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Does gender matter in effective management of plant disease epidemics? Insights from a survey among rural banana farming households in Uganda

Enoch Mutebi Kikulwe[1*], Stanslus Okurut[2], Susan Ajambo[1], Eisabetta Gotor[3], Reuben Tendo Ssali[3], Jerome Kubiriba[4] and Eldad Karamura[1]

[1]Bioversity International/ CGIAR Research Program on Roots, Tubers and Bananas (RTB), P. O. Box 24384, Kampala, Uganda.
[2]Department of Agribusiness and natural Resource Economics, Makerere University, P. O. BOX 7062, Kampala, Uganda.
[3]Bioversity International/CGIAR Research Program on Roots, Tubers, and Bananas, Via dei Tre Denari, 472/a 00054 Maccarese, Rome, Italy.
[4]National Agricultural Research Laboratories of the National Agricultural Research Organization (NARO), P. O. Box 7065, Kampala, Uganda.

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Crop diseases significantly suppress plant yields and in extreme cases wipe out entire crop species threatening food security and eroding rural livelihoods. It is therefore critical to estimate the extent to which shocks like disease epidemics can affect food availability and the capacity of smallholder farmers to mitigate and reverse the effects of such shocks. This study utilizes sex-disaggregated data from 341 households in Uganda to analyze: first, gender and access to agricultural resources and their control; second, whether men and women in the targeted banana-farming communities share similar perceptions toward the effectiveness of the banana Xanthomonas wilt (BXW) control technologies and their respective information dissemination pathways; third, whether gender and farmer perceptions influence on farm adoption of BXW management practices. Lastly, it determines the impact of adoption of BXW control practices on food security. Results show that whereas most household assets are jointly owned, men have more individual ownership, control, and decision-making on income from household assets than women. Perceptions on effectiveness of BXW control practices and communication channels also differed between men and women. Men rated cutting down of infected plants to be more effective than women, but tissue culture, removal of male buds and disinfecting of farm tools were perceived to be equally effective by both men and women. In addition, apart from newspapers which were more effective in delivering BXW information to men, we found no differences in the effectiveness of other BXW information sources. More importantly, the study finds both gender and farmer perceptions on BXW control to significantly affect adoption of BXW control practices and household food security. For better and sustainable management of plant epidemics in Uganda, it is therefore critical that existing gender-based and underlying perception constraints are addressed.

Key words: Gender-based constraints, food security, perceptions, technology adoption, Xanthomonas wilt.

INTRODUCTION

Crop pests and diseases are some of the major causes of global food production losses. Actual losses are estimated between 10 and 35.6% of total crop production (Oeke and Dehne, 2004; Strange and Scott, 2005; Bentley et al., 2009). In Africa, for example, the arrival and spread of banana Xanthomonas wilt (BXW) and the recent outbreak of the fall army worm (Spodoptera frugiperda) have caused significant yield losses, and in some instances have wiped out entire plantations, eroding livelihoods and rendering regions and countries' food insecure (Karamura et al., 1998; Chakraborty and Newton, 2011; FAO, 2017). Reducing these losses therefore offers a first line of defense against food and nutrition insecurity, especially in sub Saharan Africa where crop production systems are highly vulnerable to pests and diseases.

Banana is the main staple crop in Uganda; it is an important source of income and provides 17% of the daily caloric needs in the country (Fiedler et al., 2013). However, crop production has been greatly constrained by the outbreak and spread of BXW caused by Xanthomonas campestris pv. Musacearum since 2001 when the disease was first reported in the country (Tushemereirwe et al., 2000). Unlike other diseases that establish gradually, BXW establishes and spreads rapidly over a large area in a short time, killing plants and causing considerable yield and production losses. Currently, all banana cultivars in Uganda are susceptible to BXW (Tripathi and Tripathi, 2009; Blomme et al., 2017). Crop losses from BXW are very high. Literature estimates potential losses in Uganda at 17% (Kalyebara et al., 2006), 52% (Karamura et al., 2010), 65% (Mwangi and Nakato, 2009), and 71.4% (Ainembabazi et al., 2015).

The only disease management strategy for crop protection against BXW in Uganda is the use of one or a combination of cultural BXW control practices. Cultural practices including; removal of the male buds, destruction and disposal of infected plants, disinfecting tools used in the plantation and use of clean planting materials have been identified and promoted as a good first step for preventing BXW related crop losses (Ssekiwoko et al., 2006; Karamura et al., 2008; Mwangi and Nakato, 2009), and have been found to completely prevent the spread of BXW if implemented correctly (Karamura et al., 2008). On-farm adoption of these practices however remains low (Bagamba et al., 2006; Kagezi et al., 2006; Tinzaara et al., 2013).

Bagamba et al. (2006) reports that adoption rates of cultural BXW control practices is low even in areas where households are fully aware of their benefits. It is therefore instructive to understand the reasons for this low adoption. In this paper, we substantiate that gender and perceptions are among the main factors that greatly constrain the adoption of cultural BXW control practices in Ugandan. Surprisingly, this has not been studied before.

An earlier study by Jogo et al. (2013) evaluated the factors that affect farm level adoption of cultural practices for BXW control in Uganda. The study however, only examined inter-household socio-economic factors affecting adoption of BXW control practices. The study did not investigate how intra-household factors, like gender and perceptions influence adoption of BXW control practices. To address this gap, the current study examines how gender-and perceptions affect management of BXW in Uganda. We also further examine if control of BXW has an effect on household food security.

Gender effects on agricultural productivity and technology adoption has been extensively studied (Udry, 1995; Lubwama, 1999; Doss and Morris, 2000; Doss, 2001; Peterman et al., 2011; Ragasa, 2012; Ndiritu et al., 2012; Croppenstedt et al., 2013; Kilic et al., 2013; Mukasa and Salami, 2015; Murage et al., 2015; Ali et al., 2016; Mudege et al., 2017).

Gender has also been explored in emerging frontiers like climate change adaptation (Mehar et al., 2016). However, how gender affects management of plant epidemics like BXW has not been studied. In addition, most existing gender studies use sex of the household head or sex of the respondent to define gender. Okali (2011) and Peterman et al. (2011) argue that this is methodologically flawed as it oversimplifies the diversity of crop farming systems in Africa where men and women within the same household cultivate and own crops either independently or jointly. In addition, such analysis reinforces cultural constructs of gender roles as opposed to actual roles. To overcome this challenge, the current study only examined male headed households (referred to as dual households) and stratified sample observations by sex of the farmer other than sex of household head. On the other hand, evidence on how perceptions affect agricultural technology adoption is mixed. Adesina and Baidu-Forson (1995), Adrian et al. (2005) and Joshi and Pandey (2005) found perceptions to positively influence technology adoption.

Conversely, Murage et al. (2015) found perceptions to have no significant effect on technology adoption. Information on farmers' perceptions has been found to be important in shaping technology dissemination efforts and enhancing technology adoption. Meijer et al. (2014) argue that whereas most adoption studies tend to emphasize the role of extrinsic factors like the characteristics of the adopter, intrinsic factors like knowledge, perceptions and attitudes of a potential

*Corresponding author. E-mail: e.kikulwe@cgiar.org.

adopter towards the technology have been given less attention yet they greatly influence technology adoption decisions. In the current study, we estimate how farmer preferences affect adoption of BXW control practices. We hypothesize that male and female farmers have heterogeneous preferences towards BXW control practices and these preferences in turn affect their likelihood of adopting of the practices.

METHODOLOGY

Data and data collection

Using a multi stage sampling procedure following Torres (1960), FAO (1989) and Gallego (2015), data for this study was collected from 321 randomly selected respondents in 18 banana-growing districts in eastern, central and western Uganda using face-to-face interviews and structured questionnaires between November and December 2015.

First, 18 districts were purposively selected based on banana production to obtain a geographically representative sample for the banana growing population in Uganda. Within each district, the two biggest banana-producing sub Counties were purposively selected. At Sub County, one parish was randomly selected, and in each of the selected parishes, one village or community was randomly selected.

Thereafter, approximately 18 banana farmers were randomly selected per village to participate in the study from a listing of banana farmers provided by local community leaders. The study collected information on access, control and ownership of resources; perceptions on effectiveness of BXW control practices and their information dissemination pathways; adoption and use of BXW control practices and household socioeconomic characteristics.

Field observations were used to validate the data collected. Although data was collected from 321 households (including both male-and female-headed households), only 227 observations were used in analyzing perceptions on access, control and ownership of household resources, effectiveness of BXW practices and for determining factors affecting adoption of BXW control practices. This is, only 227 households were male-headed, and the current study uses male-headed (dual) households to examine intra-household gender dynamics, perceptions and management of BXW.

For each male-headed household, one respondent (either a male or a female farmer) was interviewed. However, in the regression of determinants on food security, all the 321 observations were included. This is because the information used in constructing the household food insecurity access scale (HFIAS), a dependent variable in the regression was for the entire household and was not disaggregated by gender.

Data analysis

Data were analyzed by a combination of descriptive statistics (with t-tests and chi-square tests) and nonlinear econometric methods in STATA version 14 (StataCorp, 2015). T tests and chi-square tests were used to analyze how perceptions on access to resources, effectiveness of BXW control methods and effectiveness of BXW information channels differs between men and women within the same household. However, because farmers can simultaneously and sequentially adopt more than one practice, we used a multivariate Probit model as used by Mittal and Mehar (2015) to determine the factors that influence adoption of the four BXW control practices (that is, cutting down of infected plants, removal of male buds, disinfecting of farm tools and use of tissue culture).

Cappellari and Jenkins (2003) argue that where farmers simultaneously adopt more than one technology, estimation of independent technologies ignores the trade-offs and complementarity across the different technologies and may lead to biased estimates. As such, they suggest the use of a multivariate Probit model using simulated maximum likelihood. The multivariate probit model is used in circumstances where technologies are interdependent and might be adopted simultaneously or sequentially. The theoretical multivariate probit model is specified in equation (1) below:

$$Y_{im}^* = \beta_m' X_{im} + \varepsilon_{im} \quad (1)$$

Where;

Y_{im}^* = a vector of latent dependent variables
Y_{im} = a vector of observed dependent variables (the four BXW control practices in our case)
X_{im} = a vector of explanatory variables
β_m' = coefficients of the explanatory variables
m = 1, 2, 3, m
Y_{im} = 1 if Y_{im}^* > 0 and 0 if otherwise (0 = non-adoption, 1 = adoption)
ε_{im}, m = 1, …, M are error terms distributed as multivariate normal, each with a mean of zero, and variance-covariance matrix V, where V has values of 1 on the leading diagonal and correlations $\rho_{kj} = \rho_{jk}$ as off-diagonal elements.

Positive correlation between practices indicates synergies while negative correlation indicates trade-offs (Kassie et al., 2009). We hypothesize that since extrinsic and intrinsic factors enhance adoption of BXW control, they have a resultant effect on food security. As such, this study extrapolates and explores the effects of relationship between the factors that affect technology adoption and food security at household level using a Tobit model as suggested by Tobin (1958). The standard Tobit model is shown in Equation 2 below:

$$y_i^* = \beta X_i + \varepsilon_i$$
$$y_i = y_i^* \quad \text{if } y_i > 0$$
$$y_i = 0 \quad \text{if } y_i \leq 0 \quad (2)$$

where:
y_i^* is the latent dependent variable, y_i is the observed dependent variable, X_i is a vector of the independent variables, β is the vector of coefficients, and the ε_i is assumed to be independently normally distributed: $\varepsilon_i \sim N(0, \sigma^2)$ (and therefore $y_i \sim N(\beta X_i, \sigma^2)$). The observed 0s on the dependent variable could mean either "true" 0 or censored data. For the model to fit, some of the observations must be censored, or y_i would always equal y_i^* and the true model would then be a linear regression not a Tobit.

Dependent and independent variables used in econometric analysis

In the multivariate probit (MVP) model, the outcome variables of interest were the farmer adoption decisions for each of the four cultural BXW control practices (that is, cutting down of infected plants, disinfecting of farm tools, use of tissue culture and removal of male buds). For all the four practices, adoption was estimated as binary decision where a farmer could either adopt (this was coded as 1) or not adopt a practice (this was coded 0).

To estimate the effect of BXW control on food security, the outcome variable in the Tobit model was the household food insecurity access scale (HFIAS) index following Coates et al. (2007) and Castell et al. (2015) that is, whether the condition in the

Table 1. Explanatory variables used in the regression models.

Variable	Type	Model	Mean	S.D
Household size	C	Both	6.850	2.866
Sex of the household head (0 = Male, 1=Female)	D	F	0.270	-
Responding farmer (0 = Husband, 1=Wife)	D	A	0.304	-
Age of Household Head	C	F	49.380	18.312
At least secondary education (0 = No, 1 =Yes)	D	Both	0.441	-
Banana Acreage (acres)	C	Both	1.170	1.487
BXW Trainings (0 = No, 1 =Yes)	D	Both	0.358	-
Annual expenditure on farm inputs (USD)	C	Both	85.763	162.903
Production objective (0= commercial, 1 = Subsistence)	D	Both	0.361	-
Resorts to purchasing Banana (0 = No, 1 =Yes)	D	Both	0.379	-
Efficiency of cutting down infected plants (0=No, 1 = Yes)	D	Both	0.449	-
Efficiency of removal of male buds (0=No, 1 = Yes)	D	Both	0.291	-
Efficiency of disinfecting tools (0=No, 1 = Yes)	D	Both	0.291	-
Efficiency of tissue culture (0=No, 1 = Yes)	D	Both	0.163	-

Type refers to type of variable used: D = dummy variables and C = continuous variables; Model refers to the model in which the variable was used; F = Food security; A = Adoption of BXW control practices.

question happened at all in the past four weeks (yes or no). If the respondent answers “yes” to an occurrence question, a frequency of occurrence question is asked to determine whether the condition happened rarely (once or twice), this is coded as 1, sometimes (three to ten times), this is coded as 2 or often (more than ten times), this is coded as 3 in the last four weeks. This is done for all the nine food security-related questions. To generate the HFIAS, all codes for each of the nine frequencies of occurrence questions were summed. However, before summing the frequency of occurrence codes, all frequency of occurrence codes where the answer to the corresponding occurrence question was “no” (that is, if Q1=0 then Q1a=0, if Q2=0 then Q2a =0, etc.) were recoded as 0. From this, the maximum HFIAS score possible is 27 for an extremely food insecure household and the minimum score possible is 0 for an extremely food secure household.

The explanatory variables used in the two regression models and their means are shown in Table 1, and their *apriori* expectations are discussed herein. Kasirye (2009) and Jogo et al. (2013) found household size to have a significant positive effect on agricultural technology adoption, while Kidane et al. (2005), Mannaf and Uddin (2012), Negash and Alemu, (2013), and Ndobo and Sekhampu (2013) found household size to have a negative effect on household food security. Evidence also suggests that men are more likely to adopt technologies than women (Morris and Doss, 1999; Doss and Morris, 2001; Uaiene, 2011; Tanellari et al., 2013; Hailu et al., 2014; Murage et al., 2015).

Female headed households are more likely to be food insecure than male headed households (Musemwa et al., 2013; Zakari et al., 2014). However, Silvestri et al. (2016) found gender to have no significant explanatory power on food security. Age of the household head was found to have a negative effect of food security in Bangladesh (Mannaf and Uddin, 2012) compared to South Africa where age had a positive effect (Ndobo and Sekhampu, 2013). Elsewhere, in Ethiopia, age was found to have no significant effect on food security (Negash and Alemu, 2013).

Morris and Doss (1999), Hojo (2002) and Uaiene (2011) found education and training to be positively correlated with technology adoption, while Tanellari et al. (2013) found education to negatively affect uptake of improved groundnut technologies in Uganda. Access to education and training has been reported to enhance food security (Kidane et al., 2005; Musemwa et al., 2013). Farm size has also been found to either influence technology adoption positively (Morris and Doss, 1999; Murage et al., 2015) or negatively (Ogada et al., 2014). The reported effects of farm size on food security are however positive (Kidane et al., 2005; Husseinl and Janekarnkij, 2013; Negash and Alemu, 2013).

Another factor that has been identified to have a positive effect on technology adoption in literature is access to extension advise (Morris and Doss, 1999; Uaiene, 2011; Tanellari et al., 2013; Hailu et al., 2014), which also positively affects food security (Husseinl and Janekarnkij, 2013; Negash and Alemu, 2013). Whereas a recent study by Murage et al. (2015) found perceptions on technology effectiveness to have no effect on adoption of climate smart push and pull technology in East Africa, a number of earlier studies found a positive relationship between perceptions and technology adoption (Adesina and Baidu-Forson, 1995; Adrian et al., 2005; Joshi and Pandey, 2005). We also explore how the production objective and the relative importance of banana in the household diet (proxied by the household resorting to the buying of bananas after their plots are affected by BXW) affect the control of BXW and food security.

RESULTS AND DISCUSSION

Gender differences in ownership, control and decision making on household assets

Overall, apart from land, which is mostly owned by men, we found out that men and women within the household jointly own most household assets. However, results show that men have more individual ownership of household assets than women. Women own between 4.00 and 30.54% of household assets individually, while men own between 37.57 and 46.00% of the assets. The study findings are similar to other studies (Deere and Doss, 2009; Doss et al., 2013; Johnson et al., 2016),

Table 2. Differences in ownership, control and decision making on household assets by men and women.

Variable	Land	Cereals	Bananas	Roots and tubers	Cash crops	Cattle	Sheep/goats	Poultry
Ownership – Who makes claims on the asset? (%)								
Women	30.45	10.16	8.67	7.51	4.43	4.00	7.14	16.67
Men	40.45	41.71	40.31	37.57	43.67	46.00	40.18	40.48
Joint	29.09	48.13	51.02	54.91	51.9	50.00	52.68	42.86
Gender gap	10.00	31.55	31.64	30.06	39.24	42.00	33.04	23.81
Control – Decision to purchase/use or sell asset (%)								
Woman	4.52	8.47	8.63	8.72	5.06	4.00	7.96	11.81
Man	44.34	36.51	34.01	30.81	35.44	34.00	25.66	29.13
Joint	51.13	55.03	57.36	60.47	59.49	62.00	66.37	59.06
Gender gap	39.82	28.04	25.38	22.09	30.38	30.00	17.70	17.32
Decision on use of income from asset (%)								
Woman	5.00	8.47	9.18	7.60	6.92	4.00	7.96	13.60
Man	40.45	34.92	34.69	30.99	33.33	34.00	27.43	28.80
Joint	54.55	56.61	56.12	61.40	59.75	62.00	64.60	57.60
Gender gap	35.45	26.45	25.51	23.39	26.38	30.00	19.47	15.20

which also found men to have more individual ownership of household assets. The gender asset gap (difference between men and women individual asset ownership) was highest in cattle (42.00%) and lowest in land (10.00%). The land gender gap is partly because culturally land belongs mostly to men and the tendency of men to own most of the high value productive assets within the households. The study findings are consistent with Deere et al. (2010) who found a large gender gap in asset ownership in Nicaragua. Similarly, a large gender gap is observed in the control of assets and the decisions on the use of income from household assets (Table 2). Asset ownership was stratified by farmer sex in the study. Results show significant perception differences between men and women concerning ownership of roots and tubers, cash crops, cattle and sheep/goats. For example, women consider themselves individual owners of 14% roots and tubers. Men, on the other hand, consider women to own 4% of roots and tubers individually. It is apparent that women either over report their ownership of these crops or that men under report women ownership. Similarly, for cattle, men under report women ownership and inflate their ownership. On the other hand, women deflate men's ownership of cattle and inflate their ownership. It is therefore evident that whereas both women and men agree that most household assets are owned either jointly or by men, there exists no consensus on the exact proportions of these assets owned by men and women individually. The study results are similar to that of Twyman et al. (2015) who found gendered intrahousehold perception differences in asset ownership and agricultural decision making in Ecuador.

Furthermore, similar perception differences are observed in the control of assets and the decisions on the use of income from household assets (Table 3)

Gender issues and adoption of BXW control practices

The current study also investigated the effects of gender on the adoption of BXW control practices. Overall, adoption was higher in men owned plots than women owned plots. Specifically, adoption of tissue culture was significantly higher in men owned than women owned plots. This maybe because men have more access to physical and financial resources and as such they can afford to buy tissue culture bananas, which are relatively expensive. This is in line with earlier studies that found men to be more likely to adopt agricultural technologies (Morris and Doss, 1999; Doss and Morris, 2001; Uaiene, 2011; Tanellari et al., 2013; Hailu et al., 2014; Murage et al., 2015). On the other hand, we found that actual implementation of BXW control practices is mostly done by women even on men owned plots (Table 4). This maybe because women are more involved in the day-to-day management of banana plantations.

Effectiveness of BXW control practices

Overall, both men and women ranked cutting down of infected plants as the most effective BXW control practice (45%) followed by removal of male buds and disinfection

Table 3. Differences in ownership, control and decision-making on household assets as reported by men and women.

Variable	Ownership		Control		Decision on income	
	Men	Women	Men	Women	Men	Women
Land						
Female	32.24	26.47	2.61	8.82	3.29	8.82
Male	37.50	47.06	47.71	36.76	43.42	33.82
Both	30.26	26.47	49.67	54.41	53.29	57.35
N	152	68	153	68	152	68
Chi2	1.80 (0.404)		5.49 (0.064)		4.09 (0.129)	
Cereals						
Female	7.14	16.39	4.76	15.87	5.56	14.29
Male	43.65	37.70	38.89	31.75	36.51	31.75
Both	49.21	45.90	56.35	52.38	57.94	53.97
N	126	61	126	63	126	63
Chi2	3.90 (0.142)		6.83 (0.033)		4.17 (0.124)	
Bananas						
Female	6.02	14.29	4.51	17.19	4.55	18.75
Male	43.61	33.33	37.59	26.56	38.64	26.56
Both	50.38	52.38	57.89	56.25	56.82	54.69
N	133	63	133	64	132	64
Chi2	4.25 (0.104)		9.61 (0.008)		11.31 (0.03)1	
Roots and tubers						
Female	4.27	14.29	4.35	17.54	4.35	14.29
Male	40.17	32.14	33.04	26.32	33.04	26.79
Both	55.56	53.75	62.61	56.14	62.61	58.93
N	117	56	115	57	115	56
Chi2	5.72 (0.057)		8.43 (0.015)		5.45 (0.066)	
Cash crops						
Female	1.85	10.00	1.87	11.76	4.63	11.76
Male	45.37	40.00	40.19	25.49	37.04	25.49
Both	52.78	50.00	57.94	62.75	58.33	62.75
N	108	50	107	51	108	51
Chi2	5.39 (0.067)		8.91 (0.012)		4.04 (0.132)	
Cattle						
Female	1.54	8.57	1.54	8.57	1.54	8.57
Male	49.23	40.00	38.46	25.71	36.92	28.57
Both	49.23	51.43	60.00	65.71	61.54	62.86
N	65	35	65	35	3.28	0.193
Chi2	3.25 (0.196)		4.02 (0.134)		3.28 (0.193)	
Sheep/Goats						
Female	2.63	16.67	3.90	16.67	6.49	11.11
Male	40.79	38.89	28.57	19.44	28.57	25.00
Both	56.58	44.44	67.53	63.89	64.94	63.89
N	77	36	77	36	77	36
Chi2	7.94 (0.047)		5.86 (0.053)		0.77 (0.679)	

Table 3. Contd.

Poultry						
Female	12.79	25.00	5.81	24.39	8.24	25.00
Male	41.86	37.50	33.72	19.51	32.94	20.00
Both	45.35	37.50	60.47	56.10	58.82	55.00
N	88	40	87	41	86	40
Chi2	3.91 (0.271)		10.64 (0.014)		7.77 (0.051)	

Note: Values in parentheses are p-values.

Table 4. Gender issues and BXW control.

Variable	**Land ownership**				**Action taker**			
Control strategy	**Men**	**Women**	**Both**	**Sig**	**Men**	**Women**	**Both**	**Sig**
Cutting down infected plants	41.06 (62)	30.46(46)	28.48(43)	-	30.46 (46)	42.38 (64)	27.15 (41)	***
Removing of male buds	40.00(46)	28.70(33)	31.30(36)	-	31.30 (36)	39.13 (45)	29.57 (34)	-
Disinfecting tools	35.42 (34)	31.25(30)	33.33 (32)	-	30.21 (29)	38.54 (37)	31.25 (30)	-
Tissue culture	42.86(18)	33.33(14)	23.81 (10)	*	28.57 (12)	42.86 (18)	28.57 (12)	-

Note: Numbers in parentheses represent the number of respondents. *** And * are significant differences at 1% and 10% levels, respectively. - denotes not significantly different at less than 10% level.

Table 5. Gendered differences on the effectiveness of BXW control practices (n=227).

BXW control practice	**Pooled (%)**	**Men (%)**	**Women (%)**	**Chi^2**
Cutting down of infected plants	44.93	50.63	31.88	6.82***
Removing of male Buds	29.07	29.11	28.99	0.00
Disinfecting tools	31.65	23.19	29.07	1.67
Use of tissue culture	16.03	17.09	14.49	0.24

Note: *** denotes significant differences at 1% level.

of tools (29%), use of tissue culture had the least rank (16%). The study findings are similar with Blomme et al. (2014) and Blomme et al. (2017) who reported that removal of infected plants (referred to single diseased stem removal) in a systematic manner is more effective at reducing BXW incidences, but should be expended together with the use of clean garden tools and male bud removal. Apart from cutting infected plants which men ranked to be more effective, farmer self-reported effectiveness of other BXW control practices did not differ between men and women as shown in Table 5. Table 6 shows differences in self-reported effectiveness of BXW control practices stratified by farmer socioeconomic characteristics. Results show that farmer sex (male=1), access to BXW trainings, farm income (proxied by expenditure on farm inputs), farm commercialization and banana importance in family diets (proxied by farmers resorting to buying of bananas during disease incidence) to be positively correlated with the effectiveness of BXW control strategies. Training enhance better application of practices and make them more effective. Similarly, commercial farmers and men may have more resources (labor and money) to effectively implement BXW control. In addition, farmers whose livelihoods depend mostly on bananas may attach more resources (time and money) to BXW control for increased resilience because they have less diversified livelihood options.

Effectiveness of BXW information channels

Understanding and pursuing the most efficient communication pathway is very important in increasing farmer access to relevant BXW control information, and can enhance adoption of BXW control. The current study investigated the effectiveness of the various sources of information on BXW. Overall, results show that both men and women reported radio as the most effective source of BXW information. Furthermore, extension agents, famer groups and non-governmental organizations were the

Table 6. Effectiveness of BXW control practices by farmer socio economic characteristics (n=227).

Variable	Cutting infected plants		Removal of male buds		Disinfecting tools		Use of tissue culture	
	Effective	Other reasons	Effective	Other reasons	Effective	Other reasons	Effective	Other reasons
Household size	7.17	6.59	7.06	6.76	6.98	6.80	7.08	6.81
Responding farmer (1=Wife)	0.22	0.38***	0.30	0.30	0.24	0.33	0.27	0.31
Secondary education	0.46	0.42	0.50	0.42	0.47	0.43	0.35	0.46
Banana acreage	1.25	1.11	1.33	1.10	1.28	1.13	1.38	1.13
BXW trainings	0.51	0.23***	0.56	0.28***	0.59	0.26***	0.57	0.32***
Expenditure on farm inputs	126.11	52.84***	127.45	68.67**	142.22	62.62***	151.92	72.88***
Subsistence-oriented farmer	0.30	0.41	0.24	0.41**	0.27	0.40*	0.11	0.41***
Resorts to purchasing banana	0.45	0.32**	0.41	0.37	0.41	0.37	0.38	0.38

Note: ***, **, * denote significant differences at 1, 5, and 10% levels, respectively.

second, third and fourth most effective information channels, respectively. Televisions and newspapers on the other hand are the least effective sources of information. The study findings are similar to Bagamba et al. (2006) which found radio to be the main source of information on BXW in Uganda. The effectiveness of radio may be because most households have access to a radio, and the fact that there is a variety of radio stations in the country with agricultural-related programs broadcasting in a variety of local languages. Therefore, this makes it easy for farmers in rural communities to access BXW information. Conversely, the penetration level of newspapers in rural farming communities is low and very few households own televisions. This may explain the ineffectiveness of these information channels. In this study, we also examined how the effectiveness of the information channels differs between men and women. Results show a significant difference in the effectiveness of newspapers between men and women (15.57% for men vs. 5.56% for women). This is presumably because men have more access to and control over resources and can afford to buy newspapers. It could also be that men are more educated (Table 7).

Factors that influence adoption of cultural BXW control practices

The multivariate regression model we used in this study analysis was significant at 1% with a Wald chi square value of 167.33 and a log likelihood value of -286.59. This means the study model significantly explains the factors that affect farmer control of BXW. From results in Table 8, the coefficients of explanatory variables and their significance levels vary across the four different practices. Similarly, the likelihood ratio test of correlation amongst the equations in the model was significant. This justifies our choice of MVP regression. Study results unexpectedly found household size to have a negative effect on adoption of the use of tissue culture. This is contrary to findings by Jogo et al. (2013) and Kasirye (2009). This could be because tissue culture is more capital intensive than labor-intensive technology. Large families tend to have less disposable income, and may thus find it difficult to purchase tissue culture plants. On the other hand, men were more likely to cut infected plants. This is similar to earlier findings that suggest men are more likely to adopt agricultural technologies (Morris and Doss, 1999; Doss and Morris, 2001; Uaiene, 2011; Tanellari et al., 2013; Hailu et al., 2014; Murage et al., 2015). Higher technology adoption by men could be because men have more ownership, control and decision making on bananas. It is therefore important that affirmative women empowerment efforts be adopted to enhance their adoption of BXW control practices. However, results show that actual cutting down infected plants is done mostly by women even on male owned plots (Table 4), it is also essential that men are targeted and challenged to participate more in field implementation of BXW control practices. Furthermore, results showed that farmers who had accessed trainings were more likely to adopt all the four BXW control practices. This finding corroborates earlier studies (Morris and Doss, 1999; Uaiene, 2011; Tanellari et al., 2013; Hailu et al., 2014). This is because training equips

Table 7. Effectiveness of BXW information sources (%).

Information channel	Pooled	Men	Women	Significance
Radio	79.28 (176)	81.88 (113)	75.00 (63)	-
Newspaper	11.86 (23)	15.57 (19)	5.56 (4)	**
Mobile phone	7.25 (14)	5.13 (6)	10.53 (8)	-
Television	5.15 (10)	5.88 (7)	4.00 (3)	-
Posters	11.70 (22)	11.50 (13)	12.0 (9)	-
Farmers/Social groups	28.14 (56)	28.00 (35)	28.38 (21)	-
Extension agents	37.75 (77)	36.22 (46)	40.26 (31)	-
Seed Stockists	10.77 (21)	10.83 (13)	10.67 (8)	-
NGOs	24.76 (51)	26.92 (35)	21.05 (16)	-

Note: Numbers in parentheses represent the number of respondents. ** denotes significant differences at 5% level.
- denotes not significantly different at less than 10% level.

Table 8. Factors influencing adoption of BXW control measures using a multivariate regression.

Independent variables	Cutting infected plants	Removal of male buds	Disinfecting tools	Use of tissue culture
Household size	-0.042 (0.036)	0.000 (0.032)	-0.005 (0.040)	-0.116** (0.052)
Responding farmer (0 = Husband, 1=Wife)	-0.333* (0.199)	0.034 (0.198)	-0.220 (0.237)	0.113 (0.242)
At least secondary education (0 = No, 1 =Yes)	0.263 (0.187)	-0.105 (0.195)	0.404* (0.225)	0.182 (0.255)
Banana acreage	0.051 (0.062)	-0.040(0.079)	0.093 (0.075)	0.050 (0.080)
BXW Trainings (0 = No, 1 =Yes)	0.453** (0.201)	0.817***(0.191)	0.903*** (0.226)	0.297 (0.253)
Annual Expenditure on farm inputs (USD)	0.001 (0.001)	0.002***(0.001)	0.001 (0.001)	0.000 (0.001)
Production objective (0=commercial,1= Subsistence)	-0.110 (0.200)	-0.145(0.190)	-0.026 (0.242)	0.034 (0.249)
Resorts to purchasing banana (0 = No, 1 =Yes)	0.727*** (0.189)	0.420**(0.182)	0.181 (0.226)	0.782*** (0.235)
Efficiency of practice (0=No, 1 = Yes)	0.605*** (0.179)	0.827***(0.174)	1.712*** (0.223)	1.648*** (0.257)
Constant	-0.685** (0.293)	-1.247***(0.298)	-1.921*** (0.379)	-1.388*** (0.383)

Number of observations =226
Wald chi2 (36) = 167.33
Log likelihood = -286.593
Prob > chi2 = 0.0000
Likelihood ratio test of rho21 = rho31 = rho41 = rho32 = rho42 = rho43 = 0: chi2(6) = 166.825 Prob > chi2 = 0.0000
Notes: Values in parentheses are standard errors, ***, **, and * denote significant at 1, 5 and 10% levels , respectively.

farmers with the necessary technical skills needed to implement the practices. In addition, annual expenditure on farm inputs (a proxy for wealth) is positively associated with removal of male buds (de-budding), suggesting that wealthier farmers are more likely to control BXW in their fields by removing male buds (the main source of infection by insects). Results also show access to extension advice to have a positive effect on disinfecting of tools. Similar to access to BXW trainings, this could be extension access equips farmers with the necessary technical skills needed to implement the practices and enables farmers to appreciate its net benefits. Farmers who coped to the outbreak of BXW by purchasing bananas were more likely to adopt removal of male buds, disinfecting of farm tools and use of tissue culture. Resorting to purchasing bananas is an indicator that bananas make a significant contribution to daily food requirements of a household. For such households controlling BXW is very essential for their livelihoods; this may explain why resorting to purchasing bananas influences the adoption of BXW control practices. Findings also show that perceptions on effectiveness of practices have a positive effect on adoption of all the BXW control practices. This finding is similar to earlier studies (Adesina and Baidu-Forson, 1995; Joshi and Pandey, 2005; Adrian, 2005) which also find perceptions to have a significant effect on adoption of agricultural technologies. This is because farmers usually adopt technologies if they anticipate the technologies to have positive benefits.

Food security and adoption of BXW control practices

The study results show that farmers that perceive removal of male bud and disinfecting of farm tools to be beneficial to be more food secure (Table 9). This maybe because as seen in Table 8 and hypothesized in section 2, farmers who perceive technologies to be beneficial are more likely to adopt BXW control practices which ensures

Table 9. Determinants of food insecurity among banana growing households using a Tobit regression.

Variable	Coefficients	Standard errors
Efficiency of cutting down infected plants	1.302	1.219
Efficiency of de-budding	-2.353*	1.356
Efficiency of disinfecting farm tools	-2.669*	1.372
Efficiency of tissue culture	2.005	1.601
Household size	0.177	0.173
Sex of household head	3.327*	1.252
Age of household head	-0.038	0.030
Secondary education	-2.581**	1.134
Banana acreage	-0.434	0.357
Received training	0.770	1.074
Annual expenditure on farm inputs (USD)	-0.005	0.004
Production objective (0= commercial, 1 = Subsistence)	3.797***	1.023
Resorts to purchasing Banana (0 = No, 1 =Yes)	1.090	0.986
Constant	2.983	2.162

Observations = 335
LR chi2(13) = 46.50
Prob > chi2 = 0.0000
Log likelihood = -804.86951
134 left-censored observations, 201 uncensored observations
***, **, and * significant at 1%, 5% and 10% levels of significance.

more household food production resulting into more food security. Farmers with at least secondary education were also found to be more food secure. This is in line with findings by Kidane et al. (2005) and Musemwa et al. (2013) who also found education to have a positive effect on food security. This may also be because farmers with at least secondary education adopt BXW control practices more than those who do not attain that level of education or it may be because such farmers have more access to off-farm income. Similar to findings by Musemwa et al. (2013) and Zakari et al. (2014), the study results also show female-headed and subsistence households to be less food secure. This maybe because female-headed and subsistence farmers have limited resource endowments to enable them cope with shocks like BXW outbreaks or it may be because these households are less likely to adopt BXW control practices that can help reduce crop-related production losses with direct effects on food production and food availability.

Conclusion

The study found gender and farmer perceptions to have a significant effect on adoption of BXW control practices. Women are less likely to adopt BXW control practices compared to men. Similarly, farmers who perceive BXW practices to be beneficial are more likely to adopt them. Women may be less likely to adopt because they have limited access, ownership and decision-making powers on household resources. Farmer perceptions reflect farmer-anticipated benefits from technology adoption. The more the anticipated benefits the more likely farmers are to control BXW, which in turn ensures increased food production and food security. These findings suggest that addressing gender-based constraints and improving farmer perceptions are critical and essential for scaling up and scaling out BXW control and management. It is important then that women empowerment (through increase in ownership/access, use and decision making on key household assets) is an inherent component of all BXW management efforts and programs. In addition, technologies should be more affordable and accessible to women, and gendered preferences should be considered in technology design. Conversely, BXW communication and training programs should inherently address farmer biases on BXW technologies and explicitly document and disseminate the economic, production, social and resilience benefits of technology adoption.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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