African Journal of Biotechnology Vol. 8 (23), pp. 6548-6555, 1 December, 2009
Available online at http://www.academicjournals.org/AJB
ISSN 1684–5315 © 2009 Academic Journals

Full Length Research Paper

Smallholder adoption and economic impacts of tissue culture banana in Kenya

Milu Muyanga

Department of Agricultural, Food and Resource Economics, Michigan State University, 012 Cook Hall, East Lansing MI 48824 USA. E-mail: muyangam@msu.edu. Tel: +1-517-353-4545.

Accepted 21 October, 2008

This study was conducted with an objective of determining the correlates of adoption of tissue culture banana technology and its impacts on household incomes in Kenya. The results show that while some households have opted not to adopt tissue culture banana biotechnology, almost all the adopters are growing tissue culture bananas alongside non-tissue culture banana varieties. The scale of production and productivity of non-tissue banana varieties significantly exceeds that of tissue culture bananas. The cost of production of tissue culture bananas exceeds that of non-tissue varieties. Among the key drivers of adoption include education level of the household head, land tenure and credit availability. Incomes of households that have adopted tissue culture banana biotechnology are not a significantly different from those of the non- adopters. The results generally indicate that smallholder farmers in Kenya are yet to realize the full potential of tissue culture banana biotechnology.

Key words: Biotechnology, adoption, tissue culture bananas, Kenya.

INTRODUCTION

Most sub-Saharan African countries, if not all, are grappling with the challenge of food insecurity. Top of the agenda for world leaders today is the alleviation of poverty and hunger, with the goal to cut poverty 50 percent by 2015. Food insecurity problem in sub-Saharan Africa has attributed to declining land productivity, insufficient rainfalls, soil infertility, inappropriate farming techniques, poor market infrastructure, poor access to farm inputs and conflicts. Critical challenges also relate to increasing population, thus increased food deficiencies. The HIV/Aids pandemic has also created a big dent in the regions efforts to ensure food security through loss of agricultural labor.

The majority of the population in sub-Saharan African countries derives its livelihood from agricultural production. Agricultural biotechnology has been touted to offer increased production and incomes in developing countries (Pinstrup-Andersen and Cohen, 2000; Carpenter and Gianessi, 2001). Biotechnology may be defined as any technique that uses living organisms, or parts of organisms to make or modify products to improve plants and animals, or to develop micro organisms for specific applications. The use of biotechnology generated disease-free planting materials helps to increase the yields and also reduces the time taken for the crop to mature (Dubois et al., 2000). Use of genomics allows the identification and characterization of individual genes that are resistant to pest, stress or diseases. Recent studies about the agronomic and economic impacts of biotechnology demonstrate that on average adopting farmers benefit from income increases through reduced pest control costs and higher effective yields (Ismael et al., 2001; Carpenter and Gianessi, 2001; Traxler, 2004). These studies even suggest that the farm-level benefits tend to be bigger in developing than in developed countries.

The dream of improving the livelihoods of rural farm households in sub-Saharan African countries through increased agricultural productivity will remain a mirage if the adoption rates of proven agricultural technologies remain low (Morris et al., 1999; Langyintuo and Mekuria, 2005). While developed countries are already forging ahead in harnessing the application of biotechnology to increase productivity in their agricultural sectors, the reverse is happening in developing countries. Consequently, development economists have been preoccupied with the challenge of accurately identifying factors limiting the uptake of improved technologies in developing countries.

Low adoption rates of agricultural biotechnology in developing countries have been associated with factors such as the lack of credit, limited access to information, aversion to risk, inadequate farm size, inadequate incentives associated with farm tenure arrangements, insufficient human capital, absence of equipment to relieve labor shortages (thus preventing timeliness of operations), chaotic supply of complementary inputs (such as seed, chemicals, and water), and inappropriate transportation infrastructure (Feder et al., 1985). The rapid evolution and divergent perception of biotechnology also affects its adoption (Sandy, 2003). The uncertainty about the long term effects of genetic modification technology on health and the environment coupled with incomplete or absent national legislations act as major barrier to the safe and effective application of biotechnology in developing countries.

In Kenya, biotechnology has been introduced in plant and animal tissue culture, characterization, gene relationship, maintaining purity, molecular marker-assisted selection of parents (tracking genes or flanking), and genetic engineering. In livestock, this technology has been adopted in diagnostics (identification of viruses and rapid characterization of diseases).

The general objective of this study is to examine the adoption of tissue culture (tc) banana in Kenya and whether the technology is improving households welfare using econometric methods. First, correlates of biotechnology adoption are identified using a probit model. Next, household incomes model is estimated with the intention of establishing whether adopters of tissue culture banana technology incomes are significantly differently from that on the non-adopters.

The rest of the paper is organized as follows: section two presents an overview of tissue culture technology in Kenya. Methodology and data sources are presented in sections three. Section four presents and discusses the results while section five concludes.

Overview of tissue culture banana technology in Kenya

Mbogoh et al. (2002) and Qaim (1999) provide detailed background of banana production in Kenya. Banana is one of the most important food crops in Kenya. Apart from its value as a food crop in Kenya, sales from surplus banana output provide additional household income for small-scale farmers. Production of bananas in Kenya is basically a small-scale farm activity, with a national average of 0.32 ha of bananas per farm (Mbogoh et al., 2002). Banana production in the country has been on the decline over the last decade due to invasions by pests and diseases. Traditional cultural practices in banana production have been a major cause of this problem. Farmers transmit inadvertently most of the banana pests and diseases through banana suckers through the practice of sourcing planting material from fellow farmers.

Responding to this challenge of declining banana production, Kenya Agricultural Research Institute (KARI) and several non-governmental organizations (NGOs) have been in the forefront promoting adoption of tissue culture banana technology since 1997. Tissue culture technology, popularly known as *tc*, is the simplest form of biotechnology and consists of using parts of a plant and placing it in a sterile nutrient medium where it multiplies. The main aim is to provide clean and disease free planting material. This process does not alter any genetics make up of the plant. Molecular characterization or the markers assisted selection involves targeting significant major genes (pest and drought resistant) for selection and mapped on the genome for production.

Earlier studies on tissue culture banana technology have shown that while increase in yields especially on small-scale farms has been substantial, adoption rates are still low (Mbogoh et al., 2002; Qaim, 1999; Wambugu and Kiome, 2001). Several constraints to the adoption of tissue culture banana technology have been noted. These include: high cost of the tissue culture plantlets compared to conventional suckers, higher labor and inputs requirements, limited availability of clean land, limited established marketing and distribution systems. However, several NGOs have sought to address some of these constraints by introducing facilities to provide credit, information, the orderly supply of necessary and complementary inputs, infrastructure investments and marketing networks.

DATA AND METHODS

Data sources

Data used in this study came from a survey conducted by Tegemeo Institute (Egerton University). Adoption of agricultural biotechnology is at various levels in Kenya. The survey interviewed 180 households in five districts (Embu, South Imenti, Murang'a, Maragwa and Kirinyaga) around Mt. Kenya region. The districts were purposively selected because they were the pioneers in tissue culture banana technology and adoption rates in the districts are relatively high.

With help of government agricultural officers and NGOs promoting biotechnology adoption in the region, farmer groups in high adoption areas were selected. For logistic reasons, the number of groups included in the study was restricted to thirteen (13). The number of groups to include per district was based on a weight that depended on total number of active groups in each district. At the group level, a list of adopters and non-adopters was drawn. The selection of adopters and non-adopters was done randomly. This was to ensure that both the adopters and non-adopters had equal access to information, extension services and others services extended by the government and NGOs through farmer groups. The sample distribution across districts was as follows: Embu (17%), South Imenti (27%), Murang'a (14%), Kirinyaga (20%) and Maragwa (22%).

Conceptual framework

Decision to adopt a technology is a behavioral response arising from a set of alternatives and constraints facing the decision maker. The household aim is to maximize their utility under certain constraints. A standard linear regression model (1), where

y_i represents the decision to adopt or not and X_i is a vector of explanatory variables, cannot be used to estimate adoption when the dependant variable is a dichotomous binary variable as in the present case.

$$y_i = X_i\beta + \varepsilon_i \quad (1)$$

Linear regression assumes that the dependent variable being tested is both continuous and measured for all of the observations within the sample. The use of Linear Probability Model (LPM) to estimate model (1) when the dependent variable is a dummy results in violation of the basic assumptions of the classical linear regression model. Since the expected value of the dependent variable y given the independent variable X is $X\beta$, the variance of y depends on X_i, which implies that the variance of the errors depends on X and is not constant therefore not homoscedastic. In addition, binary values (0/1) result in errors not being normally distributed, hence breaking the normality assumption as well. To overcome this problem, probit model is used.

Let's first define a latent variable y_i^* in (1):

$$y_i^* = X_i\beta + \varepsilon_i$$
$$y_i = \begin{cases} 1 \ if \ \ y_i^* > 0 \\ 0 \ if \ \ y_i^* \le 0 \end{cases} \quad (2)$$

In equation (2), y_i^* is continuous and thus problems that are encountered when using the LPM are generally circumvented. The only shortcoming now is that the dependent variable cannot be observed so the model cannot be estimated using ordinary least squares (OLS).

The probit model is derived as follows:

$$prob(y_i = 1) = prob(y_i^* > 0) = prob(X_i\beta + \varepsilon_i) = prob(\varepsilon_i > -X_i\beta)$$
$$prob(y_i = 1) = 1 - prob(\frac{\varepsilon_i}{\sigma} < -X_i\frac{\beta}{\sigma}) = 1 - \Phi(-X_i\frac{\beta}{\sigma}) = \Phi(X_i\frac{\beta}{\sigma}) \quad (3)$$

This implies

$$prob(y_i = 0) = 1 - \Phi(X_i\frac{\beta}{\sigma}) \quad (4)$$

where Φ is the cumulative distribution function for the standard normal distribution and β is standardized by σ. The probit model is thus non-linear prompting use of maximum likelihood estimates (MLE). The log likelihood function to be estimated is specified as follows:

$$\ln L = \sum_{i=1}^{n}\{y_i \ln\Phi(X_i\beta) + (1-y_i)\ln[1-\Phi(X_i\beta)]\} \quad (5)$$

To estimate correlates of households' incomes, a classical linear regression model is estimated. The model is specified as follows:

$$Y_i = X_i\alpha + \mu_i \quad (6)$$

where Y_i is log of household income, X_i is a row vector of explanatory variables where tissue culture banana biotechnology adoption dummy is included, α is a column vector of the coefficients to be estimated and μ_i is the random error term. Of principal interest is the statistical significance of the adoption dummy coefficient.

Variables

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 range of explanatory variables have been hypothesized to influence the adoption of agricultural technologies (Feder et al., 1985; Fernandez-Cornejo et al., 1994; Johnson, 1993; Thrikawala et al., 1999; Ameden et al., 2005). These variables are explained as follows:

Net household farm and off-farm income

Adoption is expected to be positively related to income. Biotechnologies are input intensive and thus require financial resources. However, in areas where there are rural financial services, households' financial resources may not be significant.

Highest education attainment by household head

Educated farmers are better able to process information and search for appropriate technologies to alleviate their production constraints. The belief is that education gives farmers the ability to perceive, interpret and respond to new information much faster than their counterparts without formal education.

Age of household head

The role of a farmer's age in explaining technology adoption has been controversial. Older people are sometimes thought to be less amenable to change and hence reluctant to change their old ways of doing things. In this case, age is expected to have a negative impact on adoption. On the other hand, older people may have higher accumulated capital, more contacts with extension and preferred by credit institutions predisposing them more to technology adoption than younger ones.

Gender dummy

This variable captures the importance of gender in technology adoption. In most parts of Africa, extension workers are men and are usually biased towards men in their extension activities. Yet women play a significant role in agriculture.

Household land holding

Farmers with larger farms are more likely to adopt an improved technology compared with those with small farmers as they can afford to devote part of their fields to try out the improved technology. It is also known in the literature that technologies require economies of size for it to ensure profitability.

Marital status dummy

This variable captures the importance of family structure in technology adoption. It is intended to examine whether biotechnology adoption varies across family structure (monogamous, polygamous, single, widowed, etc).

Availability of credit services

Smallholder farmers lack the resources to purchase inputs. They may need to borrow to finance seedlings as well as complementary inputs to maximize benefits from new technologies. Thus, technology adoption could be constrained by lack of credit facilities at close proximity to the farmer.

Distance to the nearest output and input markets

Input and output markets are also known to influence the adoption of improved agricultural technologies. It is often useful to determine market accessibility of the villages being surveyed.

Religion dummy

Religious, moral and ethical perspectives vary as far as biotechnology adoption is concerned. While some churches have fiercely accused scientist for 'playing God', others have supported biotechnologies.

Distance to motorable roads

Distance to motorable roads is as equally important as distance to markets. Passable roads ease transportation of perishable farm output to markets as well as timely delivery of farm inputs.

Variable choice in the income estimation model is guided by economic theory, practice and data availability. The log of per capita household income is used as the dependent variable. Household incomes are estimated as a function of human capital factors and land endowment. Human capital theory clearly points to education as a key factor in income. Other human capital measures include age (as a proxy for experience), and educational attainment. Household land holding and credit availability are also included. Studies have shown that land is a very important asset as far as wealth generation is concerned. Credit availability and access to both input and output markets determine the economic returns to household production. Credit availability assists households to bridge the short-term liquidity gaps that may limit procurement of the required farm inputs, in the right quantities and in timely manner.

RESULTS AND DISCUSSION

Descriptive analysis

The summary of the variables is provided in Table 1. On average, households had an annual income of Ksh269, 710. Most of the households in the sample were found to be male headed (88 percent). The average household size was five members. The household head average age was 54 years old while the average formal education attainment was 10 years. Majority of the household's heads (80%) were monogamously married. About 27 percent were single parents out of which 89 percent were windows. Polygamous households were only three percent. With regard to religious affiliation, majority of the households (77%) were Catholics. Protestants households were 23 percent. Household land holding averaged 3 acres while distances to input and output markets was 2 kms. About 32 percent of the household reported that credit facilities were available in their respective localities.

About 48 percent of the farmers included in the sample had adopted tissue culture bananas. However, out of this number, only seven percent had specialized in tissue bananas. Majority of the tissue culture banana adopting households were growing tissue culture bananas along side non-tissue culture bananas but in separate plots. This observation could be attributed to a number of factors. First, it could be interpreted to mean that the adopting farmers are risk averse and are thus not willing to do away with their local banana varieties in favour of tissue culture bananas. Secondly, it could be an indicator that farmers are yet to be fully convinced of the superiority of tissue culture bananas or/and have not yet realised the full potential of adopting the biotechnology.

Summaries of value production, net income and productivity of both tissue and non-tissue bananas are presented in Table 1 below. The total value of production indicates the scale of production and is calculated as total annual production by household multiplied by prevailing market prices at the time of harvest. Net banana income is calculated as the difference between value of production and production (seed, fertilizer, chemicals, and land preparation) costs. Banana crop productivity is calculated as value of production per acre (value of production divided by acreage). The results indicate that the scale of banana production by non-tissue bananas exceed that of tissue banana. On average, non-tissue banana growing households are realizing KSh44,186 compared to KSh26,896 realized by tissue culture banana growing households. The difference is statistically significant at 5 percent significance level. The value of banana production increases with household income levels for both tissue and non-tissue banana growers (Table 2). Banana growing requires substantial financial and labour resources and thus relatively economically well-off households are bound to undertake high production scales.

Similarly, household growing non-tissue culture bananas were raising relatively higher income compared to tissue culture banana growing households. Non-tissue culture banana growing households are realizing KSh43, 657 while tissue culture banana gets KSh 25,521. The difference is statistically significant at 5 percent significance level. The production of tissue culture bananas is more resource intensive compared to non-tissue bananas. The production cost of non-tissue culture bananas as a percentage of total banana production value averaged 1.2 percent while that of producing tissue culture bananas averaged 5.1 percent. This implies probably due to high cost involved in tissue culture banana production, on average, most households opted to produce either more non-tissue culture bananas compared

Table 1. Household characteristics summary (mean).

Parameter	Mean	Std. Err.	[95% Conf. Interval]	
Total household income ('000Ksh)	269.71	21.94	226.41	313.01
Education level attainment – no of year	9.99	0.46	9.10	10.89
Age of household head	53.84	1.03	51.81	55.87
Household size	4.78	0.14	4.50	5.06
Gender (%)				
Male	88	2	83	93
Female	12	2	7	17
Religion (%)				
Catholic	23	0.03	17	30
Protestant	77	0.03	70	83
Household land size (acres)	2.85	0.22	2.41	3.29
Distance to nearest market (km)	2.06	0.19	1.69	2.44
Credit availability (%)				
Availability	32	3	25	39
Unavailable	68	3	61	75
Marital status (%)				
Monogamous	80	3	74	86
Polygamous	3	1	1	6
Single parenthood	27	3	21	34
District (%)				
Embu	17	3	11	22
South Imenti	27	3	21	34
Muranga	14	3	9	20
Kirinyaga	20	3	14	26
Maragwa	22	3	16	28

Table 2. Production, income and productivity of bananas.

Income quintile	Value of production (KSh)			Net banana income (KSh)		
	Non-tc	Tc	Difference	Non-tc	Tc	Difference
1 (lowest)	8,722	8,345	377	8,687	7,725	962
2	20,243	11,031	9,211*	19,293	9,750	9,543*
3	22,546	21,657	890	21,935	19,196	2,739
4	44,923	27,273	17,650	44,360	27,139	17,221
5 (highest)	85,992	47,366	38,626*	85,573	45,520	40,054*
Overall	44,186	26,896	17,290**	43,657	25,521	18,136**

Data Source: Tegemeo Institute Agricultural Biotechnology Study.
Tc=tissue culture; *Significant at 10%; **Significant at 5%.

or non-tissue culture bananas only. The net banana income also increases with household income levels for both tissue and non-tissue culture banana growers probably owing to costs implication.

Next, we examine banana productivity (value of production per acre). The results indicate that productivity of non-tissue culture banana exceeds that of tissue culture banana. Non-tissue banana growing households were realising about KSh113,000 per acre while tissue culture banana growers were getting KSh95,000 per acre. Banana productivity increases with household income levels for both tissue and non-tissue culture banana growers. Productivity of non-tissue culture bananas remain below that of tissue culture bananas across all income levels (Figure 1). As alluded to a while ago, while banana production is generally resource intense undertaking, production of tissue culture is even more resource demanding. Thus, probably farmers are applying less that

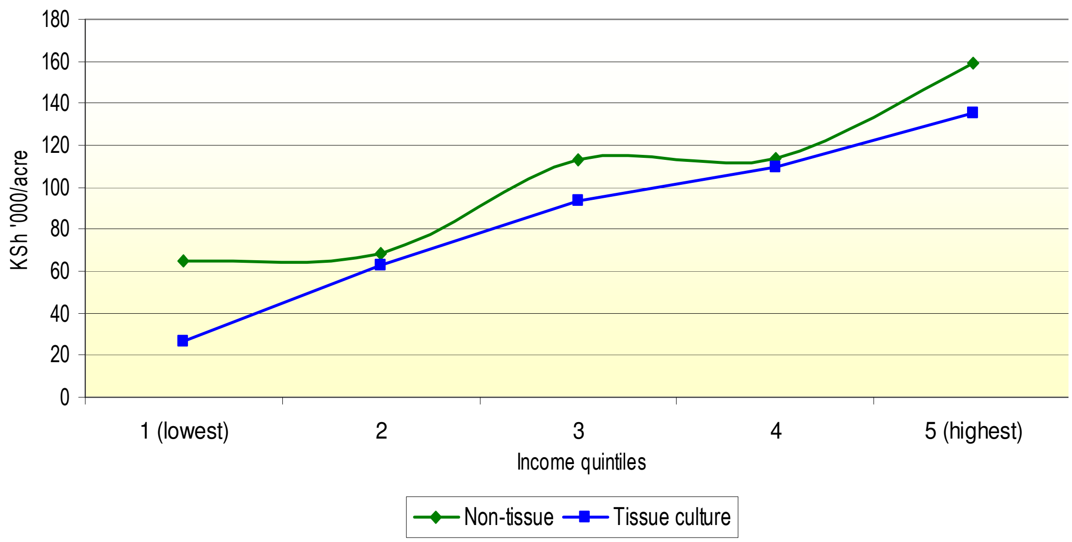

Figure 1. Productivity of tissue and non-tissue culture bananas (Ksh/acre). Data Source: Tegemeo Institute Agricultural Biotechnology Study.

Table 3. Probit model for tissue culture bananas adoption.

Adoption [1=adopted; 0=non-adopter]	Coef.	Robust Std. Err.	dF/dx
Log of household income	0.158	0.170	0.062
Gender [1: male; 0: female]	-0.587	0.408	-0.231
Marital status [1=monogamous; 0=other]	0.512	0.381	0.192
Log of education level household head	0.403	0.171*	0.159
Log of household head's age	0.897	0.534	0.353
Log of household size	-0.089	0.301	-0.035
Log of household land holding	-0.068	0.165	-0.027
Land tenure [1=with title; 0=without title]	0.621	0.281*	0.238
Log of distance to motorable road	-0.094	0.080	-0.037
Log of distance to market	-0.216	0.126	-0.085
Credit availability [1=available; 0=not available]	0.521	0.239*	0.205
Religion [1: catholic; 0: protestant]	-0.252	0.253	-0.098
_cons	-5.739	2.326**	
Number of obs	162		
Log likelihood	-92.31		
LR $chi^2(12)$	37.96		
Prob > chi^2	0.00		
Pseudo R^2	0.17		

*Significant at 10%, **significant at 5%; ***significant at 1%; dF/dx is for discrete change of dummy variable from 0 to 1.

the optimal input requirements in tissue culture banana production resulting in the observed low productivity.

Regression analysis results

Probit results on correlates of tissue culture banana adoption are found in Table 3. Variable coefficients, their standard errors and marginal probabilities are presented. Only the statistically significant results and their respective marginal probabilities are discussed. The results show that all the variable coefficient signs were as expected. The likelihood ratio chi-square of 37.96 with a p-value of 0.00 (1% confidence level) tells us that the model as a whole is statistically significant, as compared to model with no predictors.

Table 4. Determinants of household incomes model.

Log household income	Coef.	Robust Std. Err.
Adoption (1: adopter; 0: non-adopter)	-0.004	0.140
Log of net income from bananas	0.211	0.035**
Gender [1=male; 0=female]	0.144	0.217
Log of education level of household head	0.226	0.077**
Log of household size	0.613	0.140**
Log of household head's age	0.093	0.281
Marital status [1=monogamous; 0=other]	-0.198	0.165
Log of household land holding	0.326	0.063**
Credit (1=available; 0=not available]	-0.021	0.151
Log of distance to motorable road	0.063	0.043
Log of distance to market	0.073	0.065
_cons	1.317	1.174
Number of obs	162	
R-squared	0.49	
F(11, 150)	13.01	
Prob > F	0.00	
$\hat{\sigma}^2$	0.55	

* Significant at 5%; ** significant at 1%.

Contrary to the expectations, the results indicate that household income is an insignificant determinant of tissue culture banana adoption. Education level of the household head is a significant predictor of adoption at five percent significance level. An additional year of schooling increases probability of tissue culture banana adoption by 16 percent.

Another significant predictor of adoption is land tenure. Ownership of land with title deed increases the probability of adoption by 24 percent. Household with secure land rights are more likely to undertake resource intensive investment on land. Contrary to some other studies in sub-Saharan Africa (Ameden et al., 2005; Ismael et al., 2001), land size did not emerge a significant predictor of biotechnology adoption. Credit availability is also a very significant determinant of adoption. Credit availability increases probability of adoption by 21 percent. The model found no significant relationship between tissue culture banana technology adoption and other variables such as gender, household size, marital status, land size, distance to motorable road and religion.

Results of the correlates of household income are found in Table 4. The objective of this model was to examine whether adoption of tissue culture banana is making a difference in household incomes. The results show that contrary to the expectations, adoption of tissue culture bananas reduces households' income. However, the finding is not statistically significantly. Generally the net income from bananas is a significant predictor of household income level. This underscores the importance of banana crop in the welfare of smallholder farmers in the study area.

The other significant correlate of household income is the households head's educational attainment and household size. Household's income is an increasing function of household heads educational attainment. Highly educated heads have higher income earning potential and more alternative income earning opportunities, thus better able to improve the quality of their respective households' welfare. These results underscore the importance of education in poverty reduction.

Household income is an increasing function of household size in the study area. The relationship between income and household size can either be positive or negative. In areas with low few livelihood options, large household sizes may mean high dependency ratio thus low income. In areas with many livelihood options like the area under study, large households imply labour availability. Given the importance of banana enterprise in the study region and that banana growing is a labour intensive crop, labour availability is a positive predictor of household income.

Household land size holding is also found significant correlate of household incomes. Farm is the most important source of income in rural Kenya. As noted in the descriptive analysis section, average land sizes are extremely too small in the study area. Thus, small changes in land size are supposed to produce significant swings in household incomes.

It may be argued that inclusion of the adoption dummy in the income model as an exogenous variable when adoption is expected to be dependent on income may cause endogeneity. Also, it is known that incomes depend on ability which is highly correlated with education and thus a potential endogeneity cause. A joint Heckman test (Wooldridge, 2006) endogeneity test for variables suspect to be potential causes of endogeneity (adoption, education, and credit) returned negative results. Other diagnostic tests were undertaken to ensure that crucial classical linear regression model assumptions are not violated. Variance inflation factor test of multicollinearity similarly returned negative results.

It was perceived that as household heads' age advance, they gain experience that may increase their precision in decision making as far as farm investment and seasons' timing is concerned. Such trends may results in reduced variability in income with age and thus a potential cause for heteroscedasticity. However, Goldfeld and Quandt heteroscedasticity test posted negative results. However, to check against any other heteroscedasticity not tested for, White's robust standard error estimation approach was used.

Conclusion

The goal of this study was to identify the determinants of tissue culture banana technology adoption among smallholder farmers in the Mt. Kenya region and to determine whether incomes of adopting households are significantly different from those of non adopters. The findings indicate that while some households have not adopted tissue culture bananas, others are growing them alongside other non-tissue culture banana varieties. Even though earlier studies (e.g. Mbogoh et al., 2002) of the economic worth of tissue culture banana production in Kenya have concluded that the enterprise is economically worthwhile, the current study finds evidence to the contrary.

Average tissue culture banana production and incomes were found to be significantly lower than those of non-tissue culture banana growers. The tissue culture banana productivity was also found relatively lower than that of non-tissue culture banana. Tissue culture production costs are relatively higher than those of non-tissue culture bananas. The high cost of tissue culture banana production could be attributed to the following observation: 1/ households growing tissue culture bananas are doing that alongside other non-tissue culture banana varieties, 2/ some households have opted not plant tissue culture bananas at all, and 3/ relatively low scale of tissue culture production compared to non-tissue culture varieties.

Contrary to the expectations, household incomes were found an insignificant determinant of tissue culture banana technology adoption. Variables found significant and positive determinants of adoption are education level of the household head, land tenure and credit availability. The finding that household income is insignificant determinant of tissue culture banana adoption elicits several questions. How come availability of credit is more important than household income in the adoption model. Do farmers feel more comfortable using resources from other sources especially when trying new technologies? Or was credit availability tied to tissue culture banana adoption? If so, could the observed adoption rates be supply driven (attributed to NGOs supporting tissue culture technology in the region)? What are chances that the adoption rates will be sustained when the NGOs pull out?

In the determinants of household incomes model, tissue culture banana adoption was found insignificant predictor of household incomes. Incomes from adopting households were not significantly different from those of the non-adopters. The only variables found significant predictors of household incomes include income from bananas, education level of the household head, household size and household land holding.

The study results are generally interesting and especially when considered against the backdrop of increasing literature in support of biotechnology and its potential impacts on household incomes in developing world (Qaim, 1999; Pinstrup-Andersen and Cohen, 2000). Even though literature generally indicates that biotechnology has the potential to increase smallholder farmers incomes, this dream is not yet realized among the tissue culture banana growers in the Mt. Kenya region.

ACKNOWLEDGEMENTS

Comments and advice received from Songqing Jin of Department of Agriculture, Food and Resource Economics, Michigan State University are highly appreciated. Time and effort by Raphael Gitau, Research Fellow, Tegemeo Institute in data compilation is also acknowledged.

REFERENCES

Ameden H, Qaim M, Zilberman D (2005). Adoption of agricultural biotechnology in developing countries. In: Cooper J, Lipper L, Zilberman D, Editors, Agricultural biodiversity and biotechnology: Economic issues and framework for analysis, Springer Publishing, Boston pp. 329-358.

Carpenter JE, Gianessi LP (2001). Agricultural Biotechnology: Updated Benefit Estimates. National Center for Food and Agricultural Policy, Washington, DC.

Feder GR, Just RE, Zilberman D (1985). Adoption of agricultural innovations in developing countries: A survey. Econ. Dev. Cultural Change 33(2): 255-298.

Fernandez-Cornejo J, Beach ED, Wen-Yuan H (1994). The Adoption of IPM Techniques by Vegetable Growers in Florida, Michigan, and Texas, J. Agric. Appl. Econ. 26(1): 158-72.

Ismael Y, Beyers L, Lin L, Thirtle C (2001). Smallholder adoption and economic impacts of Bt cotton in the Makhathini Flats, South Africa. Paper presented at the 5th ICABR International Conference on Biotechnology, Science and Modern Agriculture: A New Industry at the Dawn of the Century, Ravello, Italy.

Langyintuo AS, Mulugetta M (2005). Accounting for neighborhood influence in estimating factors determining the adoption of improved agricultural technologies. Paper presented at the American Agricultural Economics Association Annual Meeting, Providence, Rhode Island, July 24-27.

Mbogoh SG, Wambugu FM, Sam W (2002). Socio-economic Impact of Biotechnology Applications: Some Lessons from the Pilot Tissue-Culture (tc) Banana Production Promotion Project in Kenya, 1997-2002. Paper presented during the XXV IAAE Conference, August 2003, Durban, South Africa.

Morris ML, Tripp R, Dankyi AA (1999). Adoption and impact of improved maize production technologies. A case study of the Ghana Grains Development Project. Economics Program International maize and Wheat Improvement Center (CIMMYT), Mexico. Paper 99-01.

Pinstrup-Andersen P, Marc JC (2000). Agricultural biotechnology: risks and opportunities for developing country food security. Int. J. Biotechnol. 2(1-3): 145-163.

Qaim M (1999). Assessing the Impact of Banana Biotechnology in Kenya. ISAAA Briefs No. 10. ISAAA: Ithaca, New York, USA.Sandy, T. 2003. Critical Issues Pertaining to the Gender Dimension of Biotechnology Policy. Paper for the Gender Advisory Board, United Nations Commission on Science and Technology for Development (July).

Traxler G (2004). The Economic Impacts of Biotechnology-Based Technological Innovations. ESA Working Paper. Agricultural and Development Economics Division. The Food and Agriculture Organization of the United Nations, pp. 04-08.

Wambugu FM, Kiome RM (2001). The Benefit of Biotechnology on Small-scale Banana Producers in Kenya. Brief Published by ISAAA 22-2001.

Wooldridge JM (2006). Introductory Econometrics: A Modern Approach, Third Edition. South-Western College Publishing Company.