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

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ATPS RESEARCH PAPER No.1

PublishedbytheAfricanTechnologyPolicyStudiesNetwork,P.O.Box10081,
0100GeneralPostOffice,Nairobi,Kenya.

PUBLISHEDBYTHEATPSCOMMUNICATIONSDEPT.

ISBN: 9966-916-06-7

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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 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 Agribiotech 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. On the 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 a 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 decentralising 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 challenge lies 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

AEZ	Agro-ecologicalzone
ATPS	AfricanTechnologyPolicyStudies
GDN	GlobalDevelopmentNetwork
GTL	GeneticTechnologiesLimited
IDRC	InternationalDevelopmentResearchCentre
INIBAP	InternationalNetworkfortheImprovementofBananaandPlantain
ISAAA	InternationalServicefortheAcquisitionofAgri-biotechApplications
ITSC	InstituteofTropicalandSub-tropicalCrops
KACE	KenyaAgriculturalCommodityExchange
KARI	KenyaAgriculturalResearchInstitute
MALDM	MinistryofAgriculture,LivestockDevelopmentandMarketing
MOA	MinistryofAgriculture
NGO	Non-GovernmentalOrganisation
PRA	ParticipatoryRuralAppraisal
tc	tissueculture
WHO	WorldHealthOrganization

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1 Introduction & Background

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 wide 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 orientations to fully embrace a new practice. The process is more complex in the transfer of technology to poor communities where a change of cultural practice is involved, for example, the transfer of tissue culture technology on bananas that forms the thesis of this paper.

Tissue culture (tc) is a form of biotechnology that refers to 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 tc techniques broadly classified in 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 a synergistic increase 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 levels of farm inputs and poor farming practices aggravated the problem.

The process of tissue culturing bananas plantlets

Juvenile potted tc banana plantlets

These factors, coupled with the fact that the banana has 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 ready supply of highly 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 livelihood depends on banana production.

In an effort to respond to the above problem 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 neighbouring countries of Tanzania and Uganda.

Family that has now taken up tc banana farming

2 Literature Review

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 market place 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 in 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 low. An acceptance analysis showed that this was partly due to the fishy taste of the algae leading to slow adjustments by households.

In Nigeria, Madukwe (1994) investigated factors related to the adoption of improved farm practices specifically the yam Minisett 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 a 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 colour 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 Oduol and Karugu (1993) indicated that the decision to allocate and use technological innovations is made along gender lines and is largely 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 stereotyped technological trends.

Agricultural biotechnology is often assumed to hold great potentials 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 a non-going national project, titled "Biotechnology to benefit small-scale

Banana products in Kenya". The study analyzes the impact of tissue culture (tc) technology in the Kenyan banana sector.

The overall tissue culture project was sponsored by the Rockefeller Foundation, USA, the International Development Research Center, (IDRC) Canada, and the African 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 materials 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.

Under temperate plantation conditions, the physiological changes that occur from the tc 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 are not yet known but is expected to be longer. This implies that the economic window of enhanced production using the tc 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 tc micro-propagation. However, viruses, such as the banana bunchy top and the episomal form of banana streak virus are not eliminated through tc unless measures, such as virus indexing are taken to prevent disease transmissions.

Tissue culture is a fairly simple technology compared to other forms of biotechnology, such as genetic engineering. However, the young tc 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 on-set 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 tc 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 tc technology was responding to banana priority constraints among farmers (appropriateness of the technology).
- To determine the most preferred banana varieties among farmers.
- To describe acceptability of tc bananas among farmers and consumers.
- To identify farmers' perceptions of the production and management constraints of tc 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.

3 Methodology

The study used participatory approaches 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 towards the tc technology. The methods also suited the mostly semi-illiterate 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 tc bananas 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)

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

Source: *MALDM (1996, 1997).* ****Study sites***

Informal questionnaires that also served as interview schedules, observation 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 in understanding group dynamics as an appropriate method for technology transfer. The interview schedule elucidated data on management practices and/or constraints, true-to-typness of the tc bananas, for example, size, colour, taste, among others. Data on the suitability of the tc banana within the existing environmental and socio-economic conditions, for example, inputs, accessibility and placement of banana against other crops in the field was also explained. During visits to farms and markets, observation 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. Visits to markets were also used to collect data on consumer acceptance, marketability of the product and in 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

A PRA in Maragua, Central Province, one of the study sites.

- suggestinterventionmeasures

Market studieshelpedtoidentifyconsumervariety preferencestoensurethatfarmers wouldgrowthe desiredbananasandfortheresearchertounderstandthemarketingofbananas.

Farm visits helped to assess how well thefarmers accepted thetechnology, their perceptions ofthe 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.

Ineacharea,agriculturalextensionofficersguidedtheresearcherstolocationswheretheycouldconduct thePRAs.Theyalsoadvisedonmethodstocapturetherelevantaudience.Consequently,marketdaysand othersocialfunctionsinthestudyareas,suchaschurchgatherings,welfaregroupmeetingsandschools wereusedtopublicizethestudy.

4 Results & Discussions

Thestudyidentifiedthefollowingfactors,inorderofpriority,asmajorconstraintstobananaproduction:

- pests(moles,weevils,nematodes)
- diseases(Panamadisease,cigar-endrot,Sigatoka)
- lackofcleanplantingmaterial
- exploitationbymiddlemenduetopoororganizationinmarketing
- lackofextensionservices
- inadequatemanureandotherinputs,especiallywater
- poorinfrastructureoftenresultinginheavypostharvestlosses

Allfarmersacrossthestudysitesreportedpests,diseasesandlackofuninfestedplantingmaterialasthe most pressing problems. These reports concur with what the researchersidentifiedearlier. Farmers reportedlytriedtocontrolpestsanddiseasesthroughcroprotationandbuyingsuckersfromgovernment prisonsdepartments,expectingfairlycleanplantingmaterialbuttheyweredisappointed. Theresearchers used thisopportunitytoexplainthetctechnologyindetail. Theyalsoshowedthefarmerssamplesof plantletstheycarriedduringthePRAsandthey(farmers)readilyacceptedtotestthetechnology.

Themostpopularbananavarietiesrankedinorderofrelativeimportancewere:

- GrosMitchel,(AAA)–rankedfirstinCentralProvince
- *Israel*,(AAA)–rankedfirstinEasternProvince
- *Muraru*,(AA)
- UgandaGreen(EAAAA)–rankedfirstinNyanzaProvince
- Applebanana

Importantcharacteristicsthatinfluencedtherankingofcultivarswere:

- abilitytoattracthighpricesinthemarket
- consumeracceptanceandpreference
- longshelf-life
- culturalattachment(e.g. *Muraru* inEasternandCentralprovinces)
- preferenceformultipurposevarieties,forexample,cooking,dessertandfodder

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 tc technology received some resistance since the introduced varieties were the dessert Cavendish. One farmer complained saying, *"a child can go hungry when those bananas are available because they cannot be cooked"(Joseph, pers. Com)*.

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

The acceptability and appropriateness of the tc technology was gauged against the characteristic 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 tc 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 long 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 tc materials purchased. The interest of those who had waited for long 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/or 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-users through on-farm demonstrations is key to diffusion.

- Disseminatingagoodtechnologywithoutproperinformationonmanagementcouldcreatea wrongimpressionofcomplexity,negativelyinfluencingdiffusion.

Availabilityof the product, onceend-usersaresensitizedisanotherimportant lesson. Initially, the tc bananaswereonlyavailableinthepublic domain (JKUAT) thatwasnotable,atthetime,toproduce adequate materialstomeetthedemandcreatedthroughmediaannouncements. Involving theprivate sector,liketheGeneticTechnologiesLimited(GTL),aprivatetissueculturelaboratoryinNairobi,offered timelyresponse to farmersneeds. TheprivatelaboratorylaterteamedupwithKARItoformapublic-private partnership contributing significantly to successful diffusion that is an appropriate policy recommendation. Accessingmaterialstothewidertargetgroupswhoarescatteredallovethecountry, however,isstillamajorchallengesinceadistributionsystemfortheplantletsisyettobeestablished.

Farmers,naturally,areinterestedintechnologiesthatgivehigherreturnstoscarcefactorsofproduction, suchaslabour,cash,landandcapital. Profitabilityofbananaswasdetermined, *interalia*, by thebunch sizeandthenumberofbunchesharvestedatatime. Fieldobservationsindicatedthatthetechnologyhad madeitpossibleforfarmersto:

- access superior clean planting material that mature early (12-16 months compared to the conventionalbananaof2-3years)
- harvestbiggerbunchweights,(30-45kgcomparedtothe10-15kgfromconventionalmaterial)
- attainhigher annual yieldperunitofland(40-60tonsperhectareagainst10-20tonspreviously realizedwithconventionalmaterial)

Moreover, two additional attributes: uniformity in orchard establishment and simultaneous plantation developmentthatarenotpossiblewithtraditionallygrownbananasappearedtohavestrengthenedthe caseforthetechnologyamongfarmers.

It was, however,observed thatthecostofplantlets,aboutoneandahalfdollars($1.5),andthehigh requirementsforwaterandmanurewerelimitingfactorstothediffusionprocess.Manyfarmers,therefore,

Uniformityinfruitingfortcbananasencouragescommercialmarketingwithpotentialtotransformbananagrowing frommerelysubsistencetocash-basedenterprise,anappropriatepovertyreductionstrategy.

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 tc technology for bulk-marketing, they were pessimistic on profitability because of what they disgustedly explained as, “a chain of numerous exploitative middlemen and women.” The poor state of infrastructure was another concern and farmers reported heavy losses while transporting bananas to urban markets where they hoped to fetch better prices.

These findings revealed several aspects for policy considerations on resource-challenged farmers to benefit from innovations. First, is the availability of essential inputs to deploy the technology successfully. In this case, providing micro-credit stimulated the diffusion process and policy makers should consider it as 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 banana 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 harvests they cannot dispose of. Close proximity to urban markets, such as Nairobi is an advantage to farmers in Central Province. For the 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 a 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 tc banana demonstration trials in all the project areas. Participating and non-participating farmers were thus convinced that the tc 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 abandoning of a technology. This risk is real because tc 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 tc 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 tc 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 tc plantlets from dying. This task was tedious and impractical for farmers with many mats of tc bananas unless alternative water provision techniques are introduced. To avert such a crisis, farmers are being encouraged and trained on simple techniques of harvesting rain water. 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 tc 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 tc 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 banana stover 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 commercialisation 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

Left: A well-managed banana orchard.

Below: On-farm training of tc banana orchard.

for banana 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 tc 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 as the technology uptake increased, more entrepreneurs came in to distribute plantlets. Chances of reaping maximum benefits from the tc 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 researchers 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 applications enhanced yields. However, old habits die hard and an appropriate strategy would be to give farmers the option of using artificial fertilizers or organic manure since the latter would be cheaper and more environment-friendly than the former. Several local initiatives from grassroots organizations, such as Wangu 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 tc 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

A third 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 tc banana technology.

Ninety five percent (95%) of the farmers were categorized as literate. The farmers' age bracket ranged from eighteen to over sixty years. The oldest farmer encountered with tc 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 wide range in wealth between the very low and the very high within the target smallholder was found to have an affect 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 be more beneficial to the very poor only if institutional mechanisms are put in place to avail additional resources. The major limiting factors to adopting tc technology for banana to 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 adopting the technology. Younger tc farmers were uncertain whether they would inherit the piece of land they were farming and so they preferred to grow short-term crops like beans, vegetables, and groundnuts. On the contrary, farmers above 40 years old owned the land in which they farmed while those above 60 years were retirees seeking alternative sources of income and they found the tc bananas 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 tc 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 tc bananas while in Eastern and Nyanza, the figure was hardly 200 farmers. Therefore, if a technology were introduced to individual farmers hoping that others would take up from those individuals, it would take far much longer to diffuse. Group approach seems 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 tc 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 tc plantlets. The modified Grameen Model of loan repayment adopted for groups has kept the micro-credit fund solvent. These groups offer a good entry point for training farmers on tc banana management practices and other farm 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 tc banana uptake. An interesting observation was that despite banana 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 half-half. There were divisions on varieties that could be marketed by gender. In Kisii for instance, women mainly marketed apple banana that is 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 tc banana assuring bigger sized banana and with the introductions of other varieties, women now have equal opportunities as the men to market high value bananas. The men have also been attracted to the technology and there are no conflicts over land-use as feared earlier. The men support the technology and as household heads who make decisions on what is 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.

SummaryofLessonsLearnt

- Educationandfamiliarizationwithtechnologytoend-usersthroughon-farmdemonstrationiskeyto diffusion.
- Diffusionisdirectlylinkedtoendusers'impressionabouttheeaseoftheprocessandthetechnology, itsacquisitionandavailability.
- Theprivatesector,forexample,theGeneticsTechnologiesLtd.(GTL)isbetterplacedtooffertimely response to farmers' needs as decisions can be madefaster compared to public institutions,for example,JKUATthatmustadheretoinstitutionalproceduresbeforedelivering.
- Farmersarenaturally interestedintechnologiesthatmaximize productivity,thatis,givinghigher returnstoscarcefactorsofproduction,suchaslabour,cash,land,timeandcapitalwithoutimpacting negativelyontheirculturalpracticesfromtheon-set.
- Newdemands,forexample,costofplantletsatUS$1.5andhighrequirementsforwaterandmanure forthebananatcarelimitingfactorstothediffusionprocessandtheimplementingorganizationhasto availtheessentialinputsorbringinnewpartnerstodeploythetechnologysuccessfully.Micro-credit, therefore,wouldstimulatediffusion.
- Thehighyieldsresultingfromtctechnologydemandsanewmarketingapproach,especiallytargeting urbanmarkets.Farmers,therefore,mustbeinductedintobasicmarketingtechniques,forexample, costing, pricing, transportation andtheeliminationofmiddlemen.The implementingorganization shouldincorporatemarketingaspectaspartofthepackageandwherepossible,offerassistancein thesame,besidesthetraining.
- Farmers will not risk adopting a new technology until they are convinced that it will perform successfullyintheirownfarms.Thisfearisonlyallayedbysettingfarmermanageddemonstration trialswithintheirlocality,toprovidehands-onexperienceswiththeinnovation.
- New technologies stand a better chanceofadoptioniftheyarecompatible with currentfarming practices, forexample, tcbananatechnology involvedthepurchaseofplantletsthusslowingthe adoption process. Other aspects, likeusingstocks to feed thefarmers'animalsencouraged the adoptionofthetctechnologygiventheenvisagedincreaseincropandlivestockproduction.
- Technologies that allowgradualadoptionalongsidetraditionalmethodsstandhigherchancesof successbecausethefarmersdo notfeelover-exposed.
- The farming environment, especially the agro-climatic condition determines the adoption of a technologysinceclimatecaninfluenceperformance.
- Diffusion of technologyisalsodeterminedbythecharacteristicsof thefarmers,forexample,age, education, wealth, gender and group membership. The more educated, wealthier and exposed farmersreadilyadoptnewtechnologiesbecausetheyhavestop-gapsanddonogettrappedwiththe feelingoflosingeverything.Menaremoreeasilyabsorbedinprojectsthatshowobviouseconomic benefitsandalsobecauseculturally,theycontrolthelandandheadhomes.

SummaryofPolicyImplicationsfromtheStudy

- Forbetterresultsthemainpolicychallengewillbetoestablishefficientbiotechnologydistribution channels inKenya. This involves improving community-basedinitiative for the retailingofthetc bananaplantsandrelatedextensionservices. Thisproject-studyhasdemonstratedthatthepotential gainsofappropriatebiotechnologycanbegreatestforthesmall-scalefarmers.
- The promising potentials of tc bananas need to be translated into action by making the new technologyaccessibletoallKenyanfarmers.

- Public research and development (R&D) funds should be made available to develop biotechnology that explicitly tackles the need 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 successful use of biotechnology presupposes extensive capacity building in the national system of agriculture 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 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 inceptives through low to zero interests schemes like micro-credit (or small business loans) to poor farmers and tax exemptions for agricultural inputs for investors as 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 tc experience, an assemble, 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 as each group or team brought in their expertise and experience and also worked with the project to improve and acquire new experience and knowledge from and through each other.
- Establishing strong links and networking with end user, 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 onset is necessary to ensure favourable early reaction from the end users (e.g. farmers) whose attitude would substantially effect subsequent adoption rates.
- The new technology must be marketed and add value to agricultural produce, for example, design how and what to do with the increased production, establish new markets or diversify into value-adding by introducing new by-products. The new technology must go beyond the harvest stage to post-harvest utilization to benefit the end user (or farmers in this instance).

5 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 application 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 tc 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 4th 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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African Technology Policy Studies Network

Acknowledgment

This study was made possible through the collaborative efforts of many persons and institutions whom I wish to acknowledge. Firstly, my heartfelt thanks are due to Professor Lynn Mytelka, for linking me up with the Director of ISAAA AfriCenter, Dr. Florence Wambugu and to ISAAA Africenter for the anchorage throughout the project period. Secondly, my appreciation to the African Technology Policy Studies Network (ATPS) for the financial support to carry out this study. I worked very closely and cordially with persons in the following institutions: KARI, ISAAA, DuRoi, ITSC, GTL, ZEF, ATPS and the various NGOs. My special gratitude to the researchers who kindly accommodated my social science inputs, in particular Dr. John S. Wafula, Mrs Faith Nguthi, Mrs Margaret Onyango, Mr Joel Mutsiya, Mr J. Muthamia, Mr Francis Muniu all from KARI, Mrs Lucy Njuguna from Beam Business Consultants, Dr. Zaag De Beer from ITSC, Dr Matin Qaim from ZEF, Dr. Florence Wambugu and Michael Njuguna of ISAAA. Sincere thanks are due to IDRC, Canada and the Rockefeller Foundation of USA for jointly providing financial support to the overall national project without which this technology diffusion study would have been just another "post-mortem". Lastly and in a very special way, I would like to acknowledge the participating farmers. It was their enthusiasm and hard work, above everything, that made the overall project such a resounding success.

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