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Abstract

Slow adoption rates of Agricultural technologies continue to beset Africa's food insecurity reduction efforts and economic development generally. Household survey data and focus group discussions were used to identify determinants of adoption of tissue culture bananas among smallholder farmers in Western Kenya. Logit analysis shows that gender, off-farm employment, household size, education level, age, land size, off farm income and extension services had significant influence on adoption of tissue culture banana production. More significant is sustainable access to Tissue culture plantlets which is a crucial input. Successful interventions should target youth, women famers and access to extension information. Policies targeting land consolidation will also help increase technology adoption.

Key words: *Tissue culture banana, Technology adoption, Subsistence Economy, Western Kenya*

Introduction

It has been widely argued that gateway to Africa's economic development hinges on innovation, diffusion and utilisation of Agricultural technologies (Tripp 2003). There is intense academic enquiry and public policy discourse to develop modern biotechnology suitable for economic transformation in developing countries (Nyande 2012, Rigaud 2008). Contemporaneously, there is a growing debate about potential impacts of biotechnology in these countries. The debate centers on whether biotechnology is a blessing or a curse. Proponents argue that the technology is a source of solution to many of agricultural, economic, social and environmental problems faced by these countries. Those with dissenting view base their argument on the suspicion that the technology could bring more ills (Nyande 2012, Smale and Groote 2003).

Absence of awareness creation and capacity building of target beneficiaries about new technology is thought to create knowledge gaps leading to misinformation and subsequent delay in adoption or non-adoption of otherwise beneficial technology (ABSF 2009). Coupled to this is lack of enabling environment, especially policies and regulations that affect input availability, interactions of private sector with public agricultural research, and agricultural enterprise development (Tripp 2003). These factors are largely blamed for slow progress in development and adoption of the promising technologies in the developing economies.

Agricultural sector in Kenya has been identified as one of the six sectors aimed at delivering 10 percent economic growth rate under the Vision 2030. One key policy goal of the sector is to increase agricultural productivity through generation and promotion of technologies and increased resource allocations. Crop development and management is also one of the major programmes undertaken by the sector, beside policy regulation and coordination, and information management among others (GoK 2011). Biosafety Act, 2009 was passed into law by Kenyan parliament in December 2008. The Act establishes National Biosafety Authority with an objective to facilitate research and regulation in development, transfer, handling and use of genetically modified organisms in the country (NBA 2012).

Banana is one of staple foods for both rural and urban populations in Kenya. The crop is predominantly grown by peasant farmers for both home consumption and national market (Qaim 1999). It has a potential to contribute to food and nutritional security and income enhancement of smallholder farmers. It is estimated that average banana cultivation area in the country is 0.21 hectares, accounting for nearly 10 percent of total farm area (AHBFI 2008). The farm holdings of less than 0.5 hectares contribute 83.5 percent of banana production in Kenya. In the early 1990's, incursion of the crop by pests and diseases coupled with traditional agronomic practices led to decline in its productivity. It is estimated that banana yields reduced by up to 90 percent (Qaim 1999). It is also estimated that, between 1992 and 1994, banana yields declined from an average of 12.8 tonnes to 9.9 tonnes per hectare. The spread of pests and diseases was mainly occasioned by the traditional propagation of banana through banana suckers as planting materials.

In an attempt to reverse this trend, Kenya Agricultural Research Institute (KARI), in partnership with International Service for Acquisition of Agri-biotech Applications (ISAAA), with financial support from Rockefeller Foundation (RF) and International Development Research Centre (IDRC), developed the first ever tissue culture (TC) banana in Kenya (Qaim 1999). Production, distribution and utilization of tissue culture derived bananas on a pilot scale demonstrated suitability and adaptability of the technology to farming situations in Kenya (AHBFI 2008). Commercial production in other developing countries has shown that under good management, tissue culture technology has a potential to contribute significantly to yield gains (Vuylsteke, 1998).

Despite its potential for high yields, farmers in Kenya are yet to take up tissue culture banana technology (Olembe 2010, Kikulwe *et al* 2012, Kabunga 2012). It is projected that less than 10 percent of all banana farmers in Kenya have so far adopted TC banana production in the country (Njuguna *et al* 2010). Marginal adoption rates of up to 15 percent have been reported in Central and Eastern Provinces where most of the dissemination programs started (Kabunga *et al* 2012). Above observations underscore adoption bottlenecks as major downsides to realizing full potential of tissue culture technology in Kenya. Adoption constraints are environmental, institutional or behavioural. Inherently, high potential impact of any given technology would leverage farmers' adoption rates. A decade down the line the impact of tissue culture banana technology is yet to be felt among smallholder farmers in the country. A common believe among many technologists is that any beneficial innovation will naturally sell itself, that the obvious benefits of a new idea will be widely realized by potential adopters, and that the innovation will therefore diffuse rapidly (Toborn 2011). However, most innovations have diffused at a disappointingly slow rate (Rogers 1995).

Previous studies on adoption and impact of tissue culture banana in Kenya have found mixed results (Kikulwe *et al.*, 2012, Kabunga *et al*., 2011, Muyanga.,2009, Mbogoh, Wambugu and Wakhusama, 2003, Qaim1999). Qaim (1999) showed that tissue culture banana had substantial potential growth especially among smallholder farmers in Kenya. Kikulwe *et al* (2012), Mbogoh, Wambugu and Wakhusama, 2003 showed that adoption of technology increased productivity and profitability of banana production. Kabunga *et al* (2011) however, found no significant difference in the mean yields of adopters and non- adopters. While Muyanga (2009) found that scale and productivity of non-tissue culture banana varieties exceeded those of tissue culture bananas. Significant impact of tissue culture on yield was found in Kabunga *et al* (2011) only after controlling for negative selection bias.

The aim of this study was to identify determinants of adoption of tissue culture bananas among smallholder farmers in Western Kenya. Previous studies have been conducted mainly in Central and Eastern provinces of Kenya, where large scale commercial farms are found. High prevalence of smallholder farms of banana production is found mainly in Western Kenya (Qaim 1999). This study is based on the premise that significant impact of any technology adoption can only be felt fully if farmers who need it most actually adopt it (ABSF 2009).

This study contributes significantly to the current intense debate on whether biotechnology plays a complementary or contradictory role to sustainable agriculture (The Economist online biotechnology debate, November 2012). The argument centres on the arguments of the advocates of agricultural biotechnology and proponents of sustainable farming techniques like the organic farming. The two camps, however, have a lot in common; both are looking for new ways to produce food that minimise environmental impact, can cope with climate change and can be scaled across the developing world. This study will also contribute to better understanding of the paradox of economic growth and prevalent poverty rates apparent in Africa currently.

This study employs mainly reviews and cross-sectional survey data elicited directly from farm households in Western part of Kenya. Descriptive and econometric approaches are used to analyse data. The paper proceeds as follows: in section two we present the analytical framework and estimation procedure for our study. In section three we describe the data and undertake some descriptive analysis. Section four follows with presentation and discussion of the results and observations. Conclusions and recommendations are included in section five.

Methods and Materials

Theoretical underpinnings

Agricultural technology adoption is based on seminal work of Everett Rogers, in his theory of diffusion of innovations in 1962. The theory seeks to explain how, why, and at what rate new ideas and technology spread through cultures. Rodgers distinguished five key characteristics that explain the rate of innovations adoption, these include: 1) The relative advantage reflecting how the innovation is subjectively perceived superior to the previous idea; 2) Compatibility reflecting how the innovation is perceived “consistent with the existing values, past experiences, and needs of potential adopters”; 3) Complexity reflecting the perceived difficulty to understand and use the innovation; 4) Trialability is “the degree to which an innovation may be experimented with on a limited basis”; and 5) Observability reflecting how the results of an innovation are visible to others (Toborn 2011).

The diffusion of innovations according to Rogers follow a logistic function reflecting the response of an individual in adopting a new idea compared to other members of society. Five categories of adopters each with its own characteristics are: 1) innovators, 2) early adopters, 3) early majority, 4) late majority, and 5) laggards. The rate of adoption is the relative speed with which an innovation is adopted. Rogers' work did not however provide theoretical explanations of adoption decision process. The classic theoretical analysis of decision making by Feder (1985) is often pursued by economist instead. The decision maker is assumed to maximise the utility of asset use over time, subject to various resource constraints, usually assuming a concave utility function.

According to (Feder et al 1985), decision-making process is characterized by choice of the optimal combinations of the components of a technological package over time. The decision maker is assumed to maximise the utility of asset use over time, subject to various resource constraints, usually assuming a concave utility function. This can be expressed by static models, or by dynamic, sequential models that consider changing knowledge and conditions (Toborn 2011).

Two major underlying assumptions of most farm household technology adoption models are that markets are perfectly competitive and the production and consumption decisions are separable. This is contrary to the economic environment of rural households in developing countries which is often characterized by imperfect or missing markets, resulting in non-separability of the household production and consumption decisions. The impact of factors such as credit, information availability, risk, and farm size on farmer adoption behaviour remain the focus of investigation in adoption studies. Studies of the factors influencing adoption of agricultural technologies focuses mainly on household resource endowments, characteristics of the household head, location of the household, the nature and extent of information provided before adoption, and the characteristics of the technology. Agricultural technologies can be classified and categorized according to several parameters and characteristics (Sonnino 2009, Sunding 1999). One such classification includes mechanical, biological, chemical, biotechnical, and informational innovations.

Empirical Model

Observed outcome variable of adoption of tissue culture is dichotomous. This requires consideration of models with dummy dependent variables against a mixed set of qualitative and quantitative explanatory variables. Qualitative models have been used extensively in adoption studies although they have been criticized for their inability to account for partial adoption (Feder *et al*., 1985, Karki and Siegfried 2004).

There are several methods to analyse regression models where the dependent variable is a zero or 1 (Madala 2001). Least square method is the simplest to use. This is called linear probability model. Another method which is closely related to linear probability model is called linear discriminant function. The limitation of linear probability model is that the estimates of parameter estimates using OLS give rise to heteroskedasticity problem which could easily lead to predicted values which lie outside the interval (0, 1) and very large predicted errors.

The other alternative specifications approach of qualitative choice models include the use of probit and logit models. Following from Madala (2002), we assume that we have a regression model

$$y_i^* = \beta_0 + \sum_{j=1}^{k} \beta_i x_{ij} + \mu_i \qquad [1.1]$$

Here we assume an underlying or latent variable y^* which we do not observe. Such that what we observe is

$$y_i = \begin{cases} 1 & if \;\; y^* > 0 \\ 0 & otherwise \end{cases} \qquad [1.2]$$

The probit and logit models differ in specification of the distribution of the error term u in equation [1.1]. From the relationships [1.1] and [1.2] we obtain

$$p_i = \Pr ob(y_i = 1) = \Pr ob\left[u_i > -\left(\beta_0 + \sum_{j=1}^{k} \beta_i x_{ij} + \mu_i \right) \right] \qquad [1.3]$$

$$= 1 - F\left[-\left(\beta_0 + \sum_{j=1}^{k} \beta_i x_{ij} + \mu_i \right) \right] \qquad [1.4]$$

Where F is the cumulative distribution function of u.

If the distribution of u is symmetric, from 1-*F (-*Z*)* =*F (*Z*),* such that we have

$$p_i = F\left(\beta_0 + \sum_{i=1}^{k} \beta_i x_{ij} \right) \qquad [1.5]$$

We write the likelihood function from the observed y_i which are the outcomes of a binomial process with probabilities given by equations [1.5] and varying from trial to trial

$$L = \prod_{y_i=1} P_i \prod_{y_i=0} P_i (1 - P_i) \qquad [1.6]$$

Functional form for F in [1.5] depends on the assumption made about error term u. If the cumulative distribution of u_i is logistic then we have logit model such that

$$F(Z_i) = \frac{\exp(Z_i)}{1 + \exp(Z_i)} \qquad [1.7]$$

Rearranging [1.7] and taking logs will give us

$$\log \frac{F(Z_i)}{1 - \exp(Z_i)} = Z_i \qquad [1.8]$$

The logit model will thus

$$\log \frac{P_i}{1 - P_i} = \beta_0 + \sum_{j=1}^{k} \beta_j x_{ij} \qquad [1.9]$$

Left hand side of [1.9] gives the *log odds ratio* which is a linear function of explanatory variables. This is different to that of linear probability model where P_i is assumed to be a linear function of the explanatory variables.

However, if we assume that the errors u_i in [1.1] follow a normal distribution, then we have the *probit* model given by

$$F(Z_i) = \int_{-\infty}^{Z_i/\sigma} \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{t^2}{2}\right) dt \qquad [1.10]$$

Maximization of the likelihood equation [1.6] for either the probit or logit model is possible through nonlinear estimation methods. Both Probit and Logit models are the most frequently used models in explaining the socio-economic phenomena. Parameter estimates for the two models are similar making it difficult to distinguish between them statistically. Binomial logit model is employed here since it is easier to estimate and simpler to interpret.

Once the parameter estimates β_i, are obtained we predict effects of change in any of the explanatory variables on the probabilities of any observation belonging to either groups. The effects for logit will be given by

$$\frac{\partial P_i}{\partial x_{ij}} = \beta_i P_i (1 - P) \qquad [1.11]$$

The effects of prediction for the logit model on the log-odds ratio will be constant since

$$\frac{\partial}{\partial x_{ij}} \left(\log \frac{P_i}{1 - P_i} \right) = \beta_i \qquad [1.12]$$

Model Specification

The dependent variable in the adoption model is a dummy variable taking the values 1 if a household had adopted tissue culture banana biotechnology and 0 if not. A number of explanatory variables have been hypothesized to influence the adoption of agricultural technologies (Feder *et al.*, 1985; Muyanga, 2009). We attempt to include variables that capture the most important factors influencing decision adoption in subsistence farming.

Farmer characteristics variables included; gender, employment status, family size, education level and age, while farm characteristics included; farm size, land tenure, off-farm income, distance to the nearest market, income diversification and access to extension service. Adoption of tissue culture banana is expected to be positively related to employment status, education, farm size, off farm income, income diversification and access to extension services. Distance to the market is expected to be negative while gender, age, family size, land tenure could take any sign.

Gender of head of household captures the importance of gender in technology adoption. Several gender issues are associated to gender disparity in Africa. Women play a significant role in agriculture yet they are also dogged by limited access to land due to land tenure and cultural barriers. Employment status of head of household also plays a significant role in terms of access to quality modern inputs and dependence on farm as a source of income and labour supply. Family size influences the labour supply and dependence level of the household. Educated farmers are better able to process information and search for appropriate technologies to alleviate their production constraints. Farmers with formal education are believed to have the ability to perceive, interpret and respond to new information much faster than their counterparts without formal education. Age is also a significant factor in agriculture in Africa today. However, the influence on technology adoption is controversial. Younger farmers thought to be more amenable to change since they are informed, knowledgeable and educated compared to their older counterparts. On the other hand older farmers possess endowed with more capital and hence better access to credit.

Farmers with larger farms are more likely to adopt an improved technology compared with those with small farmers since they can afford to allocate part of their fields to try out the improved technology. It is widely argued in the literature that technologies require economies of size for feasible gains. Land tenure; a farmer with a freehold land tenure is likely to adopt agricultural technology compared to those with a leasehold land tenure. A freehold tenure farmer has incentive to adopt the technology because he has a comparatively wider horizon to plan. Off-farm income complements farm income thus affording the farmer ability to try on a new technology. Distance to the nearest market, is a disincentive to the famer in technology adoption. Market distance give rise to spatial biases which hinder access to information on the new technologies and their potential in the market. Income diversification; income diversification is a risk management strategy which act also as an incentive to adopt new technology. A farmer with more than one farm enterprise will have its risks spread and thus will be willing to try on the new technology**.**

Nature and sources of data

Household survey, focus group discussions and general observation was used to collect data from smallholder famer in Bungoma North district, Western Kenya. Multistage cluster sampling was followed, and respondents were picked through systematic sampling. A total of 120 farm households were interviewed. Both primary and secondary data were collected for analysis. Primary data was obtained through a household survey through a specifically prepared questionnaire where data was elicited directly for the farmers. Secondary data from desk review of several documents, reports and research papers; focused group discussions with different stakeholders; field visits to banana farms, hardening nurseries, village and town markets, discussions with farmers, farmers' group leaders and scientists.

Results and Discussions

General Characteristics of farmers considered for Adoption of Tissue Culture Banana

Table 1 presents the average land size of the total respondents in acres (about, 1.7 hectares) with an average household size of about 7 persons and average distance to the market with the longest distance of 15 kilometres to reach the market.

The scale of production is generally subsistence with limited commercial production. The distance also plays a crucial role in terms of access to several services like extension, health care and market for produce and purchase of inputs.

Of the total respondent farmers, 42 percent adopted tissue culture banana technology (Figure 1). Majority of the farmers who did not adopt tissue as expected sourced their planting materials from neighbours. Research institutes were the major sources of planting materials for tissue culture where other sources had insignificant contribution to tissues culture banana. Lack in elaborate market for tissue culture plantlets was found to be a major bottleneck. Through focus group discussions, farmer groups who used to operate an orchard for hardening had abandoned it since the plantlets where not readily available and expensive to acquire.

Table 2 present the summary of respondents in the sample. Majority of the respondents were men with schooling level beyond primary. The respondents also reported farming to be their major source of income. Remarkably, majority of the farmers have no formal off-farm employment.

Logit Analysis on Factors Influencing Adoption of Tissue Culture Banana:

Table 3 present the logistic regression predicting likelihood of reporting banana adoption.

The results show that gender, employment, household size, education level, age, land size, off farm income and extension services had significant influence on adoption of tissue culture banana in western Kenya. Variables such as land tenure, market distance and diversification had no significant influence on adoption of tissue culture banana.

Gender, employment and age of head of household had negative influence on tissue culture adoption. Female headed of households favoured tissue culture banana production compared to their male counterparts. Banana is a food crop and women would tend to give more attention. Farmers with off farm employment also did not favour adoption of tissue culture banana. Older household heads were also reluctant to adopt the technology.

Education level of head of household, household size, off farm income, farm size and extension information were found to favour adoption of tissue culture banana. Educated household head and with access to extension information will have access to more information and therefore likely to try on the new technology compared to their counterparts with less schooling. More members of a household could either imply more labour force or demand for more food necessitating the need to increase food household food supply. Off farm income favour the technology since it may be correlated to the level of schooling and hence off farm employment. Off farm income may also imply that households have sufficient resources to try on new technology and it is also a form of diversification which is a risk diversification necessary for technology adoption. Size of the farm is also an incentive for diversification which affords famers the opportunity to try on new technologies.

Conclusions and Policy Implications

Agricultural production in western Kenya is majorly subsistence with little commercialization. Generally there are more male headed households than female. There is overdependence on land due to unemployment and limited alternative off-farm businesses. Farm business remains the sole source of livelihoods for the majority of farmers in western Kenya. Any factor constraining smallholder production will impact negatively on their livelihoods. Smallholding capacity coupled with increasing population adds more pressure to the existing land potential. With farm-business as the sole source of income and given the average land size (table 1) it is obvious that with increasing population household food security will continue to be an issue among the residents in this area.

Suckers borrowed from the neighbours are the most common method of propagation with limited adoption of tissue culture bananas. It is also very difficult to observe any progress made in adoption of tissue culture banana from those who claim to have adopted. Farmers who had earlier accessed TC banana in Bungoma district, could no longer access the plantlets since the hardening orchards were no longer in existence. There were no organized marketing organizations for farmers for access of inputs and/or sell their produce. Proximity to major markets was also a major concern. Majority of farmers sold their produce at the farm gate. Pests and diseases in banana production is also a major challenge. Farmers apply biological and IPM (Integrated Pest Management) in the control of pests and diseases. There were no deliberate interventions to support farmers' production under the prevailing circumstances. Generally, tissue culture banana production presents untapped potential for increasing the production and food security. Overly these issues underscore the urgent need to support farmers with appropriate technologies that will significantly improve their farm productivity.

From analysis of data, focus group discussions and general observations interventions are recommended to boost the adoption of tissue culture banana. This may also apply in to any other agricultural technology targeted at smallholder households. For maximum impact, technologies should be designed and targeted to women and youth with some level of education. These will act as early adopter and motivate the rest to follow suite. There is also a need to intensify extension services specifically for new agricultural technologies. Government should also design policies to reverse the land fragmentation and thus favour technology adoption. Strategies to reduce overdependence on farm as a source of income will also favour technology adoption.

Government and private initiatives are needed to stimulate the whole banana value chain and by guaranteeing sustainable source of inputs and favourable market for farmers produce. Selection of suitable and better performing varieties should be driven by farmer preferences for traditional banana varieties with proper crop husbandry practices and hygiene. There is need to integrate the market needs and those of the farmers when developing proper varieties of TC banana varieties. Suitable varieties for the agro-ecological zones, coupled with the farmer-market needs will likely win the adoption of the farmers. A multi-disciplinary approach is needed to develop suitable varieties that meet all these conditions. There is need to explore the seed acquisition process and the cost implications, farmers' perceptions of use attributes and the performance of improved TC banana varieties as compared to the traditional varieties. With better attributes over traditional varieties, especially in yield performance and resistance to diseases, improved TC banana varieties will be the most preferred by farmers. There is need to demonstrate to the farmers that TC technology can produce large numbers of clean planting material with fast and uniform growth and high yielding. There should be a deliberate effort to respond to these problems through projects that would establish a self-sustaining system of production, distribution and utilization of farmer-preferred varieties of TC banana in western Kenya. Developing TC banana and hardening orchards to enable farmers' access banana planting material. This can be done by supporting farmers to establish group-bulking site and hardening nurseries. Cataloguing and documenting the traditional technologies already available or traditional knowledge about a particular problem to be solved before embarking on introduction and/or up scaling new technologies will be necessary.

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References

Mbogoh, S., Wambugu, F. and Wakhusama, S. "Socio-Economic Impact of Biotechnology Applications: Some Lessons from the Pilot Tissue-Culture (Tc) Banana Production Promotion Project in Kenya, 1997-2002": International Association of Agricultural Economists, 2003).

Africa Harvest Biotech Foundation International (AHBFI). (2008) Socio-economic impact assessment of the tissue culture banana industry in Kenya. Nairobi, Kenya; Johannesburg, South Africa; Washington DC, USA. 40 pp.

Morris, M.L. and Heisey, P.W. "Estimating the Benefits of Plant Breeding Research: Methodological Issues and Practical Challenges." *Agricultural Economics*, Vol. 29, (2003) pp. 241-252.

ABSF (2009) Opens first TC Banana Demonstration Site in Kenya, Africa Biotechnology Stakeholders Forum. http://www.absfafrica.org/

Muyanga, M. "Smallholder Adoption and Economic Impacts of Tissue Culture Banana in Kenya." *African Journal of Biotechnology*, Vol. 8, (2009) pp. 6548-6555.

Obembe, O.O. "The Plant Biotechnology Flight: Is Africa on Board?" *African Journal of Biotechnology*, Vol. 9, (2010) pp. 4300-4308.

Qaim, M. "Assessing the Impact of Banana Biotechnology in Kenya " *ISAAA Briefs*, Vol. 10, (1999).

Rao, E.J.O. and Qaim, M. "Supermarkets, Farm Household Income, and Poverty: Insights from Kenya." *World Development*, Vol. 39, (2010) pp. 784-796.

Robinson, J., Fraser, C. and Eckstein, K. "A Field Comparison of Conventional Suckers with Tissue Culture Banana Planting Material over Three Crop Cycles." *Journal of Horticultural Science*, Vol. 68, (1993) pp. 831-836.

Crouch, J. H. D. Vuylsteke, R. Ortiz (1998) Perspectives on the application of biotechnology to assist the genetic enhancement of plantain and banana (*Musa* spp.), *Electronic Journal of Biotechnology*, v.1 n.1

Government of Kenya (GoK) (2011 December) Medium Term Expenditure Framework 2012/13–2014/15 Report for the Agriculture and Rural Development Sector. Cited as (GoK 2011) .

National Biosafety Authority (2012) Biosafety Act 2009. www.biosafetykenya.go.ke. Cited as (NBA 2012).

Nyende A. B. (2012) Message from the Director, Institute for Biotechnology Research (IBR), Newsletter of JKUAT, issue 03, June.

Rigaud N. (2008) OECD International Futures Project on "The Bioeconomy to 2030: Designing a Policy Agenda" Biotechnology: Ethical and social debates.

Kabunga, N.S., Dubois, T., Qaim, M. 2012a. Yield effects of tissue culture bananas in Kenya: Accounting for selection bias and the role of complementary inputs. Journal of Agricultural Economics 63, 444-464.

Kabunga, N.S., Dubois, T., Qaim, M. 2012b. Heterogeneous information exposure and technology adoption: The case of tissue culture bananas in Kenya. Agricultural Economics DOI: 10.1111/j.1574-0862.2012.00597.x.

Freshplaza (2008) Scientists call for adoption of tissue culture technology, Global Fresh Produce and Banana News. www.freshplaza.com/news

Dubois, T., Y. Dusabe, M. Lule, P. Van Asten, D. Coyne, V. Bauer, V. Hoffman, J.-C. Hobayo, S. Nkurunziza, E. Ouma, N. Kabunga, M. Qaim, E. Kahangi, M. Peter and D. Kisii, (2011) Tissue Culture Banana for Smallholder Farmers: Lessons Learnt from East Africa. symposium organized by ProMusa and hosted by Embrapa, in Salvador, Brazil from 10 to 14 October.

AATF [African Agricultural Technology Foundation] (2009) Feasibility Study on Technologies for Improving Banana for Resistance Against Bacterial Wilt in Sub-Saharan Africa. Nairobi, Kenya: African Agricultural Technology Foundation.

Vuylsteke, D. 1998. Field performance of banana micropropagules and somaclones. In: Jain, S., Brar, D., Ahloowalia, B. (Eds.), Current plant science and biotechnology in agriculture. Kluwer Academic Publishers, Dordrecht, pp. 219-232.

Njuguna, M., Wambugu, F., Acharya, S., Mackey, M. 2010. Socio-economic impact of tissue culture banana (Musa Spp.) in Kenya through the whole value chain approach. In: Dubois T., Hauser, C., Staver, D., Coyne, D. (Eds.), in Proceedings of the International Conference on Banana and Plantain in Africa: Harnessing International Partnerships to Increase Research Impact, 5-9 October, 2008, Mombasa, Kenya. Acta Horticulturae, pp. 77–86.

The Economist online Biotechnology debate, November, 2012, http://www.economist.com/debate/overview/187

Smale, M. and H. D. Groote (2003) Diagnostic research to enable adoption of transgenic Crop Varieties by Smallholder farmers in Sub-Saharan Africa, *African Journal of Biotechnology* Vol. 2 (12), pp. 586-595.

Feder G.R., Just R.E. and Zilberman D. 1985. Adoption of agricultural innovations in developing countries: A survey. *Economic Development and Cultural Change* 33:255-298.
Rogers, E.M. 1995. Diffusion of Innovations. The Free Press.

Toborn Johan, (2011) Adoption of Agricultural Innovations, Converging Narratives, and the Role of Swedish Agricultural Research for Development? Discussion Paper.

Sunding (1999) cited in Toborn Johan, (2011) Adoption of Agricultural Innovations, Converging Narratives, and the Role of Swedish Agricultural Research for Development? Discussion Paper.

Sonnino, A. et al. 2009. Socio-economic impacts of non-transgenic biotechnologies in developing countries: The case of plant micropropagation in Africa. FAO.

Karki, L. B. and B. Siegfried (2004) Technology Adoption and Household Food Security. Analyzing factors determining technology adoption and impact of project intervention: A case of smallholder peasants in Nepal, The Deutscher Tropentag, on 5 - 7 October, 2004, Humboldt-University, Berlin.

Madala, G.S., (2001), *Introduction to Econometrics*, John Willey & Sons, England, UK.

Smale, M. and Tushemereirwe, W. *An Economic Assessment of Banana Genetic mprovement and Innovation in the Lake Victoria Region of Uganda and Tanzania* (Washington DC, International Food Policy Research Institute, 2007).

Table 1: Summary Statistics of Continuous variables

	Total Land Size (Acres)	Household Size	Market Distance (KM)
Valid	85	85	85
Mean	4.135178	6.89	6.921
Minimum	0.1800	1	0.3
Maximum	20.4500	14	15.0

Source: Authors' Survey data, 2010

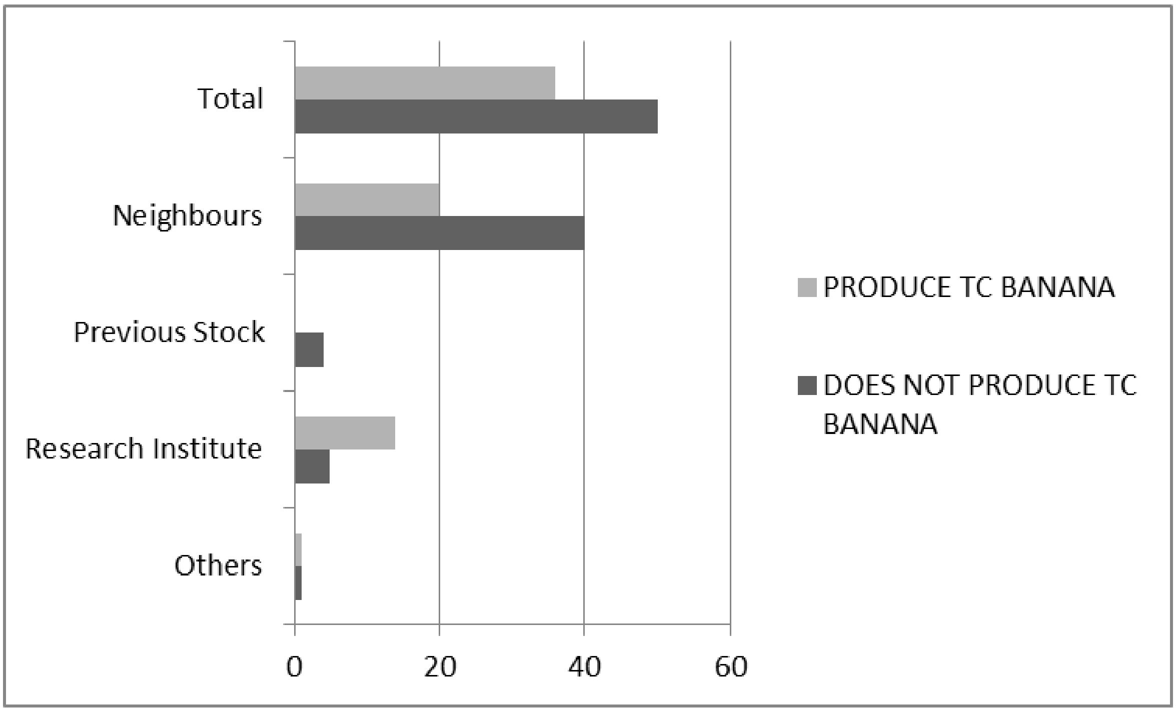

Fig 1: Tissue culture Banana Adoption and Source of Seedlings ***Source: Authors' Survey data, 2010***

Table 2: Summary Statistics of Categorical Variables

		Frequency	Percentage
Age of head of Household	Between 20-30 Years	4	5
	Between 30-40 Years	19	22
	Between 40-50 Years	21	25
	Between 50-60 Years	19	22
	Between Above 60 Years	22	26
Off-farm Business	Without Off- farm Business	59	69
	With Off-Farm Business	26	31
Education Level of head	Pre-pri/primary	22	26
	Sec/vocational	49	58
	College/University	14	16
Gender of Household Head	Female	11	13
	Male	74	87
Extension information	No Access	31	36
	Access	54	64
Land Ownership	Freehold	38	45
	Communal	47	55
Employment status	Unemployed	73	86
	Employed	12	14

Table 3: Logit estimates of coefficients of various determinants affecting adoption of Tissue Culture Banana in Bungoma district, Kenya,

	B	S.E.	Wald	Exp(B)	95.0% C.I.for EXP(B)	
					Lower	Upper
Gender of head of Household- GDRHH(1)	-3.876	1.498	(6.695)***	0.021	0.001	0.391
Employment of Head of Household- EMLYT(1)	-7.627	3.554	(4.605)**	0.000	0.000	0.516
Household size-HHSIZE	0.802	0.233	(11.822)***	2.231	1.412	3.524
Education level of Head of Household-EDULVL	3.824	1.144	(11.1780***	45.769	4.865	430.543
Age of Head of Household- AGEHH	-3.021	0.804	(14.124)***	0.049	0.010	0.236
Total Land Size-TOLNDSZ	0.316	0.147	(4.634)**	1.371	1.029	1.828
Land Tenure-OWNERSHIP	-1.240	0.810	(2.345)	0.289	0.059	1.415
Off Farm Income-OFFRM(1)	3.215	1.137	(7.992)***	24.891	2.680	231.174
Market distance-MKTDST	-0.094	0.090	(1.106)	0.910	0.763	1.085
Land diversification DIVINDEX	0.067	0.162	(0.170)	1.069	0.778	1.470
Extension Information-INFOEX(1)	2.261	0.987	95.244)**	9.592	1.385	66.418
Constant	-19.215	40193.091	(0.000)	0.000		

5% and 1% Significance levels given by ** and *** respectively