RESEARCH AT A GLANCE

IFPRI IPGRI CIMMYT International Maize and Wheat Improvement Center

Genetic Resource Policies

Promising Crop Biotechnologies for Smallholder Farmers in East Africa: Bananas and Maize

Brief 20

Crucial Determinants of Adoption: Planting Material Systems for Banana and Maize

Melinda Smale, Enoch Kikulwe, Svetlana Edmeades, Mgenzi Byabachwezi, Jackson Nkuba, and Hugo De Groote

Trait-based genetic change is broadly defined as the selection of traits for insertion and the choice of background planting material. For the technology to materialize, growers must perceive the yield advantages of the inserted traits. Field surveys confirm that farmers can readily discern stemborers and the losses they cause to maize crops (De Groote et al. 2004). In contrast, farmers have greater difficulty observing hidden biotic agents, such as nematode infestation of banana roots. This is further complicated by farmers incorrectly identifying the cause and effect of the pest or disease; for example, farmers often attribute the visible damages caused by Fusarium wilt, a soil-borne fungus, as well as nematodes, to weevils, and vice versa (Gold et al. 1993). Aware of these challenges, Uganda's National Agricultural Research Organization has targeted more than one trait for insertion.

The choice of host variety also has implications for planting material systems. The type of system used for planting material exchange reflects the characteristics of the crop, for example its biology, reproduction system and improvement status. At present, the East African cooking banana varieties targeted for transformation are farmers' varieties, while the maize varieties preferred for *Bt* transformation are hybrids or improved open-pollinated varieties. The fact that bananas are vegetatively propagated crops whereas maize is predominantly cross-pollinating underlies major differences in the structure of current and future systems for disseminating planting material. The structure of planting material systems has implications for the public investments that will be needed to promote the sustained use of improved transgenic varieties by smallholder farmers in Africa.

Banana Planting Material

The planting material of a banana is not a seed but a "sucker" (shoot or plantlet) that grows from and is a clone of the mother plant (mat). The sucker must be uprooted from an existing mat to reproduce the variety and, because of its bulk, transports poorly. Once farmers have acquired a new type, they can propagate it themselves and maintain its yield advantages for many years if the material is kept free of pests and diseases. Farmer propagation of bananas takes nearly two years. The frequency with which farmers require replacement material is in part a function of their management practices. This is particularly true for the management of diseases or pests that are soil- and root-borne, which account for several of the major pests and diseases of bananas in East Africa.

Comparatively little is known about the mechanisms by which banana planting mate-

About the Authors

Melinda Smale *is a senior research fellow in the Environment and Production Technology Division of the International Food Policy Research Institute (IFPRI) and was also a senior economist with the International Plant Genetic Resources Institute (IPGRI) at the time this research was conducted.*

Enoch Kikulwe *is a doctoral student at the Department of Environmental Economics and Natural Resources at Wageningen University in the Netherlands, and a researcher at the Banana Program of the National Agricultural Research Organization (NARO) in Uganda.*

Svetlana Edmeades *is a postdoctoral fellow in the Environment and Production Technology Division of the International Food Policy Research Institute (IFPRI).*

Mgenzi Byabachwezi *is a doctoral student at the Department of Agricultural Extension and Education at Sokoine University in Morogoro, Tanzania, and a researcher at the Lake Zone Agricultural Research and Development Institute (LZARDI-Maruku) in Tanzania.*

Jackson Nkuba *is a doctoral student at the Department of Agricultural Economics and Agribusiness at Sokoine University in Morogoro, Tanzania, and a researcher at the Lake Zone Agricultural Research and Development Institute (LZARDI-Maruku) in Tanzania.*

Hugo De Groote *is an economist in the Social Sciences Group of the International Maize and Wheat Improvement Center (CIMMYT), based in Mexico.*

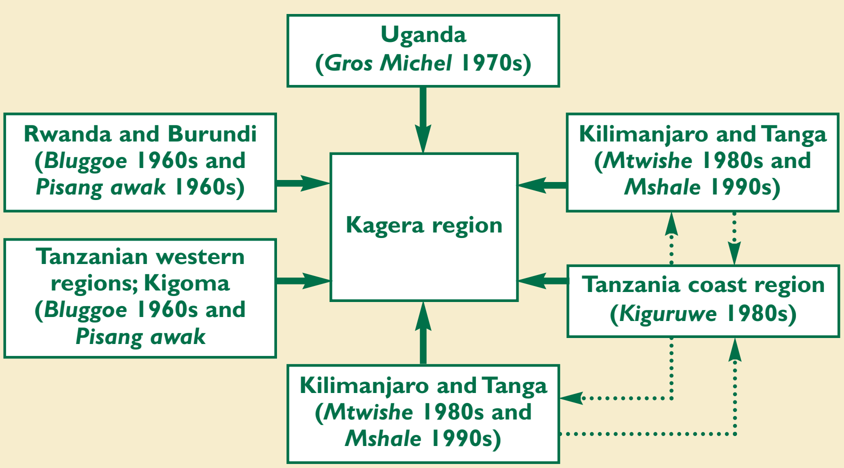
rial circulates among farmers and communities. However, historical records and personal interviews in Tanzania indicate that banana growers have long sought to counteract biotic pressures from plant pests and diseases by procuring new, clean planting material for local varieties both from within their communities and from other, in some cases far-distant, communities. In many instances this process has contributed to the spread of pests and diseases, because farmers did not recognize infested or diseased planting material or fully understand the life-cycles and transfer mechanisms of pests and diseases, especially given the continual evolution of new races and pathogens. In areas along the shores of Lake Victoria, growth in the rural population led to intensified banana production to meet food and cash needs, which was accompanied by a substantial deterioration in the performance of local banana varieties. Farmers tried other varieties cultivated outside Kagera region, termed "exotic" banana varieties, obtained through farmer-to-farmer exchange. These included varieties introduced from Uganda, Rwanda, and Burundi, and the coastal areas and southern highlands of Tanzania (Figure 1).

In the initial period after introduction, the exotic varieties appeared to withstand most biotic pressures and spread rapidly into areas where they replaced local varieties; subsequently, however, they succumbed to other banana pests and diseases. During the 1980s, farmers diversified their production into other food crops, including maize, roots and tubers, to compensate for declining food and income from bananas. In mid-1997, the governments of Belgium and Tanzania agreed to co-finance the Kagera Community Development Program (KCDP)—a major effort to infuse clean, higher yielding planting materials, including the first banana hybrids in the world, bred by the Fundación Hondureña de Investigación Agrícola (FHIA) and provided by the International Plant Genetics Resources Institute (IPGRI). According to the KCDP report, about 1 million banana suckers had been distributed among farmers in Kagera region by 2002, following testing. These high numbers were achieved through direct (nursery to farmer) and indirect (farmer-to-farmer) diffusion (Gallez et al. 2002).

Quantitative data from the Ugandan survey confirm the significance of farmer-based systems for banana planting material. The survey results revealed that the most frequently supplied and received materials in these transactions were endemic cooking varieties, since the dissemination effort was targeted to specific communities and included elite local materials. The vast majority of planting material changed hands without the exchange of money. When the quantity of suckers supplied is taken into account, the planting material of non-endemic and noncooking banana varieties (including banana hybrids) dominated transactions in Uganda. The suckers of hybrid bananas were typically sold for cash. On average Ugandan farmers traveled 15 kilometers to reach the point of acquisition, compared with only 3 km in the Kagera region of Tanzania. The maximum distance in Tanzania, however, was 88 km! This could be viewed as a large transaction cost, given the limited means of transportation for these farmers.

Ugandan farmers were also asked about their willingness to pay for planting material. Farmers in more commercially oriented areas reported a higher willingness to pay for plant-

Figure 1. Introduction of exotic banana varieties to Kagera region by farmers



Source: Personal interviews with farmers in Kagera region conducted by M.S.R. Byabachwezi and J. Nkuba.

Note: In each box, the name of the region is provided along with the name of the variety, in parentheses, and the approximate period of introduction. The solid arrows indicate the original introduction of the exotic varieties, while the broken arrows denote subsequent exchange of planting material across regions.

ing material, as well as those located in areas where elite farmers' varieties or banana hybrids had already been introduced. In Tanzania, KCDP initially distributed planting material free-of-charge and subsequently charged 100 TShs per sucker. Given this approach, few farmers were willing to pay for them (Table 1).

The sheer bulk of the planting material, and the fact that bananas are propagated by cloning, limit opportunities for small-scale seed enterprises, and some public resources are always likely to be necessary for sustainable diffusion of new banana varieties (De Vries and Toenniessen 2001). NARO's work has confirmed that farmer-participatory selection and dissemination improve farmer confidence in new banana varieties, and help farmers to acquire skills and develop criteria to select genotypes suitable for them. Planting material distribution systems designed by the farmers themselves appear to be efficient schemes enabling step-by-step and systematic diffusion of improved varieties to farming communities. Furthermore, the overwhelming significance of planting material and information in farmer-to-farmer exchanges underscores the importance of village social structures in determining whether new varieties are taken up. The analysis undertaken by Katungi et al. (2006 forthcoming) confirms that village social structure influences whether individual farmers use recommended practices for managing bananas.

In addition to the informal farmer-to-farmer germplasm exchange discussed above, other farmer distribution systems for banana planting material have been reported in Uganda (Nowakunda et. al. 2002). In one such system, the four farmers hosting the original evaluation banana plots initiated the formation of an association to supply planting materials at a cost. The formation of this association was driven by the belief that when farmers are given free material, they do not attach any value to it or care for the plants. In another instance, an association was formed whereby the farmer who received the evaluation plot was required to pass on 100 free suckers to another farmer, who in turn was required to do the same. Under this system, after a farmer has transferred the initial 100 suckers, he or she is free to sell planting material, although priority is given to association members. In a third example, farmers organized themselves into a "community." One of the members of this community was selected to receive and host the evaluation plot, which was to be maintained purely as a "mother garden" belonging to the group. Members were able to obtain free planting material from the garden, which they subsequently multiplied in their own banana groves. In a fourth instance, farmers were not organized into groups. The original plot was maintained as a mother garden/demonstration plot by the contact farmer with the support and supervision of the agricultural extension program of the subcounty. Extension workers occasionally organized training workshops at the site, and, after attending these workshops, farmers were given free planting materials. Although plants from this garden were not for sale, some farmers who obtained planting material from the mother gar-

Table 1— Selected characteristics of banana planting material transactions in Uganda

Characteristic	
Percent of farmers supplying materials within or outside village	60.31
Percent of farmers receiving materials introduced to the village	17.58
Total suckers supplied within or outside village	22,819
Total suckers received that were introduced to the village	2,662
Average number of suckers received per years of growing among farmers	5.79
Mean distance traveled to point of supply (km)	1.14
Mean distance traveled to point of acquisition (km)	15.17
Percent of suckers supplied for cash within or outside the village	11.29
Percent of suckers received for cash from outside the village	22.95
Mean willingness to pay among farmers for new planting material (Ugandan Shillings)	502

Source: Edmeades et al. 2006 (forthcoming).

dens did sell them or give away free samples. Of course, farmers who have sufficient resources can purchase tissue culture plantlets at commercial rates from a private laboratory (AGT) based in Kampala or public laboratories at Kawanda and Makerere University. Kawanda and AGT are currently piloting community-based weaning nurseries of tissue culture banana plants in central Uganda, as another source of planting material.

Although a rigorous analysis has not been done, banana researchers and extension staff believe that farmer-participatory dissemination systems may be more efficient than other systems for the dissemination of cooking-type bananas for local consumption, particularly when compared to export-quality dessert bananas, such as those produced in neighboring Kenya for the urban market in Nairobi. One approach to supplying improved planting material is to maintain large planting stock nurseries in the project area for direct sale to farmers and wholesaling to stockists; another is to establish nurseries managed by "expert" farmers through community organizations.

Maize Seed Systems

Morris (1998) has aptly summarized the properties of maize that influence the nature of seed genetic change. Unlike banana planting material, maize seed is compact and easy to store and transport. Maize is also predominantly a cross-pollinating crop, with high rates of exchange of pollen among neighboring plants. Unless carefully controlled, all of the maize plants in a given field will differ genetically from the preceding generation and from each other. To maintain the significant yield advantages offered by maize hybrids, farmers need to purchase their seed annually and are therefore reliant on a well-functioning commercial seed industry. The converse is also true: a hybrid-based maize sector requires large-scale commercial seed enterprises, whose profits can be sustained only by strong seasonal demand by farmers to renew their seed. Improved open-pollinated varieties are popular, but farmers must also renew their seed periodically. Given that farmers do not need to purchase seed for these varieties annually, the economic incentive for commercial seed enterprises to produce them is limited.

While most maize farmers in Sub-Saharan Africa grow local varieties and reproduce their own seed, many have grown hybrids at one time or another. Due to market imperfections and cash constraints, farmers often save F1 (first-generation hybrid) seed, "recycling" it by planting advanced generations. Such practices are widely reported for countries in Sub-Saharan Africa, including Kenya.

High rates of cross-pollination mean that the advantages of F1 seed of maize hybrids can degenerate rapidly when farmers save and replant the seed, though evidence suggests that in some cases advanced-generation hybrids significantly outperform the varieties that the farmer was growing previously—depending on the type of hybrid (single, three-way, or top-cross) and the control that serves as the basis for comparison. Maize is one of the most highly bred crops in the world, and in industrialized countries, its seed industry is one of the most highly concentrated in terms of the share of seed sales held by leading private companies (Heisey, Srinivasan, and Thirtle 2001).

Although the maize seed industry functions well compared with those of other grains and legumes in eastern and southern Africa, seed supply problems have accompanied the still incomplete process of seed market liberalization. Growth in seed sales in Kenya slowed in the 1980s and has fluctuated during the past decade, apparently provoked by inefficiencies and seed quality problems with some private companies.

Demand-driven provision of planting material is a critical ingredient for genetic technical change in a cropping system. De Groote, Owuor, and Doss (2004) cite various reasons why Kenya has not met many of the conditions for successful liberalization of the maize seed sector. Although the mechanism for allowing companies to release seed of new varieties has been changed to encourage participation by private seed companies, and the number of new firms in the market has in fact increased, the market share of new companies has remained small in high-potential areas where farmer demand for seed is stable. The national market is still dominated by a single company and a few varieties, and improved maize sales have stagnated. Community-based or alternative seed suppliers have emerged in the lower potential areas, where farmer demand for purchased seed is less consistent. Most of these community-based efforts depend on external financing and are not considered to be sustainable. Concurrently, public support for agricultural services, including research and extension, has been severely curtailed and formal credit to farmers has all but disappeared. Assuring the physical quality (seed viability) of the planting material is one problem, but its genetic quality (trueness to type) is another; farmers tend to find the genetic quality of seed to be credible only if they or trustworthy neighbors have grown the seed (Morris 1998). These are some of the challenges that will need to be resolved by a combination of private and public funding if the potential for *Bt* maize production in Kenya is to be met.

References

De Groote, H., J. O. Ouma, M. Odendo, and L. Mose. 2004. Estimation of maize crop losses due to stemborers: Preliminary results of a national field survey in Kenya. In *Integrated approaches to higher maize productivity in the new millenium*, D. K. Friesen and A. F. E. Palmer, eds. Proceedings of the 7th Eastern and Southern Africa Regional Maize Conference, Nairobi, Kenya, February 11–15, 2002. Mexico City: International Maize and Wheat Improvement Center.

De Groote, H., G. Owuor, C. Doss, J. Ouma, L. Muhammad, and K. Danda. 2005. The maize Green Revolution in Kenya revisited. *Journal of Agriculture and Development Economics* 2 (1): 32–49.

De Vries, J., and G. Toenniessen. 2001. *Securing the harvest: Biotechnology, breeding and seed systems for African crops*. Wallingford, U.K.: CAB International.

Edmeades, S., M. Smale, J. Nkuba, E. Kikulwe, and E. Katungi. 2006. Characteristics of banana-growing households and banana cultivars in Uganda and Tanzania. Chapter 5 in *An economic assessment of banana genetic improvement and innovations in the Lake Victoria Region of Uganda and Tanzania*, M. Smale, and W. Tushemereirwe, eds. IFPRI Research Report. Washington, D.C.: International Food Policy Research Institute (forthcoming).

Gallez, A., O. Machiels, C. Mbehoma, R. Mitti, and G. Patrick. 2002. *Impact of superior banana varieties (SBVs) in Kagera, Tanzania*. KCDP annual report. Leuven, Belgium: Kagera Community Development Program.

Gold, C., M. Ogenga-Latigo, W. Tushemereirwe, I. Kashaija, and C. Nankinga. 1993. Farmer perceptions of banana pest constraints in Uganda: Results from a rapid rural appraisal. In *Biological and integrated control of highland banana and plantain pests and diseases*. Proceedings of a research coordination meeting. Kampala, Uganda: International Institute of Tropical Agriculture.

Heisey, P. W., C. S. Srinivasan, and C. Thirtle. 2001. *Public sector plant breeding in a privatizing world*. Agricultural Information Bulletin No. 772. Washington, D.C.: Economic Research Service, U.S. Department of Agriculture.

Katungi, E., M. Smale, C. Machethe, and W. Tushemereirwe. 2006. Social capital and soil fertility management in the banana-based production systems of Uganda. Chapter 7 in *An economic assessment of banana genetic improvement and innovations in the Lake Victoria Region of Uganda and Tanzania*, M. Smale and W. Tushemereirwe, eds. IFPRI Research Report. Washington, D.C.: International Food Policy Research Institute (forthcoming).

Morris, M. L., ed. 1998. *Maize seed industries in developing countries*. Boulder, Colo., U.S.A.: Lynne Rienner.

Nowakunda, K., W. K. Tushemereirwe, C. Nankinga, P. Nahamya, and P. Ragama. 2002. Evaluation and dissemination of introduced banana germplasm: A preliminary assessment of the planting material distribution systems. Paper presented at the Rockefeller Foundation/National Agricultural Research Organization meeting on Biotechnology, Breeding, and Seed Systems for African crops, June 4–7, 2002, Entebbe, Uganda.

For further information, please contact Melinda Smale (m.smale@cgiar.org).

This work was made possible in part by support from the Swedish International Development Agency (SIDA), System-wide Genetic Resources Program of the CGIAR, European Commission, and the U. S. Agency for International Development (USAID).

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

2033 K STREET, NW, WASHINGTON, DC 20006-1002 USA
TEL +1.202.862.5600 FAX +1.202.467.4439 EMAIL ifpri@cgiar.org WEB www.ifpri.org