EVALUATION OF BANANA BACTERIAL WILT MANAGEMENT IN

NTUNGAMO SUB COUNTY, NTUNGAMO DISTRICT

BY

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LIST OF ACRONYMS

BBW	Banana Bacterial Wilt
BXW	Banana *Xanthomonas* Wilt
LC	Local Council
MAAIF	Ministry Of Agriculture Animal Industry And Fisheries
NAADS	National Agricultural Advisory Services
NARO	National Agricultural Research Organisation
PDC	Participatory Development Communication
SPSS	Statistical Package for Social Scientists

DEDICATION

I would like to dedicate this project to the Almighty God who, by his grace, has guided me throughout my life, granted me strength, knowledge and life. Without him, it would have been impossible to study and complete this course. I give glory back to him and may his name be praised forever.

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May the Almighty God bless you all.

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ABSTRUCT

The study was conducted to evaluate BBW management in Ntungamo sub county Ntungamo district. Banana bacterial wilt (BBW) is a vascular disease that results in permanent wilting and eventual death of the plant. The general objective was to assess the effectiveness of banana bacterial wilt management practices used by farmers to manage BBW in Ntungamo sub county. Socio-demographic data was collected and BBW management assessed through questionnaires, interviews and observation. Eighty farmers from four parishes in Ntungamo Sub-county were randomly sampled and eight key informants were purposively sampled and data was analysed. Results revealed that those farmers who experienced BBW mostly practiced removing infected plants at first sight (42.9) and disinfecting tools with jik was the list practiced at 2.4%. However, it was further revealed that farmers combined at least three of the control strategies in order for them to be effective. According to the study findings, most of the farmers reported that the strategies were fairly effective (47%). It was recommended that the capacity of various stakeholders like extension workers, religious leaders among others should be built more to enable them easily detect and provide information to the general public on how to prevent and manage BBW. Also there is need for the government to implement policies to enable microfinance institutions to provide credit to farmers. This will enable farmers to buy chemicals like jik for sterilizing the tools and also to buy tools like pangas and hoes, hence avoiding sharing of tools which will reduce on the disease spread.

CHAPTER ONE:

GENERAL INTRODUCTION

1.1 Introduction

This chapter contains the background, the statement of the problem, the research objectives, questions, hypotheses, scope of the study, justification of the study, significance of the study, conceptual frame work, limitation of the study, operational definitions and organisation of the study.

1.2 Background

Banana and plantain, hereafter referred to as bananas, are the most important staple food crop in Uganda and a number of other countries in the East African Great Lakes region. Cooking bananas account for one third of the calorie intake from starchy staples in Uganda (Biruma *et al.,* 2007). Bananas are also an important income source for about 30 percent of the Ugandan farmers, being marketed at a rate between 25 and 50 % of production, particularly in Western Uganda (Okech *et al*., 2004). The production of bananas is affected by diseases of fungal, bacterial and viral origins.

Banana bacterial wilt (BBW) also known as banana *Xanthomonas* wilt (BXW) caused by *Xanthomonas vasicola* pv.*musacearum* (*Xvm*), formerly *Xanthomonas campestris* pv *musacearum* (Biruma *et al*., 2007) is an emerging disease of bananas in East Africa. It is a vascular disease that results in permanent wilting and eventual death of the plant. Although no detailed studies on the assessment of crop losses due to this disease have been presented, field observations indicate that the disease reduces yields to varying levels, depending on the growth stage of the crop, degree of cultivar susceptibility and prevailing climatic conditions (Biruma *et al*., 2007).

It has spread to the Great Lakes region of East Africa, where it poses a threat to food and income security. No resistant cultivars have yet been identified, but some cultivars possess characteristics that make it harder for the bacteria to infect the plants under natural conditions (Tripathi *et al.,* 2008).

Unlike most other diseases, which mainly reduce yield, The disease affects the fruit and eventually kills the entire plant. Bacteria-laden exudates provide the means of transmission to new plants by insects and contaminated tools (Tinzaara *et al*., 2006).

Although earlier records report a disease consistent with these symptoms as present in the 1930s, spread beyond Ethiopia was not reported until the disease was found in Uganda in 2001 (Tushemereirwe *et al.,* 2004). Subsequent spread to other countries in eastern Africa has proceeded rapidly. In many instances, however, the exact time of introduction is not known. Although it is said to have been first observed in 2001 by farmers in the North Kivu Province, the disease was not confirmed in the Democratic Republic of Congo until 2004 (Ndungo *et al.,* 2005). In Rwanda, *Xanthomonas* wilt was first observed in the northern part of the country in 2005 (Reeder *et al*., 2005). It was also reported to have spread to Tanzania in 2005 and to Kenya and Burundi in 2006 (Mbaka *et al*., 2009).

Internal symptoms revealed by doing a cross-section of an infected pseudostem are yellow-orange streaking of the vascular tissues and the presence of yellow bacterial ooze. The pulp of the rotting fruits shows rusty brown stains (Muhangi *et al.,* 2006). According to Mwangi (2009), the wilted leaves may also snap at the petiole and hang down the pseudostem. In plants affected by *Xanthomonas*, the wilting can begin with any leaf and the infected leaves tend to snap along the leaf blade (Mwangi, 2009).

1.3 Statement of the problem

Banana bacterial wilt is a serious threat to both household and national food security (Turyagyenda *et al*., 2008) because 70% of the farmers in Uganda rely on banana as a main source of livelihood with banana consumption ranging from 220-460kg per capita (Mugisha and Ngambeki, 2004). Preliminary reports from households show that farmers who used to harvest 16 bunches per week are now harvesting only one, which is a 90% yield loss (Eden-Green 2004). Due to the gravity of the problem, Uganda Government, through the Ministry of Agriculture Animal Industry and Fisheries (MAAIF) and National Agricultural Organization-Banana Research Programme, has been implementing a programme of making farmers aware of the problem and what they can do to control it. A number of approaches have been used including media, training of local extension staff and local leaders, reaching out to civic leader and policy makers and participatory development communication (Bagamba, 2006). Inspite of these efforts, the disease has continued to spread in Uganda including Ntungamo district.

Ntungamo is the third highest producer of matooke in western Uganda, after Isingiro and Bushenyi. With more than 90 per cent of the families in the district depending on matooke for food while another 60 per cent depending on the crop for income. (Daily monitor, September, 2011). If the disease continues to spread, poverty and food insecurity are likely to strike in the district. Therefore, there is an urgent need to assess whether the disease management practices were adopted by the people of Ntungamo.

1.4 Objectives of the study

1.4.1 General objective

To assess the effectiveness of banana bacterial wilt management practices used by farmers to manage BBW in Ntungamo sub county.

1.4.2 Specific objectives

1. To assess the disease management practices that have been introduced in the sub-county and their acceptability and adoption rate.
2. To establish the extent to which BBW has affected banana production in Ntungamo sub-county.
3. To evaluate the effectiveness of the introduced BBW management practices in controlling the disease in the Subcounty.

1.5 Research questions

1. What BBW disease management practices have been introduced in the subcounty and what is their acceptability and adoption rate?
2. To what extent has BBW affected banana production in Ntungamo sub county?
3. How effective are the introduced BBW management practices and to what extent have they worked in controlling the disease in the Subcounty?.

1.6 Significance of the study

The research findings can be used to sensitize people of Ntungamo about the devastating effects of banana bacterial wilt disease and the need to take action.

The findings will help the various stakeholders to determine whether the disease management strategies were adopted or not and to design better strategies if they are to reduce on the disease incidence.

The district leaders, extension agents and other stake holders could use these findings to decide whether there is need for further sensitization about the disease spread, symptoms and management strategies.

Lastly, the research findings might pave way for more researchers to find out more information about banana bacterial wilt disease.

1.7 Justification of the study

Since farmers are still witnessing challenges of production due to effects of banana bacterial wilt and difficulty in controlling the disease, a lot needs to be done to enable farmers meet their dual objective of high productivity and increased household income. This study is therefore one of the ways to tackle some of the problems affecting farmers.

1.8 Scope of the study

1.8.1 Geographical scope

The study was conducted in Ntungamo Sub- county which is found in Ruhaama county of Ntungamo district. Ntungamo district is located in south western Uganda and is comprised of three counties of Kajara, Rushenyi and Ruhaama. The district boarders with kabala in the south, Rukungiri in the west, Bushenyi in the north, Mbarara in the east and Tanzania and Rwanda in the south east. The district has 12 sub counties, two municipal divisions and two town councils.

The researcher's case study area of Ntungamo Sub -county has seven parishes of Butare, Nyarubaare, Kahunga, Nyaburiza, Kikoni, Kizaara and Ruhoko. However, due to limited time and financial resources, only four parishes of Nyarubaare, Butare, Kahunga and Ruhoko were sampled. These parishes represented the whole Sub- county.

1.8.2 Content scope

The study focused on three objectives which were; To establish the extent to which BBW has affected banana production in Ntungamo sub county and the disease management practices that have been introduced, to assess the acceptability and adoption rate of the introduced disease management practices and to evaluate the effectiveness of the introduced BBW management practices and the extent to which they have worked in controlling the disease in the Subcounty.

1.8.3 Time scope

The research took eight months. It started in January and ended in September 2017. The researcher believed that this time was convenient to do thorough research using the available resources. Besides, it was sufficient time for the researcher to complete the work and get the academic award in time.

1.9 Limitations of the study

- Research is a process that took a lot of time and yet the time was not enough. However, a leave from the place of employment was requested to enable completion of research.
- Suspicion of some respondents- Some respondents became reluctant in giving out information about the study asking why data was being collected from them.

Explaining to them that their data was to be confidential and used for academic purposes helped to solve the problem.

- Difficult to trace/busy- respondents especially civil servants and even tracing key informants caused some delay in answering questionnaires because most of them were always a way for workshops and thus hard to be seen. To solve this problem, their phone contacts were taken and appointments were made with them. This made it possible to collect data from them.
- Lack of enough funds to successfully carry out the study- The money needed for processing the work in form of typing, printing, photocopying and binding using hard cover were quite a lot. This demanded to seek for financial help from friends.

1.10 Operational definitions of key concepts

Adoption

It means taking up something new. In this case it means taking up the banana bacterial wilt management practices which were released by the government of Uganda to farmers.

Banana bacterial wilt

It is a bacterial disease of bananas caused by *Xanthomonas campestris p.v musacearum*

Management practices

These are strategies which are employed to control the spread of banana bacterial wilt.1.12 Organization of the study

The study was organized in to six chapters which include; introduction, literature review, methodology, presentation and discussion of findings, conclusions and recommendations).

CHAPTER TWO:

LITERATURE REVIEW

2. I Introduction

This chapter outlines the literature that the researcher has read which is related to the dependent and independent variables, including the theoretical frame work. The literature reviewed is in line with the research objectives.

2.2 The pathogen: Diagnostic tools

The pathogen *X. vasicola* pv. *musacearum* belongs to agroup of bacteria that are found only in association with plants or plant materials. In media or environments that are rich in glucose content, the pathogen produces copious amounts of extracellular polysaccharide, called xanthan gum, which can contribute to significant blockage of vessels in infected plant tissues (Buruma 2006).

As with other Xanthomonads, *Xvm* grows much slower than other bacterial species such as *Pseudomonas*, *Burkholderia* and *Ralstonia*. Thus, outside of the host, *Xvm* does not compete well with other bacteria and it is thought that this slow growth trait has implications for survival of the pathogen in the soil when it is released from infected plant.

Studies have been initiated to understand pathogen survival in the soil. However, the initial progress was hindered due to the absence of a selective medium specific to *Xvm*. Preliminary evidence showed that the bacteria can survive in chopped plant debris in the soil for over six months (Tushemereirwe et al. 2003).

Understanding pathogen survival is important because it is interlinked to recommendations on disease management measures based on crop rotation or fallowing. Recent advances in developing semi-selective media are contributing to progress in studies on pathogen survival and epidemiology, and determination of the insect species involved in pathogen transmission (Agrios, 2005).

Progress is being made to develop serological tests of the pathogen, with polyclonal antibodies already successfully generated and tested and plans are underway to develop monoclonal antibodies. Initiatives are on course for development of PCR-based protocols that would be useful for studies on many aspects especially understanding the population structure of the pathogen (Agrios, 2005).

2.3 Sources of inoculums of Banana bacterial wilt

Many bacterial plant pathogens propagate and survive on floral parts, stems and leaves as epiphytic populations that play a significant role in disease epidemiology. This is true with fire blight pathogen of apple and pear caused by *Erwinia amylovora* and blossom blights caused by pathovars of *Pseudomonas syringae,* and some leaf spot diseases caused by *Xanthomonas* sp. (Agrios, 2005).

Epiphytic populations of *Xvm* have not been described and they are not known to play any role in the epidemiology of banana bacterial wilt. Eden-Green (2004) noted that, plant residues, contaminated soils and water, infected mats and traded products including fruits, leaves and planting materials are thought to be the major sources of inoculum of *Xanthomonas* wilt.

Eden-Green (2004) noted that the contribution contaminated sources make to the spread of the disease depends on the survival of the bacterium and its mode of transmission. **Agrios** (**2005**) also noted that all diseases in which the pathogen is carried internally or externally by one or a few specific vectors, dissemination of the pathogen depends to a large extent or entirely on that vector. Although the relative importance of many of these factors is not fully known, tentative conclusions can be drawn on the basis of field observations and knowledge from other banana bacterial diseases.

2.4 Mode of infection of banana bacterial wilt

Successful infection of a host plant by a bacterium involves the movement of the bacterium towards the host, contact between the two, penetration of the host by the bacterium and proliferation of the bacterium inside the host immediately following ingress (Tushemereirwe et al 2003).

Field observations in Uganda suggest that*Xvm* infects banana plants either through the lower parts of the plant (roots, mats and cut leaf petioles) possibly from soil-borne inoculum and/or through the inflorescence from inoculum dispersed by insects and perhaps aerosols (Karamura et al., 2006).

2.5 Modes of transmission of banana bacterial wilt disease

Insects, farm tools and infected planting material are the main agents of transmission. Their relative importance in spreading the disease depends on the management practices being applied, the type of cultivar and agro ecological conditions (Tushemereirwe *et al., 2004).*

Transmission through insects: An insect visiting the male bud of an infected plant can get bacteria on its body through a wound that exudes bacteria-laden ooze (figure 4). The bacteria on the insect's body can then infect healthy plants when the insect visits healthy plants that have similar wounds (Tinzaara et al., 2006).

Fresh wounds offer bacteria a point through which they can enter or leave the plant. Bacteria have been isolated from the sap and ooze collected from the cushions to which the male flowers were attached and the scars made by the fallen bracts, and to a lesser extent from the nectar of flowers (Tinzaara *et al.*, 2006).

Even though female flowers are more visited than male flowers and the loss of their bract also leaves a scar, experiments suggest that infection only occurs through the cushions of male flowers as no flower infection occurred when the male bud was removed (Blomme *et al*., 2009).

In Uganda, the bacterium was isolated from stingless bees (*Plebeina denoiti* and undetermined species of the Apidae family), honeybees (*Apis mellifera*), fruit flies (Drosphilidae family) and grass flies (Chloropidae family) (Tinzaara *et al.*, 2006).

Cultivars that have persistent bracts and flowers are less likely to contract the disease from flying insects visiting the male bud, although some cultivars whose bracts and flowers do fall off also seem to escape infection. In general, East African highland bananas seem less prone to insect transmission, maybe because their inflorescence is less attractive to insects. The cultivar Kayinja, on the other hand, is very prone to floral infection (Kagezi *et al*., 2006). Insect transmission is less frequent at altitudes of 1,700m and above (Ahimelash *et al.*, 2008).

Transmission through contaminated tools: Tools are used for removing leaves, weeding, harvesting and removing excess suckers and dry fibres. When a machete or knife is used on an infected plant and subsequently on another healthy plant without disinfecting first, the pathogen is propagated further. The equipment used to remove contaminated leaves is one of the key factors of Xanthomonas wilt spread. Leaves have various domestic uses, feeding livestock, providing mulch and generating income.

Farmers prune leaves to avoid plant toppling during strong winds as plants near maturity, to reduce shading or to clean the plant of senescent and diseased leaves. In this area, green leaves have a ready market, especially in urban centres. In a study in Luwero district, leaf removal was observed to be the second most practiced operation, representing 25-30% of the time spent in banana farms in six villages (Ssenyonga et al., 2005). After losing plantations to Xanthomonas wilt, some farmers have been reported to maintain their plantations for the sole purpose of harvesting leaves for sale (Bagamba et al., 2006). The risk of disease spread is therefore significantly increased due to use of tools on fresh plant parts that are likely to be more receptive to the pathogen once it is introduced.

Cutting tools used by farmers, such as a machete, can be a key mechanism by which the disease is spread in intensively managed cropping systems. Transmission occurs when a farmer uses a cutting tool on an infected plant, where it comes in contact with the bacteria in the sap or ooze, and then on a healthy plant (Tumushabe et al., 2006).

Where disease spread is predominantly through tools, susceptibility of cultivars is also important, as observed in Ntungamo and Mbarara districts of Uganda where cooking East African highland banana cultivars are more abundant. Although farmers in this area vigorously practice debudding, some of the recent outbreaks were difficult to eradicate due to use of contaminated tools (Tushemereirwe *et al*., 2006).

Transmission through infected planting materials: In East Africa, the demand for suckers has recently increased drastically as farmers seek to re-establish plantations lost to Xanthomonas wilt. In a participatory study in central Uganda, Ssenyonga et al. (2005) found suckers to be an important source of income, with 26% of the suckers produced being sold locally. However, suckers are an important means of spread for systemic bacterial diseases of banana (Hayward, 2006).

In the six countries surveyed, over 90% farmers were obtaining suckers from their own or neighbours' fields. Due to the latent nature of Xanthomonas wilt infection, especially in the early stages, farmers often transplant already diseased materials.

The economic importance of banana derives largely from profitable trade with markets often far from the production areas. The long-distance movement of bananas presents a considerable risk for Xanthomonas wilt spread. For example, dessert bananas (‘Gros Michel’ and ‘Sukari Ndizi’) exported from Uganda to Kenya are routinely wrapped in pseudostem sheaths to protect fruits from blemishes. If contaminated with bacteria, such packaging residues could provide primary inoculum for Xanthomonas wilt.

Quite often, there are no well-structured procedures for handling banana residues at destination markets, and some farmers collect and use them as mulch. In a recent study, Tumushabe et al. (2006) demonstrated the ability of freshly infected banana residues to provide inoculum when they are thrown into farms where banana roots are injured, either mechanically (during weeding) or by pests.

The spread, over short and long distances, has been associated with the movement of symptomless but infected suckers for replanting. Banana plant residues can also spread the disease (Tumushabe et al., 2006).

In Uganda, the demand for suckers has recently increased drastically as farmers seek to re-establish plantations lost to *Xanthomonas* wilt. In a participatory study in central Uganda, Ssenyonga *et al*. (2005) found suckers to be an important source of income, with 26% of the suckers produced being sold locally. However, suckers are an important means of spread for systemic bacterial diseases of banana (Hayward, 2006). Due to the latent nature of *Xanthomonas* wilt infection, especially in the early stages, farmers often transplant already diseased materials.

It is possible that traders bring in residues from diseased plants. The discarded fruit stock may also be a source of infection if the bunches have been infected without showing the symptoms of the disease (Green, 2004).

2.6 Banana Cultivars and Disease Spread

Although there is considerable diversity of banana germplasm in East and Central Africa, a recent review suggests that all cultivars are susceptible to Xanthomonas wilt though those grown for juice extraction seem to succumb faster to the disease (Biruma et al., 2007). Therefore, where outbreaks occur, the disease has a continuous belt of susceptible hosts, which complicates efforts to prevent spread.

The existence of ecological conditions suitable for insect vectors is also believed to influence infection (Mwangi et al., 2006). It has been suggested that the exotic cultivars 'Pisang Awak', 'Kivuvu' (ABB genome, syn. 'Bluggoe'), 'Bogoya' (AAA genome, syn. 'Gros Michel') and 'Sukari Ndizi (AB genome) have higher sugar content in their nectar which makes them more attractive to insect vectors (Kagezi et al., 2006).

One key trait that influences disease spread in different varieties is the male bud. In varieties that have dehiscent male buds, all known insect transmission of Xanthomonas wilt occurs through the scars that are left behind when the male flowers fall. Varieties that have persistent male flowers and bracts do not get infected through the male flowers (Biruma et al., 2007). For varieties with dehiscent male flowers, the risk of infection is believed to be reduced when male bud removal is practiced, as it is in the cultivation of some cooking cultivars in western districts of Uganda (Bagamba et al., 2006). However, this study found that a majority of the farmers in the six countries are not practicing debudding (Table 2) as has been recommended for control. In a previous study in central Uganda, Kagezi et al. (2006) reported inconsistencies in implementation of debudding, with most farmers debudding sporadically or when the bud is already too old for the practice to be effective. Some farmers are reluctant to remove male buds, citing traditional customs or a belief that debudding affects juice quality or because of a lack of time (Bagamba et al., 2006).

In some regions of Ethiopia and central Uganda where 'Pisang Awak' is abundant and debudding is rarely practiced, higher rates of Xanthomonas wilt spread have been noted at altitudes below 1700 m above sea level (Addis et al., 2004; Blomme et al., 2005; Kagezi et al., 2006). Abundance of these cultivars with minimal debudding could accelerate disease spread where insect vectors thrive. During this survey, all countries were found to have mid-altitude regions (850-1400 m) that are suited to insect vectors. Above 1700 m, as in Rwanda and Masisi (east D.R. Congo), Xanthomonas wilt infection through flowers is less, even when 'Pisang Awak' is abundant (Mwangi et al., 2006), which indicates a reduced role for insect vectors. Where disease spread is predominantly through tools, susceptibility of cultivars is also important, as observed in Ntungamo and Mbarara districts of Uganda where cooking East African highland banana cultivars are more abundant. Although farmers in this area vigorously practice debudding, some of the recent outbreaks were difficult to eradicate due to use of contaminated tools (Tushemereirwe et al., 2006). During this survey, a few cultivars were identified that do not succumb to infection through the inflorescence thanks to their persistent male flowers and bracts, which restrict insect access to infection sites. These cultivars are mostly East African highland types, e.g. 'Mbwazirume', 'Nakitembe' and 'Gonja' in Uganda, and 'Inkazikamwa' and 'Incakara' in Rwanda, but they are not preferred by many farmers and thus are unlikely to have much impact.

2.7 Banana bacterial wilt management practices

2.7.1 Cultural practices to manage the spread of Banana bacterial wilt

Experience and research, as well as an understanding of how the bacteria move through the plant, have shown that the impact of *Xanthomonas* wilt can be mitigated by the adoption of crop management strategies that have proved successful against other banana bacterial wilts. (Blomme *et al*., 2009).

Debudding: The risk of infection through the inflorescence has been shown to be markedly reduced by the removal of the male bud by means of a forked stick (not cutting it off with a knife) (Blomme *et al*., 2009). In disease-free and infected areas, the recommendation is to remove male bud of healthy plants as soon as the last hand of fruit has formed. Using a forked stick not only avoids the risk of moving bacteria around on knives if the plant is infected, but also enables farmers to remove out-of-reach male buds (Tushemereirwe *et al*., 2003)

Disinfecting tools: According to Tushemereirwe *et al*. (2003), once the disease has been detected in a field, disinfecting tools (pangas, knives, leaf removers, hoes etc.) before using them on other plants would help prevent the spread of the bacteria to healthy plants. The tools can be sterilized by flaming until just too hot to touch (not red-hot) or by soaking in a sodium hypochlorite solution (one cup of household bleach/ jik in 5 cups of water).

The bacteria was detected on cutting tools kept at room temperatures up to 22 days (Buregyeya 2010). During that period, banana bacterial wilt is spread from the tools to banana plants up to 18 days. This implies that if traders who collect bananas from the fields do not disinfect the tools between plants and farms, they can spread the disease over long distances.

Removing infected plants: Removing infected plants at the first signs of infection is a key part of controlling the disease. A herbicide can be injected into the pseudostem (Okurut *et al*., 2006). But this practice is impractical for the majority of smallholder farmers and there are health and environmental issues to consider. The most widely advocated approach has been for infected plants to be dug up and cut into small fragments to accelerate desiccation and decomposition. The pieces should be heaped into a mound outside the limits of the banana field and left to rot. Studies on the survival of bacteria in the soil suggest that it should be safe to replant bananas after six months (Turyagyenda *et al.*, 2008).

Destroying the mat, however, is labour intensive and as a result cannot be expected to be readily adopted by smallholder farmers. An alternative that has been experimented with in Uganda is cutting off the pseudostem at soil level at the first sign of a flower infection (early shrivelled bract stage). Removing the pseudostem at that stage prevented the bacteria from reaching the rhizome and infecting the rest of the mat. Removing the pseudostem when symptoms were visible on the rachis or the fruits was not as effective (Turyagyenda *et al*., 2008).

Use of tissue culture seedlings: In areas where *Xanthomonas* wilt is present, the practice of using banana plant material as mulch is discouraged as it may contribute to the spread of the disease (Tushemereirwe *et al*., 2003).

It is recommended that farmers avoid getting suckers from plantations where the disease has been sighted. The use of tissue culture seedlings is encouraged as opposed to the common practice of obtaining planting materials from neighbor's (Mugisha *et al.,* 2006).

Quarantine measures: Use of local quarantine measures are considered to supplement the disease management measures that restrict transportation of planting materials such as suckers from one plant to another (Mugisha *et al*., 2006).

2.7.2. Institutional approaches for stakeholder mobilization to manage banana bacterial wilt

Conventional approaches: Every stakeholder in the banana value chain should be engaged in the battle against the disease. Subsistence farmers have substantial difficulties in managing the disease partly because they cannot see the organisms that cause it (Kubiriba and Tushemereirwe 2014).

It is therefore important to package the message in a clear and concise manner stating the epidemiological underpinnings, negative impacts of failure to implement the intervention as well as benefits of such interventions to individual farmers and large community.

The choice and design of communication strategy should take in to account of the target area like literacy levels, number of radio receivers and availability of extension support. The strategies would include training of trainers, posters, pamphlets, leaflets, brochures, billboards (Tushemereirwe *et al*., 2006)

Participatory approaches: The awareness campaign deployed by Uganda was successful with more than 85% of farmers knowing how to identify banana bacterial wilt, how it spreads and how it is controlled (Bagambe *et al*., 2006) . However, only 30% of the farmers were undertaking the disease control. It is possible to improve on the proportion of the farmers that adopt control measures at community level using participatory approaches (Tushemereirwe *et al*., 2006).

Participatory development communication (PDC): This is the use of communication to facilitate community participation in a development initiative like control of banana bacterial wilt. Developing PDC facilitates dialogue among the different stakeholders around a common problem has an aim of developing and implementing an action plan to solve the problem (Kubiriba and Tushemereirwe 2014).

Farmer field schools: These empower to learn in an informal setting within their own environment. Farmer field schools are schools without walls where groups of farmers meet with their facilitators. It is a participatory method of learning, technology development and dissemination based on adult learning principles. It was introduced in Uganda between 2006-2008 to control banana bacterial wilt. The approach has potential benefits because it is cheap, flexible, incorporates farmers' aspirations and empowers them (Kubiriba and Tushemereirwe 2014).

2.8 Effects of Banana bacterial Wilt and implication for management strategies

The effects of BXW are both extreme and rapid as compared to other diseases which have caused gradual losses over years. The economic impact of BXW is due to the death of the mother plant that would otherwise contribute to the ratoon plant production cycles (Tripathi *et al.*, 2007).

The trend of banana production since the outbreak of BXW has declined tremendously as compared to the situation before the outbreak of the disease. The disease has negatively affected food security and household income.

In Uganda, at the height of epidemics (between 2001 and 2004), 33% of the total banana mats were infected with BXW in four heavily affected districts (Karamura et al., 2010). Total banana yield losses due to BXW infection were estimated at 10-17% per year during this period (Kalyebala et al., 2006).

Compared to pre-infection levels, the total banana yield loss due to BXW infection is estimated at 30-52 % between 2001 and 2004 (Karamura et al., 2006). This has caused a reduction in the amount of banana harvested by households which has impacted livelihoods negatively. Many households have switched to other crops while others have abandoned banana cultivation.

Although an economic analysis of BXW has to be based on findings from Central Uganda, where the disease has occurred first and is presently most common, it is possible to forecast the economic impact of a BXW pandemic in Uganda by extrapolating the observations made in this region. BXW has now been reported in 34 districts in Uganda, apparently spreading from Central Uganda, where banana production is less intensive and mainly subsistence oriented to the high-production areas in Western Uganda. However, whereas in Central Uganda infestation rates reach levels of 18 - 27%, the major banana producing areas in the South-West of Uganda still show little or no infection (Tushemereirwe and Opolot, 2005)

This may be due to the fact that in Western Uganda, mainly cooking banana (AAA) is cultivated, which is less susceptible to insect-borne BXW than the exotic varieties such as 'Pisang awak' that are primarily planted in Central Uganda.

Kayobyo et al. (2005) reported that if uncontrolled BXW spreads at an infection rate of 8% per annum in cooking bananas, the total production loss of bananas is expected to be about 56% over a ten-year period, translating into a reduction from 4.5 million tons to eventually 2.1 million tons per year. Such a Biruma et al. 957 spread over the whole of Uganda would induce economic losses of 2 billion dollars over a decade, arising from price increases and significant reductions in production.

However, producers would benefit either in the first few years of the pandemic, or during a whole decade if the infestation rates are lower than 8% (Abele and Pillay,2007). This is due to the fact that in a normal market development, with increasing income, demand for cooking bananas will decline, and so will prices, because of the typical characteristics of a starchy staple food, that is, the perceived inferiority of the good

This means that at moderate production losses due to BXW,farmers over-compensate these quantity losses through the price increases, which are at present occurring in Uganda (FOODNET/MIS 2006). While initially producers are benefiting, consumers are losing from the first outbreak of the disease, due to reduced quantities and increasing prices.

The above described scenario has significant implications for the management of the disease. Generally, management measures in particular curative measures are taken when a certain disease damage threshold is reached, normally when or shortly before the economic losses are greater than the costs of pest management (Peterson and Hunt, 2003).

BXW management in this respect has two problems: as the producers have to decide when to commence management, they will probably begin too late with the management from an overall economic perspective, as they do not take into account the much higher and much earlier occurring consumer losses (Karamura et al., 2006).

This problem is aggravated by the fact that there are no curative but only preventive measures to control the disease. This shifts the timeline for management backward, implying that the producers are even less willing to engage in management long before the disease affects their fields (Karamura et al., 2006).

A third additional factor is that the disease affects the respective local plant population quickly and effectively, so that by the time the farmer becomes aware, it will be too late to respond. The above factors explains the presently low awareness of farmers in areas that are not yet heavily affected by the disease, and the even lower rate of farmers that know or apply preventive BXW control measures (Tushemereirwe and Opolot, 2005).

Prices for Ugandan cooking bananas are considerably high at the moment, so that farmers, especially in the unaffected high producing areas of western Uganda have no incentive to adopt control measures since they benefit from higher prices. Solutions to this dilemma are the provision of public goods, especially publicly financed measures to prevent the spread of the disease. At the same time, these measures have to conform to the market, that is, not affect market prices and quantities. The most prominent measure is breeding for resistance, and the publicly financed multiplication of resistant cultivars (e.g. through tissue culture or other controlled multiplication methods) and dissemination through public extension services (Karamura et al., 2006).

To be in 958 Afr. J. Biotechnol. conformity with the market, the new varieties should be introduced whenever obsolete plants have to be replaced on farmers' fields, according to farmers' decisions on how to most profitably introduce new cultivars to replace the old ones (Tushemereirwe and Opolot, 2005)

2.9 Current status and management challenges of banana Xanthomonas wilt

The impact of BXW on banana production in eastern Africa is not yet fully determined. Although the economic loss of BXW on the welfare of the farmers and the economy of the countries is not well documented, the impact of banana bacterial wilt on food security is very significant (Tushemereirwe and Opolot, 2005).

As the disease emerged in the region, significant progress in research on various aspects of the disease such as biology of the pathogen, epidemiology and management of the disease has been initiated. While significant advances have been made in understanding the pathogen and its management practices, some major challenges still exist. One of the major challenges is the identification of resistant germplasm and development of resistant cultivars through conventional breeding (Tushemereirwe et. at 2003).

Screening of both local and elite banana germplasm for resistance is a major ongoing activity. Differential responses of the cultivars to the pathogen have been observed in the field. The mechanisms leading to differential responses by the host plants need to be investigated. Germ-plasm screening trials and field observations in Uganda have shown that some cultivars are able to escape the disease because of their inflorescence morphology (Tushemereirwe and Opolot, 2005).

Very little is known about the life cycle of Xvm. A clear understanding of the pathogen's life cycle and its significance to the epidemic development in bananas is critical to the wilt research agenda. Information on pathogen population structure, pathogen diversity and phylogeny is still lacking and yet important in determining the best strategy for deployment of resistance (Tushemereirwe and Opolot, 2005).

The duration of survival of the bacteria in the soils is not well documented and the relative importance of different routes of infection remains a major challenge. Although prevention of airborne dispersal of the bacteria between inflorescences may be the most important means of controlling the primary spread of the disease, especially between farms and villages, other modes of infection undoubtedly occur and are critical to containment. For example, even in areas of greatest infestation, farmers continue with the habit of borrowing farming tools (Karamura et al., 2006).

The majority of the farmers who control the disease by rouging infected plants do not sanitize their tools with bleach or heat as recommended. Infected plants are not buried but left to decompose in the farm. These diseased plants might serve as sources of inoculum for new infections. Control options such as destruction of infected mats and routine de-budding to reduce the rapid spread of the disease are difficult to organize with sufficient rigor to eradicate the problem in developing countries where farmers lack the structured organizations required to apply eradication programs throughout affected zones or districts and funds are lacking to enforce them. De-budding is also labor intensive and some farmers are unable to cope with this additional task because of old age or infirmity; in other cases plantings (especially of 'Pisang awak') are owned by "absentee" farmers who are difficult to engage in community control campaigns (Karamura et al., 2006).

Alternative food sources such as sweet potato and cassava have been provided to farmers in badly affected areas by NGOs. While some farmers have adopted alternative crops, others still prefer banana as the staple food. One of the most susceptible cultivars in Uganda 'Pisang awak', locally as 'kayinja', is widely grown for the production of "banana beer" that is source of an income for many farmers (Karamura et al., 2006).

Farmers are reluctant to destroy 'kayinja' and other ABB cultivars such as 'Bluggoe' (Kivuvu) even if the plants are infected. It is difficult to persuade farmers to destroy diseased mats since occasionally a diseased mat may still produce a normal bunch. Many farmers also obtain cash income from selling 'kayinja' leaves that are used in preparation of food (Karamura et al., 2006).

'Kayinja' produces numerous suckers, which are able to proliferate well in large mats, needs very little attention and produces large laminas that are not shredded easily by wind. Therefore farmers tend to preserve stands of these plants even if they are infected with Xvm (Peterson and Hunt, 2003).

2.10 Factors that affect adoption of an agricultural innovation

Age: Age may affect a decision to adopt an innovation. It may be that older farmers are more risk averse and less likely to be flexible than younger farmers and therefore have a less likelihood of adopting new technologies. However, it could also be that older farmers have more experience and are better able to assess the characteristics of a modern technology than younger farmers and therefore more probability of adopting the practice (Wozniak, 1994).

Level of education: Education auguments one's ability to receive, decode and understand information relevant to making innovation decisions and this creates an incentive to acquire more information and more efficient in evaluating and interpreting information than those who are less educated (Wozniak, 1994).

Availability of related in puts: The decision to adopt any innovation depends on the availability of related inputs. This suggests that the decision to adopt a current technology may be conditional on the utilization of previously available complementary inputs (Wozniak, 1994).

Availability of credit: The availability of credit may also previously affect adoption of technology by relaxing the binding capital constraints that farmers face during initial investments or help to finance the available costs associated with a technology (Wozniak, 1994).

Agricultural extension: Agricultural extension also enhances the efficiency of making adoption decisions. In the world of less than perfect information, the introduction of new technologies created the demand for information useful in making the adoption decision. Of the much information available to farmers, extension is the most important for analyzing the adoption process (Wozniak, 1994).

Opinion leaders: Opinion leaders are those who others seek information and advice from. They have power to influence the people who follow them. Innovations are more likely to gain popularity within a social system where opinion leaders are supportive (Rogers, 1995).

Gender: Males are faster at adoption of an agricultural innovation than females. This is attributed to access and control of resources that may be necessary for adoption of an innovation. Tushemereirwe et al, (2004) observed that banana bacterial wilt was more common among widow headed household and elderly female headed households. This is because they lack the capacity to adopt innovations.

2.11 Summary of literature review

This chapter reviewed key concepts underlying the study with the view of establishing gaps in knowledge required to generate a solution to the problem in chapter one above. It highlighted the modes of spread of banana bacterial wilt disease, the disease management practices, and factors that affect the adoption of the disease management practices. The reviewed literature provided the researcher with knowledge on all the research objectives and an insight of how to design the questionnaires and interview guides.

CHAPTER THREE:

METHODS AND MATERIALS

3.1 Introduction

This chapter includes the methodology that was employed in conducting the research. It includes research design, study population, structure of the sample, sampling method, data collection methods and instrunments, measurement of validity and reliability, procedure of data collection, data analysis, budget and time frame.

3.2 Study design

Case study design was used, using both qualitative and quantitative research approaches. The study population was the banana farmers of Ntungamo Sub county in Ntungamo district. The quantitative approach enabled adequate number of variables to be investigated. It also permitted more investigation so that data could be generalized to a broad range of people. This research approach permitted the use of simple descriptive and preferential statistics to reach the study conclusion.

Qualitative approach on the other hand made it possible to assess the attitudes, opinions and behaviour of the farmers. In other words it involved the description of aspects of banana bacterial wilt in Ntungamo Sub county that could not be depicted quantitatively.

3.3 Study population

The research was conducted amongst banana farmers of Ntungamo Subcounty. The subcounty has a total population of 22,255 people and 3,790 households (Ntungamo district local government data, 2015). About 85% of the households grow bananas as a major crop. The sub county has nine parishes, namely Butare, Nyaburiza, Nyakyera, Kikoni, Rukoni, Nyarubare, Kahunga, Kizaara and Ruhoko (Ntungamo district local government data, 2015). A sample of 80 farmers and eight key informants was randomly chosen from four major banana growing parishes in the sub county. Every banana farmer had an equal chance of being included in the sample.

3.4. Sample size and sampling procedure

3.4.1. Structure of the sample size

The table below shows what it constituted.

Table 1: Structure of the sample size

Group	Research Participants
Farmers	80
NAADS service providers	1
Agriculture officers	1
LC3 chairman	1
LC2 chairmen	4
Subcounty chief	1
Total	88

3.4.2 Sampling techniques and procedure

Both probability and non-probability sampling methods were used. The probability method was simple random sampling where every farmer had an equal chance of being involved in the study. This method helped to generalize the results to the whole population. Four parishes of Nyarubare, Butare, Kahunga and Ruhoko were randomly sampled and a 20 farmers were randomly sampled in each parish, making a total of 80 farmers.

Non probability sampling/ purposive sampling was used for sampling key informants. This is because such people are very important for the study and random sampling may lead to them not being sampled hence their information may be lost if not purposively sampled. These included 4 parish chairpersons, one subcounty chief, LC3 chair person, one extension worker and District Agriculture officer.

3.5. Data types and collection methods

3.5.1 Data types

Questionnaires, interview guides and observation checklists were used to collect primary data from farmers and key informants while document review was used to collect secondary data.

3.5.2 Data collection Methods

3.5.2.1 interviewing

The researcher used interviewing method. Interviewing enabled the researcher to ask questions to the farmers face to face without the need for farmers to write. This is because some farmers in the area cannot read and write. Besides, the method was convenient for every one who can speak and can enable the researcher to know people's attitudes and feelings. Key informants were interviewed face to face.

3.5.2.2 Questionnaire

Questionnaires were used to collect data from farmers who have the capacity to read and write without anyone guiding them. These constituted both open ended and closed ended questions and were divided in to sections according to the information required.

3.5.2.3 Observation

Observation was used to enable the researcher to observe banana fields affected by the disease and the disease management practices that the farmers are carrying out. This gave the researcher a clear view of the study problem.

3.5.2.4 Documentary review

This was used to capture data which could not easily be available using other data collection instruments. Reports from other researchers in the relevant study area were reviewed.

3.6 Validity and reliability

Validity of the instrunments was ensured through pre-testing on the non-target sample population. This helped the researcher to know if the respondents were providing the required responses or not and to also see if all the questions were answered hence generally accepted. Pre-testing was done in Nyaburiza parish. In order to address content validity, the researcher also used the professional in the field of agriculture to read through the interview guides and questionnaires to see if the questions were valid according to the topic. After pre-testing, some questions were reviewed basing on the responses and comments. The reliability of the instrunments were tested using test-re test method where they were tested in Nyaburiza and then after sometime retested again. And then the results from the two processes were compared.

3.7. Ethical considerations.

The researcher ensured that all research ethical standards were adhered to. Anonymity and confidentiality were ensured and there was informed consent. The lives of the respondents were not put at any risk as interacting was naturally in open places so that it did not raise suspicion. The researcher ensured accuracy of the data and plagiarism was avoided by referencing.

3.8. Data analysis

Data was analyzed both qualitatively and quantitatively. Qualitative analysis analyzed qualitative data. This involved coding the data where the responses were assigned numerical values and then the coded values were interpreted and described using descriptive statistics. Quantitative data was processed and analyzed by editing where by the errors collected were identified and eliminated. This ensured completeness, accuracy, legibility and comprehensibility before analysis was done. It was then coded, analyzed and interpreted.

A computer software package, SPSS was used in data entry and analysis. The researcher carried out both univariate and bivariate analysis.

3.8.1. Univariate analysis

Analyzing the individual characteristics of each variable was done using frequency tables to check for the percentage and number of occurrences. Graphs were also used to give a clear picture of the percentages. These included bar graphs and pie charts.

3.8.2. Bivariate analysis

Cross tabulations and correlations were used for bivariate analysis.

CHAPTER FOUR

DATA PRESENTATION, ANALYSIS AND INTERPRETATION

4.0 Introduction

This chapter presents the research findings, i.e. data presentation, analysis and interpretation.

4.1 Presentation of findings

4.1.1 Demographic characteristics of respondents

4.1.1.1 Sex of respondents

The results in Table 2 below show that 80% of the respondents were males and 20% were females. This is not a surprise because perennial crop production is often dominated by males who are often more involved in cash crop production while women are often more involved in the production of food crops.

Table 2: Sex of respondents

Sex	Number of respondents	Percent
Male	64	80.0
Female	16	20.0
Total	80	100.0

Males are faster at adoption of an agricultural innovation than females. This is attributed to access and control of resources that may be necessary for adoption of an innovation. Tushemereirwe et al, (2004) observed that banana bacterial wilt was more common among widow headed household and elderly female headed households. This is because they lack the capacity to adopt innovations.

4.1.1.2 Age of respondents

Table 2 below shows that the majority, (35%), of the respondents were between 20-39 years, followed by those between 40 -59, at 30%. There were very few respondents below 20 years (5%). This is not surprising since most people below 20 years do not have families and also do not own land for agriculture.

Table 3: Age of respondents

Age	Number of respondents	Percent
Less than 20	4	5.0
20 – 39	28	35.0
40 – 59	24	30.0
60 – 79	18	22.5
80+	6	7.5
Total	80	100.0

It may be that older farmers are more risk averse and less likely to be flexible than younger farmers and therefore have a less likelihood of adopting new technologies. However, it could also be that older farmers have more experience and are better able to assess the characteristics of a modern technology than younger farmers and therefore more probability of adopting the practice (Wozniak, 1994). In this case, it was observed that most old farmers adopted the management practices as most of them used atleast thee at once (table5).

4.1.2 Specific objective No. 1 results

Objective 1: BBW Management Practices and their acceptability and adoption

4.1.2.1 Cases of farmers who had experienced BBW in their banana plantations

Table 4: Respondents who had experienced BBW in their banana fields

Experienced BBW in their banana fields	Number of respondents	Percent
Yes	16	20.0
No	64	80.0
Total	80	100.0

Table 4 above shows that only 16 (20%) of the 80 respondents reported that they had experienced Banana Bacterial Wilt in their banana fields. The high percentage of farmers, (80%), who were not affected by BBW is attributed to the government's quick effort in conjunction with NARO to establish a task force to control the disease. The fact that the disease started in the central and eastern regions of the country before spreading to the south west was a big advantage to the farmers of Ntungamo as by the time it spread there, the experts/agriculturalists had gained more experience on containing the disease and even sensitization via radios was already going on; so farmers were more alert and careful.

4.1.2.2 Symptoms of BBW

Table 5: Responses on symptoms of BBW

Symptoms of BBW	Number of respondents	Percent	Percent of Cases
Premature ripening of fruits	78	29.3%	97.5%
Yellowing/scorching of leaves	68	25.6%	85.0%
Yellow puss-like fluid oozing out of the cut stem	51	19.2%	63.8%
Brown colouration in the middle of the cut banana finger	31	11.7%	38.8%
Rotting of male buds	38	14.3%	47.5%
Total	266	100.0%	332.5%

Table 5 above shows the respondents' answers on the symptoms of BBW. Most farmers were able to identify the BBW symptoms as shown in the above table. Premature ripening of fruits was the easiest symptom of BBW to be identified by farmers (29.3%) and brown colouration in the middle of the banana finger was reported by the lowest number of farmers (11.7%). It was revealed that the majority of the respondents could easily know the diseases by a common symptom of premature ripening of fruits and yellowing/scorching of leaves.

In an interview with one of the key informants, he said;

"No farmer in the whole district does not know the symptoms of banana bacterial wilt because no plant disease has ever been talked about like it. Farmers get information from almost everywhere around them. Even those who do not go for trainings can access it through radios and neighbours. If any farmer tells you that he does not know how the disease is spread, it is like a person telling you that he does not know that having sex with an infected person can make one acquire HIV/AIDS. In other words it is a lie".

4.1.2.3 Sources of information on BBW

Table 6: How farmers learnt about BBW in Ntungamo Subcounty

Source of information	Freq	Percentage
Extension agents	09	56.3
Religious leaders	04	25
Friends and neighbors	02	12.5
Political leaders	01	6.2
Total	16	100

The affected farmers were able to identify the disease with the help of many stake holders including extension agents 56.3%, political leaders 6.2%, religious leaders 25%, friends and neighbours 12.5%. This means that the participatory approach towards controlling the disease was well incorporated in the area.

In an interview with one of the extension agents, he said,

> *"When I noticed how the colour of leaves was changing and the way banana fingers were unevenly ripening when they were still young, I had to rush and started informing community members I could reach to be aware of the diseases by telling them how it attacks and showing them samples from the already affected parts".*

The NAADS extension agents had to move to every village training the farmers on how to identify and manage the disease. Those who noticed the signs were told to report to the extension agents immediately. The disease was also talked about in churches and all other social gatherings.

During the interview, one of the respondents said, *"It was one Sunday afternoon after the church service when the reverend was requesting and cautioning people that had come for the services to diversify their economy instead of relying only on matooke for food and income, then he mentioned the new diseases that attacks bananas and they end up ripening prematurely or gets rotten by calling it "kajunde" in the local language".*

Agricultural extension enhances the efficiency of making adoption decisions. In the world of less than perfect information, the introduction of new technologies created the demand for information useful in making the adoption decision. Of the much information available to farmers, extension is the most important for analyzing the adoption process (Wozniak, 1994). This explains why most farmers whose crops were affected by BBW got information from extension workers.

Opinion leaders have power to influence the people who follow them. Innovations are more likely to gain popularity within a social system where opinion leaders are supportive (Rogers, 1995). Farmers were able to get information from opinion leaders like Local council chairpersons, politicians, and religious leaders among others. This made the management practices easily adopted and accepted.

4.1.2.4 BBW Management Practices used in Ntungamo Subcounty

Table 7: BBW Management Practices used

	Number of respondents	Percent
Removing infected plants at the first signs	18	42.9%

Using clean planting materials	10	23.8%
Debudding with a forked stick	8	19.0%
Disinfecting tools with fire	5	11.9%
Disinfecting tools with jik	1	2.4%
Total	42	100.0%

Table 7 above shows five BBW management practices used by farmers in Ntungamo Sub county. It was observed that the farmers who experienced banana bacterial wilt were aware of the BBW management practices and they were able to control it by practicing them with removing infected plants at the first signs being the most practiced at 42.9%. Using clean planting materials followed at 23.8%, then debudding with the forked stick was 19%. Although all the farmers were debudding immediately after the last hand was formed, most farmers were using knives, which is not a recommended practice. Farmers find using knives faster than forked sticks. Disinfecting the tools was the least used practice, especially using Jik (sodium hypochlorate) which was done by only 2.4%. This is because farmers saw it expensive to buy and also laborious to disinfect after every cut. 11.9% disinfected with fire. This concurs with Buruma et al., (2004) who observed that the majority of the farmers who control the disease by rouging infected plants do not sanitize their tools with bleach or heat as recommended. Infected plants are not buried but left to decompose in the farm. These diseased plants might serve as sources of inoculum for new infections. The management practices enabled the affected farmers to contain the disease. These findings correspond with Blomme *et al*, (2009) that the risk of infection through the inflorescence has been shown to be markedly reduced by the removal of the male bud by means of a forked stick (not cutting it off with a knife). The study findings further concur with Tushemereirwe *et al*. (2003) that once the disease has been detected in a field, disinfecting tools (pangas, knives, leaf removers, hoes etc.) before using them on other plants would help prevent the spread of the bacteria to healthy plants.

41.2.5 Challenges of BBW management in Ntungamo Subcounty

Table 8: Challenges of BBW management in Ntungamo Sub county

	Number of respondents	Percent
Laborious	10	62.4
Expensive	06	37.6
Total	16	100.0

From the study findings presented in Table 8 above, it was established that 62.4% of the respondents who were affected by the disease confessed that it was laborious to manage the disease while 37.6% of the farmers who also got affected by the disease indicated that it was expensive. Basing on the fact that it involves too much labour to remove the affected species by cutting and burying them, then using fire or jik to clean the tools used to remove the affected ones, it’s too much work and expensive to pay for labour.

4.1.2.6 Effect of education level on adoption of BBW management practices

Figure 1 below shows the education level of the respondents. It was observed that the highest number of respondents, (47.5%), had primary level of education, followed by 32.5% who had secondary level of education and 17.5% who had attained tertiary level of education. This means that majority of the farmers had attained some level of education. 0nly 2.5% of the respondent farmers had never gone to school.

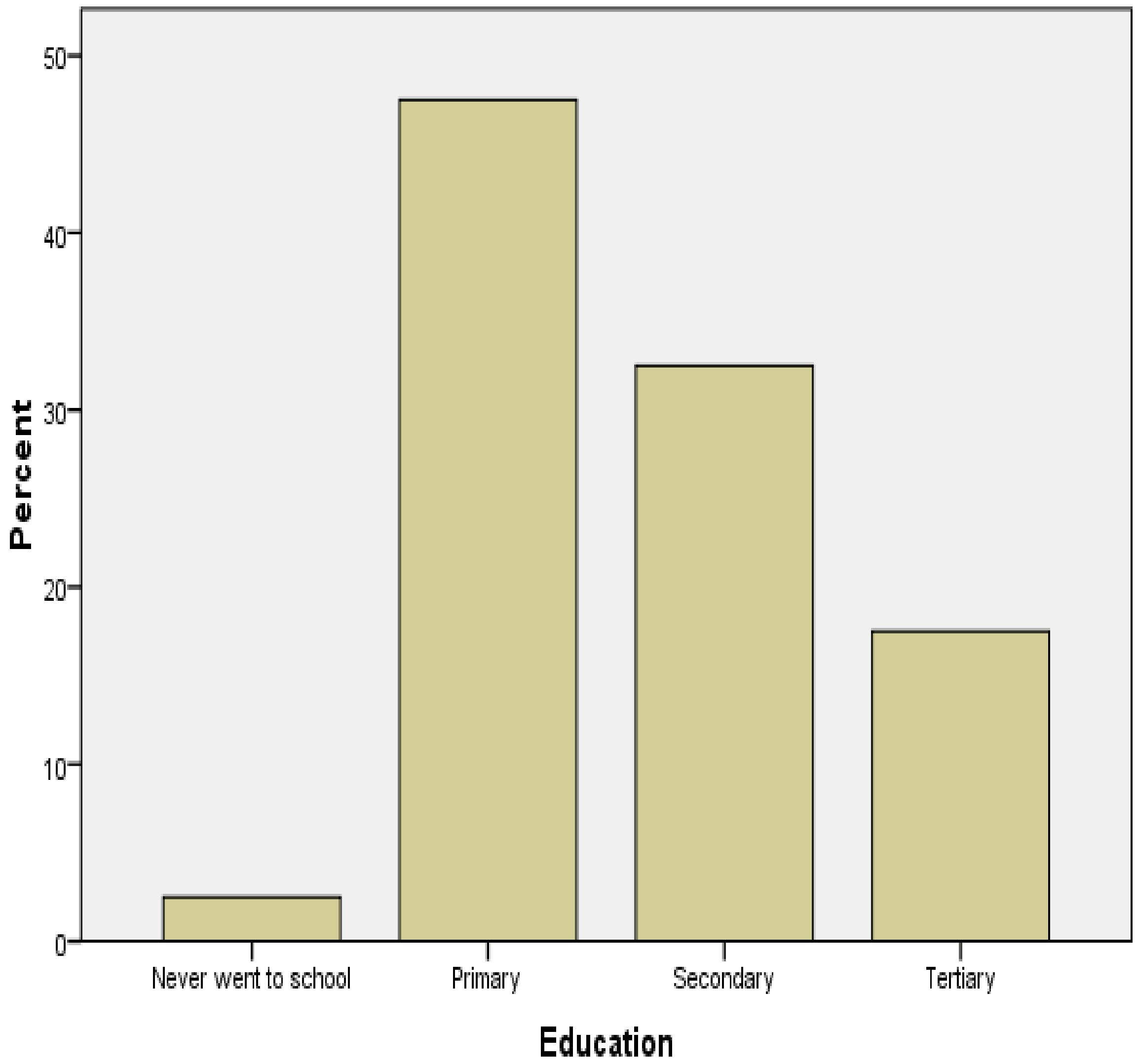

Figure 1: Education level of the respondents

Farmer level of education is generally assumed to affect the adoption and application of new technologies. It is assumed that farmers with a higher level of education are better at implementing and adhering to new practices and technologies. Education auguments one's ability to receive, decode and understand information relevant to making innovation decisions and this creates an incentive to acquire more information and more efficient in evaluating and interpreting information than those who are less educated (Wozniak, 1994). However, in this case it was found that the correlation between education level and BBW management was 0.193; this is a low correlation. This means that the farmer level of education did not have a significant effect on the effectiveness of BBW control and management.

Table 9: Correlation between education level and BBW management

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.193	.077	1.740	.086[c]
Ordinal by Ordinal	Spearman Correlation	.210	.088	1.899	.061[c]
N of Valid Cases		80			

4.1.2.6 Effect of income on adoption of BBW management practices

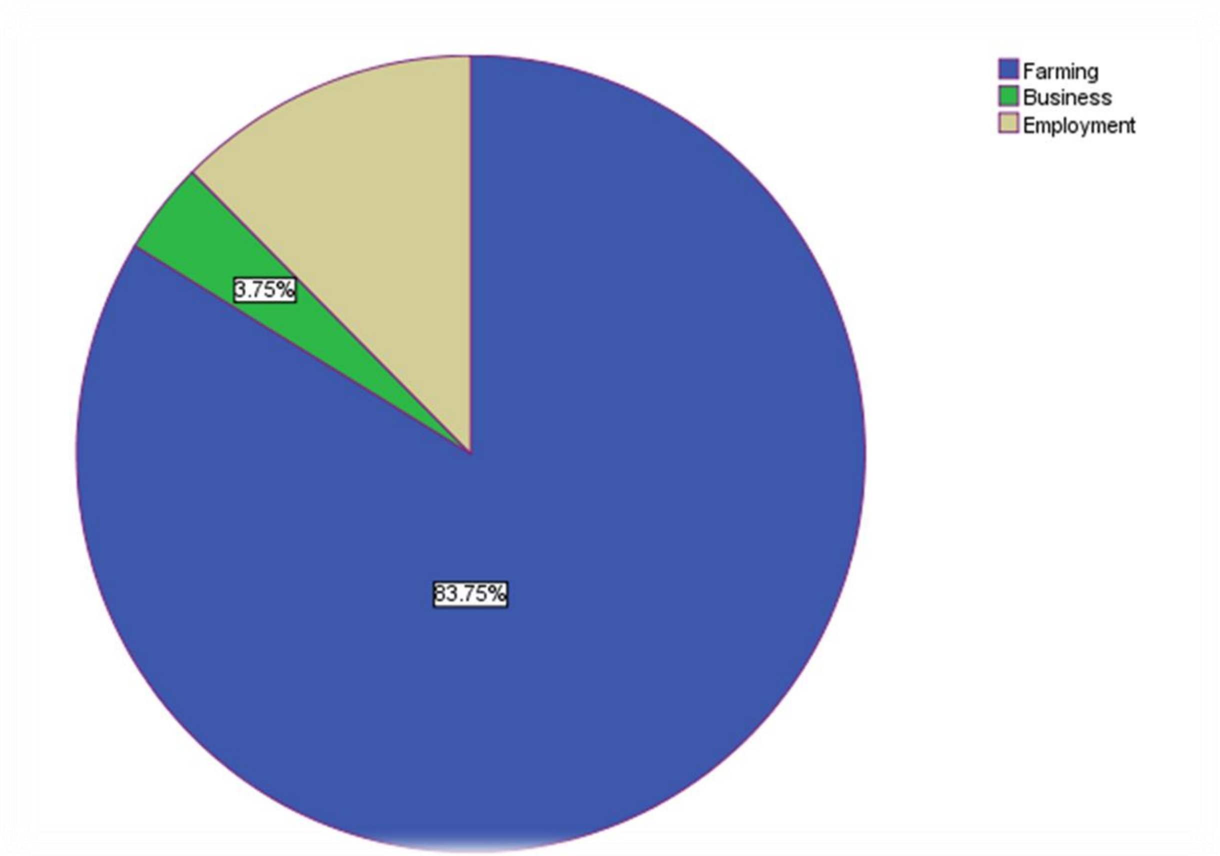

Figure 2: Main source of income

The figure 2 above shows that most people's (83.8%) main source of income was farming. Only 12% of the respondents reported employment as their major source of income while only 3.8% reported business. This implies that most people in the sub county are farmers, which is the main economic activity in all Uganda's rural areas. This also meant that BBW was very likely to have a big impact on most of the people's income in the sub county. However, again the correlation between the level of income and BBW management was found to be 0.21; a low negative correlation. This means that a farmer's level of income does not affect BBW control methods used. In other words, having additional income to invest in the plantation does not guarantee control of the disease as there is no cure for BBW.

Table 10: correlation between level of income and BBW management

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.021	.095	.188	.852[c]
Ordinal by Ordinal	Spearman Correlation	.034	.105	.305	.762[c]
N of Valid Cases	80				

4.1.2.7 Challenges of BBW management in Ntungamo Sub county

Table 11: Challenges of BBW management in Ntungamo Sub county

	Number of respondents	Percent
Laborious	10	62.4
Expensive	06	37.6
Total	16	100.0

From the study findings presented in Table 10 above, it was established that 62.4% of the respondents who were affected by the disease confessed that it was laborious to manage the disease while 37.6% of the farmers who also got affected by the disease indicated that it was expensive. Basing on the fact that it involves too much labour to remove the affected species by cutting and burying them, then using fire or jik to clean the tools used to remove the affected ones, it's too much work and expensive to pay for labour.

Objective 2 Extent to which BBW has affected banana production in Ntungamo sub county

4.1.3.1 Effects of BBW on people's livelihood in Ntungamo Sub county

Table 12: Effects of BBW on people's livelihood in Ntungamo Sub county

Effects of BBW on	Number of respondents	Percent
Food security	10	62.5%
Reduced income	6	37.5%
Total	16	100.0%

Table 6 above shows the effect of BBW on the livelihoods of the 16 respondents who had experienced BBW in their banana fields. Ten, (62.5%), of the 16 respondents reported that the disease had mainly affected their food security, while 6 respondents, (37.5%), reported that the disease had reduced their incomes. Food security was the most affected because all the farmers grow bananas foremost for food. Not all of them grow bananas for sale, a reason why effect on income was less. However, these effects also lead to other problems like inability of parents to pay school fees and pay for other household expenses as a result of increased spending on buying posho for food and also on controlling the disease.

During the interview with one of the respondents on whether he had ever experienced BBW he said, *“Hhhhhmmmmm….please don’t take me back to sorrows that I have been trying to forget about because before that disease had attacked my banana plantation, my children had never lacked school fees since it was my main source of income”.*

4.1.3.2 Effect of BBW on banana production

Table 13: Land size of the respondents and land under banana production

	Land size		Land under bananas	
Land size (in acres)	Number of respondents	Percent	Number of respondents	Percent
Less than 5.0	12	15.0	27	33.8
5.0 - 9.9	21	26.2	31	38.8
10.0 - 14.9	16	20.0	17	21.2
15.0 - 19.9	13	16.2	5	6.2
20.0+	18	22.5	0	0
Total	80	100.0	80	100.0

Table 13 above shows land size of the respondents, and the size of land under banana production. It shows that 26.2% of the respondents own between 5 and 10 acres of land, followed by 22.5% with 20+ acres, 20% with 10 – 14.9 acres and 16.2% with 15 -19.9 acres. Only a few respondents (15%) own less than 5 acres (2 hectares). This means that most of the respondents generally own small pieces of land, mainly for subsistence crop production.

The same Table, (13) shows that majority (38.8%) of respondents produce bananas on between 5-10 acres followed by 33.8% who produce bananas on less than 5 acres and 21.2%

on 10 -15 acres. Only 6.2% of the respondents had between 15-20 acres under bananas. Therefore 72.6% of the respondents produce bananas on less than 10 acres or 4 hectares of land. The same table shows that the 18 respondents who own 20 acres (8 hectares) and above do not grow bananas at all.

Table 14: Acres of land affected by banana bacterial wilt

	N	Minimum	Maximum	Sum	Mean	Std. Deviation
Acres affected	16	.5	6.0	40.0	2.500	1.6633
Valid N (listwise)	16					

The above statistics show that the land under banana production which was on average 6.57 acres was reduced by 2.5 acres as a result of banana bacterial wilt. If an acre produces 2.5 tonnes per annum, it means that 6.2 tonnes of banana were lost per annum. On average, a bunch of matooke is 30kg which means that 206 bunches were lost per annum. If each bunch costs 8000 shillings, then it is estimated that the farmer lost an average of 1,648,000 million shillings.

4.1.4 Specific objective No. 3 results

Objective 3: Effectiveness of the introduced BBW management practices in controlling the disease

From the data collected, effectiveness of BBW management practices was reported at different levels. However, all the farmers reported using at least three of the BBW control and management practices concurrently. Findings presented in Figure 3 below reveal that

47% of the farmers reported that the practices are fairly effective. This is probably due to the fact that the farmer needs to put in some personal additional effort if they are to be very effective which was reported by 9% of the farmers. For example one has to always inspect the plantation, to prevent neighbours from cutting banana leaves and fibres as they may be using contaminated tools, in order for the practices to be effective, which was reported by 40% as very effective. Ineffectiveness which was reported by 4% is probably due to the fact that it is expensive and laborious so those who do not have enough money and man power do not find them effective.

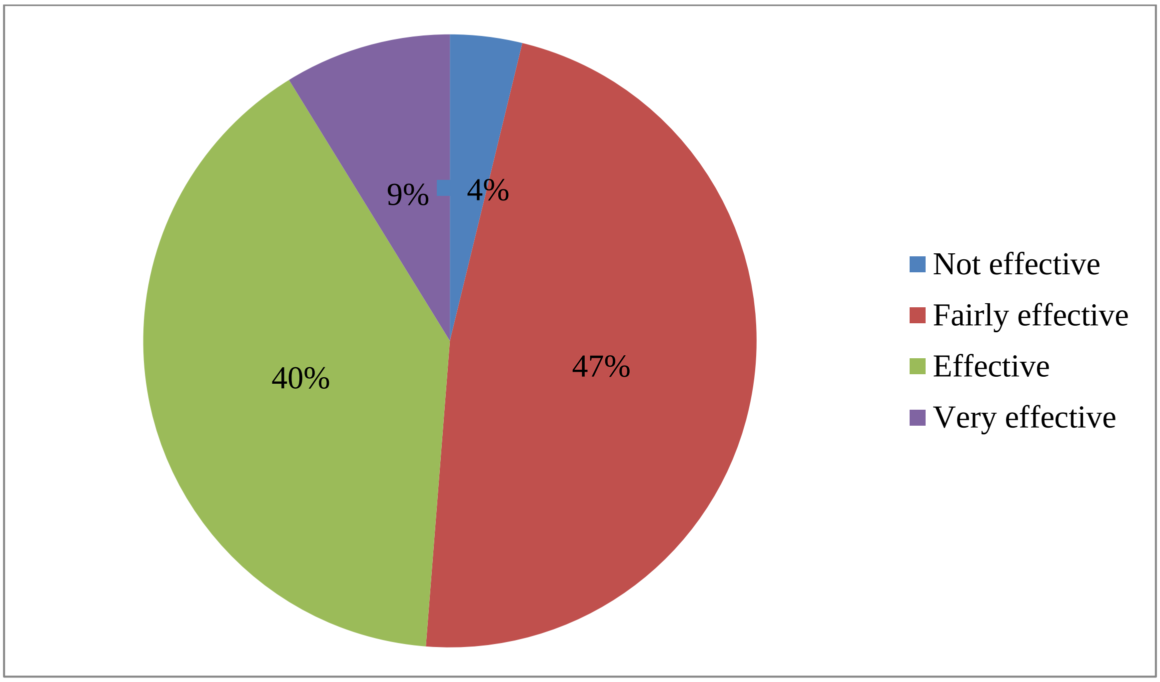

Figure 3: Effectiveness of BBW management practices

In an interview with one of the key informants, he said,

"The management practices are all effective but we have been telling farmers that they have to integrate all the practices together in order to be very effective and they have tried to comply. One cannot work without others. For example if you destroy the affected plants but you do not infect the tools you used, you will affect the healthy plants"

4.1.4.1 Acreage under banana production

The assumption is that farmers with a larger acreage under banana production have a higher income therefore more income to invest in controlling banana wilt management. Thus they reported as the BBW management practices being effective

The correlation is 0.099; this is a low positive correlation. This means that acreage under banana production has no significant effect on the effectiveness of BBW management/control methods

Table 15: Correlation between land under banana production and effectiveness of Banana bacterial wilt management

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Interval by Interval	Pearson's R	.099	.117	.878	.382[c]
Ordinal by Ordinal	Spearman Correlation	.099	.114	.877	.383[c]
N of Valid Cases		80			

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This chapter consists of the conclusion and recommendations concerning the study phenomena

5.1. Conclusions

5.1.1 Objective 1: Assessing the disease management practices that have been introduced in the sub-county and their acceptability and adoption

According the objective one which was about assessing the disease management practices that have been introduced in the sub-county and their acceptability and adoption rate, findings revealed that farmers are aware of the BBW management practices and they are practicing them with removing infected plants at the first signs (42.9) and using clean planting materials (23.8%) being the most practiced. Disinfecting tools with jik was the least used practice at 2.4%.

20% of the farmers had experienced banana bacterial wilt while 80% had not. It was discovered that most farmers who experienced BBW were able to identify the disease symptoms, with premature ripening of the fruit being the easiest to identify (29.3%).

Farmers were able to identify the disease with the help of many stake holders especially extension workers(56.3%).others included religious and political leaders, friends and neighbours.

Removing infected plants was the most reported management practice with 42.9% while disinfecting the tools with jik was the least reported with 2.4%. it is assumed that farmers with higher education level are better adopted to manage the disease (Wozniak, 1994) but the correlation between education and management was 0.193, which is a low correlation. This means that there is no significant relationship between education level and adoption of management practices. Also, there was no significant relationship between level of income and adoption of BBW management practices as the correlation was 0.21. This disagrees with the Wozniak (1994) study.

Farmers also reported that they have challenges with the adoption of these management practices as they said they were very laborious (62.4%) and expensive (37.6%). These challenges have made it hard for the disease to be completely eradicated.

5.1.2 Objective2: Establishing the extent to which BBW has affected banana production in Ntungamo sub-county

Basing on study objective two about establishing the extent to which BBW has affected banana production in Ntungamo sub-county, study findings revealed that the land which was used for banana production was reduced by 2.5 acres per affected farmer. This is a very big loss which has led to other effects like reduced income (35.5%) and food insecurity (62.5%).

5.1.3 Objective 3: Effectiveness of the introduced BBW management practices

According to the study findings, effectiveness was reported at different levels however all the farmers reported as using all three of the BBW control and management methods like, Debudding with a forked stick, Removing infected plants at the first signs and using clean planting materials

According to study findings by use of correlation it helped to determine if BBW is better and more effectively managed when the control methods are introduced at the early stages of infection. The correlation is -0.5173: this a high negative correlation. This means that the fewer plants infected by BBW the more effective the control methods are.

According to study findings, 47% of the farmers reported that the practices are fairly effective and 40% of the contacted respondents indicated that the practices were very effective. It was also revealed that farmers use different practices at the same time in order to control the disease.

Study findings further indicated that farmer level of education may affect the effectiveness of BBW management methods, it is assumed that farmers with a higher level of education are better at implementing and adhering to these methods. The correlation is 0.193; this is a low correlation. This means that the farmer level of education does not have a significant effect on the effectiveness of BBW control and management methods used.

5.2 Recommendations

According to the study findings, the following recommendations were made;

According to study findings, it was revealed that; early disease detection is very important to enable the farmers be able to devise means of dealing with the diseases. However the input of various stakeholders like extension workers, religious leaders among others in informing the public about the presence of the disease in the area played a big role in creating awareness about the presence of the disease. Therefore, the capacity of such structures should be built more to enable them easily detect and provide information to the general public on how to prevent and manage BBW.

There is also need for the government to implement policies to enable microfinance institutions to provide credit to farmers. This will enable farmers to buy chemicals like jik for sterilizing the tools and also to buy tools like pangas and hoes, hence avoiding sharing of tools which will reduce on the disease spread.

5.3 Areas for further research

Research to develop and identify materials that are tolerant to the disease should be done and those materials should be multiplied massively and supplied to farmers.

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APPENDIX 1: QUESTIONNAIRE

Section A: Personal biodata:

1. How old are you? ……………………………….

2. Sex?

i) Male ii) Female

3. Marital status?

i) Singe ii) Married iii) Widowed iv) Divorced/ separated

4. What is your level of education?

i) Never went to school ii) Primary iii) Secondary iv)Tertiary

5. What is your main source of income?

(1) Farming ii) Business iii) Salary iv) 0thers…….

6. What is the size of your land on which banana is grown in acres?

Section B: BBW Management Practices and their acceptability and adoption

7. Have you had any case of banana bacterial wilt in your plantation?

(i)Yes (ii) No

8. If yes, how did you know it was banana bacterial wilt?

i) I had already seen it somewhere else

ii) I had learnt about it from extension agents

iii) I consulted an extension worker/ an expert who told me

iv) My neighbour/ friend knew about it

9. What are the symptoms /characteristics of banana bacterial wilt?

i) Pre-mature ripening of fruits

ii) Yellowing/ scorching of leaves

iii) Yellow pus-like fluid oozing out of cut stem

iv) Brown colouration in the middle of cut banana finger

v) Rotting of male buds

vi) Others ……………

10. if you experienced the disease,What are the measures / practices that you under took to control banana bacterial wilt/ disease?

i) ………………………………………………………………………………..

ii) ………………………………………………………………………………..

iii) ………………………………………………………………………………..

iv) ………………………………………………………………………………..

v) ………………………………………………………………………………

11. If you did not practice any, why?

i) ……………………………………………………………………...........................

ii) ………………………………………………………………………………..

iii) …………………………………………………………………………………

Section C: Effectiveness of BBW Management practices

13. How effective are these measures / practices above……………………………………..

i) Not effective

ii) Fairly effective

iii) Effective

iv) Very effective

i) 14. What challenges do you face while implementing banana bacterial wilt management practices?…………………………………………………………………………………………..

ii) ……………………………………………………………………………………….

iii) ……………………………………………………………………………………….

iv) …………………………………………………………………………………………

v) …………………………………………………………………………….

Section D: Effects of BBW

15. How has the disease affected you and your household?

i) …………………………………………………………………………..

ii) ……………………………………………………………………………

iii) …………………………………………………………………………….

iv) ……………………………………………………………………………

v) ………………………………………………………………………….

16. Of the total achourage under banana production, how many acres were affected by BBW?

………………………………………………..

17. How much income from banana sales did you lose as a result of BBW?

……………………………………………………………………………

18. what other challenges did you face as a result of BBW?

19. For how long has the household head been affected by banana bacterial wilt? ....

20. What are the characteristics that make some banana varieties prone to BBW disease………………………………………………………………………………………… ………………………………………………………………………………………… ………………………………………………………………………………………… …………

21. (A) Do you have access to extension services teaching about banana bacterial wilt?

(i)Yes ☐ (ii) NO ☐

(b) if yes, how often do you receive the services?

(i) Once in a month ☐ (ii) Once in quarter ☐

(iii)Once in a year ☐ (IV) Never ☐

22 .(a) What is the source of the knowledge used?

(i)Extension worker ☐ (ii) Private services provider ☐

(iii) Farmer association ☐ (iv) Fellow farmers ☐

(v)Others specify

…………………………………………………………………………………………

……………………………………………………………………………………

☐ ☐

23. (a) How often do you apply the above methods on your crop fields?

(i) Every day ☐ (ii) Less than week ☐

(iii) After a months ☐ (IV) Once in awhile ☐

24. What have you gained from controlling BBW disease using methods shown in question 11?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

25. What challenges have you faced in using the above methods on crop production?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………….

26. How have you tried to solve the above challenges?

……………………………………………………………………………………………………

…………………………………………………………………………………………………..

…………………………………………………………………………………………………..

27. Do you think applying farmers approach will improve on banana production in your community? If yes tell me why?

28. What are the lessons learnt in managing BBW disease

…………………………………………………………………………………………….

………………………………………………………………………………………..

……………………………………………………………………………….……

29. What are the recommendations and conclusion do you give to banana farmers and researchers?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

……………………

………………………………………………

30. Any other comments about BBW in general?

…………………………………………………………………………………………………

…………………………………………………………………………………………

Thank you very much for your time

APPENDIX 2: INTERVIEW GUIDE FOR KEY INFORMANTS

1. What is the main source of income for the people around this area?
2. What is the average size of land by the households in this area, that is under banana production?
3. How do farmers access information about banana bacterial wilt?
4. Do the farmers know the BBW management practices?
5. Which strategies have they adopted and have worked?
6. Which strategies have they not adopted and why?
7. How effective are the adopted strategies in controlling BBW?
8. How has the disease affected farmers?
9. How has it affected this area?
10. How many parishes were affected by this disease in Ntungamo subcounty?
11. How has the government intervened to control the spread of BBW?

APPENDIX 3: PICTORIAL

Figure 4: Showing Mpologoma variety banana affected by bacterial wilt

Figure 5: Showing pale yellow bacterial ooze from a cut pseudo stem (source: www.promusa.com)

Figure 6: showing a colony of Ndizi banana infested by Banana bacterial wilt

Figure 7: A wasp, attracted to male banana florets.