Breeding superior banana/ plantain hybrids

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Banana (the term includes plantain in this article, *Musa* species), is a major staple crop in Africa. Although it originated in Asia and was introduced to Africa long ago, it has become more important as a food security crop in its new home in Africa than in its region of origin. From its early domestication in Southeast Asia and the islands extending toward Australia, banana spread to Africa before recorded history. Archaeological evidence suggests that it reached Central Africa several millennia ago.

The main types of cooking banana in Africa include plantain (AAB genome), East African Highland Banana (EAHB, AAA genome), and a wide range of other types including sweet dessert banana (AAA or AAB genome), starchy but sweet roasting or brewing banana (ABB genome), and a number of other types. The "genome" refers to the portion of the chromosomes that come from one of the progenitor species of banana, *Musa acuminata* (A genome) or *Musa balbisiana* (B genome). However, most banana production in sub-Saharan Africa (SSA) consists of the East Africa Highland type or plantains, two sets of varieties with very limited genetic diversity in either. This lack of genetic diversity is a serious concern. About 60% of African production occurs in Uganda and its immediate neighbor countries (Tanzania, Rwanda, Kenya, D.R. Congo; also including Burundi).

Since banana production is year-round, it serves as a buffering bridge crop to provide food in times of scarcity between cereal harvests. As a long-lived clonal crop, it (like cassava) also can serve as a famine-avoidance crop because it is less susceptible than annual crops

Pollination of banana flowers. Photo by L. Kumar.

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to catastrophic failure in the event of unseasonable drought and can act as a survival crop during cereal crop failure. Banana also provides important ecological functions for sustainable agriculture by reducing erosion in sloping highland agriculture, and recycling nutrients through the crop residue returned to the soil in each production cycle. In some locations banana leaves and cut stems are an important fodder component in the livestock sector, providing some fodder even during the dry season.

Production constraints

While precolonial banana production may have been relatively stable, pests and diseases introduced into Africa in the last century have destabilized production in some areas. Some important introduced diseases and pests include black leaf streak (also known as Black Sigatoka), Banana bunchy top virus (BBTV), burrowing nematode, banana weevil, and Fusarium wilt. More recently, banana *Xanthomonas* wilt (BXW) has emerged as an important bacterial disease that apparently originated in Ethiopia and caused a major disease epidemic in much of East Africa in the last decade. Breeding for resistance to these diseases and pests provided the initial motivation for IITA and partners to initiate breeding in Africa.

Banana breeding history

Although early efforts to breed banana using modern breeding concepts were initiated by British scientists in the Caribbean about 80 years ago, even today the world has only about seven significant banana breeding programs. IITA initiated a plantain breeding program at the Onne High Rainfall research station in southeast Nigeria in the 1980s as a new epidemic disease, Black leaf streak, arrived in the region. This program made relatively rapid progress, identified fertile plantain varieties to cross to wild sources of resistance, optimized and implemented embryo rescue as a means of boosting germination from <1% to 5–30%, and produced resistant high-yielding hybrids by the early 1990s. Realizing that the bigger portion of African banana production was in highland East Africa and also threatened by black leaf streak, in 1995, IITA initiated a banana breeding program in Uganda in collaboration with the National Agricultural Research Organization (NARO). Working together, scientists identified fertile EAHB varieties, produced resistant high-yielding tetraploid hybrids to serve as parents, and initiated a program to produce resistant high-yielding triploid hybrids that were more likely to remain seedless.

Banana breeding process

Although most of the world eats banana, few realize that wild banana are full of hard seeds and domestication resulted in the seedless fruits that we now eat. Most varieties are triploids (have 3 sets of each chromosome), which are both more productive and more likely to remain sterile and seedless. However, some edible varieties retain a bit of residual fertility and will set a few seeds if pollinated with a strong source of viable pollen. Banana breeders serve as surrogates to natural pollinators (bats), climb ladders in the early morning to collect male flowers, and carry them and the ladders over to the intended female plants to hand-pollinate female flowers. The flowers open

Manual pollination of banana flowers. Photo by IITA.

sequentially each day, so each floral bunch is pollinated daily for a week. While many pollinations produce no seeds, some produce a few and a very few produce many seeds. Unfortunately, due to the complex background of domesticated banana, most seeds will not germinate on their own. Therefore breeding programs extract embryos from surface-sterilized seeds and germinate them in test tubes in nutritious media, from which they can later be transplanted to sterile soil, hardened, and eventually planted in the field. Triploid hybrids are evaluated as potential new varieties, while diploid (2 sets of chromosomes) and tetraploid (4 sets) hybrids are evaluated as potential improved parents.

Progress

The original plantain hybrids, as well as superior hybrids developed later, are currently being tested for agronomic performance, yield, and consumer acceptability in a number of countries in West and Central Africa, including Nigeria, Cameroon, Ghana, and Coté d'Ivoire. In the meantime, IITA's original East African partner in banana breeding, NARO, has grown to be one of the largest banana research programs in the world, with internationally recognized capacity in several disciplines. Fittingly, in 2010 NARO became the first national program in Africa to officially release a banana variety bred in Africa. Kabana6 (nicknamed Kiwangaazi) is a high-yielding variety with resistance to black leaf streak and partial resistance to nematodes and weevils. More encouragingly, newer selections likely to be more acceptable to Ugandan consumers are "in the pipeline," and procedures are now in place to move some jointly developed NARO-IITA hybrids to countries where their cooked texture and appearance fit the traditional variety "type" better than they do the "*matooke*" variety type of Uganda. A couple of promising hybrids are finding acceptability in Burundi and eastern D.R. Congo, and hopefully will also be released as varieties. IITA recently opened a second East African breeding site near Arusha, Tanzania, a country with a broader range of environments and irrigation opportunities, potentially better to breed widely adapted varieties and providing the opportunity to screen more systematically for drought tolerance.

Other aspects

To support the breeding program, other genetics studies are being conducted, including development of populations for molecular mapping studies, mapping genes controlling important traits, manipulating ploidy to try to create fertility in "sterile" lines, developing molecular "tools" to make breeding more efficient, and investigating gene expression in response to drought. IITA has excellent capacity for screening for resistance to pests and diseases.

The entire banana improvement program depends on collaborative relationships, both within IITA and from a range of partners within Africa and in other continents. The pending release of the reference genome sequence from La recherche agronomique pour le développement (CIRAD)/Genoscope in France should greatly accelerate genetics research on banana and its relatives. In light of the challenges of breeding and the lack of good sources of resistance for two important pathogens (BXW and BBTV), IITA is also investing in biotechnology approaches to banana improvement, with promising signs of resistance in early laboratory, screenhouse, and confined field trials (companion article by Tripathi on page 58).

Challenges

While encouraging progress is being made, banana breeding is challenging, slow, and expensive. Low fertility, poor seed set, and low germination rates mean that it is difficult to produce large numbers of progeny to evaluate. Banana plants are large, so evaluation plots are likewise large and expensive, and plants require up to 3 years to progress through two fruiting cycles. Much of the background

Physical measurements of banana fruits. Photo by IITA.

genetics underlying key traits have yet to be properly investigated, so the list of research opportunities to make breeding more efficient and productive is long. Musa is one of the major crops in the world for which wild relatives have yet to be systematically collected, so access to wild species for breeding for more resistant or more nutritious hybrids is problematic. Unfortunately, the global gene pool with the resistance and quality genes for future breeders remains at risk. Hopefully arrangements can be made for collection expeditions in the center of origin (Southeast Asia) in the near future while wild *Musa* still remain.

Future

Although banana has been a neglected crop in terms of research investment and scientists' effort in many countries, key decision makers are beginning to realize the essential role of banana/plantain in food security, enhanced livelihoods, and resilient agricultural systems for Africa. The potential to breed superior hybrids has been demonstrated, and there are numerous opportunities for improving both the process and the product, and for realizing impact from already developed hybrids. The future for banana crop improvement looks promising.

16th Triennial Symposium

International Society for Tropical Root Crops

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Background
The 16th Triennial Symposium of the International Society for Tropical Root Crops (ISTRC) will be held at the Federal University of Agriculture, Abeokuta (FUNAAB), Ogun State, Nigeria, 23–28 September 2012.

About the Symposium
Tropical roots crops are essential to meeting global food security and sustaining the livelihoods of many millions of people. Climate change provides both opportunities and challenges for attaining the potential contribution of tropical roots for sustainable human development. Strategies need to be developed to address key issues in productivity, crop plant-soil/water/energy resources management, and postharvest utilization as food and feed, nutritional and health value addition, and trade and commercialization, so that the role of tropical roots in ensuring sustainable development can be enhanced. The symposium provides an opportunity for experts from around the world to meet and address this agenda.

Theme: The Roots (and Tubers) of Development and Climate Change

Subthemes
1. Policies favorable to enhancing the contribution of RTCs to development
2. Global scenario on production, utilization and marketing of root and tuber crops
3. Progress in science and technology for enhancing the contribution of tropical root crops to development
4. Applying new scientific and technical knowledge on RTCs to contribute to development