Understanding the economic impact of BXW and its management practices in East and Central Africa

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November 2018

ISBN: 978-92-9255-116-2

Correct citation: Di Cori V, Kikulwe E, Kozicka M, Gotor E (2018) Understanding the economic impact of BXW and its management practices in East and Central Africa. Bioversity International, Rome, Italy. p. 16, ISBN: 978-92-9255-116-2

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Acknowledgments

The research leading to this paper was made possible thanks to the discussion during the Workshop on long-term socio-economic consequences of BXW spread in Uganda, held in Kampala on the 1st and the 2nd of February, 2018. Therefore, we would like to thank Eldad Karamura, Guy Blomme, David Brown, William Tinzaara, Walter Ocimati, Jerome Kubiriba, Juliet Nakakawa, Godfrey Taulya and Gloria Mbabazi. We also would like to thank for the financial support the GCIAR Program on Roots, Tubers and Bananas (RTB) and the scholarship program “Torno Subito” founded by the Italian government and EU. Finally, we would like to thank Professor Francesco Caracciolo who contributed to the conceptual framework and Vincent Johnson for the proofreading.

Abstract

Banana Xanthomonas wilt (BXW) is a widespread banana disease in East and Central Africa (ECA). It has the ability to cause up to 100% yield loss, severely compromising food security and livelihoods for banana-based farming households. There are no BXW-resistant varieties, and cultural management practices offer the only means of control. However, adoption of these practices by farmers has been lower than expected, mainly because of their high cost and labour-intensiveness. There are also other actors, both in public and private sectors, playing an important role in the disease management and facing different costs related to it.

Our literature review reveals that a cost analysis of the banana value chain as a whole is missing. By this we mean consideration of not only farmers, who have to sustain the cost of management practices, but also other stakeholders involved, as national and local governments, research institutions and agricultural extensionists. In this study we identify economic actors involved in the banana value chain together with their costs related to the disease management and propose a cost analysis conceptual framework. Further, we review determinants of adoption of the BXW management practices and finally relate them to the estimates of costs of inaction (losses due to BXW spread). In this way, we present a comprehensive picture of costs of BXW spread vis-a-vis the costs of management practices and indicate possible ways to tip the balance in favour of the disease eradication.

Ongoing research needs to carry out ex-post analyses on different costs sustained by the stakeholders of banana value chain, and ex ante analyses to predict future scenarios which represent possible alternatives, depending on whether and how the disease will be managed in the coming years. Those results will better inform decision-makers at national, regional, and international levels and provide support in designing strategies to cope with the BXW spread across the ECA region.

1. Introduction

Approximately one-third of bananas produced globally are grown in sub-Saharan Africa, where the crop provides more than 25% of food energy requirements for more than 100 million people (Tripathi et al., 2009). East and Central Africa (ECA), make up the largest banana producing and consuming region in Africa. Banana and plantain are indeed one of the most important staple food crops, contributing to rural populations' household food security and revenues (Ouma et al., 2010). Food security studies reveal that in Uganda, Rwanda and Burundi, for example, bananas constitute more than 30% of the daily per capita caloric intake, and as high as 60% in some regions (Abele et al., 2007). This high level of local consumption also makes bananas an important cash crop.

Additionally, bananas play an important role in environmental conservation, whereby they provide a good soil cover that reduces soil erosion on steep slopes and are a principal source of mulching material for maintaining and improving soil fertility (Kalyebara et al., 2006).

Regarding the production systems in the region, there is complexity that derives from the diversity in agro-ecological conditions, as well as the socio-economic variability across the region. According to Karamura et al. (1998), the diversity can be found in the intensity and/or level of management associated with a given system. It can range from diversity in crop management practices—planting materials used, irrigation, pest control practices, cropping system (mixed/intercropping) employed, yields attained and associated end uses and incomes—to socioeconomic factors around the farmer, including their perceptions, options, priorities, availability of inputs and extension support and returns to investment.

The banana system in ECA can be divided in three broad categories: backyard garden systems, smallholder systems and plantation systems.

Backyard garden systems are low-input, found throughout the region, most often in the suburban regions of ECA, where land is a key determinant of farm size. In this system, farmers usually pay minimal attention to crop management, as the purpose of the crop is usually to supplement other food sources. As a result, banana backyard garden systems tend to be an important pest and disease reservoir, from where other banana stands in the vicinity may be infested (Karamura, et al., 1998).

The **smallholder banana systems** are those that dominate the banana farming system in the region (Kikulwe et al., 2018). They are perennial, low-input, small (0.25- 5 ha) and rural-based systems in Africa. The primary purpose of these systems is food security, but commercial interests have more recently increased in importance. Consequently, these systems have attracted a lot of technical attention, particularly with regard to pest management. Despite this, the system has been identified as being more vulnerable to banana pests and diseases than the plantation banana system (Karamura et al., 1998, Kikulwe et al., 2018).

The **Banana plantations system** is the least complex (i.e., single cultivar, uniform management), but it is no less important, as it accounts for most of the dessert banana exported to temperate markets. With clearly defined commercial objectives, it is intensively managed from selection and treatment of planting materials and stand management (including pest and disease control), through to marketing and/or processing. Consequently, production and income, as well as consumer/market requirements, are predictable (Karamura et al., 1998) and the importance of pests and diseases is limited.

A series of stakeholders other than farmers are involved in the banana systems in different ways, and each actor plays a distinct role to ensure that the level of infection of pests and diseases, such as BXW remains as low as possible, without compromising income and food security for farmers. These actors belong both to public and private sectors, including semi-autonomous research centres.

Currently, the production of bananas is being affected by diseases of fungal, bacterial and viral origins, as well as other environmental issues linked to climate variability, including extreme rainfall as floods and droughts, hail-storms, and high surface air temperatures (Ddumba et al., 2016). These two factors are therefore connected; in fact, there are more frequent or severe outbreaks of the diseases due to the climate variability and climate change. And it is expected that further climate change will increase the pressure from biotic stress factors in the future (Rosenzweig et al., 2001)

This broad range of banana diseases does not only affect the African continent, but also Asia and Latin America. As a matter of fact, independent of a region and production system, pests and diseases have been considered the main constraints responsible for yield losses and low productivity among bananas worldwide (Blomme et al., 2017).

Banana Xanthomonas wilt (BXW), also known as banana bacterial wilt (BBW), caused by *Xanthomonas vasicola pv. musacearum* (*Xvm*) (Valentine et al., 2006), represents a widespread illness among banana crops in ECA region, especially in the countries surrounding the Great Lakes region (this region includes Burundi, Democratic Republic of Congo, Kenya, Rwanda, Tanzania and Uganda). It is a vascular disease that results in permanent wilting and the eventual death of the plant. All banana cultivars and genome groups are susceptible to BXW, which has the ability to cause up to 100% yield loss, severely compromising food security and livelihoods for banana-based farming households (Blomme et al., 2017).

Although a number of regional, national, and international institutions have developed a series of practices for BXW management, efforts to control the disease have met with only partial success, and the disease has continued to encroach into previously disease-free areas and to resurge in areas where it had previously been controlled (Tinzaara et al., 2016).

Since there is no resistance to BXW so far reported among the local *Musa* germplasm in East and Central Africa, the control strategies for BXW are mainly based on cultural practices (Kubiriba and Tushemereirwe, 2014). Nevertheless, the development of disease-resistant banana cultivars remains a high priority since farmers are often reluctant to employ labour-intensive disease control measures (Namukwaya et al., 2011) severely compromising its eradication.

This study aims to investigate the current knowledge about socio-economic consequences of BXW spread and determinants of implementation of its management practices in East and Central Africa. The reason lies in the fact that the spread of the disease is inevitably reflected in reduction of yields and other provisional and non-provisional services delivered by banana plants. This entails not only economic losses for farmers and other actors in the banana value chain, but also an increasing risk of food insecurity, considering that banana is still a predominantly staple crop in the region. Therefore, it is vital to understand the reasons behind low adoption of control practices and the distribution of costs related to them among different actors, as well as gender and other socio-economic factors in this framework. By doing so, the socio-economic paradigm will help institutions, organizations and research on BXW to understand better its economic consequences, having the ability to empower the stakeholders of banana value chain.

2. Methodology

The authors conducted a systematic literature review in order to investigate causes and outcomes of BXW spread in a complex framework of local, regional and global food systems. The first step was to look broadly for literature regarding the banana production system and market, and why bananas have been important in ECA for decades. Subsequently, authors conducted a more specific review about Banana Xanthomonas Wilt and how it has become a threat in the region, trying to identify all the actors of the banana value chain involved in fighting its spread. Therefore, authors focused on studies based on the economic impact of BXW and its management practices in ECA, trying to improve understanding of the distribution of costs.

After having acquired a solid basis of knowledge through the review, authors built up a framework based on the banana system, using Uganda as a case study and identifying which are the main economic factors that contribute to combating the spread of BXW.

The rest of the paper is organized as follows; section 3 first describes the spread of BXW, then outlines disease management practices recognized as most effective, and finally analyses the main sources of cost borne by the stakeholders involved; section 4 focuses on socio-economic determinants of the BXW control techniques adoption; section 5 explains the economic impact caused by the spread of the disease within the ECA region; and section 6 draws conclusions and discusses the way forward.

The final goal is to understand which are the costs that all the stakeholders in the banana value chain have to face in order to fight the disease. These results can be also used for further research on economic losses and food security risks related to different policy measures in pest and disease management.

3. BXW spread, actors and management practices

Initially identified in Ethiopia in 1960s, Banana Xanthomonas wilt was first reported in Uganda in 2001, and then subsequently recorded in northern Rwanda, eastern Democratic Republic of Congo, Tanzania and Burundi (Biruma et al., 2007; Carter et al., 2010). In western Kenya, initial outbreaks of Xanthomonas wilt begun between 2004 and 2006 (Ochola et al., 2014).

Banana Xanthomonas wilt has affected farmers differently from country to country, both in terms of spread and in terms of incidence. For example, in the Kagera region of Tanzania, a total of 44% of BXW incidence in the villages was reported by agricultural district departments in 2011 (Nkuba et al., 2015). In Rwanda, BXW was first reported in 2005, but farmers reported symptoms having appeared in their fields in 2003; the percentages of banana fields with BXW in this country ranged from between 11% to 89% depending on the region (Nkuba et al., 2015). In Burundi, BXW disease has appeared from 2010 in eleven of the sixteen provinces of the country, with a mean incidence of 25.5% of banana households. (Nkuba et al., 2015).

In Uganda, BXW has been reported in 34 districts, apparently spreading from the Central region (where banana production is less intensive and mainly subsistence oriented) to the high-production areas in the Western region (Biruma et al., 2007). However, whereas in Central Uganda infestation rates reached levels of 18 - 27% in 2005, the major banana producing areas in the South-West of Uganda showed little infection in the same period (Biruma et al., 2007). During 2013 more than 50% of banana farms in Uganda were affected by BXW, but in 2015 the situation was reported to be under control, with less than 2% of banana farms infected (data from National Research Agricultural Organization).

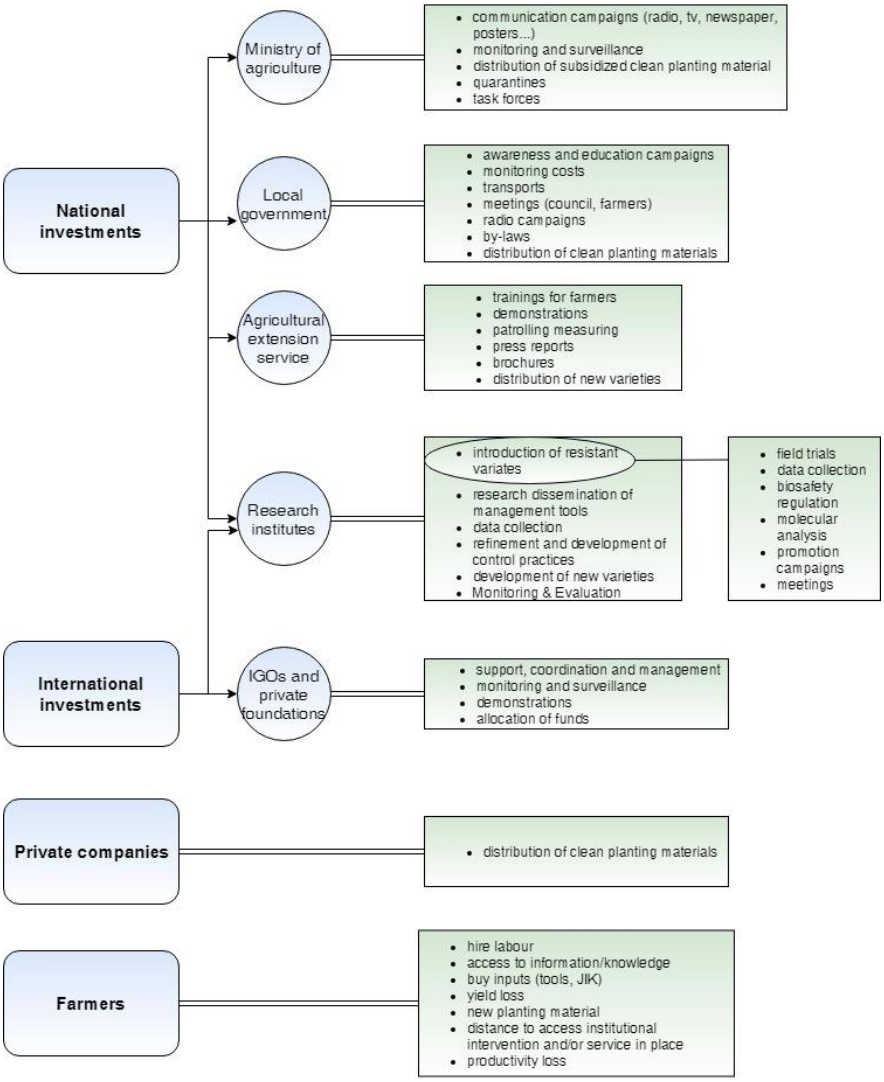
Indeed, across the range of prevalent banana diseases in the region, Banana Xanthomonas Wilt has been recognized as the most dangerous bacterial disease because of its ability to cause severe yield loss. Unlike other diseases, which cause gradually increasing losses over the years, the impact of BXW is both extreme and rapid (Nkuba 2015).

Different actors are involved in fighting the spread of BXW, from public and private sectors, and international agencies, are facing different kinds of costs.

Authors have selected Uganda as a targeted country in order to study the structure of the costs system. The same framework can be easily adapted to the other countries of ECA region.

Figure 1 shows a conceptual framework for all the possible costs related to BXW, establishing the role of stakeholders involved.

Figure 1: Cost analysis conceptual framework



Source: authors' representation

The framework shows how both public and private sectors, as well as international agencies, operate at different levels and in different areas (e.g. communication, monitoring, awareness and education) with the joint purpose of supporting farmers in to help them to apply the correct practices effective against BXW.

At national level, the government of Uganda operates through the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), as well as the National Agricultural Advisory Services (NAADS) that is responsible for public agricultural advisory/extension services.

The public sector also operates at local level through the crop production department of each district present in the country, as well as extension agencies under the directive of NAADS.

Research centres also play an important role in fighting BXW, receiving support from both public and private sectors.

Several NGOs, UN agencies and private foundations are also involved, collaborating especially as donors. A few private companies also play a role, providing clean planting material across the country. Finally, farmers can be considered the direct beneficiaries of the joint effort between public and private sectors, even though they face the higher risk for yield loss in terms of income and food insecurity.

The different costs that each stakeholder has to face are shown in figure 1. In general, costs related to communication and awareness are outsourced to public institutions, both at national and local level. Costs related to trainings and demonstration link to the prevalent agricultural extension service, while research centres currently work dissemination of management tools, as well as introduction of new resistant varieties. Lastly, farmers have to buy inputs and hire labour among others.

Since there is no resistant variety for the disease so far reported and cultural management practices have represented the only means to fight the disease, until now the entire cost system is concentrated on implementing these (with the exception of research about new resistant varieties). If carefully implemented, it has been shown that cultural management practices will reduce drastically the spread of the disease (Kubiriba et al., 2014).

As a first prevention technique, **timely removal of the male bud** interrupts the insect transmission cycle and prevents the spread of the disease in banana types that are considered to be at greatest risk of infection. Removal of male buds (de-budding) by twisting the peduncle with a forked stick, instead of a cutting tool, is one of the practices emphasized for preventing the disease spread (Tripathi et al., 2009), because it effectively blocks the spread of BXW infection by insect vectors within the same field and between different fields.

BXW disease spread via cutting tools can be managed by **sterilizing tools** with fire or JIK (Commercial Sodium hypochlorite), or by **suspending the use of cutting tools** for at least 3 months (Tushemereirwe et al., 2006).

Reduction of inocula can be achieved both by **uprooting** all the plants in affected fields, using **herbicides** to kill infected plants and by **single stem removal technique**- whereby only those diseased stems are removed by cutting them at soil level (Kubiriba et al., 2014). A six-month **fallow period** is adequate to avoid reinfection from soil-borne inoculum if all infected plant material is removed (Tripathi et al., 2009). Even if the former represents a more effective way to eradicate the disease, most farmers prefer the latter because it causes less economic damage, since they only have to cut the infected stem as opposed to the whole mat.

Another important practice is to avoid infected planting material by using **clean planting material**. Among smallholder banana farming systems in East and Central Africa, more than 90% of the farmers rely on suckers from informal sources such as own fields, farmer-to-farmer exchanges and local sales to expand and establish new farms (Smith et al., 2008). As farmers rarely verify whether the source of the suckers is disease-free, there is a high risk of transmitting pests and diseases through planting material within and across farms, and even across national borders (Jogo et al., 2013).

These methods have been widely promoted and proved to be very effective in controlling BXW in some parts of ECA, using awareness campaigns, community action, trainings for farmers and other participatory methods.

Notwithstanding, while these measures, if adhered to, will contribute to slow down the spread of the disease, they hardly constitute a remedy in already infected areas and do not offer promise for long-term control of the disease, given the rapid spread of BXW (Karamura and Tinzaara, 2009). A study from Kubiriba et al. (2014) carried out field experiments over a 12-months period in BXW disease hot spots in Kenya, Uganda and DRC. The disease management method adopted consisted of single stem removal by uprooting, cutting infected plants at the base, injecting infected plants with herbicide and uprooting infected mats. Other recommended practices (e.g. male bud removal and weed control) were applied uniformly on all the plots. Plots with mats affected by BXW disease where no management option practice was applied comprised the control (Kubiriba et al., 2014)

Results assert that in all targeted countries the incidence of BXW was significantly reduced where the management practices were applied, resulted in a corresponding increase of bunch yield. In Kenya for example, the usable yield

increased from about 5 kg per plot to about 70 kg in some plots in the 9th and 10th month of application of the control practices (Kubiriba et al., 2014)

Current research is also focused on the creation and dissemination of **new resistant varieties**, both obtained from **genetic modification** and **conventional breeding**, which may be considered a solution in the long run. Namukwaya et al. (2011) state that the lack of natural resistance against BXW, labour intensive and unsustainable cultural practices, and the difficulties of conventional breeding with this highly sterile crop, favour a transgenic approach.

In their study, Namukwaya et al. (2011) aimed to determine whether the expression of sweet pepper (*Capsicum annuum*) plant ferredoxin-like protein (Pflp) gene in transgenic banana provides resistance to BXW. Results showed that about 67% of transgenic lines evaluated were completely resistant to BXW. These transgenic lines did not show any disease symptoms after artificial inoculation, whereas non-transgenic control plants showed severe symptoms resulting in complete wilting (Namukwaya et al., 2011). These observations favour genetic modification for resistance to BXW as a low-cost pre-emptive measure, with minimal market distortion, as previous stands are gradually replaced by improved material. However, genetic modification has to take into account the potential loss of natural biodiversity that could lead to a higher risk of losses due to other diseases (Tripathi et al., 2009).

Besides that, since resistant varieties are still a work in progress and not yet a reality, efforts have been focused on cultural practices and distribution of clean planting materials.

The next section explores the socio-economic impact of management practices, explaining how farmers perceive the use of those practices and what is the actual incidence among ECA region. Moreover, it investigates the relation with gender and food security.

4. Socio-economic determinants of BXW control technologies adoption

While management practices have been thoroughly studied, the adoption by farmers has been lower than expected. For example, a study conducted by Bagamba et al., (2006) shows that the BXW awareness campaign in Uganda has reached more than 85% of the banana farmers, who became able to identify BXW, how it spreads and how it is controlled. However, eventually only 30% of those farmers were adopting BXW control techniques (Kubiriba and Tushemereirwe, 2014).

Several factors that influence farm-level application of the different Xanthomonas wilt control strategies have been identified. One reason lies in the relationship between the economic impact of the disease spread and the cost of control measures. For example, the destruction of the whole mat is not only labour intensive, but also represents a high and long-lasting income loss for the farmer. In this case, the single stem removal practice is preferred. De-budding is also labour intensive and some farmers are unable to cope with this additional task because of old age or infirmity (Biruma et al., 2007). Regarding the sterilization of farm tools, a study conducted in western Kenya by Ochola et al., (2014) shows that the majority of households identified the high cost of JIK (sodium hypochlorite- bleach) as a key constraint to this practice. Even heat sterilization of tools with fire was reportedly curtailed amongst households by its laborious nature during farm operations.

To date, there have been few studies that quantify the direct and indirect costs of control measures at farm level. Shepherd and Ettling (1991) defined direct costs as those that drain household and public sector resources as a result of eradicating or preventing a disease. Such costs include expenditures on herbicides, pesticides or inputs such as JIK, farm implements and gumboots, transport to purchase inputs and hired labour. (Sebikari, 2010). Abdalla et al. (2000) reported that costs of disease control at farm level were directly related to availability of family labour, knowledge about disease and availability of farm inputs.

On the other hand, Alam and Rolfe (2006) defined indirect costs as the value of time lost due to controlling the disease. The productivity losses resulting from lost time come about when a household member diverts time to other activities

such as roguing to control BXW that would not lead to increased output. In this case the time lost can include that for monitoring plantation regularly to identify sick plants, searching for inputs to use and the actual activity of controlling or preventing the disease outbreak (Sebikari, 2010).

A study by Sebikari (2010) captured the observed costs of the main control methods for BXW in Mukono and Luwero Districts in Uganda. Results show that the most expensive technique was to replant with disease free suckers in new fields, while the less expensive was the sterilization of farm tools.

At the same time, there are other costs that stakeholders other than farmers are facing. Kubiriba and Tushemereirwe (2014) analysed the cost of an action plan executed by communities to control the BXW in Ruganda, Mbarara District, Uganda. Authors took into account the costs for the creation of awareness about BXW (e.g. sensitization workshops, trainings), mobilization of farmers for community action, supervision and monitoring and sharing of information. Results show that the total amount was about 884.000 Ugandan shillings (US$330) provided in 4 different rounds, from March 2005 to June 2006. The source of funds was from both national and international sectors (e.g. District, Sub County and NGOs).

From a social perspective, is also important to understand how gender interacts with the BXW management practices and how it matters when we talk about the spread of the disease.

A study from Ntamirwa (2014) reported that, in Uganda, women handle the light tasks associated with management, e.g. male bud removal and training other members of the society, while the heavy tasks e.g. uprooting of mats, are left for men or hired labour. Men confessed that some tasks were more suited for, and therefore more effectively implemented by, women. The elderly are disadvantaged and often have to rely on the support of their communities (Ntamirwa, 2014).

Kikulwe et al., (2018) conducted a study in 2015 that examines how intra-household gender dynamics and perceptions of the effectiveness of BXW practices influence adoption of BXW control practices. The study also examines if control of BXW has an effect on household food security (Kikulwe et al., 2018). Data for this study was collected from 321 respondents in 18 banana-growing districts in eastern, central and western Uganda. The data analysis was conducted with a combination of descriptive statistics and nonlinear econometric methods. Results regarding gender issues and the adoption of BXW control practices reveal that the practice mostly done by women is cutting down of infected plants, probably because it's not labour intensive but also because women are more involved in the day-to-day management of banana plantations (Kikulwe et al., 2018). At the same time, the study examines the ties between adoption of the cultural practices and food security. Results show that household using the removal of male bud and disinfecting of farm tools are more food secure (Kikulwe et al., 2018). It's important to take results about gender and food security into account, in order to have a better perspective on determinants of adoption and socio-economic impact of the BXW management practices.

Policies and institutions also play an important role in fighting the BXW spread. In Uganda and Tanzania, regions with active political leadership have achieved over 90% control of BXW, whereas the disease prevalence has almost quadrupled in eastern Democratic Republic of Congo due to civil instability (Mwangi et al., 2008).

This has generated information channels that have been used to encourage the management practices between farmers, as well as creation of awareness about the spread of BXW around ECA. Bagamba et al. (2006) and Kikulwe et al. (2018) have found radio campaigns to be the main source of information on BXW in Uganda, for both women and men. Furthermore, extension agents, farmer groups and non-governmental organizations were the second, third and fourth most effective information channels, respectively. On the contrary, televisions and newspapers were found to be the least effective sources of information (Kikulwe et al., 2018).

Overall, Tinzaara et al., (2013) assert that sustainable management of Xanthomonas wilt has, to a large extent, been elusive in ECA region, due to the poor understanding of the dynamics of its spread and control among stakeholders along the banana value chain. Moreover, banana farmers lack leadership to integrate a sustainable management of BXW in their cropping systems, and do not practice the recommended cultural control options. Farmers also expect immediate results from recommended control measures and, when these are not achieved, they become discouraged and abandon the management practices (Tinzaara et al., 2013).

The next section considers which are the economic costs related to BXW spread in terms of disease incidence, yield loss and consumption.

5. Economic impact of BXW spread

BXW spread is affecting countries of ECA region in different ways. Mwagi et al., (2007) have estimated that the extent of devastation in East and Central Africa is around $500 million. As an example, Karamura et al. (2006), suggest that, compared to pre-infection levels, in Uganda the total banana yield loss due to BXW infection was estimated to be 30-52 % during the period 2001 – 2004. Data on disease incidence, yield loss and adoption of recommended control measures was obtained from a study conducted during 2005 by Kalyebara et al. The survey covered 360 farm households randomly selected from 8 districts representing Eastern, Central, Western and South-western Uganda. Moreover, the same study made a projection of incidence and associated output loss for the period 2000 - 2019 using a logistic growth function (Kalyebara et al., 2006). Kalyebara et al. assert that, in Uganda, about 1.5 million of households are threatened by the disease (2006). Results show that the estimated total loss of banana output if BXW is not controlled is about $5.6 billion ($4.1 billion for cooking bananas and $1.5 billion for beer bananas), while the average loss of food and income per household per year would be around $200 worth of output valued at farm gate prices (Kalyebara et al., 2006). By the time the study was conducted, losses were very high in endemic districts where BXW was concentrated, however over 75% of the potential loss was expected to be incurred by farmers in border districts in the western region of Uganda (Kalyebara et al., 2006).

Such spread of BXW throughout Uganda would induce economic losses, arising from price increases and significant reductions in production (Biruma et al., 2007). From a market perspective, this means that, at moderate production losses due to BXW, farmers over-compensate for these quantity losses through price increases; thus, while initially producers are benefiting, consumers are losing from the first outbreak of the disease, due to reduced quantities and increasing prices (Biruma et al., 2007).

There has been little analysis of the economic impact of BXW in countries neighbouring Uganda. However, the few BXW socio-economic studies that have been done to date have not fully quantified the economic losses and effects of BXW on household food security and incomes in the ECA countries (Nkuba et al., 2015).

In the Democratic Republic of the Congo, for example, a study by Mwangi et al. (2006) estimated household income losses of about US$ 1,500 per year, while Kayobyo et al., (2005) predicted declines in per-capita consumption of bananas by 42% and total household incomes by about 32% by the end of 2004 in the BXW-affected areas, compared with the non-affected counterparts. The same study also asserts that, if uncontrolled, BXW would spread at a rate of 8% per annum in cooking banana plantations, causing an estimated production loss of about 53% over a ten-year period (by Kayobyo et al 2005). Overall, economic losses were estimated to range from $2 billion to $8 billion over a decade, arising from price increases and significant reductions in production (Tripathi et al., 2009).

A household survey conducted by Nkuba et al., between 2009 and 2011 in seven districts of Kagera region of Tanzania, sixteen provinces of Burundi and twelve districts of Rwanda, shows that the number of banana bunches harvested before and after BXW was significantly different in all countries. Similarly, banana bunches per household, sold and consumed before and after BXW, were significantly different, with a decline of 35% in the number of bunches sold and 25% in the number of bunches consumed (Nkuba et al., 2015). In addition, the banana price per bunch increased from an average of US$ 3.30 in 2007, before the BXW became a threat, to US$ 4.80 during BXW peak in 2009. Lastly, it is estimated that a total banana economic loss of US$ 14.05 million was caused by BXW disease in the three countries of Tanzania, Rwanda and Burundi in 2012 (Nkuba et al., 2015).

Disease management technologies have to be assessed for their financial viability in terms of development and dissemination costs against adoption and returns for farmers, and thus, on research investment (Tripathi et al., 2009). For banana production, improved agronomic practices rank highest in returns on investment, followed by genetic modification

for disease resistance. Traditional breeding methods are less profitable, as they take longer to achieve usable outputs (Kalyebara et al. 2007).

Although the impact of BXW on household level has been studied since its outbreak in ECA, and especially in Uganda, little has been done to understand the effect of the disease on other stages of the banana supply chain. In general, a crop disease has consequences that go from the early stage of production, to its final use (which, in this case, can be both sale and self-consumption) and involves different actors, as private sector and governmental institutions.

A case study about the impact of BXW on beer – banana value chain by Rietveld et al., conducted in Central Uganda, shows that not only beer-banana production, but also processing and sales are making large contributions to the livelihoods of people involved, especially among brewers (2014). Although brewing is time-consuming and labour-intensive, it is one of the few options available to raise relatively large amounts of cash throughout the year from their crop production (Rietveld et al., 2014). From this perspective, BXW has severely reduced the income derived from beer banana for all the stakeholders of the beer-banana value chain.

Overall, costs related to BXW spread throughout the banana value chain are not fully quantified, not only for farmers but also for national and local governments, research institutions and other actors related to the banana market. At the same time, the literature seems to show inconsistencies regarding the economic impact of BXW in the short and medium run, and so far there seem to be a lack of clear estimates about the impact in the long run.

6. Conclusions

Eastern and Central Africa are the largest banana producing and consuming regions in Africa. Banana and plantain are a source of income for most of the smallholder farmers in the region, and are important for fighting food insecurity, as the crops provide more than 25% of food energy requirements for over 100 million people (Tripathi et al., 2009).

BXW has posed a threat to all banana producers in the ECA region for almost 20 years. Due to the extreme and rapid impact of the disease, farmers have suffered heavy economic losses and risks to their food security, especially because to date there are no banana cultivars known to be completely resistant to BXW.

This study analysed the socio-economic impact of the disease from two different points of view. The first one is focuses on socio-economic determinants of BXW management practices adoption, while the second one is about the economic impact of BXW spread in the ECA region.

Although management practices have been implemented by several national, regional and international organizations, to date, there has been no systematic evaluation of costs or cost-effectiveness, especially in terms of costs affecting different actors in relation to the implementation and adoption of management practices. The use of those recommended practices (e.g. timely removal of the male bud with a forked stick, sterilization of cutting tools with fire or JIK, use of clean planting material) has been to some extent limited, because most of them are perceived as expensive and labour intensive by farmers. Furthermore, they do not guarantee the long-term control of the disease. The continued presence of the disease is also partially attributed to both inadequate knowledge and awareness of farmers, local leaders and other stakeholders along the banana value chain. The quality of stakeholder response will depend partly on the quality of messages received. All key stakeholders need to be given clear and appropriate messages, stating what needs to be done by whom, how, where and when, so that they in turn can play their roles effectively (Tinzaara et al., 2013). This is the reason why governments from each country play an important role in fighting the disease. National, regional, and international institutions can provide not only funds in order to help smallholder farmers bearing the cost of management practices, but can also reach a large number of people through communications channels in order to create awareness among the farmers.

Therefore, in this study authors identified a cost analysis conceptual framework based on the banana system in Uganda, in order to understand who are the economic actors involved in the banana value chain. This framework will be used for further analysis to quantify all costs incurred in controlling the spread of the disease, ranging from awareness and communication campaigns supported by national institutions to the purchase of inputs and labour costs faced by farmers.

Regarding the economic impact of BXW spread among ECA region, even though there is a lack of research analysing the banana value chain as a whole, it is certain that the disease has the ability to cause up to 100% yield loss, severely compromising food security and livelihoods for banana-based farming households (Blomme et al., 2017). Broadly, Mwagi

et al., (2007) have estimated that the extent of devastation in East and Central Africa costs around $500 million per annum. While the majority of the literature focused on Uganda, there has been little analysis of the economic impact of BXW in the neighbour countries.

Besides, these concerns have to find a place within in the complexity of the production system, which is characterized by smallholder production, and the market system of the region, in which smallholder farmers struggle to enter, often because of high transaction costs. This leads to the question about banana market systems in the ECA, as a direct consequence of the banana production. Therefore, there is the need to look beyond agricultural production along the entire banana value chain.

Is more important than ever to understand and quantify the economic impact of BXW management practices and what is going to happen to the banana yields in ECA region, if these management practices are not adopted by banana-based farming households.

In general, what is missing from the literature is a costs analysis of the banana value chain as a whole, not only for farmers, who have to sustain the cost of management practices, but also for other stakeholders involved, as national and local governments, research institutions and agricultural extensionists.

Moreover, even though some studies estimate the potential yield losses in the short run, to date there are no projections of yield loss in the long run, taking into account all the factors that can contribute to the spread of the disease (e.g. climate change, lack of sensitization from governmental institutions, lack of adoption of the cultural practices from farmers), as well as introduction of new resistant varieties.

Therefore, the current research needs to carry out analysis on two different levels: an *ex-post* analysis on different costs sustained by the stakeholders of banana value chain, and an *ex-ante* analysis to predict future scenarios which represent possible alternatives, depending on whether and how the disease will be managed in the coming years. These results could be useful for better informing decision-makers at national, regional, and international levels and providing support in designing strategies to cope with BXW spread across the ECA region.

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