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XW Disease shock, household livelihood strategies and welfare: evidence from banana producing households in Uganda

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ABSTRACT

Farmers experience various shocks that result into massive crop failure there by affecting their livelihoods. Besides the shocks related to climate change, the effects of other types of shocks along with the alternative livelihood strategies farmers employ to cope have not been largely explored. This study focused on a specific disease shock (BXW) that resulted into extreme crop losses thereby affecting farmers' livelihoods. We provide evidence on the impact of BXW shock on the welfare of banana producing households as well as the alternative livelihood strategies they pursued to improve their welfare over time in addition to adopting the BXW control practices. Utilizing panel data from over 1000 households in the four banana-growing regions in Uganda that were drastically affected by BXW, we examined the likely coping strategies that they employ once hit by the pandemic. Farmers devised short-term livelihood strategies to recover from the BXW shock. The key coping strategies employed include increased production of annual crops mainly maize and beans, reduction in consumption of bananas, diversifying into livestock production and off-farm activities to earn a living. Several institutional and household characteristics such as size, education level of the household head and access to loans/savings are found to be important determinants of coping strategies. As a result, households were able to improve their welfare over time after experiencing the effects of BXW. Based on the findings, we conclude that: first, taking longer to devise mitigation measures to shocks may have a negative impact on productivity but this can be reduced by timely adoption of recommended technologies; and second, the government needs to devise and implement policies to sustainably overcome effects of disease outbreaks in a timely manner.

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XW Disease shock, household livelihood strategies and welfare: evidence from banana producing households in Uganda

INTRODUCTION

About a third of the global banana production is in Sub-Saharan Africa (SSA) where the crop is a very important staple and a cheap source of minerals and vitamins, particularly vitamins A, C and B6 (Karamura et al. 2008). Only 13% of the production in Asia, Africa and Latin America is internationally traded which acts as an indicator of its relative importance for domestic markets and food security, especially in East and Central Africa. For instance, the crop is a major dietary component accounting for between 20% of daily total food intake in Uganda and 80% in parts of Rwanda (Lescot, 2013, Price, 1995). Furthermore, the crop also has great environmental value in most farming systems as it reduces soil erosion on steep slopes, conserves soil fertility and provides cover to other crops such as beans, groundnuts and coffee that are often intercropped with it (Geberewold and Yildiz, 2019; Uwamahoro et al. 2019).

Despite its importance in the region, the banana crop is faced with Banana Xanthomonas Wilt (BXW) disease. In the early 2000s, banana farmers in Uganda were hit by a BXW epidemic which spread at an alarming rate to the extent that every mat with a stem that exhibited symptoms had to be uprooted and buried (Tripathi et al. 2009). According to Nkuba et al. (2015), BXW is currently the leading constraint to banana production in East and Central Africa with no cure and all the cultivars grown in SSA being susceptible (Kubiriba and Tushemereirwe, 2014). Kalyebara et al. (2007) estimated that, if not controlled, Uganda stood to lose US$295 million dollars of banana output valued at farm gate prices. Similarly, Kayobyo et al. (2005) also noted that uncontrolled BXW can spread at an infection rate of 8% per annum in cooking bananas, resulting into a total production loss of 56% over a 10-year period. Karamura et al. (2010) stated that at the peak of the BXW epidemic (i.e., between 2001 and 2004), 33% of the total banana mats were infected with BXW in four heavily affected districts and when compared to pre-infection levels, the total yield loss due to BXW was estimated at 30-52% during that period which led to a reduction in the amounts of bananas harvested by households in Uganda.

Due to the negative impacts associated with BXW, farmers resorted to different strategies to cope with the outbreak, some of which negatively affected banana production and productivity. For example, Nkuba et al. (2015) assessed the impact of BXW on farmer's livelihoods in the Kagera basin of Rwanda, Tanzania and Burundi. They noted that bananas are a key component in farming communities in the region and that the production losses resulting from BXW had adverse effects on household food security and income. This prompted most farmers to diversify into other food crops such as maize, cassava and sweet potatoes, which led to a reduction in the area under bananas. In addition, Vezina (2014) noted that about 80% of the bananas grown in Katana village (overlooking Lake Kivu) in DRC got infected in the period of two years, which prompted many farmers to clear their plantations to give way for other crops. In Uganda, the households whose plantations were infected with BXW experienced a decline in consumption of own produced bananas, sales, farm-gate prices received, and total household income compared to their non-infected counterparts (Karamura et al., 2010). As a result, the affected households resorted to consuming and trading with other food crops other than bananas. Coulibaly et al. (2015) also reported that farmers in Malawi resorted to engaging in casual labour, small businesses and the sale of forest products as coping strategies to crop failure. Additionally, Regassa (2011) revealed that farmers resorted to reduction in quantity and number of meals consumed per day and migration of household members as coping strategies for food insecurity and hunger.

In light of the above and the fact that BXW has no known cure, several strategies have been recommended to curtail its spread. It was observed that effective management of BXW requires the use of a set of cultural practices such as planting healthy suckers, breaking of male buds with a forked stick, disinfection of farm tools, and removal of infected plants. Moreover, these have to be applied as a package since there is no single method that is effective in the management of BXW (Kubiriba and Tushemereirwe, 2014). The cultural practices reduce the inoculum's density and limit the spread of the pathogens. More importantly, male bud removal (de-budding) has been cited as one of the most effective ways of controlling the disease since male buds are the primary site for insect-mediated infection (Biruma et al., 2007). On the other hand, single diseased stem removal (SDSR) has also been recommended as a very effective method for managing BXW because of its labour-saving and cost-effectiveness compared to complete mat removal. If SDSR is properly implemented, BXW incidence reduced to less than 10% in one month and 1% in the 10th month (Blomme et al., 2017). Similarly, restoration of banana plots was observed in plots that initially had over 80% plant disease incidence after implementing SDSR. New findings by Uwamaharo et al. (2019) in Rwanda revealed that farms having a mixture of both indigenous and improved cultivars of bananas are likely to have low BXW severity and this was attributed to the increase in genetic diversity in cultivar mixtures which results in variations in insects visiting the male flower depending on the availability of their preferred cultivar. Based on this evidence, the recommended package of three practices abbreviated as BCC (Breaking the male bud; Cleaning tools through disinfection and Cutting down diseased stems) has been widely promoted and adopted (Kikulwe et al., 2019; Jogo et al., 2013). Adoption of this package has been found to significantly increase banana productivity and sales (Kikulwe et al, 2019).

Unfortunately, adoption of this BXW control package and other management practices remains a challenge to many farmers in Uganda despite the massive sensitization campaigns (Blomme et al., 2014; Kubiriba and Tushemereirwe, 2014; Karamura et al. 2010). Nakakawa et al. (2017) asserted that for effective BXW management, adoption needs to be maintained even when the disease is undetectable to eliminate possible resurgences, but this is not the case with most farmers. Several reasons have been suggested for farmers' failure to adopt or maintain the control strategies. For example, Bagamba et al. (2007) revealed that although a good proportion of farmers know the importance of BXW control practices, only a few of them were putting them into practice. The authors cited lack of labour, traditional limitations (such as the practice of not removing male buds on kayinja), and inadequate information as some of the factors limiting adoption, while Jogo et al. (2013) also pointed out that some farmers fail to adopt all the control measures due to the high costs involved and their perceptions on the effectiveness of some of the practices. In addition, more than 90% of smallholder farmers in the banana farming systems in East and Central Africa rely on suckers from informal sources, such as own fields, farmer-to-farmer exchanges and local sales to expand and establish new farms with no means of verification whether they are disease-free (Jogo et al. 2013; Smith et al. 2008), which has led to the continued spread of BXW. Since the onset of BXW, combined efforts from local and international stakeholders have contributed towards the management and control of the disease shock.

However, there is limited knowledge on understanding and assessing the coping strategies employed by farmers in response to a shock affecting a particular crop. For example, Coulibaly et al. (2015) analyzed the coping strategies employed by farmers in response to crop failure in Malawi, while Shuaibu et al. (2014) and Mengistu (2011) investigated the coping strategies that farmers employ in response to climate change. In the face of climate change, however, there is an influx of diseases such as BXW which can lead to total crop failure. Ochola et al. (2014) used a screen house to mimic drought conditions that can arise from climate change. Their results revealed that the water stress resulting from drought significantly increased the incidence and severity of BXW. Recent work by Ocimati et al. (2019) revealed that high precipitation favours the multiplication of the bacteria (Xanthomonas campestris) whereas extreme temperatures affect the vectors. Thus, in the face of climate change, BXW thrives and results into crop failure. This study focuses on a specific disease shock (BXW) that results into massive crop failure thereby affecting farmers' livelihoods. We explore the effect of BXW exposure on farmers' livelihood strategies and their household outcomes using panel data. That is, the paper provides evidence on the coping strategies employed by farmers in the face of a BXW shock that affects a major crop (banana) and the long-term impact of the adoption of these strategies alongside the recommended disease control practices on household welfare.

METHODOLOGY

CONCEPTUAL FRAMEWORK

This study was guided by the sustainable livelihood framework (DFID, 1999). Sustainable livelihood analysis determines what combination of capital assets result in the ability of a household to follow specific combination of livelihood strategies to achieve livelihood outcomes under a particular context (Scoones, 1998). For this study, we analyze different livelihood strategies and livelihood outcomes of banana farmers under the context of an infectious disease shock.

Agricultural shocks affect farmers' production systems and cause significant negative impacts on their livelihoods. Yet, rural households normally have limited access to well-developed credit markets, insurance and savings to address these shocks. Several studies (Salazar-Espinoza et al., 2015; Kubik and Maurel, 2016; Mutaqin, 2019; Carpena, 2019) indicate the impact of the shocks on household welfare and how households cope with the shocks. Results show that farmers use different livelihood strategies in response to shocks, but resource reallocation and crop choices are key coping strategies.

Crop disease shocks cause significant yield losses and can lead to human life losses and other socio-economic disasters. BXW is one of the plant disease shocks that affected farmers in East and Central Africa. The disease is considered to be one of the most important infectious diseases in developing countries (Vurro et al., 2010). BXW was first reported in Uganda in 2001 (Tushemereirwe et al., 2004) and spread rapidly to all the major banana growing areas of the country. By 2005, in the areas where the disease was fully established, more than 76% of the fields were affected (Tushemereirwe et al., 2006).

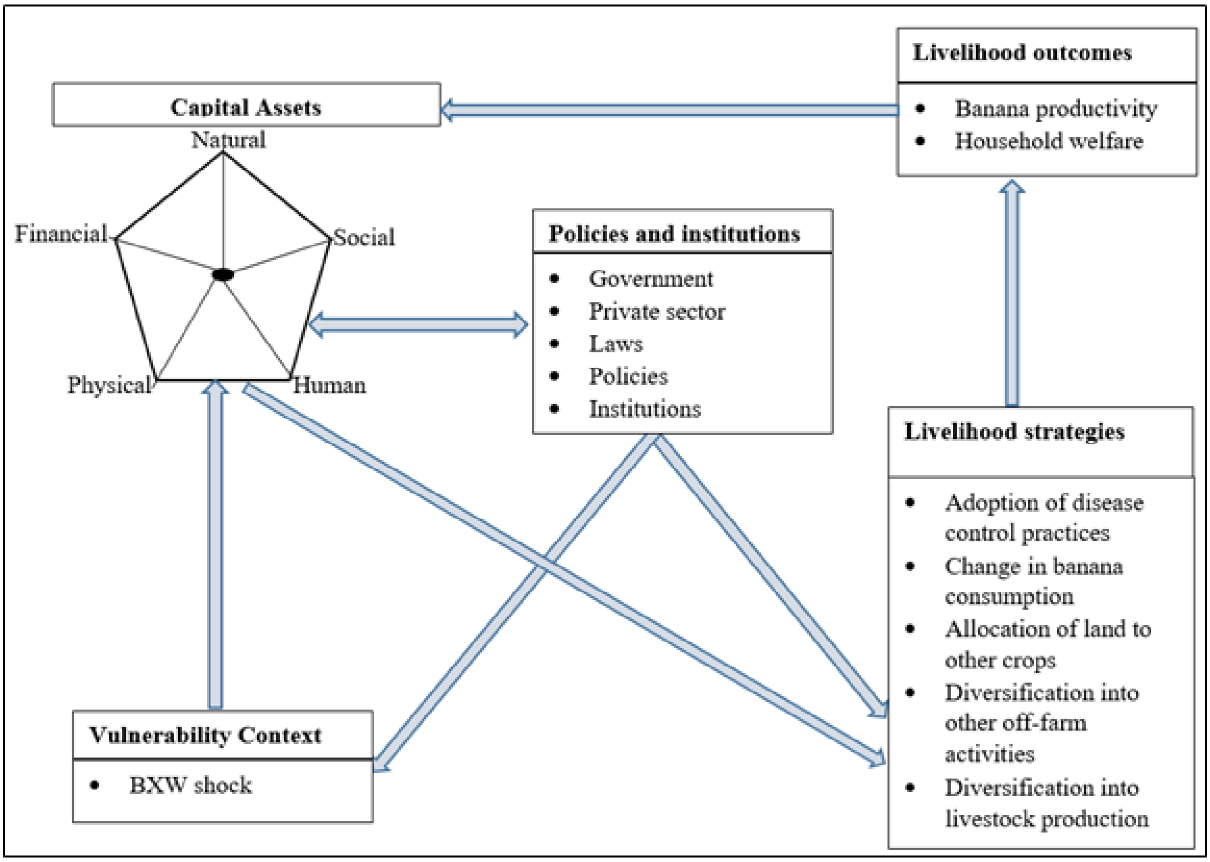
Just like many other rural households in sub-Saharan Africa with limited access to insurance and financial markets to address agricultural shocks, we hypothesize that banana farmers changed their production systems through changes in crop choices and land allocation to cope with the BXW shock. Figure 1 shows pathways through which farmers coped with the BXW shock: 1) increasing land allocation to other crops such as beans, maize and coffee which in turn reduced acreage under bananas, 2) diversification into off-farm income generating activities and 3) reduced banana consumption.

During the early years of BXW shock, there was limited understanding of the disease epidemiology (Blomme et al., 2014). As a result, farmers who were affected by the disease first were hard hit and were more likely to abandon bananas, increase acreage allocation to other crops such as beans and maize and engage in off-farm income generating activities to meet their food and income needs. Karamura et al. (2010) indicated that nine percent of affected households cleared the plots and planted similar or different banana cultivars, or different crops whereas five percent of households report abandonment of the field. The results are also supported by the fact that in the initial years of the disease outbreak farmers employed complete mat removal as opposed to single stem disease removal to control the disease (Karamura et al., 2006; Blomme et al., 2014). Complete mat removal is time consuming and cumbersome and therefore farmers may find it more productive to engage in other crops and/or off-farm income generating activities.

The level of application of the coping strategies depend on the level of adoption of the disease control practices. Empirical evidence shows that application of the recommended control practices significantly reduces the disease incidence and improves banana productivity and income (Kikulwe et al., 2019; Tripathi et al., 2009). For farmers that adopted the control practices, it is hypothesized that banana productivity increased with the level of adoption of the control practices. Further, given that banana is a key crop among these farmers, those who adopted the control practices were less likely to increase acreage allocation to other crops and more likely to increase their per capita banana consumption compared to farmers that never adopted the control practices.

Overall, the different coping strategies employed together with the level of adoption of the control practices will have an effect on household welfare. Household welfare was measured as the sum of the value of production of the major crops produced (banana, maize, beans and coffee), the income received from livestock sales and off-farm income.

Figure 1: conceptual framework



MATERIALS AND METHODS

SAMPLING AND SAMPLE SIZE

Data used was collected from Uganda, the leading banana producer in East and Central Africa and it has the highest per capita consumption of bananas in the world (FAO, 2017; Kilimo Trust, 2012). BXW was first reported in Uganda in 2001 and continued to spread to all major banana growing regions (Tushemereirwe et al., 2004). Data comes from two rounds (2015 and 2018) of household surveys from 1,224 randomly selected banana farmers from four major banana growing regions of Uganda. Details of sampling and sample size determination are found in Kikulwe et al. (2019).

In both survey rounds, face-to-face interviews were conducted using a structured questionnaire to collect data on: socio-demographic characteristics of the farmer; status of BXW at farmer level; BXW control practices adopted by the farmer to manage BXW disease; number of years since BXW was first observed on the farm; banana production details and production details of major crops; income from livestock; and income from off-farm income activities. More than 86 percent (1,056) of the baseline households were interviewed during the second-round survey with an attrition rate of 13.7 percent. An unbalanced panel of 2,280 observations from 1,224 households was used for analysis.

ANALYTICAL METHODS

MODELLING IMPACT OF THE BXW SHOCK

Our interest is to evaluate the impact of BXW on household welfare and on intermediate outcomes to explain the influence of the shock. We employ panel models of the following form:

$$Y_{jt} = \theta + \emptyset DS_{jt} + \chi V_{jt} + \delta T_t + \mu_{jt} \qquad \text{Equation 1}$$

where Y_{jt} is the outcome variable including off-farm income, livestock income per capita consumption of banana, acreage of key crops such as beans, maize and coffee for household j in year t. DS_{jt} is the disease shock which is the treatment variable of particular interest. A positive estimated treatment effect $\emptyset$ would imply that BXW affects income from other sources (e.g. livestock sales, off-farm activities), per capita consumption of banana or other outcomes in a positive way. Other household, farm and contextual characteristics that may affect outcomes are controlled for by including the vector V_{jt}. Some of these characteristics may vary over time while others are time invariant. T_t is a year dummy to control for time fixed effects. θ, χ and δ are other parameters to be estimated, and μ_{jt} is the random error term with a standardized normal distribution.

The model in equation 1 can be estimated with random effects (RE) panel estimator. However, the treatment effect $\emptyset$ would be biased in case there are any unobserved factors that influence DS_{jt} and Y_{jt}. Since farmers decide on their own which course of action to take in the face of BXW, it is possible that they differ in terms of unobserved characteristics. To test and control for unobserved heterogeneity, a fixed effects (FE) estimator is used, which is possible because there is sufficient variation in the treatment variable over time. Utilizing FE estimators helps to evaluate differences among households ensuring that any time-invariant heterogeneity- whether observed or unobserved- is cancelled out (Cameron and Trivedi, 2005). A comparison of FE and RE estimates is made for all outcome variables by means of a Hausman test. An insignificant test result implies that unobserved, time invariant heterogeneity is not an issue. On the other hand, a significant Hausman test indicates that the FE model is preferable to reduce bias in the estimated treatment effect while ensuring consistency. However, recent studies showed that a significant Hausman test statistic is neither a necessary nor a sufficient condition to detect unobserved heterogeneity (Snijders, 2005). Hence, we will show both results, yet preferring the FE estimates for interpretation of the treatment effects of the BXW shock.

VARIABLES USED

The treatment variable in all models is the number of years since the onset of BXW on each farm. This variable is used as a proxy for the effect of the disease shock on farming households. The farmers who experienced BXW first were more adversely affected since there was limited understanding of the disease epidemiology (Blomme et al., 2014). We therefore hypothesize that the longer the duration since the onset of BXW, the more likely are to farmers to opt for alternative livelihood strategies as coping mechanisms to the shock.

Household welfare is measured as the aggregated value in Uganda shillings (UGX) of the value production of four major crops (banana, maize, beans and coffee) grown, income from livestock sales and household off-farm income obtained over a period of one year. Off-farm income includes wages, salaries, and pensions of all household members, land rents and capital earnings, as well as any net profit (revenue minus cost) from non-agricultural businesses. Banana productivity has an effect on food security, and it influences the well-being of the household. The shock is expected to have a negative effect on banana productivity (Blomme et al., 2014; Karamura et al., 2010). Per capita consumption of bananas is another outcome variable that was considered, and it is measured as the total kilograms of bananas consumed per household per year. As a result of the shock, per capita consumption of bananas is also expected to decline as the farming households feed more on other foods and less on bananas.

On the other hand, farmers are likely to increase production of other key crops by allocating more land to them when a disease strikes a major crop. Several others may also concentrate more livestock production and off-farm activities thereby increasing their incomes from these sources.

All monetary values are expressed in Uganda shillings (UGX): 1 US$ = 3,677 UGX). To account for inflation and make monetary values comparable for the two survey rounds, 2015 data were adjusted to 2018 using the official consumer price index (UBOS, 2018).

For most of the regression models, the same vector of covariates is used, although –depending on the particular outcome – other explanatory variables are sometimes added. The vector of covariates includes household characteristics, such as age, education, and gender of the household head as well as the size of the household, social aspects such as membership in a SACCO (Savings and Credit Co-operative), farm characteristics, such as total land owned, and the level of adoption of the BXW control practices. In this paper, we are not measuring adoption per se because it has been extensively explored in various studies (Jogo et al, 2013; Karamura et al., 2010; Kikulwe et al., 2018; Bagamba et al., 2007; Kikulwe et al., 2019; Kubiriba and Tushemereirwe, 2014). However, while the concrete numbers vary, the overall patterns of adoption observed in our sample are similar to those reported in earlier research in Uganda.

RESULTS AND DISCUSSION

ADOPTION OF BXW CONTROL PRACTICES

BXW has been found to resurge due to low levels of adoption of the control practices (Jogo et al., 2013; Kikulwe et al., 2019). Over time, farmers are increasingly adopting the control practices. As seen in Table 1, the non-adopters in 2018 (9%) were much fewer than those in 2015 (23%). The highest percentage of farmers (29%) in 2015 were partial adopters employing any two BXW control practices. In 2018, on the other hand, there were more adopters of the full BXW control package (39%). Possibly, over time, more farmers were sensitized about the control measures through the various campaigns. Furthermore, through interaction with full adopters, the partial adopters could have realized the benefits and effectiveness of adopting the recommended package compared to partial adoption which might not yield the desired results.

Table 1: Adoption of BXW control practices

BXW control adoption	2015 % (n=1056)	2018 % (n=1056)	Pooled % (n=2112)	t-value
Non-adoption	23.10	9.47	16.29	8.497***
Adoption of 1 practice	28.13	29.92	29.02	-0.886
Adoption of any 2 practices	28.50	21.78	25.14	3.491***
Adoption of BXW package	20.27	38.83	29.55	-9.251***

Considering the actual practices adopted, there was a tremendous increase among those who were only removing the male buds; those who were combining male bud removal and SDSR as well as those who were using all the three practices in the BXW control package (Table 2). Adoption of the other individual control practices or their combination declined. Disinfecting tools using either fire or *jik* was the least adopted single practice.

Table 2: BXW control practices adopted in the two time periods

	2015 % (n=812)	2018 % (n=956)	Pooled % (n=1768)	t value
SDSR only	14.78	1.99	7.86	-3.638***
De-budding only	5.54	30.86	19.23	-24.719***
Disinfecting only	16.26	0.21	7.58	4.949***
SDSR x De-budding	16.26	21.97	19.34	-12.871***
SDSR x Disinfecting	12.19	0.52	5.88	-3.953***
De-budding x Disinfecting	8.62	1.57	4.81	-5.861***
BXW control package	26.35	42.89	35.30	-8.948***

Table 3 below shows some of the recommended banana management practices carried out on the plantations in 2015 and 2018 by adopters and non-adopters of the BXW control practices. The term adopters refers to those who are employing at least one BXW control practice. Almost all adopters de-sucker, de-trash and weed. Corm removal is the least employed practice by both categories of farmers. As expected, the adopters of BXW control practices manage their plantations much better than the non-adopters and the effect is significant. Ocimati et al., (2019) found that proper management of banana plantations combined with BXW control practices reduces disease pressure on farms and hence increase productivity.

Table 3: Other management practices by adoption

	2015 % (n=1,173)	2018 % (n=1,058)	Pooled % (n=2,231)	t value
De-suckering	88.1	76.9	82.8	7.025***
De-trashing	91.6	89.5	90.6	1.730***
Corm removal	79.2	58.7	69.4	10.738***
Weeding	94.4	93.2	93.8	1.148***

Table 4 shows descriptive statistics of the outcome variables and covariates used in the regression models, differentiating between adopters of BXW control practices and non-adopters in 2015 and 2018. Those who are employing at least one or two of the BXW control practices were categorized as adopters. Data for the pooled sample is shown in the last two columns.

The household welfare for the adopters in 2018 was significantly higher compared to non-adopters. As expected, the productivity and per capita consumption of bananas for the adopters was significantly higher compared to non-adopters in both time periods. Off-farm income for the adopters was significantly higher than that of the non-adopters only in 2018 whereas income from livestock sales was significantly higher for the latter than the former in 2015. The adopters had significantly higher off-farm income than non-adopters in 2018. The adopters of at least one BXW control practices had a significantly higher value of production of the four major crops produced (banana, maize, beans and coffee) compared to non-adopters. On the other hand, the non-adopters made significantly higher livestock sales in 2015 than adopters, but there was no significant difference in sales of livestock between the two categories in 2018.

The lower part of Table 4 shows the covariates used in the regression models. For many of these covariates, significant differences between adopters and non-adopters of BXW control practices can be observed. Adopters are mostly those who suffered the consequences of BXW earlier hence they were adversely affected by the disease. They are also more likely to belong to SACCOs and have bigger banana plantations than the non-adopters.

Table 4: Descriptive statistics of adopters and non-adopters of the BXW control practices

	2015		2018		Pooled Sample	
	Adopters† (N=812)	Non-adopters (N=279)	Adopters† (N=958)	Non-adopters (N=100)	Adopters† (N=1896)	Non-adopters (N=379)
Outcome variables						
Household welfare (million UGX)	5.217 (20.521)	5.443 (15.256)	32.606*** (97.021)	3.316 (0.762)	19.056*** (71.761)	4.881 (13.685)
Banana productivity (tonnes/ha/year)	4.220*** (7.154)	2.368 (4.909)	2.922** (3.904)	1.574 (4.289)	3.490*** (5.601)	2.141 (4.742)
Banana per capita consumption (kg/household/year)	359.778*** (595.111)	93.402 (233.610)	235.230*** (371.730)	40.183 (109.440)	292.692*** (491.465)	84.501 (218.587)
Off-farm income (million UGX)	2.245 (19.833)	3.097 (13.333)	1.368* (3.387)	0.740 (5.125)	1.802 (14.159)	2.475 (11.507)
Livestock income (million UGX)	0.445*** (1.773)	1.100 (5.156)	0.922 (5.111)	0.293 (0.588)	0.686 (3.847)	0.887 (4.446)
Value of crop production (million UGX)	2.527*** (3.961)	1.246 (2.194)	30.316*** (95.997)	2.282 (7.106)	16.568*** (69.677)	1.520 (4.120)
Maize acreage	0.540 (1.282)	0.547 (1.150)	1.266 (3.609)	1.193 (1.163)	0.907 (2.742)	0.718 (1.187)
Beans acreage	0.410 (1.012)	0.389 (0.715)	1.220* (4.397)	0.365 (0.482)	0.819*** (3.230)	0.383 (0.661)
Coffee acreage	2.381 (3.933)	2.990 (3.798)	1.542*** (3.880)	0.294 (0.651)	1.800 (3.914)	1.662 (3.053)
Explanatory variables						
No. years since BXW onset	6.322*** (3.761)	4.022 (4.010)	9.028*** (3.823)	6.080 (3.749)	7.689*** (4.026)	4.565 (4.041)
Sacco membership (dummy)	0.314*** (0.465)	0.204 (0.404)	0.297*** (0.457)	0.160 (0.368)	0.306*** (0.461)	0.193 (0.395)
Age of household head (years)	53.156 (15.059)	54.290 (14.496)	56.706 (14.554)	56.770 (15.105)	54.952 (14.908)	54.945 (14.679)
Male head (dummy)	0.712 (0.453)	0.720 (0.450)	0.736 (0.441)	0.760 (0.429)	0.724 (0.447)	0.731 (0.444)
Education of household head (years of schooling)	6.017 (3.904)	5.718 (3.901)	5.993 (3.900)	5.560 (3.968)	6.004 (3.901)	5.672 (3.916)
Household size (persons)	6.385 (2.768)	6.355 (3.426)	6.317* (3.043)	6.890 (3.931)	6.351 (2.910)	6.496 (3.569)
Banana acreage	2.396*** (3.627)	1.394 (2.760)	2.823*** (6.138)	0.375 (0.755)	2.611*** (5.057)	1.126 (2.440)
Total land owned (acres)	5.358 (8.911)	6.412 (17.844)	4.567 (7.297)	4.115 (6.016)	4.951 (8.128)	5.767 (15.488)

Notes: † Adopters refers to those who used at least one practice. Mean values are shown with standard deviations in parentheses. *, **, *** denote differences between BXW control practices adopters and non-adopters are significant at 10%, 5%, and 1% level, respectively.

EMPIRICAL RESULTS

LIVELIHOOD STRATEGIES

In the face of the BXW pandemic, banana producing households employed various coping strategies in addition to adoption of the control measures. These strategies include diversifying into production of maize, beans and coffee, capitalizing on livestock production and sales, and seeking off-farm employment. Table 5 shows the empirical results for the models used to evaluate the impact of the BXW disease shock on land allocated to maize, beans and coffee, following equation (1).

Table 5: Impact of BXW on land allocated to major crops

	Maize acreage		Beans acreage		Coffee acreage	
	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE
No. years since BXW onset	0.449*** (0.071)	0.025 (0.016)	0.253*** (0.090)	0.022 (0.018)	-0.067 (0.134)	0.021 (0.023)
2018 dummy		0.741*** (0.120)		0.698*** (0.148)		-0.830*** (0.195)
Sacco Membership	0.512* (0.300)	0.072 (0.135)	-0.068 (0.380)	0.071 (0.157)	-0.293 (0.705)	0.196 (0.190)
Age	-0.216*** (0.061)	-0.005 (0.004)	0.020 (0.077)	-0.007 (0.005)	0.057 (0.105)	0.009 (0.006)
Male household head	0.241 (0.515)	0.273* (0.143)	0.166 (0.652)	-0.291* (0.164)	-0.313 (1.207)	0.431** (0.205)
Education		0.013 (0.016)		0.001 (0.018)		-0.013 (0.023)
Household size		0.068*** (0.020)		0.042* (0.022)		0.038 (0.028)
Total land owned (acres)	0.013 (0.010)	0.036*** (0.007)	0.014 (0.013)	0.022*** (0.008)	0.080*** (0.022)	0.134*** (0.010)
Adopted 1 practice	0.045 (0.259)	0.162 (0.184)	-0.129 (0.327)	0.146 (0.219)	0.270 (0.646)	0.327(0.292)
Adopted 2 practices	-0.393 (0.269)	-0.026 (0.189)	-0.099 (0.341)	0.462** (0.225)	-0.032 (0.652)	0.319 (0.300)
Adopted 3 practices	-0.248 (0.281)	-0.345* (0.188)	-0.377 (0.355)	0.134 (0.223)	0.657 (0.678)	0.356 (0.287)
Constant	9.358*** (2.976)	-0.210 (0.359)	-2.195 (3.763)	0.273 (0.413)	-1.361 (5.262)	0.137 (0.543)
No. of observations	2058	2058	2058	2058	1504	1504
No. of households	1056	1056	1056	1056	1056	1056
Wald χ^2		119.19***		54.07***		231.65***
F-value	8.21***		3.97***		1.99**	
Hausman test χ^2	111.10***		41.20***		11.11	

Notes: Estimation coefficients are shown with standard errors in parentheses. FE, fixed effects, RE, random effects, *** p<0.01, ** p<0.05, *p<0.1.

The results in columns (1), (3) and (5) are based on the FE estimator, while results for the RE estimator are shown in columns (2), (4) and (6). The FE estimator is preferred for interpreting the impact of the shock since it accounts for unobserved heterogeneity between the farming households and reduces the bias in the estimated treatment effect while ensuring consistency. This is confirmed by the Hausman test statistics in table 5, which is statistically significant at less than 5% across the three estimated models. The coefficient estimates in Table 5 are interpreted as marginal effects since linear model specifications were employed for this study. Holding other factors constant, farmers who were severely affected by BXW for a long time increased their land allocation by almost half an acre for maize production and a quarter acre for bean production. The effect on coffee (a perennial crop) was insignificantly negative. This implies that as food insecurity worsens, farmers opted for growing annual crops as a livelihood strategy to help them reduce their risk of the disease. This is possibly because annual crops yield quick returns after a disease outbreak. Findings confirm earlier study by Karamura et al. (2010) who reported that some farm households that were hit by BXW in the first years of the pandemic cleared their banana plantations to plant other crops.

Similarly, findings show that younger banana farmers were more likely to increase their land allocated to maize production. This could be because growing maize is labour-intensive. The youth are energetic and can undertake more labour intensive activities than elderly farmers. Also, being a member of a SACCO increases the likelihood of growing more maize. On the other hand, findings show that those who resorted to production of other crops were less likely to adopt any of the BXW control practices, although the results are not statistically significant.

The time-variant 2018 dummy was dropped in the FE model specifications due to the high correlation with the BXW shock variable, i.e., number of years since BXW shock. Nonetheless, it is interesting to see the role played by all dropped variables regarding land allocation to other crops, which is shown in the RE estimations in columns (2), (4) and (6) of Table 5. The land allocated to maize and beans significantly increased in 2018 whereas that allocated to coffee reduced. Household size had a positive effect on increased production of maize and beans possibly because both crops are labour-intensive.

Table 6 presents the results for the impact of the disease on consumption, off-farm income and livestock sales. The Hausman test statistics is statistically significant for all models, confirming our preference for the FE models. As hypothesized, longer exposure to BXW disease reduced farm households' annual banana consumption, increased annual livestock sales and increased engagement in off-farm income generating activities. Households that were severely affected by BXW reduced their consumption of bananas by 40kg per capita per year as shown in column (1) of table 6. This is in line with Karamura et al. (2010) that households that suffered the devastating effects of BXW earlier significantly reduced their per capita consumption of banana. Similarly, our findings indicate that female-headed households were more likely to reduce consumption of banana than their male counterparts.

Table 6: Other livelihood strategies that farmers employ in the face of BXW

	Per capita consumption of banana (kg/household/year)		**Off-farm income (million UGX per year)**		**Livestock income (million UGX per year)**	
	(1) FE	(2) RE	(3) FE	(4) RE	(5) FE	(6) RE
No. years since BXW onset	-40.015*** (12.549)	2.460 (2.783)	1.352*** (0.172)	0.007 (0.040)	0.940*** (0.169)	0.001 (0.039)
2018 dummy		-146.762*** (21.795)		3.727*** (0.291)		2.521*** (0.286)
Sacco Membership	-25.265 (52.602)	28.627 (23.736)	-0.374 (0.725)	0.170 (0.338)	-1.136 (0.712)	0.889*** (0.332)
Age	-1.163 (10.582)	1.411* (0.762)	-0.156 (0.147)	-0.018 (0.011)	-0.038 (0.144)	0.011 (0.011)
Male household head	289.275*** (92.703)	51.8472** (25.238)	-1.298 (1.244)	-0.610* (0.359)	-0.207 (1.222)	0.861** (0.353)
Education		5.839** (2.856)		0.253*** (0.041)		0.188*** (0.040)
Household size		-29.283*** (3.469)		-0.025 (0.049)		0.202*** (0.049)
Total land owned (acres)	0.979 (1.823)	4.042*** (1.177)	0.012 (0.025)	0.017 (0.017)	0.107*** (0.025)	0.096*** (0.016)
Adopted 1 practice	156.989*** (48.159)	206.845*** (34.251)	-0.117 (0.625)	-0.967** (0.451)	-1.867*** (0.614)	-1.473*** (0.444)
Adopted 2 practices	162.284*** (49.579)	240.651*** (34.937)	-1.260* (0.651)	-1.923*** (0.465)	-2.095*** (0.639)	-1.848*** (0.457)
Adopted 3 practices	222.846*** (52.138)	301.447*** (35.148)	-0.409 (0.679)	-1.175*** (0.463)	-2.034*** (0.667)	-1.527*** (0.455)
Constant	255.201 (517.830)	112.523* (64.344)	8.669 (7.188)	7.547*** (0.904)	2.915 (7.058)	1.782** (0.889)
No. of observations	1997	1997	2058	2058	2058	2058
No. of households	1049	1049	1056	1056	1056	1056
Wald χ^2		198.09***		260.20***		224.60***
F-value	6.43***		24.67***		14.36***	
Hausman test χ^2	109.45***		309.54***		141.96***	

Notes: Estimation coefficients are shown with standard errors in parentheses. FE, fixed effects, RE, random effects, *** p<0.01, ** p<0.05, *p<0.1.

Households that adopted any one, two or all the three BXW control practices significantly increased their per capita consumption of banana compared to non-adopters. The effect was highest for those who adopted the recommended control package (3 practices) and their per capita consumption was 223kg higher than those who did not adopt any control practice. This implies that those who employed the recommended BXW control practices produce more bananas for their own consumption, similar to Kikulwe et al. (2019) findings.

The role of the time-invariant covariates on per capita consumption of banana can be observed from the RE model in column 2 of Table 6. The per capita consumption of banana dropped significantly in 2018 compared to 2015. This could be due to a decline in productivity of bananas in 2018 as shown in Table 7. Household heads with higher education were likely to increase their per capita consumption whereas households with more family members were more likely to reduce their per capita banana consumption.

Columns (3) and (4) show FE and RE specifications with off-farm income as the dependent variable. Those who were hard-hit by BXW (or with longer exposure to BXW shock) increased off-farm income by UGX 1,352,000 (USD 368) per year, holding other factors constant. This confirms our hypothesis that farming households opt for off-farm activities as a livelihood strategy once a major crop is affected by a devastating disease. Household heads with higher education levels are more likely to get involved in off farm activities. But households that get involved into off-farm activities are less likely to adopt any of the BXW control practices. This could be because such households commit their more labour to activities off-farm than on farm.

Livestock sales also increased as more farmers got engaged in livestock production, having incurred losses in banana production due to BXW. The FE model results in column 5 of Table 6 indicate that income from livestock increased by UGX 940,000 (USD 256) per year. The households that diversified into livestock production were majorly those with larger families, with more highly educated household heads and owning larger pieces of land that could possibly be used for grazing. These households were less likely to adopt any of the three BXW control practices.

LIVELIHOOD OUTCOMES

Livelihood outcomes were measured in terms of banana productivity and household welfare, and factors influencing both are presented in Table 7. The results in columns (1) and (3) are based on the FE estimator, while columns (2) and (4) show results with the RE estimator. Given the significant Hausman test statistic, the FE models in columns (1) and (3) provide better estimates. Results in column (1) show that the BXW shock has a negative impact on banana productivity. The households that had experienced BXW earlier realized a decline of 375kg of banana per hectare per year. That is, the longer the household is exposed to BXW shock, the greater the reduction in banana productivity. Karamura et al. (2010) observed an average decline of 2,317.8 kg/ha/year in banana productivity during the first four years after BXW onset.

Table 7: Impact of the shock on household welfare

	Banana productivity (tons/ha/year)		Banana productivity with other agronomic practices (tons/ha/year)		Household welfare (million UGX per year)	
	(1) FE	(2) RE	(3) FE	(4) FE	(5) FE	(6) RE
No. years since BXW onset	-0.375*** (0.183)	-0.032 (0.036)	-0.424** (0.187)	-0.348* (0.183)	0.640*** (0.061)	0.044*** (0.014)
2018 dummy		-1.404*** (0.291)				1.733*** (0.103)
Sacco Membership	0.573 (0.795)	0.189 (0.302)	0.573 (0.790)	0.548 (0.785)	-0.091 (0.250)	0.320*** (0.120)
Age	-0.111 (0.149)	-0.016 (0.010)	-0.094 (0.148)	-0.095 (0.147)	0.011 (0.053)	-0.002 (0.004)
Male household head	0.543 (1.443)	-0.297 (0.318)	0.411 (1.433)	0.547 (1.421)	1.463*** (0.445)	0.408*** (0.127)
Education		0.065* (0.037)				0.093*** (0.014)
Household size		0.038 (0.044)				0.044 (0.017)
Total land owned (acres)	-0.028 (0.028)	-0.019 (0.015)	-0.032 (0.028)	-0.034 (0.028)		
Adopted 1 practice	1.416* (0.830)	1.598*** (0.501)	1.030 (0.849)			
Adopted 2 practices	1.034 (0.841)	1.277** (0.509)	0.671 (0.855)			
Adopted 3 practices	2.036** (0.863)	2.006*** (0.503)	1.686* (0.893)			
Land under banana (acres)					0.036** (0.015)	0.083*** (0.011)
Adoption dummy (1=package, 0=otherwise)				0.890* (0.494)	0.271* (0.156)	0.481*** (0.112)
De-sucker (Yes=1)			1.486* (0.873)	-0.193 (1.047)		
De-trash (Yes=1)			3.202** (1.434)	3.858*** (1.421)		
Corm-removal (Yes=1)			-1.581*** (0.561)	-4.737*** (1.236)		

Weed (Yes=1)			0.162 (1.830)	-0.332 (1.824)		
Desuck*detrash*corm removal*weed inter.				3.822*** (1.320)		
Constant	10.660 (7.305)	3.438*** (0.854)	7.212 (7.445)		8.542*** (2.573)	12.417*** (0.301)
No. of observations	1766	1766	1763	1766	2116	2116
No. of households	1022	1022	1022	1022	1061	1061
Wald χ^2		50.03***				685.47***
F-value	2.58***		3.19***	4.14***	81.91***	
Hausman test χ^2	22.12***		34.01***	40.40***	513.53***	

Notes: Estimation coefficients are shown with standard errors in parentheses. FE, fixed effects, RE, random effects, *** p<0.01, ** p<0.05, *p<0.1

Adoption of the BXW control practices had a positive and significant effect on banana productivity. The households that adopted the three recommended practices obtained higher banana yields equivalent to 2,036kg per hectare per year compared to those who did not adopt any practice. However, going by the negative sign for the 2018 dummy in the RE model, productivity significantly dropped by 1.404 tons per hectare in 2018 compared to that in 2015. This decline could be as a result of other biophysical factors that we didn't consider such as declining soil fertility and soil-water imbalances (drought stress) that have resulted in low banana yields in the recent past (Taulya, 2015). Previous studies in Uganda found that abiotic stresses such as drought (Okech et al, 2004) and nutrient deficiencies particularly potassium (K) and nitrogen (N) are responsible for 28 to 68% yield loss (Nyombi et al., 2010; Wairegi and van Asten, 2010). Columns 3 and 4 demonstrate the impact of some of the agronomic practices mostly done by farmers. Results in column 3 show that de-suckering (removal of excess suckers) and de-trashing (removal of all dry leaves and fibers) increases productivity significantly, while the impact of weeding is insignificant. However, corm removal is significantly negative. This could be attributed to the timing and the way corm removal is practiced. Most farmers remove corms late, which is mostly done after planting and weeding of annual crops due to labour scarcity. Similarly, sometimes roots are cut/damaged during the uprooting of the corm. These two factors can influence yields negatively, resulting in decreased productivity. Findings in column 4 show that when adoption of BXW control practices is a dummy (adopt=1; 0 otherwise) and an interaction of all other practices is included, both variables are positive and significant. Thus, to sustainably achieve high yields, BXW control should be combined with proper management of bananas through application of the recommended agronomic practices.

Columns (5) and (6) in Table 7 show household welfare model results. Under these estimates, however, we considered adoption of the recommended BXW control package (all three practices) instead of the level of adoption as is the case in previous models. We also considered land under banana rather than total acreage because we were interested in seeing the effect of banana production on household welfare. Increasing the land under banana by one acre increased the welfare of the household by approximately UGX 36,000 (USD 10) per annum holding other factors constant. In addition, adoption of the recommended BXW control practices increased household welfare by UGX 271,000 (USD 74) per year. This implies that adoption of BXW control practices increased household welfare by more than seven-fold compared to a one acre increase in banana acreage, which justifies a need for continuous control of BXW. Otherwise, if the SDSR package is not effectively adopted, each household would lose approximately UGX 270,000 (USD 74) per annum. In addition, male-headed households increased their welfare by UGX 1,463,000 (USD 398) per year compared to their female headed counterparts. Overall, since the onset of the disease shock, a significant increase in household welfare worth UGX 640,000 (USD 174) per year was realized. This implies that households were able to mitigate the devastating effects of BXW disease shock over time through various livelihood coping strategies and hence improved their welfare.

CONCLUSION

Previous research has documented the devastating effect caused by BXW to farm households in the banana growing regions in Uganda, and in the region at large. In this article, we have contributed to the literature by analyzing the impact of BXW shock on the welfare of banana producing households as well as the alternative livelihood strategies they pursue to improve their welfare over time in addition to adopting the BXW control practices. We examined the likely coping strategies that households employ once hit by the BXW pandemic including allocating land to other crops, reducing per capita consumption of bananas and diversifying into livestock production and off-farm income activities to earn a living. The empirical analysis has concentrated on households in the four banana-growing regions in Uganda that were drastically affected by BXW. Results show that households were able to improve their welfare over time after experiencing the effects of BXW. Farmers devised short-term livelihood strategies to recover from the BXW shock. The key coping strategies employed include increased production of annual crops mainly maize and beans, reduction in consumption of bananas, diversifying into livestock production and off-farm activities. Several institutional and household characteristics are found to be important determinants of coping strategies.

Based on the findings, we conclude that: first, taking longer to devise mitigation measures to shocks may have a negative impact on productivity but this can be reduced by timely adoption of recommended technologies. Our results confirm that adoption of the recommended BXW control practices significantly boosted banana productivity and its consumption, but this needs to be combined with proper management of plantations by adopting other recommended agronomic techniques for yields to increase sustainably. Second, the government needs to devise and implement policies to sustainably overcome effects of disease outbreaks in a timely manner. If properly implemented, such policies could help affected households to embrace different livelihood coping strategies to alleviate the devastating effects of the disease shock and hence improve their livelihood outcomes.

Lastly, our study focused on banana farmers in the four banana producing regions in Uganda; so, the concrete numerical results may not be generalized widely, and the panel data of only two rounds of observations as used here have their limitations. For instance, addressing possible issues of reverse causality would benefit from panel data with more rounds of observations, and we acknowledge that additional livelihood strategies-not analyzed here-may also be important.

REFERENCES

Bagamba, F., Kikulwe, E., Tushemereirwe, W.K., Ngambeki, D., Muhangi, J., Kagezi, G.H., Ragama, P., Eden-Green, S. 2007. Awareness of banana bacterial wilt control in Uganda: 1. Farmers' perspective. African Crop Science Journal (ISSN: 1021-9730) Vol 14 Num 2. 14.

Biruma, M.; Pillay, M.; Tripathi, L.; Blomme, G.; Abele, S.; Mwangi, M.; Bandyopadhyay, R.; Muchunguzi, P.; Kassim, S.; Nyine, M.; et al. 2007. Banana Xanthomonas wilt: A review of the disease, management strategies and future research directions. Afr. J. Biotechnol. 6, 953–962.

Blomme, G.; Jacobsen, K.; Ocimati, W.; Beed, F.; Ntamwira, J. 2014. Fine-tuning banana Xanthomonas wilt control options over the past decade in East and Central Africa. Eur. J. Plant Pathol.139, 271–287.

Blomme, G., Ocimati, W., Sivirihauma, C., Vutseme, L., Mariamu, B., Kamira, M., Schagen, B., Ekboir, J., and Ntamwira, J. 2017. A control package revolving around the removal of single diseased banana stems is effective for the restoration of Xanthomonas wilt infected fields. https://www.bioversityinternational.org/fileadmin/user_upload/A_control_Blomme_2017_Preprint.pdf

Carpena, F. 2019. How do droughts impact household food consumption and nutritional intake? A study of rural India. World Development, 122, 349–369. https://doi.org/10.1016/j.worlddev.2019.06.005

Coulibaly, J.Y., Gbetibouo, G.A., Kundhlande, G., Sileshi, G.W., and Beedy, T.L. 2015. Responding to crop failure: understanding farmers' coping strategies in Southern Malawi. Sustainability 2015, *7*, 1620-1636.

DFID. 1999. Sustainable Livelihoods Guidance Sheets Introduction: Overview. Sustainable Livelihoods Guidance Sheets. https://doi.org/10.1002/smj

Jogo, W.; Karamura, E.; Tinzaara, W.; Kubiriba, J.; Rietveld, A. 2013. Determinants of farm-level adoption of cultural practices for banana Xanthomonas wilt control in Uganda. J. Agric. Sci. 5, 70-81.

Karamura, E.B., Turyagenda, F.L., Tinzaara, W., Blomme, G., Morina, A., and Markham, R. 2008. Xanthomonas wilt of bananas in East and Central Africa. Diagnostic and management guide. Bioversity International Uganda.

Karamura, E.; Kayobyo, G.; Tushemereirwe, W.; Benin, S.; Blomme, G.; Green, S.E.; Markham, R. 2010. Assessing the impacts of banana bacterial wilt disease on banana (Musa spp.) productivity and livelihoods of Ugandan farm households. Acta Hortic. 879, 749–756.

Kalyebara, M.R, Rugama,P., Tushemereirwe, W., Bagamba, F., Kagezi, G.H., Kubiriba, J.,Nankinga,K.C. 2007. Economic Importance of the Banana Bacterial Wilt in Uganda. African crop science journal, Vol 14, No.2.

Kikulwe, E.M.; Okurut, S.; Ajambo, S.; Gotor, E.; Ssali, R.T.; Kubiriba, J.; Karamura, E. 2018. Does gender matter in effective management of plant disease epidemics? Insights from a survey among rural banana farming households in Uganda. Journal of Development and Agricultural Economics 10(3) p. 87-98.

Kikulwe, E.M., Kyanjo, J.L., Kato, E., Ssali, R.T., Erima, R., Mpiira, S., Ocimati, W., Tinzaara, W., Kubiriba, J., Gotor, E., Stoian, D., and Karamura, E. 2019. Management of Banana Xanthomonas Wilt: Evidence from Impact of Adoption of Cultural Control Practices in Uganda. Sustainability 2019, 11(9), 2610

Kilimo Trust. 2012. Analysis of the Banana Value Chains in Tanzania and Uganda; Consumption, Productivity and Challenges. Kampala, Uganda: Kilimo Trust.

Kubik, Z., and Maurel, M. 2016. Weather shocks, agricultural production and migration: evidence from Tanzania. Journal of Development Studies, 52(5), 665–680. https://doi.org/10.1080/00220388.2015.1107049

Kubiriba, J. and Tushemereirwe, W.K. 2014. Approaches for the control of banana Xanthomonas wilt in East and Central Africa. Afr. J. Plant Sci. 8, 398–404.

Lescot, T., 2013. "World plantain and banana production systems," in Proceedings XX International Meeting ACORBAT. September9–13, 2013, Fortaleza, 26–3

Mehar, M.; Mittal, S.; Prasad, N. 2016. Farmers Coping Strategies for Climate Shock: Is it Differentiated by Gender? Journal of Rural Studies 44, 123-131

Mengistu, D.K. 2011. Farmers' perception and knowledge of climate change and their coping strategies to the related hazards: Case study from Adiha, central Tigray, Ethiopia. Agricultural sciences. Vol.2, No.2, 138- 145.

Mutaqin, D. J. 2019. Determinants of farmers' decisions on risk coping strategies in rural West Java. Climate, 7(1), 1–23. https://doi.org/10.3390/cli7010007

Nakakawa,J. ,Mugisha, J.Y.T., Shaw,M.W.,Tinzaara, W., and Karamura, E. 2017. Banana *Xanthomonas* wilt infection: the role of de-budding and roguing as control options within a mixed ultivar plantation. International journal of mathematics and mathematical sciences. Volume 2017 |Article ID 4865015 |13 pages | https://doi.org/10.1155/2017/4865015.

Nkuba, J., Tinzaara, W., Night, G., and Niko N et al. 2015. Adverse impact of banana Xanthomonas wilt on farmers livelihoods in eastern and Central Africa. African J Plant Sci 9(7):279–286.

Nyombi, K., van Asten, P.J.A., Corbeels M., Taulya G., Leffelaar P.A. and Giller, K.E. 2010. Mineral fertilizer response and nutrient use efficiencies of East African highland banana (Musa spp., AAA-EAHB, cv. Kisansa). Field Crops Research 117: 38–50.

Ochola, D., Ocimati, W., Tinzaara, W., Blomme, G., and Karamura, E.B. 2014. The effect of water stress on the development of banana Xanthomonas wilt disease. Plant pathology. Vol.64, Issue 3.

Ocimati, W., Bouwmeester, H., Groot, J. C. J., Tittonell, P., Brown, D., & Blomme, G. 2019. The risk posed by Xanthomonas wilt disease of banana: Mapping of disease hotspots, fronts and vulnerable landscapes. PLoS ONE, 14(4), [0213691]. https://doi.org/10.1371/journal.pone.0213691

Okech S.H., van Asten P.J.A., Gold C.S. and Ssali H. 2004. Effects of potassium deficiency, drought and weevils on banana yield and economic performance in Mbarara, Uganda. Uganda Journal of Agricultural Sciences 9: 511–519.

Regassa, N. 2011. Small holder farmers coping strategies to household food insecurity and hunger in Southern Ethiopia. Ethiopian Journal of Environmental Studies and Management Vol. 4 No.1.

Salazar-Espinoza, C., Jones, S., and Tarp, F. 2015. Weather shocks and cropland decisions in rural Mozambique. Food Policy, 53, 9–21. https://doi.org/10.1016/j.foodpol.2015.03.003

Scoones, I. 1998. Sustainable rural livelihoods: a framework for analysis. IDS Working Paper.

Shuaibu, H., Akpoko, J.G., &Umar, S. 2014. Farm households' coping strategies to climate change: a review. British Journal of Applied Science & Technology. 4(20): 2864

Smith, J. J., Jones, D. R., Karamura, E. B., Blomme, G., & Turyagyenda, F. L. 2008. An analysis of the risk from Xanthomonas campestris pv. Musacearum to banana cultivation in Eastern, Central and Southern Africa. Bioversity International, Montpellier, France.

Snijders TAB. 2005. Fixed and random effects. In: Everitt BS, Howell DC (eds.) Encyclopedia of Statistics in Behavioral Science, Vol. 2, 664–665 (Wiley, Chichester).

Taulya, G. 2015. Ky'osimba Onaanya: Understanding productivity of East African highland banana. PhD thesis, Wageningen University, Wageningen, NL (2015)

Tripathi, L.; Mwangi, M.; Abele, S.; Aritua, V.; Tushemereirwe, W.K.; Bandyopadhyay, R. 2009. Xanthomonas Wilt: A Threat to Banana Production in East and Central Africa. Plant Dis. 93, 440–451.

Tushemereirwe, W., Kangire, A., Ssekiwoko, F., Offord, L. C., Crozier, J., & Boa, E. 2004. First report of Xanthomonas campestris pv . musacearum on banana in Uganda. Plant Pathology, 2004(53), 802. https://doi.org/10.1111/j.1365-3059.2004.01090.x

Tushemereirwe, W. K., Okaasai, O., Kubiriba, J., Nanakinga, C., Muhangi, J., Odoi, N., & Opiuo, F. 2006. Status of banana bacterial wilt in Uganda. African Crop Science Journal, 14, 73–82

Uwamahoro, F., Berlin, A., Bylund, H., Bacugu, C., and Yuen, J. 2019. Management strategies for banana Xanthomonas wilt in Rwanda include mixing indigenous and improved cultivars. Agron. Sustain. Dev. 39**,** 22 doi:10.1007/s13593-019-0569-z

Vezina, A. 2014. Rehabilitating banana fields devastated by Xanthomonas wilt. http://www.promusa.org/blogpost356-Rehabilitating-banana-fields-devastated-by-Xanthomonas-wilt.

Vurro, M., Bonciani, B., and Vannacci, G. 2010. Emerging infectious diseases of crop plants in developing countries: Impact on agriculture and socio-economic consequences. In *Food Security*. https://doi.org/10.1007/s12571-010-0062-7

Wairegi, L.W.I. and van Asten, P.J.A. 2010. The agronomic and economic benefits of fertilizer and mulch use in banana systems in Uganda. Agricultural Systems 103(8): 543–550.

RESEARCH PROGRAM ON
Roots, Tubers and Bananas

The CGIAR Research Program on Roots, Tubers and Bananas (RTB) is a partnership collaboration led by the International Potato Center implemented jointly with Bioversity International, the International Center for Tropical Agriculture (CIAT), the International Institute of Tropical Agriculture (IITA), and the Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), that includes a growing number of research and development partners. RTB brings together research on its mandate crops: bananas and plantains, cassava, potato, sweetpotato, yams, and minor roots and tubers, to improve nutrition and food security and foster greater gender equity especially among some of the world's poorest and most vulnerable populations.

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