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Determinants of Farm-Level Adoption of Cultural Practices for Banana Xanthomonas Wilt Control in Uganda

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Abstract

Understanding the factors influencing farmers' adoption decisions of the disseminated Banana *Xanthomonas* wilt (BXW) control package is critical for successful management of the disease. This paper analysed the determinants of farmers' decisions to adopt the control package by smallholder banana farmers in Uganda. A binomial Logit model is applied to household survey data collected from 350 households. Results from the study show that household labour availability, technology package attributes such as labour demand and perceived effectiveness of the practices in managing the disease; and agro-ecological location and banana production system significantly influence adoption decisions. These results suggest the need for adaptation of the technology package to better suit the needs and socio-economic conditions of smallholder farmers through a farmer participatory technology development approach that takes into account research findings, farmers' indigenous knowledge and resource constraints to enhance adoption.

Keywords: adoption decisions, Banana *Xanthomonas* Wilt, logit model, Uganda

1. Introduction

Banana (*Musa* spp.) is a key crop in Uganda, supporting both rural and urban populations. Apart from being a key food crop, it is an important source of income for resource poor farmers. It is estimated that over 75% of the country's farmers grow bananas on 1.5 million hectares, an equivalent of 38% of the total land under crops (Nowakunda & Tushemereirwe, 2004). The crop is regarded as the most traded food crop in the country and accordingly contributes to income through sales in raw form and other value-added products such as juice, beer, chips, cakes and other food products (Karamura, 1991). In turn, the income from banana sales is invested in other key components of farmers' livelihoods including paying school fees, investments in productive assets and health. The crop is also a key component of the agro-ecosystem reducing soil erosion on steep slopes through its closed canopy and is a principal source of mulch for maintaining and improving soil fertility and moisture.

Despite its importance, the crop is threatened by several biotic and abiotic constraints. Among the biotic threats, Banana *Xanthomonas* wilt (BXW) caused by the bacteria *Xanthomonas campestris* pv. *musacearum* is the most recent and is perceived by smallholder banana farmers in Uganda as the most serious threat to food security and incomes (Tushemereirwe, Kangire, Kubiriba, Nakyanzi & Gold, 2004; Karamura et al., 2011). The disease was first reported in central Uganda in 2001 (Tushemereirwe et al., 2001) but has since spread to other districts across the country including the main banana growing regions (Karamura, Osiru, Blomme, Lusty & Picq, 2006).

Unlike other banana diseases which cause gradually increasing losses over years, the impacts of BXW are extreme and rapid. In many of the affected districts, the disease wiped out entire banana plantations. No banana variety is resistant to the disease, although AAA-EAHB genomes are more resistant than ABB and AAB genomes (Karamura et al., 2010).

It has been estimated that if BXW is not controlled, Uganda stands to lose an estimated US$295 million worth of banana output valued at farm gate prices, which translates to a loss of US$ 200 per year of food and income per household (Kalyebara et al., 2006). Compared to pre-infection levels, the total banana yield loss due to BXW infection was estimated at 30–52% between 2001 and 2004 (Karamura et al., 2010).

Based on the current understanding of the epidemiology of similar bacterial wilt diseases of bananas such as Moko (in Latin America) and Bugtok (in Asia), Bioversity International and partners, over the last 6 years developed a package of cultural practices for controlling BXW. The package includes four complementary practices which are aimed at eliminating the innoculum source and preventing transmission of the disease through insects and farm tools: timely removal of the male buds using a forked stick, destroying and disposal of infected plants, disinfecting farm tools used in the plantation by dipping in Sodium hypochlorite solution (sold under the trade name 'JIK') or flaming on fire and use of clean planting material (Karamura et al., 2008). The package is usually abbreviated ABCC, which stands for Avoidance (avoiding infected planting material by using clean planting material); Breaking off male buds (timely removal of male buds with forked stick); Cut out diseased plants and Cleaning cutting tools (disinfecting farm tools) (Kalyebara et al., 2006). This control package if fully (as a package instead of separate components) and correctly applied is effective in reducing the disease incidence and and can eventually eradicate the disease on affected farms (Tushemereirwe et al., 2003; Tripathi, Mwangi & Abele, 2009).

Since 2002, there has been a series of campaigns to sensitize farmers and other stakeholders on the disease symptoms, its spread mechanisms and to promote available control options in Uganda and other countries in the region. In the years following the first series of campaigns a number of ex-post studies were conducted to evaluatethe level of awareness of the disease symptoms, its transmission mechanisms and cultural control practices at the farmer and community levels (Bagamba et al., 2006; Ngambeki, Tushemereirwe & Okaasai, 2006). These studies showed that most farmers were aware of BXW symptoms, its spread mechanisms and the recommended control package. However, one of the important research gaps to date is the lack of understanding on the extent to which thecontrol package has been adopted by smallholder banana farmers and in particular the key factors that influence adoption of the control package by farmers. Therefore, the objective of this paper is to assess the socio-economic factors that influence adoption of the BXW control package by smallholder farmers in Uganda. Understanding of farmers' adoption behaviour is useful in generating insights to inform strategies for targeting technology disemination and promotion for effective control of the disease in smallholder banana farming systems.

2. Methodology

2.1 The Analytical Model

Farmers' utility maximization framework has been used in a number of studies to model farmers' adoption decisions using Tobit (e.g. Adesina & Baidu-Forson, 1995) and discrete choice models (e.g. Kabunga, Dubois & Qaim, 2011; Adesina, Mbila, Nkameleu & Endamana, 2000). The choice of any of these models depends on the issues of interest. Where the interest is on examining the role of farm and farmer characteristics affecting adoption decisions, as is the case in this study, most studies have used discrete choice models such as Logit and Probit models (e.g. Katungi & Akankwasa, 2010; Aitchedji, Tenkouano & Coulibaly, 2010) and Tobit models (e.g.Mazvimavi & Twomlow, 2009). The theoretical foundation of these models is the random utility framework.

Following Adesina and Chianu (2002), let us assume a farmer'sadoption decision is based on an underlying utility function. Since the farmer has a choice to adopt the recommended BXW control package or not to adopt, let the farmer's choice be represented by *j*, where *j*=1 if the farmer chooses to adopt the control package and *j*=0 if otherwise. The latter may include the use of other practices that are not part of the recommended control package, such as farmer-discovered concoctions. In making a decision on whether to adopt or not to adopt the control package a farmer's objective is assumed to be maximization of expected utility, and therefore the farmer's preference can be modeled through a non-observable utility function.

The underlying utility function for farmer *i*, faced with two choices *j* (adopt or not adopt) can be represented as:

$$U_{ji} = \beta_j X_i + \varepsilon_{ji} \tag{1}$$

Where, *j*=0, 1; *i*=1, 2 ….. *n*.

This utility function is the standard random utility model, where $U_{ji}$is the utility farmer *i* derives from choosing *j*; X_i is a vector of farm and farmer socio-economic, institutional and technology characteristics that influence farmers' preferences and utility; β_j is a vector of parameters and ε_{ji} is the error term.

Since utilities are random, the farmer will adopt the control package if the preference comparison is such that $U_{1i} > U_{0i}$ or if the non-observable (latent) random variable $y^* = U_{1i} - U_{0i} > 0$. The probability of adoption of the control package can then be represented as:

$$\Pr(Y_i = 1) = \Pr(U_{1i} > U_{01}) \quad (2)$$

The right hand side of Equation (2) can be re-arranged as:

$$\Pr(\beta_1 X_{1i} + \varepsilon_{1i} > \beta_0 X_{0i} + \varepsilon_{0i})$$

$$\Pr\{(\varepsilon_{1i} - \varepsilon_{0i} > X_i(\beta_0 - \beta_1)\}$$

$$\Pr(u_i) > -BX_i;\ \text{where}\ u_i = \varepsilon_{1i} - \varepsilon_{0i}$$

$$Y_i(BX_i)$$

Where, X_i is a matrix of explanatory variables, B is a vector of parameters and u_i is a random error term; $Y_i(BX_i)$ is the cumulative distribution function of u_i evaluated at BX_i.

Assuming u_i follows a logistic distribution then the probability of a farmer adopting the control package can be estimated using a Logit model, which is specified as follows:

$$P\ (y = j|x) = \frac{\exp(X_i\beta_j)}{\sum_{k=0}^{J}\exp(X_i\beta_k)} \quad (3)$$

In the empirical binomial logit model the dependent variable is binary, taking on a value of 1 if the farmer currently uses at least these three recommended practices: destroying infected plants, removal of male buds with forked stick and disinfecting farm tools (BCC)[Note 1] and 0 otherwise. These three practices if deployed together as a package can reduce and eventually eradicate the disease on farm (Muhangi et al., 2006).

The binomial logit model is estimated by maximum likelihood estimation method using STATA software. Due to the nonlinearity of the logit model, the estimated coefficients do not directly represent the effect of explanatory variables on probabilities (Long, 1997). To obtain the effects of the explanatory variables on probabilities marginal effects are computed.

The marginal effects are given as:

$$\frac{\partial P_j}{\partial x_k} = P_j\left(\beta_j - \sum_{k=0}^{J} P_k\beta_k\right) \quad (4)$$

The marginal effects (or marginal probabilities) measure the expected change in probability of a particular choice being made with respect to a unit change in an explanatory variable from its mean (Greene, 2000). The sign of the marginal effect and respective coefficient may be different, as the former depend on the sign and magnitude of all other coefficients (Greene, 2003).

2.2 Data and Sources

The data used in this study was obtained from a household survey carried out in Uganda targeting the two main banana production systems: the ‘Kayinja’ beer banana (ABB genome) and the East African highland banana (EAHB) ‘Matooke’ (AAA-EAHB genome) systems. The Kayinja dominated cropping system is mainly found in Central Uganda, at altitude of approximately 1300 meters above sea level (masl). The system is characterized by heavily leached soils with high banana pest and disease pressure. The system is usually a mix of bananas and other crops (e.g. coffee, cassava and trees). The EAHB system on the other hand, is mainly found in the south western parts of Uganda at altitudes of approximately 1700 masl, with relatively low banana pest and disease pressure. The EAHB system is more intensively managed (with frequent pruning, weeding, de-budding) than the Kayinja system. Accordingly, BXW transmission in the EAHB system is mainly through farm tools whereas in the Kayinja system insects are the main mechanism of transmission.

A household survey was conducted between May and September, 2010 using a structured questionnaire. The survey collected data on the following themes: household socio-economic and farm characteristics; BXW incidence on farm; farmers’ knowledge of BXW symptoms, mechanisms of spread and control measures; cultural practices in use; banana production, consumption and marketing; livelihoods strategies and coping mechanisms. In selecting households for the survey, a multi-stage stratified random sampling design was used. The two banana production systems described earlier constituted the first stratum. In each production system communities were mobilized and information on BXW management was delivered to them using three main delivery approaches: farmer field schools, community-based extension and the traditional top-down extension approach. Therefore, districts were purposively selected across the agro-ecological zones to represent the two production systems and the three extension approaches using expert knowledge. A total of ten districts, six districts from the EAHB system (Isingiro, Mbarara, Masaka, Bushenyi, Ibanda and Ntungamo) and four from the

Kayinja system (Kiboga, Mityana, Mubende and Mpigi) (Table 1) were selected. Occurrence of the disease and period since infection was first observed in the district were also considered in selecting these districts.

Table 1. Sample stratification design

Production system	Technology transfer approach	Districts	Number of sub-counties (communities) selected
East African highland Banana (EAHB)	Farmer field schools	Mbarara	3
	Community	Masaka, Ntungamo, Isingiro	3
	Traditional extension	Mbarara, Bushenyi, Ibanda	3
Beer banana (Kayinja)	Farmer field schools	Kiboga	3
	Community	Mityana, Mubende	3
	Traditional extension	Mpigi	3

Once the districts were chosen, three communities (sub-counties) were randomly selected to represent each of the three technology transfer approaches. Households in the selected sub-counties were then stratified according to the banana marketing strategy they use: collective versus individual. To take into account the diversity in the scale of banana production among the rural households, households were further stratified according to the size of their banana farms into large (>0.8 hectares) and small farms (<0.8 hectares) and twenty households were randomly selected in each stratum. The cut-off point of 0.8 hectares is the average banana farm size based on a previous study (Jogo et al., 2011). The final sample of households interviewed was 350 households.

2.3 Empirical Model Variables and Expected Relationships

The choice of the explanatory variables for the empirical model presented in this study is based on theoretical and empirical literature on adoption and data availability.

Previous studies on adoption of banana technologies have shown that farmers' adoption decisions depend on farm and farmer socio-economic and institutional characteristics; technology characteristics and dissemination approach and contextual characteristics (Katungi & Akankwasa, 2010; Aitchedji et al., 2010; Kabunga et al., 2011). Accordingly, we broadly categorized the explanatory variables used in the model into household demographic, farm; socio-institutional, location and perceived technology characteristics as shown in Table 2. The specific variables in each of these categories, their description and expected influence on adoption of the cultural control package are discussed below.

The demographic characteristics included in the model are SEX, HHLDSIZE, EDUC and FEXP.

SEX refers the gender of household head (whether male or female-headed) which can influence technology adoption through gender-linked disparities in access to complementary inputs, resources and services such as land, labour, equipment, extension, credit, markets and information (Doss & Morris, 2001). Gender can also influence household consumption preferences and hence consumption demand for bananas which may trigger the household to adopt yield-enhancing technologies (or loss-minimizing technologies such as BXW control package) to be self-sufficient especially given the market imperfections in rural settings. Findings of previous studies on the effect of gender on banana technologies adoption are pretty mixed. Katungi and Akankwasa (2010) and Kabunga et al. (2011) found gender to be significant in adoption of corm paring and tissue culture bananas, respectively, with female-headed households being more likely to adopt these two technologies, while Aitchedji et al. (2010) found gender to be insignificant. We therefore expect the effect of gender to be either positive or negative.

HHLDSIZE is positively related to own labour availability in smallholder farming system where the family is the main source of labour used in agricultural activities. Labour constraints can limit farmers' use of labour-intensive technologies. The study by Katungi and Akankwasa (2010) found that household size positively and significantly influenced adoption of corm paring banana technology for pest management among banana farmers in Uganda. Due to the high labour demand of some of the component practices of the BXW control package, especially destroying of infected plants and de-budding (Bagamba et al., 2006; Biruma et al., 2007) we expect large families to be more likely to adopt the control package due to the availability of labour to implement labour-intensive components of the control package and also the need to feed more people.

The level of education of a farmer is an important factor influencing technology adoption (Feder, Just, & Zilberman, 1985). Education influences the capacity of a farmer to acquire and synthesise information and knowledge about the problem and technologies which is critical for technology adoption (Katungi, 2007). BXW management practices are knowledge-intensive, requiring farmers' understanding of the disease spread mechanisms, precision in timing of implementation of some of the practices (e.g. de-budding has to be done after the formation of the last hand, Biruma et al., 2007) and correct concentration of disinfectant for farm tools to effectively manage the disease. The study by Katungi and Akankwasa (2010) found education of the farmer to be positively and significantly related to adoption of corm paring technology. We hypothesise that educated heads are more knowledgeable about the disease and the control package and are therefore more likely to adopt the control package.

Farming experience of the household head (FEXP) imply farming knowledge gained over time and is important in evaluating technology information and technology adaptation to local conditions (Feder et al., 1985). Studies on adoption of banana technologies by Aitchedji et al. (2010) and Kabunga et al. (2011) have shown that farming experience positively influences farmers' adoption decisions. Accordingly, we expect the years of experience in farming to be positively related to adoption of the BXW control package.

Three farm characteristics variables included in the model are farm size (FRMSIZE), the proportion of land under banana (PROPBAN) and predominant banana system (BANSYST).

Access to physical and financial assets influences the capacity of farm households to invest in agricultural technologies. Farm size, which is a measure of household wealth, has been widely in adoption studies (Langyintuo & Mulugetta, 2008; Nyangena, 2007). However, the effect of farm size on adoption of agricultural technologies is ambiguous. On the one hand, more land allows a farmer to take the risk of experimenting with new technologies and positively influence adoption; on the other, more land may reduce the incentive to invest in productivity enhancing technologies. A priori, we expect a positive relationship between land and adoption as more land allows the farmer to engage in other crop enterprises which generate income that can cover costs of hiring labour and purchasing inputs (e.g. JIK) required for implementing the control package.

Farmers' decisions to invest in controlling pests and diseases affecting bananas are also influenced by the importance they attach to banana as a food and income crop (Gold et al., 1991). We used the proportion of land area allocated to banana production (PROPBAN) as a proxy for importance of banana for income and food security.We expect this variable to positively affect adoption of the control package.

As highlighted in section 2.2, banana production in Uganda falls under two main production systems: the East African Highland Banana and the Beer banana systems. The intensity of management in the two systems differs, with the former being managed intensively while the latter is poorly managed (Kagezi et al., 2006; Bagamba et al., 2006). Although both systems are affected by BXW, the beer banana clones are more susceptible to the disease than EAHB cultivars (Kagezi et al., 2006). Also, the production objectives of farmers differ between the two banana systems (Bagamba et al., 2006). The different features of the production systems are likely to influence the compatibility of the new technology with the production system and the potential for adoption of the new technology. We expect adoption of the control package to be more likely in the EAHB system than the beer system as the former is more intensively managed and probably plays a much bigger role in enhancing farmers' incomes and food security.

Agro-ecological factors such as rainfall, soils and temperature are linked to banana production potential and pest and disease pressure. Mazvimavi and Twomlow (2009) argued that farmers located in high potential regions with better chances for increased crop production tend to be less risk averse and are likely to adopt new practices. Altitude influences rainfall, temperature and pests and diseases pressure. We accordingly used altitude to categorise two agro-ecological zones: high altitude and low altitude zones. Farmers in the high altitude zone are expected to be more likely to adopt the BXW control package than those in the medium to low altitude zone.

Previous studies on adoption of banana technologies have shown that information and knowledge are important determinants of adoption (Aitchedji et al., 2010; Kabunga et al., 2011; Katungi & Akankwasa, 2010). Information can be obtained from extension agents, researchers and other informal sources such as neighbours and social organizations in the community. Social organizations provide opportunities for social interaction, learning and knowledge sharing and were found to facilitate adoption of banana technologies (Katungi, 2007; Aitchedji et al., 2010; Katungi & Akankwasa, 2010). However, most community organizations generate externalities (spill-over effects) through diffusion of information and knowledge to non-members of the organizations through interactions of the social organisations and the broader community within which they are found (Dzomeku et al., 2010). We include a district level variable for access to a farmer field school (FFS) and expect that access to FFS in the community enhances adoption.

Technology specific characteristics such as complexity, relative advantage to current farmer practices, risk, input demand and compatibility with local conditions influence technology adoption (Rogers, 1983). Farmers' perceptions about the technology attributes influence their adoption decisions (Kivlin & Fliegel, 1967; Katungi, 2007; Dzomeku et al., 2010). For instance, Kagezi et al. (2006) observed that adoption of de-budding in the beer banana system is limited partly due to the perception by farmers that it has a negative impact on juice quality. In our model we include three variables capturing farmers' perception on the control package's effectiveness in controlling the disease (PERCEPEFFECT), cost (PERPCOST) and labour demand (PERPLABOUR).

Table 2. Definition of variables, hypothesized effects and summary statistics of variables used in the empirical econometric model

Variable	Definition	Measurement	Expected sign	Mean	SD
Dependent variable					
BCCADOPT	Use of BXW control package	=1 if farmer uses the control package (BCC); 0 if farmer does not use the package			
Independent variables					
A. Demographic characteristics					
SEX	Gender of household head	1=male; 0=female	+/-	0.51	0.50
HHLDSIZE	Household size	Number of members in the household	+	5.52	10.09
EDUC	Education of household head	Years of schooling of the household head	+	6.55	3.87
FEXP	Farming experience of the household head	Number of years of experience in farming	+	24.05	13.93
B. Farm characteristics					
FRMSIZE	Total farm size	Acres	+	5.97	6.64
PROPBAN	Proportion of land area under banana	Percentage (%)	+	0.47	30.06
BANSYST	Dominant banana production system	1=EAHB; 0=Beer	+	0.49	0.50
C. Socio-institutional factors					
FFS	Presence of a farmer field school in the district	1=FFS present; 0=FFS not present	+	0.27	0.45
D. Location characteristics					
AGROEC	Agro-ecological zone in which farmer is located	1=high altitude; 0=medium to low altitude	+	0.22	0.42
C. Technology attributes					
PERPLABOUR	Farmer perception on the labour demand of package	1=control package perceived to be labour-intensive; 0 otherwise	-	0.11	0.31
PERCEPEFFECT	Farmer perception on the effectiveness of the package in controlling the disease	1=control package perceived ineffective; 0 otherwise	-	0.07	0.25
PERPCOST	Farmer perception on the cost of package	1=control package is costly; 0 otherwise	-	0.11	0.31

3. Results and Discussion

3.1 Adoption of Different Components of the BXW Control Package

Farmers tend to disassemble technology packages and adopt the most relevant parts initially, followed by additional components over time (Mazvimavi & Twomlow, 2009). The percentage of the surveyed farmers practicing the different BXW practices is given in Table 3. The results show that cutting pseudostem (cutting the single plant showing symptoms instead of whole mat); removal of male buds using forked stick and disinfecting of farm tools were practiced by at least 60% of the interviewed farmers. The wide application of single plant removal can be attributed to the fact that it is less labour-intensive than removal of whole mat.The adoption rates reported here are significantly higher than those reported in an earlier study by Muhangi et al. (2006) which range from 2 to 45% for these three practices. The increase in the level of application of the three component practices demonstrates the dynamic nature of adoption and could correspond to the increasing phase of the sigmoid technology diffusion-adoption curve (Rogers, 1983). The increase could be attributed to increased exposure of farmers to information and knowledge on the management of the disease as a result of continuous farmer learning through farmer-to-farmer sharing of knowledge and experiences and sustained sensitization and awareness raising programmes by stakeholders in the banana sector.

The least practiced component of the control package is use of clean planting material. In smallholder banana farming systems in east and central Africa, more than 90% of the farmers rely on suckers from informal sources such as own fields, farmer-to-farmer exchanges and local sales to expand and establish new farms (Smith, Jones, Karamura, Blomme & Turyagyenda, 2008). As farmers rarely verify whether the source of the suckers is disease-free, there is a high risk of transmitting pests and diseases through planting material within and across farms and even across borders. Since pathogen-free tissue culture plants are inaccessible and costly for resource-poor smallholder farmers, identifying strategies to enhance smallholder farmers' access to low-cost clean planting material is critical for the management of BXW and other banana pests and diseases.

Comparing across agro-ecological zones and banana production systems the results show that cutting pseudostem and cutting plants and leaving them on the ground heaped or unheaped are more widely practiced in the low-to medium altitude zones than in the high altitude zone. On the contrary, uprooting of affected plants, removal of male buds and disinfection of farm tools are practiced more in the high altitude zone than in the low to medium altitude zone. Apart from cutting affected plants and leaving them on the ground, the other components of the technology package are more widely adopted in the EAHB production system which is mostly associated with the highland zone than in the Kayinja system. This is hardly surprising as the Kayinja system is generally poorly managed or in some cases not managed at all by farmers (Bagamba et al., 2006).

To effectively manage the disease farmers need to deploy all the component practices together as a package. However, in line with earlier findings by Muhangi et al. (2006), few farmers (<50%) deploy the three practices together and even fewer deploy all four making eradication of the disease on their farms difficult. Lack of labour (component practices such as up-rooting of infected mats, de-budding are labour intensive), high costs, inadequate information and farmers' perceptions about the practices (e.g. the perception that de-budding beer bananas reduces juice quality, and that some of the practices are ineffective) are some of the factors limiting adoption of the control package (Bagamba et al., 2006; Jogo et al., 2011). There is need for more sensitization of farmers on the importance of deploying the full package to effectively manage the disease.

Table 3. Characterization of adoption patterns of components of the BXW control package (% of interviewed farmers adopted the practices) in surveyed villages

	Agro-ecological zone		Banana production system		
Cultural practices	Medium to low altitude (<1400masl) (n=272)	High altitude (>1400masl) (n=78)	EAHB (n=172)	Beer banana (n=178)	Total sample (n=350)
Individual practices:					
Destroying infected plants (C):					
i. Cutting pseudo stem of affected plants	77.9	29.5	80.3	53.5	67.1
ii. Uprooting and burying whole mat of affected plants	33.8	67.9	52.9	30.3	41.4
iii. Cutting affected plant and leave on ground (heaped or unheaped)	43.8	20.5	27.3	49.4	38.6
Removal of male buds with forked stick (B)	62.5	79.5	77.4	65.2	66.3
Disinfection of farm tools with JIK or fire after cutting (C)	59.2	78.2	68.6	58.4	63.5
Using clean planting material (A)	15.4	8.9	17.4	10.5	14.0
Control packages:					
Package BCC	45.2	58.9	49.4	47.2	48.3
Full package ABCC	6.4	8.1	7.9	7.6	7.7

3.2 Factors Affecting Farmers' Adoption Decisions

In estimating the econometric model we checked for the presence of multicollinearity among explanatory variables, a problem normally encountered when using cross-sectional data for econometric estimation. If present, it can lead to biased parameter estimates (Greene, 2003). To explore the potential for multicollinearity among explanatory variables an Ordinary Least Squares model was fitted and the variance inflation factor (VIF) was used to test its presence. The variance inflation factors for all explanatory variables were less than 10 (ranging from 1.08 to 1.95), which indicate that multicollinearity is not a serious problem in the model.

The parameter estimates of the estimated binomial logit model are presented in Table 4. The likelihood ratio statistics as indicated by χ^2 statistics are highly significant ($P < 0.001$), suggesting that the model has a strong explanatory power.

Table 4. Parameter estimates of the logit model

Variables	Coefficient	Standard Error	Pr >z
SEX	0.165	0.269	0.538
FEXP	0.017	0.010	0.688
HHLDSIZE	0.052	0.044	0.094*
EDUC	-0.023	0.037	0.238
FRMSIZE	0.022	0.022	0.298
PROPBAN	0.004	0.005	0.389
FFS	0.111	0.341	0.745
AGROEC	1.379	0.408	0.001***
BANSYST (1=EAHB, 0=Beer)	0.303	0.354	0.096*
PERPLABOUR	-0.757	0.436	0.083*
PERCEPEFFECT	-1.920	0.674	0.004***
PERPCOST	-0.173	0.427	0.685
Intercept	0.829	0.532	0.119
Diagnostics:			
Number of observations	277		
Likelihood Ratio	35.56***		
Log-likelihood	-173.43		
Pseudo R^2	0.093		

*** Significant at 1%; * Significant at 10%.

As highlighted earlier, the parameter estimates of the logit model only provide the direction of the effect of the independent variables on the dependent (response) variable but do not show the actual magnitude of change on probabilities. To show the marginal change in probabilities as explanatory variables change from their mean marginal effects (Equation 4) have to be computed. Table 5 presents the computed marginal effects for the explanatory variables and their significance levels. The marginal effects results show that five factors are significant, at either 1% or 10% significant levels, in explaining farmers' adoption decisions of the BXW control package.

Household size (HHLDSIZE) is significant at 10% and is positively related to adoption of the BXW control package. This suggests that large families are more likely to adopt the control package than smaller ones.This result is consistent with the finding by Bagamba et al. (2006); Muhangi et al. (2006) and Jogo et al. (2011) that lack of labour is a key limiting factor for adoption of the recommended BXW control package. Katungi and Akankwasa (2010) similarly found a positive and significant relationship between household size and adoption of corm paring banana technology for pest management among banana farmers in Uganda.

The results show that the labour demand of the control package (PERPLABOUR) significantly (at 10%) influences farmers' decision to adopt it. The negative sign suggests that farmers who perceived the package to be labour-intensive were less likely to adopt the package. This result is consistent with that for household size since a farmer's perception on the labour demand of a technology package is in part influenced by the availability of labour in the household. Component practices such as uprooting and burying of diseased mats, heaping of destroyed infected plants, de-budding and disinfecting tools through flaming on fire are tedious and laborious for farmers (Bagamba et al., 2006; Biruma et al., 2007; Mwangi, 2007).

Table 5. Marginal effects from the binomial logit model

Variables	Parameter estimate	SE	Pr >z
SEX	0.041	0.666	0.538
FEXP	0.004	0.002	0.568
HHLDSIZE	0.007	0.01	0.092*
EDUC	-0.006	0.009	0.540
FRMSIZE	0.006	0.005	0.298
PROPBAN	0.001	0.001	0.389
FFS	0.027	0.085	0.746
AGROEC	0.327	0.085	0.000***
BANSYST (1=EAHB, 0=Beer)	0.131	0.077	0.092*
PERPLABOUR	-0.177	0.093	0.058*
PERCEPEFFECT	-0.366	0.079	0.000***
PERPCOST	-0.042	0.104	0.682

*** Significant at 1%; * Significant at 10%.

As expected, agro-ecological location is positively related to adoption of the BXW control package and is significant at 1%. This implies that banana farmers in the high altitude zone are more likely to adopt the control package than those in the low to medium altitude zone. Since the EAHB is highly associated with the high altitude zone, this result can be interpreted in conjunction with that of BANSYST which is also positively and significantly (at 10%) related to adoption, as expected. The high altitude zone is dominated by the EAHB system which is generally more intensively managed than the beer banana system. Banana farmers in the high altitude zone participate more actively in banana markets as sellers than those in the medium to low-altitude zone (Katungi, 2007) and therefore have income to cover the costs of hiring labour and purchasing of inputs needed to implement the control package. Even within the high altitude zone banana farmers who are market-oriented are more widely adopting the control package than those who grow banana largely for subsistence purposes (Robert Rwabubare, personal communication, 2013). Besides the ability to cover adoption costs, the importance of income from banana sales for other key component of farmers' livelihood (e.g. health, education) gives market-oriented farmers an incentive to invest in controlling the disease.

Farmers' perceptions of the effectiveness of the package in controlling the disease significantly (at 1%) influence their adoption decisions. Those who perceive the package to be ineffective are less likely to adopt the control package. In some cases farmers tried applying the practices and later abandoned them. The perceived ineffectiveness of the technology package could be due to incorrect application of the practices by farmers. For instance, studies by Kagezi et al. (2006) and Muhangi et al. (2006) found that most farmers remove male buds sporadically, and do it so late (mostly when fingers have turned upwards) when transmission is likely to have already taken place. With regards to disinfecting of farm tools a study by Mwangi, Nakato and Muthoni (2007) showed that the recommended practice of dipping of farm tools in 0.6% Jik is not effective unless the tools are dipped for more than 3 minutes. However, most farmers work with one knife and are unlikely to wait that long as that would reduce their working time. Similarly, disinfecting through flaming on fire is time-consuming and most farmers might not flame the knives long enough to kill the bacteria and can potentiallyspread infection.

The incorrect application of the control package could be a reflection of inadequate knowledge on the disease and the practices by farmers, which was also identified as a constraint to adoption (Bagamba et al., 2006). During informal discussions with key informants (extension and opinion leaders in local communities in Bushenyi) it was revealed that one of the major factors limiting effective application of control measures on farm is that men are mostly involved in sensitization and training programmes on BXW management but do not pass on the knowledge they acquire to their wives who are mostly involved in managing banana plantations.This shows that women do not have an equal chance to acquire knowledge on BXW management and strategies to eliminate this gender bias should be sought.

Farmers receive conflicting messages from different sources (and over time) on BXW management and also lack understanding of the epidemiology of the disease to appreciate the rationale behind the recommended practices (Robert Rwabubare, personal communication, 2013). Thus, continuous sensitization of farmers on new research findings on the epidemiology of the disease and involving them in the fine-tuning of control practices is essential for enhancing adoption of recommended practices by farmers.

4. Conclusions and Policy Implications

In this paper we analysed the determinants of smallholder banana farmers' adoption decisions of the BXW control package in Uganda. Some conclusions and policy implications can be drawn from the analysis presented in this paper. First, the results of this study showed that although the level of adoption of the control package by banana farmers in Uganda has improved compared to figures reported in earlier studies, still few farmers are deploying the full package on their farms making eradication of the disease difficult.There is need for more sensitization of farmers on the importance of deploying the full package to effectively manage the disease.However, the use of clean planting material, one of the component practices is still a big challenge for smallholder banana farmers who still rely heavily on the informal system for the supply of planting material given theirlimited access to the formal banana seed sector. It is therefore important to support interventions such as macro-propagation, community nurseries and mother gardens to ensure that resource-poor smallholder farmers are able to access low-cost clean planting material to avoid possible transmission of BXW and other banana pests and diseases through planting material.

Secondly, the results of the econometric analysis showed that household labour supply and technology attributes such as labour demand and farmers' perception that the practices are ineffective in controlling the disease are key constraints to adoption of the package. The latter may be the result of incorrect application of the technology package due to inadequate farmer knowledge on the disease and the control practices. These results have three important implications. The first is that there is need to empower farmers with knowledge on the disease and control options. Secondly, there is need to adapt the technology package to better suit the needs and socio-economic conditions (e.g. labour, physical and financial resources constraints) of smallholder farmers through a participatory technology development approach that takes into account research findings, farmers' indigenous knowledge and resources to enhance wider adoption. Third, these results suggest the need to evaluate and demonstrate the effectiveness of the technology package in managing the disease under farmer conditions.

The econometric results also showed that adoption potential for the control package is high in high altitude zones dominated by the EAHB banana production system. Therefore, efforts to promote BXW management technologies should initially target these areas as 'epicentres' for promotion of technologies to allow take-off and lessons drawn from these areas can beapplied to areas of low potential adoption (low altitude and beer banana systems) where control is equally important as these areas could become sources of innoculum.

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Notes

Note 1. The fourth component practice, use of cleaning planting material was not included in the econometric analysis as very few farmers (14% of our sample) apply this practice (see Table 3) and including it in the package would significantly reduce the observations and degrees of freedom in the adopter category making the estimated results unreliable.