadens* problems. They are now able to do so by adopting technologies from the project. This is motivating and rewarding!

FRONTIERS

The cassava scourge

James Legg, j.legg@cgiar.org



Who would think that delicate and exquisite little insects such as whiteflies could pose an ongoing and global challenge to humankind's need to meet its food requirements?

Whiteflies are one of the top 10 most serious pest threats to agriculture. Although whiteflies, in the taxonomic family Aleyrodidae, are a diverse group of insects of more than 1,200 species, only a few of these are economically important. Among this small group, *Bemisia tabaci* (Genn.) is by far the most important single species.

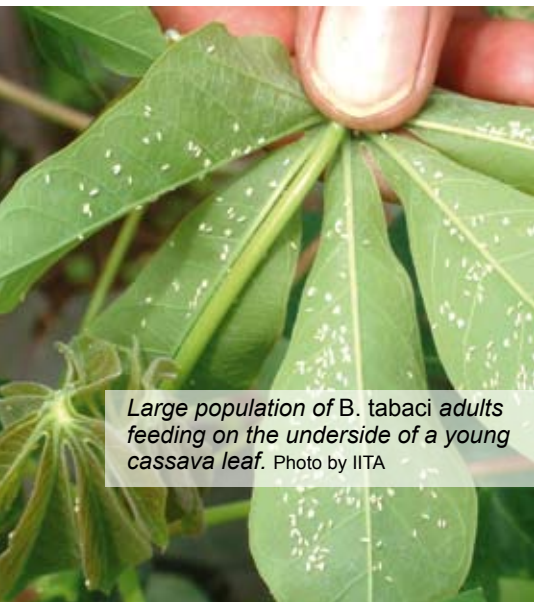
B. tabaci was first described from tobacco in Greece, towards the end of the 19th century. Its progress has closely matched developments seen in agriculture in subsequent years, and it now occurs virtually throughout the crop-growing parts of the globe. Its preference for warm weather means that it is particularly prevalent in the tropics, although it has also been able to exploit protected agricultural environments in temperate regions.

Deadly partnerships

If *B. tabaci* contented itself with doing its own thing and sucking small quantities of sap from the plants that it feeds on, it would probably have fallen under the radar of those whose job it is to protect crops. But it did not. Over time, it evolved a relationship with plant viruses, a relationship that allowed the whitefly to pick up viruses when feeding on plants, harbor them for some time, before introducing them to another plant during feeding, thereby giving rise to a new infection. This enabled the viruses transmitted to expand their ranges as *B. tabaci* populations grew and spread. These deadly partnerships thus gave rise to plant disease epidemics that had devastating impacts on the crops affected, and on the people growing them.

B. tabaci transmits many hundreds of virus species, a number that keep rising as more viruses are described and research efforts on the *B. tabaci* vector are also broadened. The viruses transmitted fall into four virus genera: *Begomovirus* (family Geminiviridae), *Ipomovirus* (Potyviridae), *Crinivirus*, and *Carlavirus* (Closteroviridae). More than 90% of the more than 100 species transmitted, however, are in the *Begomovirus* group. One of Africa's most economically destructive diseases, cassava mosaic disease (CMD), is caused by a group of viruses in the *Begomovirus* genus. Collectively, these are usually referred to as the cassava mosaic geminiviruses. Evidence also points to *B. tabaci* being the vector of cassava's other major expanding disease threat, cassava brown streak disease (CBSD) caused by the *Ipomovirus*, cassava brown streak virus.

Cassava has always been at the heart of IITA's research-for-development agenda. Thus, diseases such as CMD and CBSD,



Large population of *B. tabaci* adults feeding on the underside of a young cassava leaf. Photo by IITA



and the agents that promote their spread, have long been the focus of research efforts. From its earliest beginnings, IITA was fortunate to receive cassava germplasm, developed in East Africa through the Amani breeding program that most importantly was endowed with resistance to CMD.

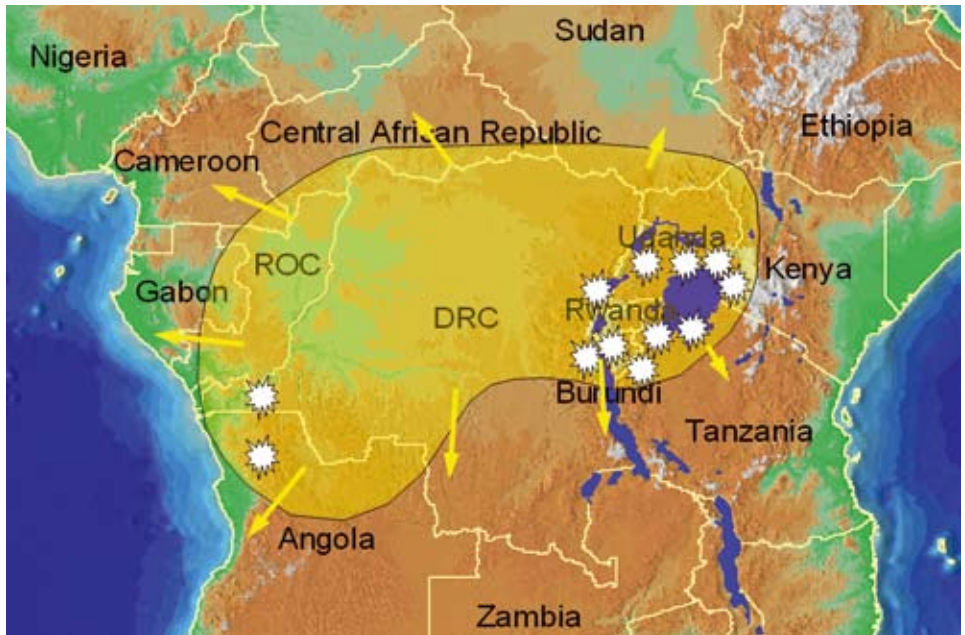
It may have been an unfortunate spin-off of the tremendous success of the CMD-resistant varieties, but *B. tabaci*, the humble vector of the CMGs, received very little research attention before the 1990s. Things were to change abruptly in the mid-1990s, however. It became increasingly clear that unusually large whitefly populations were propelling the expansion of a new, highly virulent form of CMD in Uganda.

Studying the pandemic

IITA initiated a wide-ranging research program with the dual aims of enhancing

scientific understanding of the deadly virus-vector combination as well as working with national partners to manage the pandemic.

The genetics and epidemiology of CMGs associated with the pandemic were extensively documented over the decade following the initial explosion of interest. Although less research attention was focused on the whitefly vector, a number of important advances were made in understanding the nature and role of *B. tabaci*. Perhaps most significantly, it was demonstrated that superabundance of *B. tabaci* was a key factor driving the pandemic's so-called "front", and, furthermore, that the front could be pushed forwards by up to 100 km/year in this way. Although whiteflies are weak fliers, single *B. tabaci* individuals have been shown elsewhere to fly for up to 7 km, assisted by the wind, and given a generation time of slightly less than one month, it is easy to



Whitefly pandemic map: Superabundant B. tabaci and the CMD pandemic (Yellow shaded area is the approximate region affected by the CMD pandemic by 2009. Arrows indicate the direction of pandemic expansion. White explosions indicate areas in which B. tabaci superabundance has been most prominent, together with associated physical damage to cassava crops.)

see how such a long distance spread could be achieved.

Extensive and regular disease surveys conducted by IITA and its NARS partners from 1997 up to the present have helped build up a comprehensive picture of the pandemic's expansion into 11 countries of East and Central Africa and the inter-relationships with vector populations. Moreover, these data have been used to provide risk assessments of future patterns of spread which have supported disease management initiatives.

Superabundant *B. tabaci* populations are typically 100-fold greater than those outside the pandemic zone. As well as delivering a sharply increased level of virus transmission, these cause physical damage to cassava plants. Experimental studies conducted at IITA-Uganda showed that yield losses from whitefly damage alone can be as much as 50%, and that these losses are particularly severe for some of the recent releases of CMD-resistant varieties. A gray-black sooty mold covering the lower leaves that develops on the sugary excreta produced by whitefly nymphs is a characteristic symptom of heavy whitefly infestation. These symptoms have been observed in various parts of East and Central Africa, and always occur in areas affected by the CMD pandemic.

Research priority

The obvious research question that has been thrown up from these sets of circumstances is: "what causes superabundance in *B. tabaci*?" There are two principal hypotheses. One suggests that superabundance is a result of the spread of a novel 'fitter' *B. tabaci* biotype, and the second, that superabundance is the consequence of a synergistic interaction between *B. tabaci* and CMD-infected cassava plants.

To examine the first hypothesis, IITA has been working with the University of Arizona, USA, to develop molecular

markers to allow discrimination between cassava-colonizing *B. tabaci* populations. The earliest work made use of sequence portions of the cytochrome oxidase 1 gene of mitochondrial DNA (mtCO1). MtCO1 sequences were obtained from whiteflies collected along transects straddling the pandemic "front" in Uganda. Analysis of sequence homologies showed that there were two major genotype clusters, and that one of these, the so-called "invader" was strongly associated with the pandemic-affected zone. Subsequent collections made after the pandemic had covered the whole of the cassava-growing area of Uganda, however, provided an apparently contradictory outcome, as the "invader" genotype cluster appeared only infrequently. This is not altogether surprising, however, as *B. tabaci* cassava biotypes from different countries, and even different continents, have been shown to be able to interbreed successfully.

Finding novel solutions

Current efforts are therefore focusing on developing microsatellite markers that provide a much wider coverage of the *B. tabaci* genome and will make it more likely that we can discriminate between putative superabundant and



Chlorosis on shoot tip and sooty mold on lower leaves caused by heavy *B. tabaci* infestation. Photo by IITA



normal *B. tabaci* biotypes. To investigate the intrinsic biological characteristics of different cassava *B. tabaci* populations, their associated genetics and the biology of offspring produced through inter- and intra-population mating, core funds are currently being used to run a PhD program in Tanzania. This study will also be used to examine the hypothesis of *B. tabaci*-CMD infected cassava synergism. Preliminary results from cage trials conducted at NRI using a single variety have shown increased *B. tabaci* abundance on CMD-infected plants, when compared with uninfected material.

The idea that diseased cassava makes for a better food source for *B. tabaci* has parallels in studies conducted with *B. tabaci* on other host plants, where virus infection has led to increased whitefly populations. In the cassava system there are some contradictions, however. It is significant that the greatest abundances of *B. tabaci* in pandemic-affected areas are actually observed on CMD-free resistant varieties. Further research is clearly required before a clear-cut explanation can be given for the superabundance enigma.

With whitefly numbers at record levels, and physical damage exacerbating the already grave problems posed by CMD, it has been increasingly recognized that effective measures for whitefly control need to be identified. Two main options appeared to offer greatest potential: resistance and biocontrol. Pesticides, although widely used in northern commercial agricultural systems, are easily dismissed for use on cassava in SSA, because of the extreme cost and the environmental hazard that they pose.

Is biocontrol the answer?

IITA had great success in its classical biological control programs for managing cassava mealybug and cassava green mite. Why not do a similar thing for whiteflies? Sadly, *B. tabaci* poses a greater challenge since it is considered to be African in origin,

and therefore should already be benefiting from the presence of indigenous natural enemies. Significant work was nevertheless undertaken at IITA-Uganda to characterize the natural enemies of *B. tabaci* on cassava and to investigate the potential for augmentation.

A combination of surveys, life table studies, mortality measurements, and behavioral assessments conducted over a 10-year period—from 1999 to 2008—revealed that although natural enemies accounted for significant mortality in *B. tabaci* populations, under normal circumstances this was not sufficient to keep *B. tabaci* populations at levels below those causing significant economic damage.

To change this balance, it was concluded that complementary *B. tabaci* control measures would be required, such as the introduction of climate-matched exotic *B. tabaci* parasitoids or the use of cassava varieties either less favorable to whiteflies or more favorable to parasitoids. Although no attempt has yet been made to introduce exotic *B. tabaci* parasitoids to East Africa, a significant amount of effort has been made to enhance whitefly resistance in cassava germplasm. IITA partnered with CIAT, NRI, and NARO (Uganda), under the SP-IPM's Tropical Whitefly Project, to pioneer efforts to introduce to East Africa strong sources of whitefly resistance developed in Latin America by CIAT (albeit to different whitefly species).

The NARO team have had some success in identifying Latin American germplasm that appears to have partial resistance to African *B. tabaci*, but the challenge still remains to combine these sources of resistance with the other key traits that are required by cassava in the East African farming environment. To achieve this, whitefly resistance markers will need to be built in to marker-assisted selection approaches. Much untapped potential may yet exist, however, in African germplasm, and beyond that, within wild relatives.

These are important areas of future research.

Need more studies on whitefly

The recent upsurge in the importance of CBSV in the Great Lakes region of East/Central Africa poses yet more challenges to the cassava research community. Although published reports identify *B. tabaci* as the vector, researchers remain divided on the accuracy of this claim. As such, IITA, working closely with NRI, is actively addressing this question systematically, by combining field epidemiological studies with cage-based transmission experiments, both of which are being facilitated by newly improved virus diagnostic techniques.

Preliminary results seem to support the earlier claim that *B. tabaci* is the vector, as the level of CBSV infection in whitefly-protected experimental plots was approximately half that in whitefly-infested

plots. These preliminary data will need to be confirmed by repeat trial plantings and cage trial results before any more definitive outcome can be claimed.

Whiteflies have been recognized as an important threat to cassava production for more than a century, but at the outset of the 21st century, that threat appears to be greater than ever. It appears likely that *B. tabaci* is driving a dual pandemic of CMD and CBSD through the cassava-growing heartlands of Africa.

Recognition of the importance of the twin threats to cassava is at an all-time high, with record levels of funding available to tackle them. By contrast, the role of the vector in the cassava crisis has received much less recognition. This fact will need to be addressed by IITA and its partners in developing future cassava-oriented R4D projects and programs.



Women bringing cassava to market. Photo by IITA