Small Scale Farmers’ Adoptive Responses to Banana Biotechnology in Kenya: Implications for Policy

Margaret Gathoni Karembu

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The study investigates factors that influence the adoption of biotechnological intervention on banana production among small-scale farmers in Kenya and determines policy implications for rapid technology diffusion. Scientists in Kenya found the issue of tissue culture (TC) technology an appropriate intercession for the persistent decline in banana production due to infestation by pests, diseases, and environmental degradation. The common practice by farmers of using infected suckers to propagate bananas had perpetuated the problem resulting in low yields, a situation that threatened close to 3 million Kenyans whose livelihoods depend on bananas. The sterile operational nature of TC procedures excludes fungus, bacteria, and pests from the production system resulting in timely production of large quantities of clean and superior planting material from plantlets instead of suckers. The study proceeded concurrently and within a bigger project facilitated by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and hosted by the Kenya Agricultural Research Institute (KARI). To avoid the “technology push” approach so often associated with perceived beneficial but dismally performing innovations, the researcher worked alongside scientists from these institutions to ensure unbiased representation of farmers’ perceptions of the appropriateness and suitability of the technology under their (farmer) conditions. The research design was a case study involving 500 farmers in three major banana-growing regions: Eastern, Central, and Nyanza provinces of Kenya. Variety preferences, compatibility of the technology within existing farming systems, techno-management practices, marketability of the produce, consumer acceptance, and costs' implications were investigated. Overall, the results indicated that TC technology fitted well within small-scale agriculture, had wide consumer acceptance and provided a good opportunity to transform banana farming from subsistence to cash-based enterprise. Limitations to technology diffusion included the high cost of plantlets, water scarcity, inadequate clean land, insufficient distribution system for plantlets, unorganized marketing of the banana fruit and lack of a collective mechanism to modulate the production-distribution-marketing chain. Working to improve access to planting material through provision of credit and decentralizing distribution, introducing appropriate water-harvesting techniques, linking farmers to markets through marketing information centres, introducing banana value-adding techniques and helping to establish farmer-driven banana associations were recommended as unprecedented steps towards enhancing agricultural practices using banana biotechnology. The policy challenges lie in building selective partnerships that bring institutions (public and private) with comparative advantages in specific aspects of the technology transfer chain to give timely responses to technology diffusion issues as they arise.

Abstract

The study investigates factors that influence the adoption of biotechnological intervention on banana production among small-scale farmers in Kenya and determines policy implications for rapid technology diffusion. Scientists in Kenya found the issue of tissue culture (TC) technology an appropriate intercession for the persistent decline in banana production due to infestation by pests, diseases, and environmental degradation. The common practice by farmers of using infected suckers to propagate bananas had perpetuated the problem resulting in low yields, a situation that threatened close to 3 million Kenyans whose livelihoods depend on bananas. The sterile operational nature of TC procedures excludes fungus, bacteria, and pests from the production system resulting in timely production of large quantities of clean and superior planting material from plantlets instead of suckers. The study proceeded concurrently and within a bigger project facilitated by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and hosted by the Kenya Agricultural Research Institute (KARI). To avoid the “technology push” approach so often associated with perceived beneficial but dismally performing innovations, the researcher worked alongside scientists from these institutions to ensure unbiased representation of farmers’ perceptions of the appropriateness and suitability of the technology under their (farmer) conditions. The research design was a case study involving 500 farmers in three major banana-growing regions: Eastern, Central, and Nyanza provinces of Kenya. Variety preferences, compatibility of the technology within existing farming systems, techno-management practices, marketability of the produce, consumer acceptance, and costs' implications were investigated. Overall, the results indicated that TC technology fitted well within small-scale agriculture, had wide consumer acceptance and provided a good opportunity to transform banana farming from subsistence to cash-based enterprise. Limitations to technology diffusion included the high cost of plantlets, water scarcity, inadequate clean land, insufficient distribution system for plantlets, unorganized marketing of the banana fruit and lack of a collective mechanism to modulate the production-distribution-marketing chain. Working to improve access to planting material through provision of credit and decentralizing distribution, introducing appropriate water-harvesting techniques, linking farmers to markets through marketing information centres, introducing banana value-adding techniques and helping to establish farmer-driven banana associations were recommended as unprecedented steps towards enhancing agricultural practices using banana biotechnology. The policy challenges lie in building selective partnerships that bring institutions (public and private) with comparative advantages in specific aspects of the technology transfer chain to give timely responses to technology diffusion issues as they arise.
## Abreviations & Acronyms

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>AEZ</td>
<td>Agro-ecologicalzone</td>
</tr>
<tr>
<td>ATPS</td>
<td>AfricanTechnologyPolicyStudies</td>
</tr>
<tr>
<td>GDN</td>
<td>GlobalDevelopmentNetwork</td>
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<tr>
<td>GTL</td>
<td>GeneticTechnologiesLimited</td>
</tr>
<tr>
<td>IDRC</td>
<td>InternationalDevelopmentResearchCentre</td>
</tr>
<tr>
<td>INIBAP</td>
<td>InternationalNetworkfortheImprovementofBananaandPlantain</td>
</tr>
<tr>
<td>ISAAA</td>
<td>InternationalServicefortheAcquisitionofAgri-biotechApplications</td>
</tr>
<tr>
<td>ITSC</td>
<td>InstituteofTropicalandSub-tropicalCrops</td>
</tr>
<tr>
<td>KACE</td>
<td>KenyaAgriculturalCommodityExchange</td>
</tr>
<tr>
<td>KARI</td>
<td>KenyaAgriculturalResearchInstitute</td>
</tr>
<tr>
<td>MALDM</td>
<td>MinistryofAgriculture,LivestockDevelopmentandMarketing</td>
</tr>
<tr>
<td>MOA</td>
<td>MinistryofAgriculture</td>
</tr>
<tr>
<td>NGO</td>
<td>Non-GovernmentalOrganisation</td>
</tr>
<tr>
<td>PRA</td>
<td>ParticipatoryRuralAppraisal</td>
</tr>
<tr>
<td>tc</td>
<td>tissueculture</td>
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<td>WHO</td>
<td>WorldHealthOrganization</td>
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Whether innovations in biotechnology can offer relevant solutions to problems of small-scale farmers in developing countries has been a subject of debate for a while. Of concern during the last decade has been the search for models and specific conditions to optimize the benefits of these technologies for the poor. The debate has arisen out of widespread acknowledgement from researchers of a well-developed system of learning by traditional societies guided by cultural values, practices and perceptions upon which innovations are selectively adopted (Thrupp, 1989). Oduol (1994) quoting a study by Apter in 1965 argues that no matter how attractive the innovation may be, societies never abandon their culture and environmental orientation to fully embrace a new practice. The process is more complex in the transfer of technology to poor communities where change of cultural practice is involved, for example, the transfer of tissue culture technology on banana to slash and burn farmers.

Tissue culture (TC) is a form of biotechnology that refersto the production of plants from very small plant parts, tissues or cells grown aseptically under laboratory conditions where the environment and nutrition are rigidly controlled (Hartman and Kester, 1983). There are several techniques broadly classified into two categories:

- Class I involves the regeneration of new plants from existing vegetative structure or tissue.
- Class II refers to reproduction of seedlings by excision and culture of existing reproductive structure.

The basis of the technology lies on the ability of many plant species to regenerate a whole plant from a shoot tip. It entails using tiny shoot-tips as the starter propagation material that is placed in a growth media to enhance various processes of growth, such as shoot initiation, formation of multiple shoots and rooting induction at the final stage. These activities induce vigour, commonly referred to as "hormonal kick," that brings the parent material to a juvenile stage causing remarkable physiological changes that influence the agronomic characteristics of the emerging plant. These physiological adaptations become dilute in subsequent generations and are not inheritable genetic changes. Tissue culture, therefore, does not involve genetic modification.

The wide use and distribution of infected planting material caused the acute decline in banana production in Kenya. Neighbour-to-neighbour propagation of banana suckers led to synergistic increases in banana pests and diseases. This ultimately contributed to low average yields of less than 10 tons per hectare compared to potential yields of up to 60 tons per hectare. Environmental degradation, low level of farm inputs and poor farming practices aggravated the problem.

Introduction & Background
These factors, coupled with the fact that bananas have only recently been recognized as a priority crop in the Kenyan agricultural research system because of the poor performance of major cash crops, such as tea and coffee, have created a shortage of the fruit in the local market. Wambugu et al. (2000) assert that bananas have become increasingly costly and no longer serve as a readily available supply of high nutritious food and cash for the Kenyan population, particularly women and children. In 1990, for example, 1 kilo of banana cost Kshs. 5.00; in 1995 the same was Kshs. 15; and in 2000 it was Kshs. 30 (Central Bureau of Statistics annual reports, 1990-2000). The situation threatens food, employment, and income security in banana-producing areas and could affect close to 3 million Kenyans whose livelihoods depend on banana production.

In an effort to respond to the above problems and in consultation with farmers, the project “Biotechnology to Benefit Small-Scale Banana Producers in Kenya” was initiated in 1997. The introduction of tissue culture techniques for banana propagation was recognized as having the greatest potential to help reverse the situation. Key concerns were the profitability and sustainability of producing and using biotechnology as a business venture, and its potential impact on hunger and poverty alleviation in Kenya and neighboring countries of Tanzania and Uganda.

Family that has now taken up potted banana farming.
Past experiences with new agricultural innovations show that farmers do not always adopt an innovation because of high yields or economic returns (Carr, 1989). Studies on various programs have disapproved the notion by scientists that “advantageous” technologies will find their way into the marketplace and diffuse rapidly because of the obvious benefits to potential adopters (Bwisa and Gachuhi, 1999). The World Health Organization (WHO), in an attempt to eradicate and manage world epidemics like malaria in the 1970s, overlooked the social dynamics of community-based approaches and their efforts proved futile (WHO, 1978). Elsewhere, the economic evaluation of an introduced algal protein biotechnology in Mexico by Babu (1991) confirmed that although the biotechnology product offered the cheapest source of essential vitamins and proteins, its adoption in individual households was slow. An acceptance analysis showed that this was partly due to the fishy taste of the algal leading to slow adjustments by households.

In Nigeria, Madukwe (1994) investigated factors related to the adoption of improved farm practices specifically theyam Minisette technology and identified farmer ethnography, nature of the farm, perceived attractiveness of the innovation, and characteristics of the innovators as important factors in the adoption of technology. In Kenya, the red cowpea project is an example of technology that was not successful with self-diffusion. Despite the superiority and drought resistance qualities of the pea, it had a low consumer acceptance because of the extended cooking time and the blood-red color of the broth (Ministry of Agriculture reports, undated).

In other communities, economic returns and high yields do not always imply that an innovation is acceptable. Pala (1980) and Oduland Karugu (1993) indicated that the decision to allocate and use technological innovations is made along gender lines and is highly skewed towards male benefits. Thus, diffusion of agricultural technologies aimed at improving food crops conceived as “women’s crops,” such as bananas, beans, roots, and tubers could suffer from stereotypical technological trends.

Agricultural biotechnology is often assumed to hold great potential for the small-scale farming sector in developing countries. However, lack of an analytical frame-work with which specific biotechnology products can be quantitatively evaluated based on ex-post data has made economic impact assessment impossible.

It is against this background that African Technology Policy Studies Network (ATPS) incorporated a technology diffusion study into an ongoing national project, titled “Biotechnology to benefit small-scale
BananaproductsinKenya. Thestudyanalyzestheimpactoftissueculture(tc)technologyintheKenyan banana sector.

TheoveralltissuecultureprojectwassponsoredbytheRockefellerFoundation,USA, theInternational Development Research Center,(IDRC)Canada,andtheAfrican Technology Policy Studies Network (ATPS). It was facilitated by the International Service for the Acquisition of Agri-biotech Applications (ISAAA) and hosted by the Kenya Agricultural Research Institute (KARI). It was conceived as a response to a pronounced decline in banana production in Kenya over the last two decades. The project aimed at providing resource-challenged small-scale farmers with pathogen-free banana planting material through tissue culture techniques. Through this technique, large numbers of healthy banana plantlets are produced in the laboratory in a comparatively short time. This reduces and ultimately eliminates pest and disease problems for banana growers, offering a conducive environment for introducing of new and superior germplasm.

Undertemperate plantation conditions, the physiological changes that occur from the tissue culture technology take up to about the fourth generation to revert to the original parent/traditional banana vigour and agronomic characteristics (Robinson, 1994). Under smallholder farming in tropical conditions, however, the period that it takes for changes to occur is not yet known but is expected to be longer. This implies that the economic window of enhanced production using the tissue material is enormous since even under normal traditional systems, farmers using inferior planting materials keep their orchards for a long time before replacing the plants (Nguthi, pers. com. 1997).

In six months, up to 2,000 individual plantlets can be produced from a single shoot. With the normal sucker method of propagating bananas, only about 10 suckers can be produced from one plant in the same period. These plantlets are then transplanted into tiny pots and kept in a highly humid laboratory atmosphere for 10 days to acclimatize and harden to the conditions of the natural environment. After potting, they are ready for the field in two months, at about 30 cm high. The sterile operational nature of tissue culture procedures excludes fungi, bacteria, and pests from the production system meaning that diseases, such as the Panama disease caused by *Fusarium oxysporum* f.sp. *Cubense* (FOC), and weevils (*Cosmopolites sordidus*)/nematode complexes (*Radopholus similis*) cannot be transmitted through the micro-propagation. However, viruses, such as the banana bunchy top and the epistomal form of banana streak virus are not eliminated through tissue culture transmission.

Tissue culture is a fairly simple technology compared to other forms of biotechnology, such as genetic engineering. However, the young plantlets are extremely tender and sensitive to water stress. They require special management during the first five months of establishment to perform well in the field. Planting should, therefore, coincide with the onset of long rains unless irrigation is available. Regular supply of water and manure are essential to maintain the vigour.

Since there was no data from previous studies on the performance of tissue bananas in farmers' fields when the technology breakthrough was made public, this diffusion study was commissioned to assess the adoptive responses and recommend strategies to address issues that would prevent large-scale adoption of the technology.
Objectives

The general objective of the diffusion study was to investigate factors that influence the adoption of the newly introduced tissue culture technology on bananas among farmers and determine policy implications for rapid technology diffusion within the predominant small-scale agricultural systems in Kenya.

The specific objectives were:

- To establish whether the technology was responding to banana priority constraints among farmers (appropriateness of the technology).
- To determine the most preferred banana varieties among farmers.
- To describe the acceptability of tissue-cultured bananas among farmers and consumers.
- To identify farmers' perceptions of the production and management constraints of derived bananas.
- To examine factors related to the technology that could limit diffusion.
- To suggest policy intervention and the optimal conditions under which agri-biotech products' transfer occurs among resource-challenged farmers.
Methodology

The study used a participatory approach to research where extensive field and market surveys, interviews and focus group discussions were conducted to collect data. These methods were most appropriate for this kind of study since they allowed free expression of opinion and experiences, making it easy to determine the acceptability and perceptions of farmers toward the technology. These methods also suited the mostly semi-literate target group. Three major banana-growing regions: Central, Eastern and Nyanza provinces were selected for the study (Table 1). The researcher worked closely with a team of scientists from KARI and private enterprises that propagated the banana and set up the various on-farm and on-station demonstrations in the study sites.

Table 1: Average banana production statistics for the provinces of Kenya (1996-1997)

<table>
<thead>
<tr>
<th>Province (Percent)</th>
<th>Area (ha)</th>
<th>Production (t)</th>
<th>Yield (t/ha)</th>
<th>Production share</th>
</tr>
</thead>
<tbody>
<tr>
<td>*Central</td>
<td>16,913</td>
<td>169,316</td>
<td>10.0</td>
<td>16.5</td>
</tr>
<tr>
<td>Coast</td>
<td>5,743</td>
<td>55,341</td>
<td>9.6</td>
<td>5.4</td>
</tr>
<tr>
<td>*Eastern</td>
<td>9,669</td>
<td>97,144</td>
<td>10.0</td>
<td>9.5</td>
</tr>
<tr>
<td>Nairobi</td>
<td>48</td>
<td>409</td>
<td>8.5</td>
<td>0.0</td>
</tr>
<tr>
<td>NorthEastern</td>
<td>271</td>
<td>1,522</td>
<td>5.6</td>
<td>0.1</td>
</tr>
<tr>
<td>*Nyanza</td>
<td>30,234</td>
<td>574,740</td>
<td>19.0</td>
<td>56.1</td>
</tr>
<tr>
<td>Rift Valley</td>
<td>2,688</td>
<td>39,781</td>
<td>14.8</td>
<td>3.9</td>
</tr>
<tr>
<td>Western</td>
<td>7,800</td>
<td>86,107</td>
<td>11.0</td>
<td>8.5</td>
</tr>
<tr>
<td>Total</td>
<td>73,366</td>
<td>1,024,360</td>
<td>14.0 (average)</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Informal questionnaires that also served as interviews schedules, observations sheets and Participatory Rural Appraisals (PRAs) were the key instruments used in data collection. The PRAs were used to solicit information on banana priority constraints, variety preferences in different zones, perceptions of the technology, gender issues and understanding group dynamics as an appropriate method for technology transfer. The interviews schedules elucidated data on management practices and/or constraints, true-to-type of the bananas, for example, size, colour, taste, among others. Data on the suitability of the bananas within the existing environmental and socio-economic conditions, for example, inputs, accessibility and placement of bananas against other crops in the field was also explained. During visits to farms and markets, observations sheets reinforced the latter two instruments and were used to record information on the appropriateness of the innovation within the farming systems and the suitability of the technology to alleviate hunger and poverty. Visit to markets were also used to collect data on consumer acceptance, marketability of the product and understanding important issues in banana marketing.

For most part of the fieldwork, data from farmers’ fields was collected from individual farmers or groups during meetings. Specific issues from group discussions (PRAs) were investigated in several farms. Because of fluctuations in attendance during group meetings, qualitative data analysis was more appropriate for the better part of the report and figures were based on group consensus. Where the researcher was able to capture numbers, frequencies were computed and reported.

Field Activities

The PRAs helped to ascertain whether the technology would achieve the following:
- respond to priority banana production constraints
- identify preferred cultivars
- gauge farmers’ views of the technology
Market studies helped to identify consumer variety preferences to ensure that farmers would grow the desired bananas and for the researcher to understand the marketing of bananas.

Farm visits helped to assess how well the farmers accepted the technology, their perceptions of the technology and management practices. The visits also shed light on the anticipated constraints to technology diffusion based on the characteristics of the technology, the farmers and the farming environment.

In each area, agricultural extension officers guided the researchers to locations where they could conduct the PRAs. They also advised on methods to capture the relevant audience. Consequently, market days and other social functions in the study areas, such as church gatherings, welfare group meetings and schools were used to publicize the study.
The study identified the following factors, in order of priority, as major constraints to banana production:

- pests (moles, weevils, nematodes)
- diseases (Panamadisease, cigar-endrot, Sigatoka)
- lack of clean planting material
- exploitation by middlemen due to poor organization in marketing
- lack of extension services
- inadequate manure and other inputs, especially water
- poor infrastructure often resulting in heavy postharvest losses

All farmers across the study sites reported pests, diseases and lack of uninfested planting material as the most pressing problems. These reports concur with what the researchers identified earlier. Farmers reportedly tried to control pests and diseases through crop rotation and buying suckers from government prisons departments, expecting fairly clean planting material but they were disappointed. The researchers used this opportunity to explain the technology in detail. They also showed the farmers samples of plantlets they carried during the PRAs and they (farmers) readily accepted to test the technology.

The most popular banana varieties ranked in order of relative importance were:

- GrosMitchel (AAA) – ranked first in Central Province
- Israel (AAA) – ranked first in Eastern Province
- Muraru (AA)
- Uganda Green (EAAAA) – ranked first in Nyanza Province
- Apple banana

Important characteristics that influenced the ranking of cultivars were:

- ability to attract high prices in the market
- consumer acceptance and preference
- longshelf-life
- cultural attachment (e.g. Muraru in Eastern and Central provinces)
- preference for multipurpose varieties, for example, cooking, dessert and fodder
Variety selection criteria varied depending on whether the crop was grown for subsistence or commercial purposes. For instance, where bananas were grown for cash, the bunch size and market price, determined by demand and supply, were the most important factors. In Kisii District, where the cooking variety is most commonly grown and used a lot by the local community as food, initial introduction of the technology received some resistance since the introduced varieties were the dessert Cavendish. One farmer complained saying, "a child cannot be cooked" (Joseph, pers. Com).

How Appropriate was the tc Banana Technology in Small-Scale Agriculture?

The acceptability and appropriateness of the technology was gauged against the characteristics of three main factors, namely:

- technology
- farming environment
- the farmer making the adoption decision

Characteristics of the Technology

Characteristics of a technology that can encourage or discourage adoption include its complexity, profitability, risks involved in adoption, compatibility with other technologies or farmer practices and divisibility (Rogers 1983; Morris et al., 1999).

In the study, a few farmers (15%) reported having heard of the technology on bananas but did not know where to get the materials. Others confessed to having bought one to five plantlets from the Jomo Kenyatta University of Agriculture and Technology (JKUAT) but the materials had "reverted" back to traditional bananas. Others said they had attempted, without success, to get the planting materials from JKUAT and had been placed on a waiting list generated from the initial public announcements by the university to supply plantlets. Follow-up visits to specific farmers indicated they did not know how to manage plantlets, thus explaining the poor performance of the initial materials purchased. The interest of those who had waited for a long time to get materials had waned. In some parts of Kisii District in Nyanza Province, several farmers misconceived the plantlets to be flowers and were not willing to try out the technology.

Once the national project by KARI/ISAAA on field evaluation commenced with the setting of on-farm demonstrations and systematic training on technology management, the excellent performance of the tc bananas generated high demand from farmers regardless of education and age. Nearly all tc banana farmers interviewed, within and without the project area, had some basic education with 30% having reached secondary school, 54% with primary school education, 11% with post-secondary and only 5% with no formal education. The farmers' age bracket ranged from 18 to over 60 years old. The oldest farmer encountered with tc bananas was 80 years old. This led to the conclusion that the tc banana technology is not complex to small-scale farmers and fits well within their farming system.

These observations, however, yielded two important lessons on technology diffusion:

- Education and familiarization with the technology to end-user, through on-farm demonstrations is key to diffusion.
Disseminating a good technology without proper information on management could create a wrong impression of complexity, negatively influencing diffusion.

Availability of the product, once end-users are sensitized, is another important lesson. Initially, the tissue bananas were only available in the public domain (JKUAT) that was notable, at the time, to produce adequate material to meet demand and create through media announcements. Involving the private sector, like the Genetic Technologies Limited (GTL), a private tissue culture laboratory in Nairobi, offered timely response to farmers' needs. The private laboratory later teamed up with KARI to form a public-private partnership contributing significantly to successful diffusion that is an appropriate policy recommendation. Accessing material to the wider target groups who are scattered all over the country, however, is still a major challenge since a distribution system for the plantlets is yet to be established.

Farmers, naturally, are interested in technologies that give higher returns to scarce factors of production, such as labor, cash, land, and capital. Profitability of bananas was determined, inter alia, by the bunch size and the number of bunches harvested at a time. Field observations indicated that the technology had made it possible for farmers to:

- access superior clean planting material that mature early (12-16 months compared to the conventional banana of 2-3 years)
- harvest bigger bunch weights, (30-45 kg compared to the 10-15 kg from conventional material)
- attain higher annual yield per unit of land (40-60 tons per hectare against 10-20 tons previously realized with conventional material)

Moreover, two additional attributes: uniformity in orchard establishment and simultaneous plantation development that are not possible with traditionally grown bananas appeared to have strengthened the case for the technology among farmers.

It was, however, observed that the cost of plantlets, about one and a half dollars ($1.5), and the high requirements for water and manure were limiting factors to the diffusion process. Many farmers, therefore,

Uniformity in fruiting for tissue bananas encourages commercial marketing with potential to transform banana growing from merely subsistence to cash-based enterprise, an appropriate poverty reduction strategy.
were not able to establish viable commercial units as earlier determined by an ex ante socio-economic study by Qaim (1999) to be a minimum of 80 plants. The average number of plants for close to 75% of the farmers was 20. It was not until a pilot micro-credit was introduced in Central Province that farmers were able to expand their orchards to an average of 40 plants.

Though farmers appreciated the opportunity created by the technology for bulk marketing, they were pessimistic on profitability because of what they disgustedly explained as, “a chain of numerous exploitativemiddlemen and women.” The poor state of infrastructure was another concern for farmers, and it reported heavy losses while transporting bananas to urban markets where they hoped to fetch better prices.

These findings revealed several aspects for policy considerations of resource-challenged farmers to benefit from innovations. First, is the availability of essential input to deploy the technology successfully. In this case, providing micro-credit stimulated the diffusion process and policymakers should consider it an important factor in technology transfer. Second is marketing. For perishable commodities, such as bananas, links to markets by providing marketing information is essential, while additional technology for adding value to the products, for example, processing bananas into jam, wines and crisps are important value. Otherwise, the profitability of the project from a researcher’s point of view may be disastrous for resource-challenged farmers with bulk harvesting that they cannot dispose of. Close proximity to urban markets, such as Nairobi, is a disadvantage to farmers in Central Province. For other regions, the local county councils, through appropriate government policies, could be assisted to streamline the marketing of bananas, for example, by setting up cold storage facilities.

Farmers also weigh the risks involved in adopting new technology. They may be convinced that the new technology works, but they will be uncertain how it will perform in their own farms. In this study, the uncertainty was allayed by setting up farmer-managed tct banana demonstration trials in all the project areas. Participating and non-participating farmers were thus convinced that the tct banana technology worked provided they managed the bananas as demonstrated by the researchers.

Performance during unusual climatic stress, for example, shortage of water is another risk that can lead to the abandonment of the technology. This risk is real because tct bananas have a high affinity for water and only 7% of the farmers had reliable water sources from boreholes and streams nearby. Under unfavourable climatic conditions, especially drought, it is risky to adopt tct bananas. Drought had already forced some would-be adopters to wait until the situation improved. In all the surveyed areas, farmers cited water as a limiting factor to technology uptake.

In Central Province, farmers, especially those who bought the tct banana plantlets in anticipation of the long rains in April-May were disappointed when the rains failed. They had to draw water from rivers to save the tct plantlets from dying. This task was tedious and impractical for farmers with many mat soft bananas unless alternative water provisioning techniques are introduced. To avert such crisis, farmers are being encouraged to train on simple techniques of harvesting rainwater. A highly successful method in one of the drier parts of the Rift Valley Province is harvesting surface runoff. The project team has already initiated links with the farmers’ groups in these regions to benefit from the technique.

New technologies also stand a better chance of being adopted if they are compatible with the current farming practices. The tct banana technology involved a change of practice from the traditional sucker
method where the suckers are obtained free compared to the use of plantlets, which were bought. The plantlets also required a high level of management than the farmers were used to. Nonetheless, apart from in Nyanza Province where a few farmers complained about the management requirements, the technology was compatible with the current farming practices with a management improvement bonus to traditional orchards.

Further, the tc bananas, just like those from conventional suckers, were complementary with the keeping of animals. Farmers fed bananas to the animals and obtained manure for the farm in return. The pseudostems from well-managed tc bananas were far much bigger than those from conventional suckers and farmers reported this as an advantage since they provided more feed to animals. Farmers also appreciated that some changes in banana management practices required for tc banana growing were beneficial.

Another advantage of tc banana technology is its divisibility. Although tc plantlets are expensive, farmers could buy a few plants for testing or buy a few every season and gradually replace the conventional bananas. This method, according to farmers, reduced risks of adopting the technology by allowing them to try it gradually and on a small area. Considering the shrinking farm sizes per family caused by population pressures, this factor cannot be overemphasized.

**Characteristics of the Farming Environment**

The environment in which farmers operate, such as agro-climatic conditions; the nature of prevailing cropping systems; the degree of commercialization of the cropping enterprise and the availability of physical inputs also affect diffusion. The agro-climatic conditions, as a determinant of technology adoption can be understood in the sense that they can influence the performance of a technology. Although bananas can grow in most agro-ecological zones in Kenya, the researchers carefully selected zones most suitable
for bananas growing. The prolonged drought that was unusual and the absence of irrigation in most farms were the only problems encountered.

The study established that the ctc plantlets required extra resources and high-level techno-management practices especially in preparing holes, de-suckering, watering, applying manure and, to some extent, fertilizer. Information packages on management were necessary because the technology uptake increased, more entrepreneurs came into distribute plantlets. Chances of reaping maximum benefits from the ctc technology without proper management were slim.

About half (48%) of the farmers interviewed, especially in Central and Eastern provinces, opposed the use of fertilizer because of the belief that synthetic fertilizer made the bananas soggy and tasteless affecting quality. The researcher tested for alteration of the qualities alleged but found no evidence although the period of application of the fertilizer mattered. Farmers were advised on fertilizer use and subsequent proper application to enhance yields. However, old habits die hard and an inappropriate strategy would be to give farmers the option of using artificial half fertilizers or organic manures since the latter would be cheaper and more environment-friendly than the former. Several local initiatives from grassroots organizations, such as Wangui Investments and the Kenya Institute of Organic Farming, operating in the project sites have been training farmers on making compost manure for the bananas.

Although most of the farms visited initially had banana intercrop, a good number (32%) had abandoned intercropping to bananas when they realized that they get better returns when the banana was grown as a monocrop.

**Characteristics of the Farmer Making the Adoption Decision**

Athird set of factors documented in literature (Madukwe 1994; Oduol 1996; Morris et al. 1999) as important to technology diffusion processes are farmers' personal circumstances, including age, wealth, education, gender and group membership. These factors were assessed against their potential influence on diffusion of the ctc banana technology.

Ninety-five percent (95%) of the farmers were categorized as literate. The farmers' age bracket ranged from eighteento over sixty years. The oldest farmer encountered with ctc bananas was 80 years old. The average income was about Kshs. 4,800 across the three sites with Central Province recording higher incomes (over 40% recorded earnings in the Kshs.5,000 range). Kisii District had the lowest recorded incomes with 45% reporting earnings in the range of about Kshs. 2,000. This figure is supported by the Kenyan Government Poverty Reduction Strategy Paper (PRSP) published in September 2001 citing Nyanza as the province with the highest proportion of people living below the poverty line, defined as just KShs.1,239 (US$15.6) per month (PRSP Report 2001).

The observed wider range in wealth between the very low and the very high within the target smallholder was found to have an effect on the diffusion. Farmers with higher incomes (22%) had advantages not only in the ease of making contacts with researchers and other sources of technical information but also access to inputs, mainly water and manure. These farmers also had fewer difficulties in raising cash to purchase the plantlets and they could also hire transport to deliver the fruit to urban markets. Tissue culture banana technology is thus likely to benefit more beneficial to the very poorly institutional mechanisms are put in place to provide additional resources. The major limiting factor to adopting ctc technology for banana at date is the high cost of plantlets, inadequate inputs and lack of marketing information.
Although it was not possible for this study to correlate income with adoption (annual income estimates among majority small farmers who rarely keep farm records was difficult to compute), farmers with relatively larger farms and higher incomes seemed to have less problems in adopting the technology. In the study sites, this percentage was small since 80% of the farmers had an average farm size of only 1.5 hectares. As reported earlier, nearly all the farmers interviewed had some formal education (95%) but this did not seem to affect technology diffusion.

Age was an important factor in diffusion, with more farmers (62%) above 40 years of age compared to 32% of those below this age. Adoption of the technology was higher among those who had more experience with the crop. Younger farmers were uncertain whether they would inherit the piece of land they were farming and so they preferred growing short-term crops like beans, vegetables, and groundnuts. On the contrary, farmers above 40 years old had more experience and they found the technology more appropriate. Bananas being a perennial crop, land tenure as a matter of policy affects technology uptake and should be considered.

Mostly farmers who belonged to farmer groups had adopted the technology. This was prevalent in Central Province where farmers who belonged to informal “merry-go-round” groups had been encouraged to form banana-farming groups with an average of 40 members. Diffusion was slow in Eastern and Nyanza provinces where the technology was introduced to individual farmers. In Central Province, there were more than 400 farmers with tcv bananas while in Eastern and Nyanza, the figure was hardly 200 farmers. Therefore, if the technology were introduced to individual farmers hoping that others would take it up from those individuals, it would take much longer to diffuse. Group approach seemed to be more effective in transferring technologies, especially where education and training contribute.

Farmers’ groups have been a major source of the success of the tcv banana technology transfer. KARI and ISAAA helped at least eight farmers’ groups to access a revolving micro-credit fund through their registered welfare associations to finance acquisition of tcv plantlets. The modified Grameen Model of loan repayment adopted for groups has helped the micro-credit fund to remain solvent. These groups offer good entry points for training farmers on tcv banana management practices and other farmer enterprises from other development partners. The groups have also strengthened the socio-economic fabric of the participating communities by sharing ideas and experiences on development.

Since gender has been widely acknowledged as important in technology uptake, the diffusion study investigated the gender dimension in tcv banana uptake. An interesting observation was that despite bananas being a predominantly woman’s crop, men quickly realized the opportunity and more of them started attending the group meetings. At the beginning, the proportion of women to men in the meetings was two-to-one. By the first harvest, this had been equalled to one-half. There were divisions on varieties that could be marketed by gender. In Kisii, for instance, women mainly marketed apple bananas that are small and fetches little money, while men marketed the cooking type (Ekeganda and Ng’ombe grades) that is much bigger and fetches more money in the market.

With the tcv banana assuring biggersized banana and with the introduction of other varieties, men now have equal opportunities at the market and sell high-value bananas. They have also been attracted to the technology and there are no conflicts over land-use as far as eatenears are concerned. Men support the technology and as household heads who make decisions on what to be planted, this is a boost to technology adoption. Adopting the technology has narrowed the gender gap through economic empowerment and there is more money for the family regardless of the source.
Summary of Lessons Learnt

- Education and familiarization with technology to end-users through on-farm demonstration is key to diffusion.
- Diffusion is directly linked to end-users' impression about the ease of the process and the technology, its acquisition and availability.
- The private sector, for example, the Genetics Technologies Ltd. (GTL) is better placed to offer timely response to farmers' needs as decisions can be made faster compared to public institutions, for example, JKUAT that must adhere to institutional procedures before delivering.
- Farmers are naturally interested in technologies that maximize productivity, that is, giving higher returns to scarce factors of production, such as labour, cash, land, time and capital without impacting negatively on their cultural practices from on-set.
- New demands, for example, cost of plantlets at US$1.5 and high requirements for water and manure for the banana cultivation, are limiting factors to the diffusion process and the implementing organization has to avail the essential inputs or bring in new partners to deploy the technology successfully. Micro-credit, therefore, would stimulate diffusion.
- The high yields resulting from the technology demands a new marketing approach, especially targeting urban markets. Farmers, therefore, must be inducted into basic marketing techniques, for example, costing, pricing, transportation and the elimination of middlemen. The implementing organization should incorporate marketing aspects as part of the package and where possible, offer assistance in the same, besides the training.
- Farmers will not risk adopting a new technology until they are convinced that it will perform successfully in their own farms. This fear is only allayed by setting farmer managed demonstration trials within their locality, to provide hands-on experience with the innovation.
- New technologies stand a better chance of adoption if they are compatible with current farming practices, for example, tc banana technology involved the purchase of plantlets thus slowing the adoption process. Other aspects, like using stocks to feed the farmers' animals, encouraged the adoption of the technology given the envisaged increase in crop and livestock production.
- Technologies that allow gradual adoption alongside traditional methods stand higher chances of success because the farmers do not feel over-exposed.
- The farming environment, especially the agro-climatic condition determines the adoption of a technology since climate can influence performance.
- Diffusion of technology is also determined by the characteristics of the farmers, for example, age, education, wealth, gender and group membership. The more educated, wealthier and exposed farmers readily adopt new technologies because they have stop-gaps and don't get trapped with the feeling of losing everything. Men are more easily absorbed in projects that show obvious economic benefits and also because culturally, they control the land and head households.

Summary of Policy Implications from the Study

- For better results, the main policy challenge will be to establish efficient biotechnology distribution channels in Kenya. This involves improving community-based initiative for the retailing of tc banana plants and related extension services. This project study has demonstrated that the potential gains of appropriate biotechnology can be greatest for the small-scale farmers.
- The potential of tc bananas need to be translated into action by making the new technology accessible to all Kenyan farmers.
Public research and development (R&D) funds should be made available to develop biotechnology that explicitly tackles the needs of resource-poor producers in developing countries. The actual impact of biotechnology is not only a question of technology but also hinges on an efficient institutional framework. The success of use of biotechnology presupposes extensive capacity building in the national system of agricultural research and technology diffusion.

International collaborative biotechnology projects achieve comparatively quick success in the target countries. The associated accumulation of knowledge, experience, and self-confidence pave the way for broader future biotechnology innovation.

The private sector has a primary role in the north-to-south biotechnology transfer, especially the multinational biotech companies. R&D partnerships should be strengthened between the public institution and the beneficiaries to enable the poor participate in the international biotechnology revolution.

Involving the private sector from the start signifies not only a reliable supply but also the establishment of a long-term commercial infrastructure. This requires input distribution and extension services to be part and parcel of the technological innovation frameworks, and also incorporation and improvement of infrastructure in the long-term that would go beyond the current project.

There is a requirement for economic incentives through low to zero interest schemes like micro-credit (or small business loans) to poor farmers and tax exemptions for agricultural inputs for investors. A projection against cheap imports in the liberalized market. Experience has shown that if the needs or fears of the endorsers are over-looked, then little adoption of new technology takes place.

Partnership: From the experience, an assembly at the local level, of a multidisciplinary team from several institutions with diverse backgrounds including biological scientists, socio-economists, and private and public institutions was a major strength of the project. Each group portembrought in their expertise and experience and also worked with the project to improve and acquire new experience and knowledge from each other.

Establishing strong links and networking with end users, for example, including feedback and interaction with the laboratories are essential for successful commercialization and ultimate adoption of the technology.

Use of high-quality materials from the outset is necessary to ensure a favourable early reaction from the end users (e.g., farmers) whose attitude would substantially affect subsequent adoption rates.

The new technology must be marketed and add value to agricultural produce, for example, designing how and what to do with increased production, establishing new markets, diversifying into value-adding by introducing new products. The new technology must go beyond the harvest stage to post-harvest utilization to benefit the end user (or farmers in this instance).
Conclusion

The project brought about new experiences of growing healthy bananas under tropical conditions as a commercial initiative. It provided a rare opportunity for KARI to work with industries and other stakeholders to promote the delivery of biotechnology applications to resource-poor farmers. Emphasis on collaboration between scientists, extension and social workers created mechanisms and channels for partnerships and synergy throughout the research, development and distribution.

The acquired capacity and established biotechnology dissemination channels in Kenya will facilitate the future transfer of more sophisticated innovations as soon as they become available. The technological and institutional experiences gained in Kenya will also produce technological spillover to other East African countries.

The business environment created by the project is conducive to the development of an indigenous biotechnology sector that holds promise as one of the most powerful tools available, but has not been exploited to reduce poverty and hunger, especially in the Third World. The project also demonstrates a viable option to feed in the Kenya Poverty Reduction Strategy and fits well within resolutions of the recently concluded World Summit on Sustainable Development (August 26th – September 4, 2002).

Recognition

In December 2000, the national project within which the African Technology Studies Network (ATPS) sponsored study was conducted won the First Research Medal in the Global Development Network (GDN) Award for Science and Technology for Development. Out of 500 applicants from 94 countries, five finalists were selected to present their submissions. The GDN medals and awards are sponsored by the Government of Japan and the World Bank and build upon other GDN activities, such as the Regional Research Competition and the Global Research Project. These activities promote knowledge creation and capacity building in developing countries. Such a prestigious international recognition is a source of motivation and an important lesson of the power of multidisciplinary approaches towards deploying technologies meant for resource-challenged farmers.
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