JRIIE Journal of Research Innovation and Implications in Education
Center for Research Implications & Practice

Website:www.jriiejournal.com ISSN 2520-7504 (Online) Vol.8, Iss.4, 2024 (pp. 315 – 338)

The Role of Training on Uptake of Management Technologies for Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) among small Holder Coffee Farmers in Kayunga District, Uganda

Kellet Tumuramye[1], Godfrey Kagezi[2], Blasio Bisereko Bwambale[3], Bernard Fungo[4], Florence Nassimbwa[5] and Wagoire W. William[6]

[1]Faculty of Agriculture, Uganda Martyrs University
[2,5&6] National Coffee Research Institute (NaCORI) / National Agricultural Research Organization (NARO)
[3]National Forestry Resources Research Institute (NaFORRI) / National Agricultural Research Organization (NARO)
[4]African Centre of Excellence in Agro-Ecology- Uganda Martyrs University
Email: tumuramyekellet@gmail.com

Abstract: *Both Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) are widespread in Uganda's coffee-growing regions, with national incidence rates of 68% for BCTB and 2.2% for CWD. The National Agricultural Research Organization (NARO) introduced several management practices for both diseases. A study involving 136 coffee farmers in Kayunga District assessed the impact of NARO's training on the adoption of these practices. Data analysis showed that 70% of the farmers used the management techniques for BCTB and CWD. Trained farmers had significantly higher adoption rates for most practices compared to untrained ones, particularly for BCTB management, except for chemical use. For CWD, trained farmers' adoption was higher, excluding the practice of uprooting and burning infected plants. Knowledge of BCTB management was linked to factors like gender, age, experience, and training, while CWD knowledge depended primarily on training and experience. BCTB damage has decreased by 74% since 2016, attributed to improved farmer experience. Conversely, CWD incidence has risen by 150%, partly due to reinfection from neighboring unmanaged farms and the use of susceptible coffee seedlings. Effective management of BCTB and CWD requires a community-based approach to prevent spread. Additionally, the government should provide resistant coffee varieties at subsidized rates to help farmers combat CWD*

Keywords: *Black Coffee Twig Borer, Coffee Wild Disease, Training, and management*

How to cite this work (APA):

Tumuramye, K, Kagezi, G., Bwambale, B. B., Fungo, B. & Nassimbwa & Wagoire, W. W. (2024). The role of training on uptake of management technologies for Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) among small holder coffee farmers in Kayunga District, Uganda. *Journal of Research Innovation and Implications in Education, 8*(4), 315 – 338. **https://doi.org/10.59765/jyrb42869.**

1. Introduction

Coffee is the most important cash crop in Uganda, in terms of employment (80%) and value of production (18% of the export earnings), valued at $528 million in the coffee year 2017/2018 (UCDA,2018). However, for the last decade, production has been stagnant at an average of 3.5 million 60 kg bags (MAAIF, 2013; ICC, 2015; UCDA, 2015). This stagnation has been attributed to a number of factors including losses due to poor

management practices and damage by insect pests and diseases being paramount (UNDP, 2012;Namwagala *et al.*, 2014; Kagezi *et al.*, 2016b; UCDA, 2016; ICO, 2019).

BCTB is currently the most important insect pest of Robusta coffee in Uganda, causing $45.6M loss annually (Kagezi *et al*., 2016b). In Kayunga district, the incidence of BCTB was 0.8%, 80% and 91.7% for 2009, 2013 and 2016, respectively, while damage was 0.8%, 18.3% and 16% for 2009, 2013 and 2016, respectively (Egonyu *et al*., 2009, Kagezi *et al.*, 2013, 2016b).

Also, CWD is an important disease -1990s and early 2000, it almost wiped about 50% of Robusta coffee in Uganda valued at $100M (Oduor *et al*., 2005). Surveys carried out in 2002 found the disease in all Coffee growing areas and on over 90% of the farms in Uganda (Oduor *et al.* 2005) with national average incidence of 2.2% (Kagezi *et al*., 2016b). Both pests spread rapidly within and between fields, making management difficult (Flood, 2009; Kangire, 2013;Kagezi *et al*., 2016b; Hultman, 2016).

In a bid to manage BCTB and CWD, a number of technologies have been developed, including trimming off and burning of infected plant parts, adequate pruning and de-suckering, eliminate alternate hosts, soil and moisture management and use of chemicals for managing BCTB (Kangire, 2013). Previous research shows a positive correlation between the number of farmers that have adopted the management technologies and the decrease in pest infestation *(*Kagezi *et al*., 2016b). Promoted technologies for the management of CWD including: using clean planting materials, uprooting and burning of infected trees, use of plant resistant varieties – KR1 – 7 avoid movement of infected plant materials, sterilizing farm tool by flaming after working on an infected plant or field (Kangire, 2013). However, farmers are usually reluctant to change their traditional technologies and adopt to the new promoted technologies, leading to increase in prevalence and incidence of BCTB and CWD. Several reasons such as weather variability, crop productivity and crop income, poorly integrated markets and the potential for adverse welfare effects for low uptake rates of new technologies by farmers have been advanced by a number of studies (Matsumoto *et al.*, 2013; Asfaw *et al*., 2016).

However, the factors that influence uptake of BCTB and CWD management technologies as well as the mitigation strategies are highly contextual. Means of how to improve uptake of pest and disease management technologies among coffee farmers still needs to be explored. This study aimed at assessing the role of training on uptake of Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) management technologies among small holder coffee farmers in Kayunga District, Uganda.
The study examined a number of objectives; (i) to characterize the social economic status of the coffee farmers in the study area, (ii) to determine farmers' Knowledge and use of BCTB and CWD management technologies, (iii) to determine the factors influencing the uptake of the BCTB and CWD management technologies, (iv) to compare the incidence and damage of BCTB and CWD in coffee fields of trained and untrained farmers.

2. Literature Review

Globally, Coffee is grown in more than 50 countries around the world (ICO, 2009). It is a major commodity on the global market and provides a source of revenue for many millions of farmers along the value chain (Jeffery and Peter, 2002). Globally, Brazil is the biggest exporter of coffee, providing 25 million bags (each 60 kg), which accounts for more than 30% of world coffee exports (Rutherford and Phiri, 2006). In Africa, Uganda is the second biggest coffee producer and exporter with 3.7 million bags in 2012/2013 after Ethiopia with 6.4 million bags in 2012/13 (ICO, 2009;Nahanga *et al*., 2015) contributing an estimated 2.97% of its crop to the world market (ICO, 2014).

In Uganda, two types of coffee are grown, Robusta coffee (80%), mainly in central, eastern and western Uganda and Arabica coffee (20%) mainly in eastern, northern and western Uganda (UNDP, 2012; Kangire, 2013; UCDA, 2015; ICO, 2019). It is estimated that 1.7million households grow coffee employing more than 5million people along the coffee value chain (ICO, 2019; UCDA, 2019). The crop is intercropped with food crops such as banana, beans and peanuts which are important for household food security; however banana is the most intercropped crop (Bhanu , 2014). Coffee is largely grown under shade trees to ensure sustainable coffee production. The leaves that fall from the shade trees provide manure for the coffee plants (UCDA, 2014).

For the last decade, coffee production has been stagnant at an average of 3.5 million 60kg Bags but recently we have observed a slight increment to 4.69 (UCDA, 2018). This stagnation has been attributed to several factors including losses due to poor management practices and damage by insect pests and diseases being paramount (UNDP, 2012; Kagezi *et al,* 2016b;UCDA, 2016). The downward trends have continued, and unless comprehensively addressed, coffee production is destined for further decline. It has also been noted that changes in climatic conditions that have resulted in rampant droughts, unpredictable and varied rain patterns, and temperature changes could have resulted in the appearance of new pests and severity of new and existing pest problems (Caffrey et al., 2013).

Coffee is attacked by a number of pests and diseases which have the potential to seriously disrupt production (Liebig, 2017). Management of these coffee pests and

diseases is therefore critical and must be closely monitored. In Uganda, the biggest pests and diseases threats to coffee are the Coffee Wilt Disease and the Twig Borer pest (MAAIF, 2014a; Unger, 2014). Although, there is general widespread of disease and pest attack, the spread of the Black Twig Borer in Robusta areas are a major challenge (UCDA, 2013).

2.1 Black coffee Twig Borer Pest (BCTB) *(Xylosandrus compactus)*

2.1.1 Biology and ecology

BCTB is native to Asia where it is a serious pest of Robusta coffee, but has spread to coffee growing regions throughout the world where it attacks Arabica coffee as well (Casa Brazil, 2015). In Uganda, the pest was first noticed in Bundibugyo District in 1993 and it is said to have originated from India (ICO, 2014). The second outbreak was reported in 2002 in Rukungiri, Kanungu and Bushenyi districts. The next outbreak of the pests was reported in December 2008 in Mukono and Kayunga districts (Egonyu *et al*., 2009; UCDA, 2009).

The BCTB belongs to the ambrosia group of beetles, feeds on *Ambrosia* fungus and its development from egg, through larval and pupal stage into a mature adult requires about 30 days (Hara and Beardsley, 1979a) . It is only the adult beetles that damages plants and the males are flightless, thus it is only the females that emerge from a twig as they become adult beetles. The females, however, leave the brood gallery after mating to infest other hosts/branches to lay eggs. The female bores through the xylem of a twig and chews through its pith to create a common brood chamber in which she lays eggs. The pests uses the tunnel galleries for growing ambrosia fungus which the brood feeds on until adult females disperse to infest new twigs (ICO, 2014). The fungus is the only food for the larvae and the adult beetles. Female beetle bores into the twigs and causes them to wilt eventually die in a few weeks (Kangire, 2013).

After a coffee tree gets infested, the leaves turn dull green and wilt within one week. The following week, the leaves turn brown. A pin-sized hole can often be found on the underside of the flagging stems or twigs where the insect has entered the plant; twigs and stems are hollowed out and can be seen by cutting open the affected tissue; the adult beetle is small and black, eggs and pupae are creamy white in color (Dahlqvist, 2016). The damage caused by the beetles promotes secondary infestation by bacteria and other fungi. A whitish pile of dust from boring may be seen at each BTB entry hole. Once inside the twigs, the pest does not feed on the host plant material but uses it as a medium for growing the fungus. Therefore, absence of a suitable host is not a limiting factor and hence any woody material of suitable moisture content and size supports its survival.

The transportation of infested plant parts is of more importance for long distance dispersal of BTB. BTB females can reproduce parthenogenetically (without mating), in which case the offspring are all males (Hara and Beardsley, 1979). As a result, the introduction of only a few females may lead to the establishment of an active population if suitable host plants can be found and environmental conditions are conducive. Based on its prolific reproductive potential and dispersal capacity, BTB is therefore a high-risk quarantine pest in areas not yet infested locally. The black twig borer thrives in humid conditions since humidity facilitates the ambrosia fungus upon which the borer feeds in its younger stages.

2.1.2 Incidence and damage caused by BCTB

The black coffee twig borer (BCTB), *Xylosandrous compactus*, is one of the most important constraints to coffee production in Uganda (Kangire, 2013; Kucel *et al*., 2016). The coffee twig borer have severely affected Uganda's coffee industry for more than a decade (Kagezi *et al*., 2014). According to the ICO, (2014), BCTB also attacks Arabica coffee although it seems to prefer Robusta. Approximately 70% of coffee farms in Uganda are infested by the coffee twig borer with almost 10% of coffee berry bearing branches destroyed causing an equivalent reduction of coffee yield which translates to approximately US$40 million per year (based on coffee export values for 2010 – 2012) (ICO, 2014). This resulted in increased initial investment and production costs such as the need to plant appropriate shade trees, use of irrigation, and application of pesticides, fertilizers, manure, mulch and bands.

By 2012, *X. compactus* had spread to 68% of Robusta coffee (*Coffea canephora*) farms in Uganda, where it infested 40% of coffee trees per farm and killed 8.6% of twigs (Kagezi *et al*., 2013). The pests cost Uganda US$ 40 million of foreign exchange annually and thus there is an urgency for effective management mechanisms (Kagezi *et al*., 2013). The BCTB affected regions of central, mid-eastern, south and mid-western continue to experience severe damage, with the severest damage of over 50% witnessed in mid-eastern and south-central Robusta coffee growing areas (UCDA, 2015).

2.1.3 Management of BCTB

Uganda is vulnerable to pest and disease attack especially due to environmental and weather conditions that favor availability of crops as well as pests and diseases in most parts of the region (Kagezi *et al*., 2014). Virtually every crop is affected by pests and disease and therefore requires some form of integrated pest and disease management during field management (Liebig, 2017). According to Kangire, (2013), Climate change has affected production in most traditional production areas, which has rendered the production targets unrealistic leading to intensification and occurrence of

certain insect pests and diseases. Rainfall distribution also determines the prevalence of pests and disease (in particular fungal varieties) and the susceptibility of coffee trees to diseases and pests (Bukomeko *et al*., 2017).
According to Egonyu *et al*., (2015), designing integrated pest management systems that suppress *X. compactus* infestation offers a potential alternative to *X. compactus* pests' management that relies on ecological principles. A preliminary IPM package has been assembled for use by coffee farmers that combines community-based phytosanitary actions and chemical sprays, proper management of shade trees and coffee canopies, and proper soil fertility and soil moisture management (Kagezi *et al*., 2014). For better management of BCTB, farmers need to prune out infested twigs and stems and burn them (Kangire, 2013). Flagging branches should be pruned back a few inches from the beginning of symptomatic areas; apply adequate fertilizer and irrigation to ensure that vigorous plants can speed recovery from pruning injury (Casa Brazil, 2015). However, this method of management carries the risk of spreading an older, even more dangerous, coffee disease, CWD, because the farmer uses a sharp object to cut off the twigs and moves from one coffee tree to another and some of the trees could be carriers of the CWD even if they may not yet have shown its symptoms (Ssali, 2014).

2.2 Coffee Wilt Disease (CWD)

2.2.1 Biology and Ecology

Coffee-wilt disease was first reported on Robusta coffee in the early 1990s in Bundibugyo District. The disease destroyed 44.9% of coffee trees between 1993 and 2002 (Rutherford and Phiri, 2006).Coffee Wilt Disease (CWD), also known as 'fusarium wilt' or 'tracheomycosis is caused by the fungus *Fusarium xylarioides* and affects both Arabic and Robusta coffee as well as wild coffee species. Of the possible alternative hosts investigated, the pathogen has only been recovered from within the roots of banana in Uganda. However, the symptoms of CWD have not been observed on field grown crops other than coffee (Casa Brazil, 2015) .

CWD attack leads to gradual and often unilateral dieback and defoliation which ultimately leads to the death of the tree (Rutherford and Phili, 2006). Yellowing, folding and inward curling of the leaves are among the first signs of CWD. The leaves feel limp to the touch, then dry up and become brown and eventually drop off, leaving affected trees completely leafless. However, a unique symptom of CWD is the development of blue-black discoloration of the wood directly beneath the bark. This can be seen when the bark is removed, and is usually most pronounced towards the base of the stem (Casa Brazil, 2015). The coffee plant may be affected by CWD at any stage of its development. Young plants may be killed within a few weeks of initial infection. Older trees usually die within between six and fifteen months of the first symptoms appearing, some within just three months. By the time CWD symptoms are seen it is too late to save the plant (Rutherford and Phiri, 2006).

Unlike many species of Fusarium causing diseases on plants, *F. xylarioides* appears to be a pathogen specific to coffee. It causes extensive necrosis of the water conducting vessels that results in wilting and death of the plant. The pathogen is considered to be an endemic soil inhabiting fungus. It can remain viable in soil and infected wood and retain its ability to infect coffee for at least 11 months (Rutherford and Phiri, 2006). The fungus infects coffee plants through the roots or through wounds made in the stem. It has also been shown that wounding with farm implements contaminated with spores of the fungus, during pruning and mechanical weeding for example, can result in spread of the disease. On entering the host plant, the fungus spreads upward through the water conducting vessels (xylem). Once a tree has become affected by CWD adjacent trees subsequently start to develop symptoms, usually within just a few months (Casa Brazil, 2015).

2.2.2 Incidence and damage by CWD

At national level, it is estimated that the CWD led to a 42% loss of the initial area under Robusta estimated at 242,000 Ha., this loss is equivalent to about 60,000 tons. Pegged at an average export price of US$ 600 per ton, this loss translates to about US$ 36 million. This is a very big loss to a poor economy like Uganda and has serious macro and micro-economic consequences (Fitter and Kaplinksy, 2001). In the 1990's to late 2000's, the disease led to losses of up to 45% of Robusta coffee and this greatly undermined government efforts to increase coffee production from 3.15 million bags in 2001/2 to the targeted 12 million bags by 2007/8 (Oduor *et al*., 2005). Thus, disrupting the national economy and decreasing the incomes of coffee producers.
CWD incidence varies from a few infected trees to over 90% tree mortality and can also rapidly spread from field to field (Hakiza and Birikunzira, 2000). Unlike other diseases of coffee, CWD quickly kill the tree. In the Central and some parts of the West, farmers lost up to 50% of their coffee plantations while in other parts of the country, the disease incidence was variable and the empirical evidence from farmers indicated that the disease was increasing at a decreasing rate, implying that it had attained a threshold point of the pathogen (Fitter and Kaplinksy, 2001).The introduction of the CWD-resistant and higher yielding clonal type, however, will revert the situation (Benin and You, 2007).

2.2.3 Management of CWD

According to Fitter and Kaplinksy, (2001), the policy on management of coffee wilt disease includes containing the spread of the disease through sanitary and phytosanitary farm practices; Use clean planting materials and planting in new areas as well as Continuing with research into resistant cultivars. Regulatory

management on quarantine measures, restrictions on the movement of coffee materials (seedlings, beans, husks) from affected area, are necessary to prevent entry of CWD to disease free areas (Unger, 2014).Trees adjacent to affected trees should be uprooted and burnt even if they appear healthy since they may already been infected by the fungus. Trees must be destroyed where they are, uprooted and not dragged through healthy trees as this further spread the disease. Storage and use of wood from affected trees, as firewood for example, should also be avoided. Uprooting and burning is most effective when disease symptoms are recognized quickly and any delays, then infected trees act as a source of inoculum and will rapidly infect other trees and the entire crop may be lost (UCDA, 2015b).

After removal of diseased trees, the land should be left fallow or an alternative crop grown or planted with a resistant cultivar. Replanting with coffee should be least after two years to allow inoculum of the fungus in soil to decline. While replanting with coffee will allow production of coffee to continue, it will be several years before new planting are sufficiently mature to yield a crop. Preventing introduction of CWD or taking swift action to destroy trees that develop symptoms is the best way of minimizing overall losses (UCDA, 2014a).On disease free farms introduction of CWD can be prevented by planting with plants raised from disease-free cuttings and seed collected from within the farm(Kangire, 2012). The use of clean (pest-free) seed at planting is an important strategy for managing seed borne diseases, such as coffee wilt disease (Kimani *et al*., 2002).

Similarly, there is continued support to generation and production of clean planting material through tissue culture, seed sourcing, and support to clonal propagation of the Coffee Wilt Disease Resistant lines for mass multiplication and distribution to farmers (UCDA, 2015; Kimani *et al.*, 2002). Also, NaCORI conducted multi-geographical location trials of lines of CWD resistant Robusta coffee, with high value potential, to determine their adaptability in terms of yield, quality and resistance to major diseases under different agro-ecological conditions within the Robusta coffee growing areas of Uganda (Kangire, 2013). The studies also compared on-farm and on-station (at Kituza) performance of these lines and provided an opportunity to farmers to participate in selecting good varieties, which then creates a preamble for early and quick adoption of varieties when released (UCDA, 2013).

2.3 Socio economic characteristics of smallholder coffee farmers

There are various factors that determine the success of the uptake and adoption of improved technologies, with different levels of impact depending on the nature of the technology itself, as well as the socio-economic status of the farmers (Adesope *et al*., 2012). Most farmers have attained the minimum level of education (primary level)(Abera, 2009) and this does not create an opportunity for them to access skilled employment hence an opportunity to be available at home at attend to their gardens and hence reducing the incidence of pests and diseases on their farms, an important factor in the commercialization of farming(Abera, 2009; Mordini, 2017). In Uganda, most farmers own less than two acres of coffee plantation (UCDA, 2012; Jassogne and Läderach, 2013) and in other African countries like Tanzania and Kenya (ICC, 2015).

Most of the farms in the coffee growing regions of Uganda are owned by men (Bwambale, 2015; Nabeta, 2016; Kagezi *et al*., 2018). This particular situation can cause an imbalance of female participation in decision making with regard to coffee production and resource allocation since most resources in the households are owned by men (Ousmane and Nafiou, 2019).In Uganda, most coffee farmers are aged below 60years of age (Abera, 2009; Katya, 2010;Bwambale, 2015;Mordini, 2017).This is an indicator that such farmers are energetic and can possibly implement the promoted pests and disease management technologies.

In a farming business, farmers should be organised into groups to take advantages of farmer organizations which includes but not limited to access to cheaper inputs, access to credit, access to services such as trainings and support from governments and NGO's, access to information, access to 'better' markets (Zamora, 2013).

2.4 Farmer's knowledge about management of BCTB and CWD

Pests and diseases are ranked as the major constraint in coffee production Liebig *et al*., (2016) especially black coffee twig borer (BCTB) and coffee wilt disease (CWD) (Dahlqvist, 2016; Kobusinge*et al.*, 2018). Report by MAAIF (2014), Pest Management Plan also indicates that similar pests and disease challenges are being faced by farmers in all the coffee growing districts. The ability to properly identify coffee pests and disease, as well as some basic knowledge about pest and disease epidemiology are fundamental requirements to successfully management pests and diseases and increase productivity.

Farmers believe that managing the BCTB when their neighbors are not managing causes management implications for the pest as it leaves an important sources of BCTB re-infestation in their fields (Egonyu *et al*., 2009; Kagezi *et al*., 2013). This calls for more sensitization of all farmers especially on community-based actions as an essential strategy to prevent re-infestation of BCTB from none managed neighboring farms. If properly designed, IPM can reduce the harmful impacts of chemical use on health and the environment and improve farm incomes at the same time (UNDP, 2012).

Various cultural options for management of BCTB such as appropriate shade-tree species, regular de-suckering and removal of unproductive primary branches of the coffee plant and, using *Albizia coriaria* and *Ficus natalensis* shade trees in coffee instead of *A. chinensis* minimizes BCTB infestation (Egonyu, 2009; Kagezi *et al*., 2013, 2015, 2016b; Kobusinge *et al.*, 2018) and elsewhere (Dixon *et al*., 2003) as well as CWD (Hakiza and Birikunzira, 2000; Nabeta, 2007; Unger, 2014). This calls for more farmers trainings from extension workers and researchers to emphasize the sustainable pests and disease management technologies among the farmers(Kalyebara, 1999).

2.5 Factors influencing uptake of technologies for managing Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD).

Adoption of an agricultural technology is a decision-making process involving a period of time during which an individual goes through a number of mental stages before making a final decision to adopt a technology (Bwambale, 2015). The decision-making process to adopt new agricultural practices depends on both intrinsic factors such as knowledge, and attitudes and extrinsic factors such as the characteristics of the farmer (age, education, social networks, farming experience), biophysical characteristics (soil quality, farm size, slope), farm management characteristics (land tenure, labor source, wealth) and the external (contextual) factors (Solomon and Bekele , 2010).

In the context of this research, adoption basically means the incidence of adoption of different NARO promoted technologies at the time of data collection. In this case, however, it is inappropriate to use adoption in the usual way because it's just one year since this farmers have been trained and therefore it's hard to define a cut-off point between adopters and non-adopters (Muntasir, 2017). Therefore, the word uptake will be used. Most farmers usually adopt some of the NARO Promoted coffee management technologies in their farms and while others don't. Farmers' adoption of technology use are influenced by technical training, meeting, oral transmission, trust on technician and belief level on technology (Stephen *et al.*, 2017).

Technologies are meant to be incorporated into farming systems that is adopted (Muntasir, 2017). The low adoption levels of technology is attributed to the cost of the technology itself, conservative farmers and weak belief in the new technology, lack of capital, lack of continuous trainings from the government and extension workers (Peter, 2015). It is however advised that improved technologies of coffee production such as, resistant varieties, agronomic practices, protection and other management options should be availed to the farmers(Asfaw *et al*., 2016).

Access to agricultural technologies play a great role in increment of adoption level. The more the farmer's access to agricultural technologies, the more they probably adopt. Acknowledgement of the same is made by Asfaw *et al*. (2016) that access to quality and quantity needs of coffee production technologies also contributes to the adoption levels by participating farmers. In the survey done by Egonyu *et al*., (2009) in Mukono and Kayunga Districts, results showed that 51% of the farmers had no idea of BCTB while the rest had heard about it through the electronic and/or read about it in the print media.

2.6 Incidence and damage of black coffee twig borer (BCTB) and coffee wilt disease (CWD) in coffee fields of trained and untrained farmers

According to previous studies, the incidence of BCTB has been decreasing, and damage was reducing since 2009 (Egonyu *et al.*, 2009; Kagezi *et al*., 2013, 16). Despite the continued effort by UCDA to increase awareness on the infestation and management of pests, BCTB continued to spread within the Robusta coffee growing regions (UCDA, 2016a).

Despite the increased trainings and sensitization, incidence of BCTB continues to increase. This drastic increase in BCTB incidence is attributed to drought which can cause stress and weaken the coffee plant and thereby increase the infestation level of BCTB (Wu, 2016). The prevailing environmental factors plays a vital role in the incidence and severity of pests and diseases. Increase in temperatures increases the incidence of pests and diseases because the plants becomes more vulnerable and susceptible leading to increase in the occurrence of major pest outbreaks (Dinesh *et al*., 2015).

Climate change accelerate the prevalence of pests and diseases and increase the occurrence of shock events. Also, weather patterns are becoming increasingly volatile and unpredictable, with frequent occurrences of drought and erratic rainfall occurring with increasing frequency (Caffrey et al., 2013a). Rainfall has become increasingly unreliable, with both a greater unpredictability of occurrence and shorter periods of rainfall (MoFPED, 2018).

The incidence of BCTB was 21.2%, 80 % and 91.7% in 2009, 2013 and 2016, respectively, in Kayunga District (Egonyu *et al.*, 2009; Kagezi *et al*., 2013; Kagezi *et al*., 2016). BCTB damage was recorded at 3.7% in 2009 (Egonyu *et al*., 2009), 18.3% in 2013 (Kagezi *et al*., 2013) while that of 2016 revealed a damage of 16% of the twigs (Kagezi, *et al*., 2016). In this study, mean incidence of 45% and damage of 4% were recorded for Kayunga district. These results also prove that the pest is rapidly colonizing other Robusta coffee farmers particularly where farmers have limited or no knowledge

of managing it (Egonyu *et al*., 2009;Kagezi *et al*., 2013a, 2016b).Incidentally, Robusta coffee contributes 80% of the coffee export volume (Bieysse *et al.*, 2006;UNDP, 2012 ; Kangire, 2013).

In response to increased pests and disease incidences, UCDA in collaboration with NARO, developed training materials for farmers and created awareness through radio programs; and further established demonstration sites on Integrated Pest Management (IPM) in 34 districts; procured and distributed Imax pesticide with protective equipment and spray pumps for spraying of BCTB (UCDA, 2016 ; Kagezi *et al.*, 2016b).

3. Methodology

3.1 Description of the study area

Kayunga district is in central Uganda with eight sub counties; Kayonza, Kitimbwa, Bbaale, Busaana, Kangulumila, Kayunga, Kayunga T/c and Nazigo Sub county (Kayunga Gistrict Local Government, 2009). The district has a favorable tropical climate for Robusta coffee and lies between 1000-1200 m above sea level with a bi-modal rainfall pattern which varies between 1000 mm - 1500 mm per annum (moderate to high rainfall). Rainfall is evenly distributed, and it comes in two peaks, one from March to May and the second from September to December. The vegetation cover is predominantly savannah with short grasses and thorny bushes. There are two forest reserves Nazigo and Bbaale. The area is generally flat with no remarkable hills.

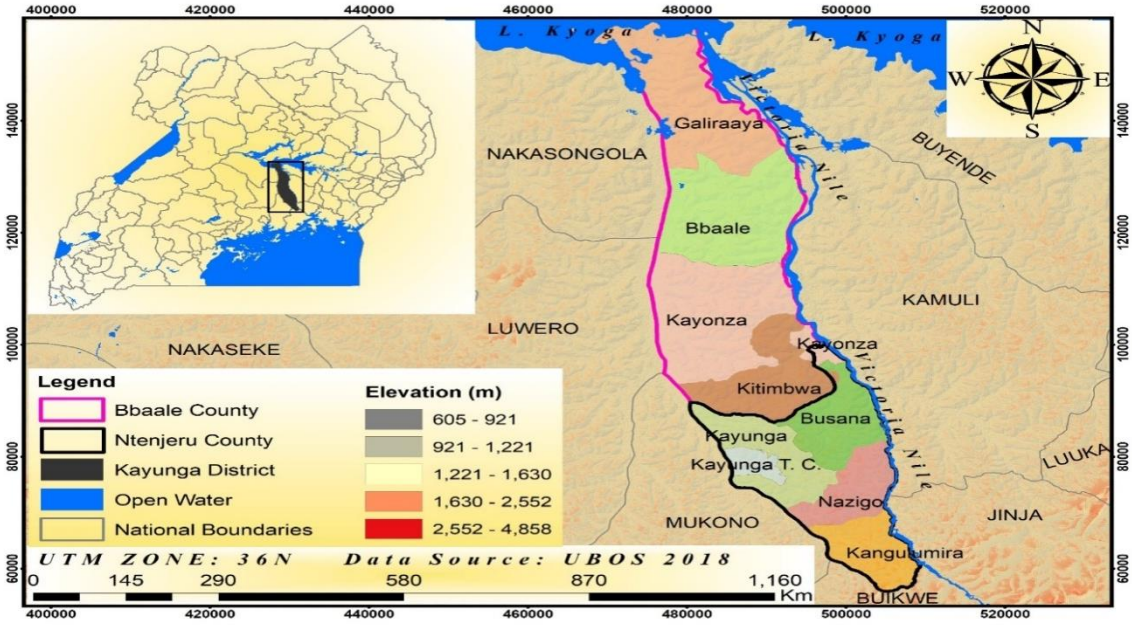

Fig. 1: Map of Kayunga district, central Uganda

3.2 Sample selection and data collection

A survey was conducted in four purposively selected Sub Counties of Kayunga District namely, Nazigo and Kayunga (where farmers were trained on managing BCTB and CWD using the NARO recommended packages) and in Kitimbwa and Busana Sub Counties (where farmers were not trained on managing BCTB and CWD using the NARO recommended practices). A structured questionnaire was administered to 68 purposively selected trained farmers and 68 randomly selected untrained farmers. The questionnaire elicited the role of training on farmers' uptake of BCTB and CWD management technologies among small holder coffee farmers.

3.3 Research design

The research employed a Cross-Sectional Survey. Both qualitative and quantitative data was collected using primary and secondary approaches. The primary data collection approaches included conducting face to face interviews, key informant interviews and observations during field work.

Table 1: Data collection methods and tools

Data collection Methods	Data collection Tools	Type of data collected
Household Survey	structured questionnaire	-Information about the technologies used in the management of CWD and BCTB. -Information on the socio-economic and demographic characteristics of respondents, -Farmers' knowledge of the NARO recommended technologies for managing BCTB and CWD. -limitations that farmers face while using such technologies as well as their corresponding suggestions to overcome these limitations.
Key informants' interviews	Interview guides	-Standard open-ended questions concerning the technologies presently used in the management of coffee twig borer pests and coffee wilt disease.
Pest and disease field assessments	Observation	-Researchers visited farmers' fields to observe their coffee management practices in respect to management of coffee twig borer and coffee wilt disease. -Incidence and damage by BCTB -Incidence and damage by CWD

3.4 Data analysis

Data was analyzed using SAS V. 9.1 for Windows (SAS, 2008). Information on Socio-economic and demographic characteristics such as gender, age, sources of income, acreages of coffee owned, education level and profession of farmers was also captured. Mean frequencies of different variables were computed, and percentage distribution tables generated. Binary logistic regression was used to determine the relationship between use of the technologies and the socio-economic factors.

4. Results and Discussion

4.1 Socio-economic characteristics of smallholder coffee farmers in Kayunga district, central Uganda

Furthermore, majority (65%) of respondents had less than two acres of coffee gardens, a similar case reported in other coffee growing areas of Uganda (UCDA, 2012; Jassogne and Läderach, 2013; Kagezi, *et al*., 2016b) and in other African countries like Tanzania and Kenya (ICC, 2015).This scenario in part favors subsistence agriculture, limits mechanization and contributes to low coffee production in the region (Coffee RoadMap, 2019).

4.2 Farmers knowledge and use of the black coffee twig borer (BCTB) and coffee wilt disease (CWD) management technologies

4.2.1 Awareness

Results from this study revealed that majority (96%) of the sampled coffee farmers in Kayunga district mentioned that they were experiencing pest and diseases problems on their coffee farms This finding agrees with survey reports in the Uganda Government Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) Pest Management Plan (MAAIF, 2014). Most farmers mentioned that the black coffee twig borer (BCTB) (84%) and coffee wilt disease (CWD) (72%) were the most important insect pest and disease of coffee in their gardens respectively. Earlier studies made similar observation in the same district (Egonyu *et al.*, 2009; Nabeta, 2007; Kagezi *et al.*, 2013; 2016b) and in other coffee growing districts of Uganda (Unger, 2014; Dahlqvist, 2016; Kobusinge *et al*., 2018) as well as elsewhere (Oduor *et al.*, 2005; Rutherford, 2006; Asfaw *et al.*, 2016).

Furthermore, half of the respondents mentioned that the damage caused by both BCTB and CWD varied with seasons - with higher damage levels being observed in dry than wet seasons. This finding was supported by observations in the Key Informant Interviews comprising of leaders and professionals conducted in this study as well as earlier studies (Hara and Beardsley, 1979; Greco and Wright, 2015; Bukomeko *et al*., 2017). The changing climatic conditions contribute to increase in the incidence of pests and diseases especially in dry season (Dinesh *et al.*, 2015; Caffrey *et al*., 2013; MoFPED,2018). This implies that rainfall distribution may influence the prevalence, incidence and damage by BCTB since humidity facilitates survival of the ambrosia fungus on the BCTB life stages feed (Hara and Beardsley, 1979).

Table 3: Farmers' awareness of black coffee twig borer (BCTB) and coffee wilt diseases (CWD) in Kayunga District, central Uganda. Significant p-values at p≤0.05 in bold.

Insect pests	Untrained (%)	Trained (%)	χ^2	p-value
Pests as a problem to coffee production	97	96	0.0052	0.9426
BCTB on coffee farm	79	84	0.1534	0.6953
Diseases				
Diseases as a problem to coffee production	91	76	1.3473	0.2457
Coffee wilt disease on coffee farm	87	72	1.4151	0.2342

4.2.2 Farmers' awareness of promoted management technologies for black coffee twig borer (BCTB) and coffee wilt disease (CWD)

It was observed that the trained respondents were significantly ($p<0.05$) more aware of all the NARO-promoted practices for managing BCTB and CWD than the untrained respondents (Table 3.3). This finding represents a common scenario that has been reported in other studies in Uganda (Kagezi *et al*., 2016b) and Kenya (Luusa *et al.*, 2018b)

Both farmers and key informants explained that they received trainings related to BCTB and CWD management from different sources including Government extension workers and research institutions

such as Uganda Coffee Development Authority (UCDA) and National Agricultural Research Organization (NARO) (UCDA, 2012; Kagezi *et al.,* 2013).
However, sometimes, the different stakeholders involved in training farmers duplicate trainings for the same communities instead of coordinating to provide comprehensive trainings (MAAIF, 2014b; Liebig, 2017; UCDA, 2019).

Table 4: Farmers' awareness of promoted management technologies for black coffee twig borer (BCTB) and coffee wilt disease (CWD) among trained and untrained in Kayunga District, Central Uganda(N=136). Significant p values at p≤0.05 in bold.

Technologies	**Percentage awareness**			
BCTB	**Untrained (%)**	**Trained (%)**	χ^2	***p-value***
Using clean planting materials	33	67	31.5077	**<.0001**
Trimming off and burning infested materials	39	61	4.84	**0.0278**
Proper spacing, pruning & de-suckering	36	64	7.81	**0.0051**
Eliminate alternate host of BCTB	27	73	21.16	**<.0001**
Soil and moisture management	28	72	19.36	**<.0001**
Using chemicals	32	68	12.96	**0.0003**
CWD				
Using clean planting materials	32	68	12.96	**0.0003**
Uprooting and burning infested plant materials	44	56	1.44	0.2301
Restricting movement of infected plant materials	22	78	31.36	**<.0001**
Sterilizing farm tools after being used	21	79	36	**<.0001**
Planting CWD-r-Lines	30	70	16	**<.0001**

4.2.3 Farmers' use of promoted management technologies for black coffee twig borer (BCTB) and coffee wilt disease (CWD)

The percentage of respondents using all the NARO-prompted practices for managing BCTB except use of chemicals was significantly ($p<0.05$) higher for trained than untrained respondents This shows that training programs have the ability to enhance farmers' adoption and use of new Integrated Pest Management (IPM) technologies and innovations in coffee production (Bhanu, 2014; Kagezi et al., 2013, 2016b; Luusa et al., 2018a) and other crops as well (Al-Zyoud, 2014;Hasan, 2017;Balasha, 2019).

Enhanced uptake and use of the NARO-promoted practices has been reported to reduce incidence and damage of BCTB and CWD in the different coffee growing agro-ecological zones of Uganda (Kagezi et al., 2016a; UCDA, 2016). For example, BCTB damage decreased from 43 to 8.5% in Masaka district and from 26.6 to 8.6% in Rakai district over a 3-year period (Kagezi et al., 2016b).

The insignificant number of respondents using chemical methods for managing BCTB reported in this study implies that training may have limited or no influence on the use of chemicals (Luusa et al., 2018a). However, this finding contradicts other studies that have showed that training positively influences uptake and usage of pesticides by farmers (Luzinda et al., 2018b); Mubushar et al., 2019). This could in part be due to the general low use of this technology in managing BCTB (Egonyu et al., 2009; Kagezi et al., 2013) as well as other pests and diseases in coffee agro-systems of Uganda (Liebig et al., 2016; Kagezi et al., 2018). The low use of pesticides could be attributed to the fact that this practice is generally expensive and sometimes may not be available or accessible. Secondly, even those which are available on market, some of them may be counterfeit or not effective (Rutherford and Phiri, 2006 ; Egonyu, et al., 2009; Kagezi ,et al., 2018). Nevertheless, NARO and UCDA trainings emphasize limited use of pesticides or should be used as the last resort where other methods have failed to work or in an Integrated Pest Management (IPM) program (Kucel et al., 2009; UCDA, 2019).

On the other hand, the percentage of respondents using all options for managing CWD except uprooting and burning was significant ($p<0.05$) higher for trained than untrained. This shows that training enhances technology uptake and use by farmers for managing CWD (Kangire, 2013). Lack of significant influence of training on uprooting and burning of infected materials as a practice

of managing CWD could be in part due to the fact that this practice is labor-intensive but, also farmers may utilize the dried CWD-infected coffee trees for other purposes such as firewood and poles (Rutherford and Phiri, 2006;Unger, 2014; Nabeta, 2016). This fact was supported by interviews with the Key Informants.

Table 5: Proportion of farmers using NARO technologies for managing the black coffee twig borer (BCTB) and coffee wilt disease (CWD) in Kayunga District, central Uganda (N=136). Significant p values at p≤0.05 in bold.

Technology	Percentage usage			
	Untrained (%)	Trained (%)	χ^2	*P-value*
BCTB				
Using clean planting materials	38	62	5.7600	**0.0164**
Trimming off and burning infested materials	40	60	4.0000	**0.0455**
Proper spacing, pruning & de-suckering for both coffee & shade	40	60	4.0000	**0.0455**
Eliminate alternate host of BCTB	27	73	21.1600	**<.0001**
Soil/moisture management to enhance plant vigor	33	67	11.5600	**<.0001**
Using chemicals	41	59	3.2400	0.0719
CWD				
Using clean planting materials	32	68	12.9600	**0.0003**
Uprooting and burning infested plant materials	52	48	0.1600	0.6892
Restricting movement of infected plant materials	17	83	43.5600	**<.0001**
Sterilizing farm tools after being used on infected plant materials	15	85	49.0000	**<.0001**
Planting CWD-r-Lines	23	77	29.1600	**<.0001**

4.3 Effect of socio-economic characteristics of the respondents on uptake

Results showed that gender of the respondent significantly (p≤0.05) negatively influenced labor-intensive practices such as trimming and burning of BCTB-infested plant materials, elimination of alternative hosts, water, and soil management as well as use of chemical for managing BCTB. Several reports have reported similar relationships in coffee (ICO, 2018; Kobusinge *et al.*, 2018; Ochago, 2018) as well as other crops (Ogato *et al.*, 2009). This could, in part, be due to the fact that males participate more in production of cash crops such as coffee whereas, females are more involved in food crops like beans (Stewart *et al.*, 2015). This could imply that since most of these labor-intensive practices are done by the males, training them is most likely to enhance the uptake and use of these practices (Kagezi *et al*., 2016b; Ochago, 2018). However, it is advisable that agricultural extension trainers should also reach out to female farmers as well as involving them in these trainings (Jack and Tobias, 2017) since they are involved in most of the day-to-day management of coffee gardens (Katya, 2010).

Additionally, age of the respondents had a negative and significant (p<0.05) relationship with the use of clean planting materials and chemicals for managing BCTB but not with other management practices, agreeing with previous studies in coffee (Kagezi *et al*., 2018) as well as other crops (Bwambale, 2015). This implies that use of the labor-intensive practices for managing BCTB decreases with increase in age of the farmers as most of these cultural-based approaches are labour intensive (Kagezi *et al*., 2016b). This therefore calls for more the efforts of different stakeholders in the coffee sector to support a new generation of coffee farmers by engaging the youth in coffee production (Mbowa *et al*., 2013).

Furthermore, this study revealed that the level formal education of the respondents had no significant (p>0.05) influence on use of all the BCTB and CWD management options. These results imply that irrespective of the level of education, farmers can still use both BCTB and CWD management practices (Kobusinge*et al*., 2018). However, these findings contradict other studies that reported significant effect of education on adoption of improved technologies in coffee production (Nabeta, 2016; Luzinda *et al*., 2018) as well as in other crops (Shita *et al*., 2018).This is in part due to the fact that more educated farmers are likely to make better agricultural-related decisions in relation to acquisition of new skills

as well as quickly adopting new technologies in farming as compared to their less educated counterparts (Nabeta, 2016;Tessema *et al*., 2016; Luusa *et al*., 2018). These results imply that majority of the coffee farmers might be lacking adequate education necessary for better modern farming (Luusa *et al*., 2018). However, this could also be that those farmers may not have specific knowledge of the technologies being promoted since they may not be part the formal education acquired (Bwambale, 2015; Luusa *et al.*, 2018).

In addition, being purely a farmer had a significant relationship (p<0.05) on using clean planting materials and proper spacing but not the use of other options for BCTB management (Cheyns *et al*., 2006). This could in part due to the fact that being purely a farmer increases the chances of concentrating on the farming activities (National Coffee Strategy, 2015) and therefore farmers are able to implement BCTB and CWD management practices effectively since they have few off-farm engagements (Coffee Roadmap, 2019).

This study further showed that experience in farming also significantly (p<0.05) influenced use of clean planting materials, elimination of alternate hosts as well as soil and moisture management but not the other management practices for BCTB. These results imply that as farmers gain experience, they are able to understand that using clean planting materials is very important in managing BCTB and CWD (Luzinda *et al.*, 2018, Ochago, 2018b).. But also, experienced farmers are able to manage their soils well hence enhance plant vigor and making the coffee plant tolerant to BCTB and CWD attack (Kalyebara, 1999).

Also, all respondents mentioned that attending trainings in coffee production had a significant (p<0.05) influence on use of all the BCTB and CWD management options except uprooting and burning of CWD-infected materials (Table 4). This is in agreement with reports from previous studies in Uganda (Bwambale, 2015) and in other African countries like Kenya (Luusa *et al*., 2018) and Tanzania (Nyasimi *et al*., 2016). This implies that trained farmers are more informed of the improved practices and how to apply them in a timely manner (Jørs *et al*., 2014; Ochago, 2018b). In addition, farmers learn from each other and share experiences during trainings, improving their performance after trainings (Bwambale, 2015; Tessema *et al*., 2016). However, it was generally observed and from the Key Informant Interviews feedback that almost all farmers were not uprooting and burning the CWD-infected coffee plants because the practices is labour-intensive (Unger, 2014). There is therefore a need to address this bottleneck so as to reduce further spread of the disease to neighbouring coffee plants or farms (Kansiime *et al*., 2017).
the NARO-recommendation practices for managing BCTB and CWD except the use of chemicals for managing BCTB (Table 9). This finding suggests that training of farmers and access to information on agricultural technologies enhance uptake, adoption and use of technologies (Kalyebara, 1999; Cheyns *et al*., 2006). Nevertheless, 35% of the respondents mentioned that the use of chemicals as a practice was expensive (Egonyu *et al*, 2009; Kagezi *et al*, 2013) and this contributes to level of adoption (1%) of the practice (Namwagala *et al*., 2014; Kansiime *et al.*, 2017). Lastly, it is worth noting that 28% of the trained respondents mentioned that use of clean planting materials was limited by their availability (Coffee Roadmap, 2017). This implies that farmers will continue planting the elite seedlings distributed by the Government that are highly susceptible to CWD, hence, further spreading the disease (Musoli *et al*., 2006).

4.4 Factors limiting farmers to use different technologies

Results from this study showed that for the untrained respondents, lack of training was the main factor limiting the use of the NARO promoted practices for both BCTB and CWD (Table 8). This implies that the untrained farmers have limited knowledge regarding BCTB and CWD. It is generally believed that access to information on new technologies enhances awareness towards technology adoption (Luzinda et al., 2018b). These farmers therefore ought to miss other opportunities that come along with continuous trainings as reported by (Kalyebara, 1999). Limited access to extension trainings has been reported to contribute to low yields in coffee production (Mugoya, 2018). However, to effectively manage both BCTB and CWD, there is a need to train all the coffee farmers in the community as using these cultural-based practices require a community-based approach to minimize re-infection/re-infestation from non-managed gardens (Kagezi *et al*., 2016b). Additionally, these trainings should be complemented with regular follow-ups by the extensionists and researchers to encourage all coffee farmers to use the promoted practices of BCTB and CWD management (Kansiime *et al.*, 2017).

On the other hand, most of the trained respondents mentioned that they experienced no limitation to using

Table 8: Factors limiting farmers to use different technologies for managing Black Coffee Twig Borer (BCTB) (Trained farmers n=68 and untrained farmers n=68). Significant p values at p≤0.05 in bold.

Limiting factors	NARO promoted practices for managing BCTB											
	Clean plant material (%)		trim and burn infested materials *%)		Proper spacing and pruning (%)		Eliminate alternate hosts (%)		Soil and moisture management (%)		Use of chemicals 9%)	
	Untrained)	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained
No limitation	2.9	51.5	2.9	58.8	4.4	64.7	1.5	54.4	2.9	45.6	1.5	27.9
Expensive	2.9	7.4	0.0	0.0	0.0	1.5	1.5	0.0	1.5	2.9	20.6	35.3
Unavailable	13.2	8.8	0.0	1.5	0.0	0.0	0.00	1.5	0.0	0.0	0.0	7.4
Laborious	0.0	1.5	14.7	11.8	10.3	13.2	4.40	8.8	10.3	14.7	0.0	2.9
Ineffective	0.0	1.5	0.0	0.0	0.0	0.0	0.00	0.0	0.0	1.5	0.0	0.0
Less training	80.9	29.4	82.4	27.9	85.3	20.6	92.6	35.3	85.3	35.3	77.9	26.5
χ^2	120.8	169.2	76.4	107.74	93.44	126.36	69.04	246.8	74.4	193.52	39.8	95.78
P value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

Table 9: Factors limiting farmers to use different technologies for managing Coffee wilt disease (CWD) (Trained farmers n=68 and untrained farmers n=68). Significant p values at p≤0.05 in bold.

Limiting factors	NARO promoted practices for managing CWD									
	Use clean plant material (%)		Uproot and burn CWD-infested materials (%)		Restricted movement of infested materials (%)		Sterilise farm tools (%)		Use of CWD-r-lines (%)	
	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained
No limitation	1.5	55.9	0.0	48.5	1.5	54.4	1.5	52.9	0.0	33.8
Expensive	1.5	8.8	0.0	1.5	0.0	0.0	0.0	0.0	2.9	10.3
Unavailable	8.8	7.4	0.0	0.0	0.0	0.0	1.5	0.0	8.8	27.9
Laborious	0.0	1.5	8.8	11.8	14.7	13.2	10.3	8.8	2.9	1.5
Ineffective	0.0	0.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
Less trainings	88.2	26.5	91.2	36.8	83.8	32.4	86.8	38.2	85.3	26.5
χ^2	99.8	213.2	91.1	67.24	26.54	118.46	91.1	67.24	36	192.96
P value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

4.4.1 Suggestions to overcome the limiting factors

Most of the trained and untrained respondents suggested that they should be given more training to overcome the factors hindering uptake and use of NARO promoted practices for both BCTB and CWD apart from use of clean planting materials and CWD-r varieties (Table10). Such trainings will revamp farmers' limited knowledge regarding improved coffee management practices (Luzinda et al., 2018b). These results imply that even though some farmers were trained, these trainings were not adequate(Luusa *et al.*, 2018). NARO and its partners therefore need to develop an approach that enables the resource-constrained farmers to continuously invest in the promoted technologies to cope with the effects of pests and disease on coffee production (Okiror, 2018).

On the other hand, more than half of the trained respondents suggested that clean planting materials and CWD-r varieties should be made more available (Table 11). However, availing clean planting materials that are not resistant to CWD might be appropriate for managing BCTB but not CWD (Kangire, 2013).

Table 10: Suggestions to overcome the factors limiting farmers to use NARO promoted practices for managing the Black Coffee Twig Borer (BCTB) (Trained farmers n=68 and untrained farmers n=68). Significant p values at p≤0.05 in bold.

Suggestions	NARO promoted practices for managing BCTB											
	Clean plant material (%)		Trim and burn infested materials (%)		Proper spacing and pruning (%)		Eliminate alternate hosts (%)		Soil and moisture management (%)		Use of chemicals (%)	
	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained
Make it cheaper	5.9	4.4	0.0	0.0	2.9	0.0	4.4	0.0	4.4	2.9	10.3	23.5
More available	20.6	51.5	0.0	2.9	0.0	4.4	0.0	2.9	0.0	1.5	5.9	32.4
More effective	0.0	1.5	0.0	0.0	1.5	7.4	1.5	17.6	1.5	14.7	0.0	1.5
Less laborious	0.0	1.5	14.7	47.1	5.9	39.7	1.5	16.2	2.9	19.1	0.0	2.9
More trainings	73.5	41.20	85.3	50.0	89.7	48.5	92.6	63.2	91.2	61.80	83.8	39.7
χ^2	75.8426	118.3590	49.8436	41.8046	223.6624	60.0984	243.9448	83.2772	233.8989	120.54	114.9002	58.438
P value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

Table 11: Suggestions to overcome the factors limiting farmers to use different technologies for managing Coffee Wilt Disease (CWD) (Trained farmers n=68 and untrained farmers n=68). Significant p values at p≤0.05 in bold.

Suggestions	NARO promoted practices for managing CWD									
	Use clean plant material (%)		Uproot and burn CWD infected materials (%)		Restricted movement of infected materials (%)		Sterilise farm tools (%)		Use of CWD-r lines (%)	
	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained	Untrained	Trained
Make it cheaper	1.5	7.4	2.9	0.0	1.5	0.0	1.5	1.5	4.4	7.4

More available	16.2	52.9	0.0	0.00	0.0	0.0	1.5	0.0	8.8	55.9
More effective	0.0	2.9	0.0	4.4	0.0	2.9	0.0	4.4	0.0	1.5
Less laborious	1.5	0.0	13.2	41.2	13.2	44.1	11.8	38.2	0.0	0.0
More trainings	80.9	36.8	83.8	54.4	85.3	52.9	85.3	55.9	86.8	35.3
χ^2	172.0988	68.6328	116.4691	40.2898	123.5774	42.7916	196.3967	84.2264	198.9312	78.8395
P value	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**	**<.0001**

4.5 Incidence and damage of black coffee twig borer (BCTB) and coffee wilt disease (CWD)

Results showed that training had a significant effect on the number of coffee trees and primary branches infested by BCTB in the district. On average, 44.7% of the coffee trees and 4.1% of the coffee primary branches were infested by BCTB in Kayunga district, (Table12), implying that this pest is still one of the most important insect pests infesting coffee in the district (Egonyu *et al*., 2009; Kagezi *et al*., 2013, 2016b). These results show that the number of BCTB-infested coffee trees and primary branches has decreased tremendously from what was observed in 2016, before this study was conducted – 92% and 16%, respectively (Kagezi *et al*., 2016b). This decline in BCTB infestation could have been due to several possible factors. Kayunga district is one of the areas where BCTB was first reported (Egonyu *et al*., 2009), implying that farmers in this district have gained experience in managing the pest to remarkable levels (Kagezi *et al*., 2016b). Secondly, probably the two studies were conducted in different seasons. BCTB population and damage levels have been reported to be influenced by seasons – with higher damages observed in dry than wet seasons (Burbano, 2010; Egonyu *et al*., 2014; Dahlqvist, 2016). This is in part due to the dormancy of the pest during the rainy season (Burbano, 2010) which causes it to be supressed (Dahlqvist, 2016) but also coffee trees are vigorous during the rainy season and stressed during the dry season which increases the occurrence of BCTB (Hultman, 2016).

Table 12: The percentage of coffee trees and primary branches infected by the Black Coffee Twig Borer (BCTB), and the percentage of coffee trees infected by Coffee Wilt Disease (CWD) (Trained farmers n=20 and untrained farmers n=20)

Sub-county	BCTB-infected trees (%)	BCTB-infested primary branches (%)	CWD-infected trees (%)
Busana	49.0±16.4 a	4.1±5.3 ab	0.7±1.4 (0.04±0.08)
Kayunga	40.0±16.7 a	2.8±4.2 b	0.7±1.4 (0.04±0.08)
Kitimba	46.0±15.8 a	5.7±7.2 a	1.0±2.2 (0.05±0.10)
Nazigo	44.0±9.2 a	3.7±5.3 ab	3.7±4.8 (0.12±0.16)
Overall mean	44.7±14.7	4.1±5.7	1.5±3.0 (0.06±0.11)
CV	32.70901	138.4557	179.2539
F value	0.73	4.56	1.51
P value	0.5393	**0.0038**	0.2296

Same letters within a column indicate means (after arcsine transformation in case of CWD) are not significantly different by Tukey's test ($P<0.05$). Values in parenthesis are transformed means (for CWD).

On the other hand, the percentage of coffee trees infected with CWD was generally low (1.5%) (Table12). However, this finding shows that CWD incidence has generally increased from the 0% observed in 2016 (Kagezi *et al*., 2016b). The increased incidence of CWD could in part be attributed to the type of seedlings that farmers plant (Table 13). Results from this study and other related studies showed that majority of the farmers in the study district as well as other parts of the country plant elite seedlings which they receive especially from government (Namwagala *et al*., 2014;UCDA, 2015; Coffee Roadmap, 2019). These materials are highly susceptible to CWD and this therefore presents a scenario of reinfection of the disease (Musoli *et al*., 2006; Flood, 2009; Kangire, 2013).

Table 13: Types and source of planting materials by farmers in Kayunga district, central Uganda. Significant p values at p≤0.05 in bold.

Type of planting materials	Frequency	% of respondents	χ^2	P value
Clonal coffee	18	13	137.007	**<.0001**
Elite seedlings	117	86		
Volunteer seeds	14	10		
Source of planting material				
Own planting materials	54	40	303.385	**<.0001**
Other respondents	14	10		
Nursery beds	8	6		
Government	97	71		
Researchers	3	2		
NGOs	1	1		
Politicians	5	4		

Furthermore, results further showed that the percentage of coffee trees infested by BCTB was higher in farms of untrained (47.5%) than trained (42.0%) though not significantly different (Table14). This implies that the pest is still a major problem in the district irrespective of the farmer being trained or not (Egonyu *et al*., 2009; Kagezi *et al*., 2013, 2016b). On the other hand, the percentage of primary branches infested by BCTB was significantly (p=0.004) higher on farms of trained (4.9%) than untrained (3.2%) respondents. These results also show that training has a significant effect on BCTB infestation at plot level though this was not the case at plot level (Kagezi *et al*., 2013a, 2016b). Previous research showed that enhanced uptake and use of the NARO-promoted practices reported reduced incidence and damage of BCTB in the different coffee growing areas of Uganda (Kagezi *et al*., 2016a; UCDA, 2016). For example, the number of primary branches infested by BCTB decreased from 43 to 8.5% in Masaka district and from 26.6 to 8.6% in Rakai district over a 3-year period (Kagezi *et al*., 2016b).

However, the percentage of coffee trees infected by CWD was higher in farms of the trained (2.2%) than the untrained respondents (0.8%), although they were not significantly (p=0.2661) different (Table14). This implies that training a farmer does not mean that CWD will be eliminated or reduced because the disease has the potential and ability to spread from neighboring farms that are not managing the disease (Hakiza and Birikunzira, 2000; Rutherford, 2006;Pinard *et al*., 2016). Spread of CWD could also be aided by movement of infected vegetative planting materials can also be an important source of infection of CWD (Hakiza and Birikunzira, 2000; Rutherford and Phiri, 2006).

BCTB like CWD has the ability to spread rapidly both at plot (tree to tree) and landscape level (farm to farm) if not managed (Flood, 2009; Kangire, 2013;Kagezi *et al*., 2016b; Hultman, 2016; Kansiime *et al.*, 2017). Managing both BCTB and CWD requires a community-based approach where all farmers participate in managing them, so as to avoid infestation or infection respectively from non-managing farmers (Rutherford and Phiri, 2006;Phiri N. and Baker, P.S., 2009 ; Kagezi *et al.*, 2016b).

Table 14: The percentage of coffee trees and primary branches infested by the Black Coffee Twig Borer (BCTB), and the percentage of coffee trees infected by Coffee Wilt Disease (CWD) (Trained farmers n=20 and untrained farmers n=20)

Category	BCTB-infected trees (%)	BCTB-infested primary trees (%)	CWD-infected trees (%)
Trained	42.0±13.3 a	3.2±4.8 b	2.2±3.8 (0.08±0.13)
Untrained	47.5±15.4 a	4.9±6.4 a	0.8±1.8 (0.04±0.09)
|t|	1.27	2.90	1.13
P value	0.2122	**0.004**	0.2661

Same letters within a column indicate means (after arcsine transformation in case of CWD) are not significantly different by Tukey's test (P<0.05). Values in parenthesis are transformed means (for CWD).

5. Conclusion and Recommendations

5.1 Conclusion

There was significant knowledge of pests and diseases identification and management. Several factors influenced uptake of pest and diseases management technologies including gender of household head, experience with coffee growing, age of household head as well as trainings. Better information flow via extension workers and training would improve the way pre-existing and newly generated knowledge from science reaches to the farmers.

Training increases uptake of the pest management technologies hence the observed decrease in the number of BCTB-infested coffee trees and primary branches which is also attributed to the gained experience by farmers in managing the pest. The current increasing spread of CWD is attributed to lack of collective action, where some farmers manage their fields but get re-infestation from neighboring unmanaged fields since most farmers did not belong to farmer groups and planted elite coffee seedlings which are susceptible to CWD.

About 70% of the farmers are Knowledgeable and about BCTB pest and CWD NARO promoted technologies. Age, accessibility, experience, and cost are the main factors influencing uptake. Reduced BCTB incidence, attributed to trainings and the gained experience by farmers in managing the pest. Increased CWD incidence, attributed to lack of collective action, some farmers manage their fields but get re-infestation from neighboring unmanaged fields but also planted elite coffee seedlings which are susceptible to CWD

5.2 Recommendations

From the findings, the study makes the following recommendations

1. Private - government partnerships should build the organizational capacity for smallholder farmers since the fight against CTB and CWD is best done through community action. There is need to better approach and target joint issues of farmer communities by the formation of farmer groups to enable farmers to access services like inputs and trainings. Also, the government should avail resistant coffee varieties to farmers (CWD-r-lines) at subsidized prices.

2. Stakeholders should adopt the stepwise approach where coffee farmers can improve their coffee quality and productivity using the available resources to implement the promoted BCTB and CWD management technologies step by step.

3. In future, further research should be done to find out the multiplier effect of the promoted technologies within in the same villages.

Acknowledgment

The research was funded by National Agricultural Research Organization (NARO).

Uganda Martyrs University for sponsoring my studies with a bursary under ACALIS

References

Africano Kangire, 2013. Intergrating disease and pest control wih quality to sustain Robusta coffee production in Uganda., in: Presentation at 3rd African Coffee Sustainability Forum. Presented at the Presentation at 3rd African Coffee Sustainability Forum, Coffee Research Centre, Uganda.

Al-Zyoud, F.A., 2014. Adoption Range of Integrated Pest Management (IPM) Techniques by Greenhouse Vegetable Growers in Jordan. Jordan Journal of Agricultural Sciences 10, 23.

Asfaw, E., Bezabh, A., Anteneh, M., Kumela, T., 2016. Adoption Study of Coffee Production Technologies in South West Ethiopia 8.

Asfaw, S., Di Battista, F., Lipper, L., 2016. Agricultural Technology Adoption under Climate Change in the Sahel: Micro-evidence from Niger. J Afr Econ 25, 637–669. https://doi.org/10.1093/jae/ejw005

Balasha, A.M., 2019. Drivers of Adoption of Integrated Pest Management among Small-scale Vegetable Farmers in Lubumbashi, DR Congo. American Journal of Rural Development 7.

Bhanu, B.P., 2014. Small scale Coffee Farmer's Response towards Management of Coffee Pest through Field Level Techniques. J. Inst. Sci. Tech. 19, 37–44. https://doi.org/10.3126/jist.v19i2.13850

Bukomeko, H., Jassogne, L., Kagezi, G.H., Mukasa, D., Vaast, P., 2017. Influence of shaded systems on Xylosandrus compactus infestation in Robusta coffee along a rainfall gradient in Uganda. Agr Forest Entomol 20, 327–333. https://doi.org/10.1111/afe.12265

Burbano, Elsie.G., 2010. Developing a monitoring tool to understand the seasonal dynamics and management techniques to estimate a sampling plan for zylosandrus compactus in Hawai'i. University of Hawai'i, Hawi'i.

Bwambale, N., 2015. Farmers' Knowledge, Perceptions, and Socioeconomic Factors Influencing Decision Making For Integrated Soil Fertility Management Practices in Masaka and Rakai Districts, Central Uganda 99.

Caffrey, P., Dr. Timothy, F., Dr. Sylwia, T., Dr. David, M., Dr. Rita, L.-O., Mr. Samuel, H., 2013. UGANDA CLIMATE CHANGE VULNERABILITY ASSESSMENT REPORT. USAID, Uganda.

Coffe Road Map, J., 2019. Consultancy to develop a detailed and costed implementation plan for the Coffee Roadmap for Uganda. Cardno Particip Consortium, Kampala, Uganda.

Dahlqvist, J., 2016. What is the view of the Black Coffee Twig Borer (Xylosandrus compactus (Eichhoff)) among farmers, advisers and experts, and is the infestation on robusta coffee trees (Coffea canephora) higher or lower when grown close to a Ficus natalensis? Swedish University of Agricultural Sciences, Department of Soil and Environment, Uppsala.

Dinesh, D., Bett, B., Boone, R., Grace, D., Kinyangi, J., Lindahl, J., Mohan, C.V., Ramirez-Villegas, J., Robinson, T., Rosenstock, T., Thornton, P., 2015. Impact of climate change on African agriculture: focus on pests and diseases 4.

E. Cheyns, H.A. Mrema, B. Sallée, 2006. SOCIO-ECONOMIC STUDY OF THE UGANDAN COFFEE CHAIN Overview of CIRAD and Ugandan consultant's work. FAO, Via Terme di Caracalla Rome 00100 Italy.

Egonyu, J., 2009. IMPACT OF THE BLACK TWIG BORER ON ROBUSTA COFFEE IN MUKONO AND KAYUNGA DISTRICTS, CENTRAL UGANDA. . Vol. 2, 8.

Egonyu, J.P., Kagezi, G.K., Kucel, P., Ahumuza, G., Ogari, I., Ogogol, R., Nakibuule, L., Kobusinge, J., Kyamanywa, S., Wagoire, W.W., 2014. Phenology and Infestation Pattern of the Coffee Twig Borer, 1.

Egonyu JP, Kucel P, Kangire A, Sewaya F, Nkugwa C, 2009. Impact of the black twig borer on Robusta coffee in Mukono and Kayunga districts, central Uganda 3.

Erbaugh, M., Donnermeyer, J., Amujal, M., Kyamanywa, S., 2003. The Role of Women in Pest Management Decision Making in Eastern Uganda. JIAEE 10. https://doi.org/10.5191/jiaee.2003.10309

Flood, J. (Ed.), 2009a. Coffee wilt disease. CABI, Wallingford, UK ; Cambridge, MA.

Flood, J. (Ed.), 2009b. Coffee wilt disease. CABI, Wallingford, UK ; Cambridge, MA.

Godfrey Kagez, Patrick Kucel, Sammy Olal, Fabrice Pinard, Joseph Seruyange3, Pascal Musoli, Africano Kangire, 2015. In vitro inhibitory effect of selected fungicides on mycelial growth of ambrosia fungus associated with the black coffee twig borer, Xylosandrus compactus Eichhoff (Coleoptera: Curculionidae) in Uganda. Uganda 10(23), 2322–2328.

Greco, E.B., Wright, M.G., 2015. Ecology, Biology, and Management of Xylosandrus compactus (Coleoptera: Curculionidae: Scolytinae) with Emphasis on Coffee in Hawaii. Journal of Integrated Pest Management 6, 7–7. https://doi.org/10.1093/jipm/pmv007

Godfrey, K., Patrick, K., Judith, K., D. Nicholas, O., Lilian, N., Winnie, N., P. Babra, N., Sammy, O., W. William, W., 2018. Farmers' knowledge and perception of the use of pesticides in Arabica coffee, Coffea arabica agro-ecologies of Uganda. JAES 7. https://doi.org/10.15640/jaes.v7n2a17

Hakiza, G.J., Birikunzira, J.B., 2000. Current •·esearcb trends on coffee wilt disease tracheomycosis 5.

Hara, A.H., Beardsley, J.W., 1979a. The Biology of the Black Twig Borer, Xylosandrus compactus (Eichhoff), in Hawaii12 17.

Hara, A.H., Beardsley, J.W., 1979b. The Biology of the Black Twig Borer, Xylosandrus compactus (Eichhoff), in Hawaii12 17.

Hultman, C., 2016. Black Coffee Twig Borer, Xylosandrus compactus (Eichhoff) on robusta coffee in Uganda 78.

ICC, 2015. Sustainability of the coffee sector in Africa. International Coffee Council. 114th Session. 2 ─ 6 March 2015. London, United Kingdom.

ICO, 2019. Country Coffee Profile: Uganda.

ICO, 2018. Gender Equality in the Coffee Sector. An insight report from the Internation Coffee Organisation. ICO, Grays Inn Road, LAndon, United Kingdom.

Jack, K., Tobias, J. ((2017. Seeding success: Increasing agricultural technology adoption through information.

Jassogne, L., Läderach, P., 2013. The Impact of Climate Change on Coffee in Uganda: Lessons from a case study in the Rwenzori Mountains 16.

Jørs, E., Lander, F., Huici, O., Morant, R.C., Gulis, G., Konradsen, F., 2014. Do Bolivian small holder farmers improve and retain knowledge to reduce occupational pesticide poisonings after training on Integrated Pest Management? Environ Health 13, 75. https://doi.org/10.1186/1476-069X-13-75

Kagezi, G., Kucel, P., Olango, N., Tumuhaise, V., Nakibuule, L., Kobusinge, J., Kabole, C., Wagoire, W.W., 2016. Current distribution and impact of the Black Coffee Twig Borer (BCTB) and Coffee Wilt Disease (CWD) in Uganda. Study report submitted to the Uganda Coffee Development Authority (UCDA).

Kagezi, GH, Kucel P, Nakibuule, L, Kobusinge J, Ahumuza G, Wagoire WW, 2016a. Current research status and strategic challenges on the black coffee twig borer, Xylosandrus compactus in Uganda, in: The 2nd Scientific Conference on African Coffee. Presented at the The Inter African Coffee Organisation (IACO) held 56th Annual General Assembly, NARO, Yaounde, Cameroon.

Kagezi, GH, Kucel P, Olango, N, Tumuhaise V, Nakibuule L, Kobusinge J, Kabole C, Chesang F, Wagoire WW, 2016b. Dynamics of black coffee twig borer damage on Robusta coffee in Uganda.

Kagezi, G.H., Patrick, K., Judith, K., D. Nicholas, O., Lilian, N., Winnie, N., P. Babra, N., Sammy, O., W. William, W., 2018. Farmers' knowledge and perception of the use of pesticides in Arabica coffee, Coffea arabica agro-ecologies of Uganda. JAES 7. https://doi.org/10.15640/jaes.v7n2a17

Kagezi, H.G., KUCEL, P., EGONYU, P.J., NAKIBUULE, L., KOBUSINGE, J., AHUMUZA, G., MATOVU, R., NAKENDO, S., LUZINDA, H., MUSOLI, C.P., KANGIRE, A., CHESANG, B.F., 2013. Impact of the black coffee twig borer and farmers' coping mechanisms in Uganda. Uganda Vol. 11, 285–292.

Kalyebara, R., 1999. A comparison of factors affecting adoption of improved coffee management recommendations between small and larger farmers in Uganda.To be presented at the CIAT International Workshop: "Assessing the Impact of Agricultural Research on Poverty Alleviation. San Jose, Costa Rica.

Kangire, fricano, 2013. Enhancing resistance to coffee wilt disease in Uganda – the conventional.

Kangire, A., 2013. INTEGRATING DISEASE AND PEST CONTROL WITH QUALITY TO SUSTAIN ROBUSTA COFFEE PRODUCTION IN UGANDA 20.

Kansiime, M., Mulema, J., Karanja, D., Romney, D., Day, R., 2017. Crop pests and disease management in Uganda: status and investment needs. Platform for Agricultural Risk Management Managing risks to improve farmers' livelihoods. CABI, Uganda.

Katya, K.E., 2010. INFLUENCE OF TECHNOLOGY ON GENDER DIVISION OF LABOUR IN HOUSEHOLDS: THE CASE STUDY OF WET COFFEE POST HARVEST HANDLING IN KASESE DISTRICT. Makerere University, Kampala, Uganda.

Kayunga Gistrict Local Government, 2009. Higher Local Government Statistical Abstract . Kayunga District.

Kobusinge, J., H. Godfrey, K., Abisagi, K., Patrick, K., Lilian, N., Ivette, P., W. William, W., 2018. Farmers' Knowledge of Pests and Diseases in the Coffee-Banana Agroforestry Systems of Mid-Eastern Uganda. JAES 7. https://doi.org/10.15640/jaes.v7n2a12

Liebig, T.I., 2017. Abundance of pests and diseases in Arabica coffee production systems in Uganda - ecological mechanisms and spatial analysis in the face of climate change. Gottfried Wilhelm Leibniz Universit at Hannover.

Luusa, J., Obara, J., Wambugu, S., 2018a. Effectiveness of Farmer Field School Training in Promoting Adoption of Best Agricultural Practices by Smallholder Coffee Farmers in Kenya. International Journal of Sciences 41, 18.

Luusa, J., Obarab, O., Wambuguc, S., 2018b. Effectiveness of Farmer Field School Training in Promoting Adoption of Best Agricultural Practices by Smallholder Coffee Farmers in Kenya. Kenya Agricultural and Livestock Research Organization. Department of Agricultural Education & Extension, Egerton University , Egerton,Nairobi, Kenya. Volume 41, pp 116-132.

Luzinda, H., Nelima, M., Wabomba, A., Musoli, P.C., Kakuru, A., 2018a. Factors Influencing

Adoption of Improved Robusta Coffee Technologies in Uganda. National Agricultural Research Organisation.Coffee Research Centre (COREC} Kituza.Uganda. Volume 18, 33–41.

Luzinda, H., Nelima, M., Wabomba, A., Musoli, P.C., Kakuru, A., 2018b. Factors Influencing Adoption of Improved Robusta Coffee Technologies in Uganda. Uganda Journal of Agricultural Sciences 9.

MAAIF, 2014. UGANDA MULTI-SECTORAL NUTRITION PROJECT. Environmental and Social Management Framework.

Matsumoto, T., Yamano, T., Sserunkuuma, D., 2013. Technology Adoption and Dissemination in Agriculture: Evidence from Sequential Intervention in Maize Production in Uganda 60.

Mbowa, S., Tonny, O., Ezra, M., 2013. Lessons for Uganda from the Vietnam Success 4.

MoFPED, 2018. Effects of changing weather patterns in the agricultural sector: How has production and livelihood been affected.

Mubushar, M., Aldosari, F.O., Baig, M.B., Alotaibi, B.M., Khan, A.Q., 2019. Assessment of farmers on their knowledge regarding pesticide usage and biosafety. Saudi Journal of Biological Sciences 26, 1903–1910. https://doi.org/10.1016/j.sjbs.2019.03.001

Mugoya, T., 2018. The Financial Viability of Coffee Farming in Uganda. UGANDA NATIONAL COFFEE PLATFORM, Kampala, Uganda.

Musoli, P.C., Kangire, A., Leroy, T., Nabaggala, A., Nakendo, S., Olal, S., Ochugo, J., Kabole, C., Pande, J., Cilas, C., Charrier, A., Bieysse, D., Ogwang, J.A., Kyetere, D.T., 2006a. Towards a Variety Resistant to Coffee Wilt Disease (CWD): a Case for Robusta Coffee (Coffea canephora) in Uganda 8.

Musoli, P.C., Kangire, A., Leroy, T., Nabaggala, A., Nakendo, S., Olal, S., Ochugo, J., Kabole, C., Pande, J., Cilas, C., Charrier, A., Bieysse, D., Ogwang, J.A., Kyetere, D.T., 2006b. Towards a Variety Resistant to Coffee Wilt Disease (CWD): a Case for Robusta Coffee (Coffea canephora) in Uganda 8.

Nabeta, N.E., 2016. Coping with coffee wilt disease (Tracheomycosis) in Uganda 70.

Namwagala, B., Ruth, Fortunate, P., Rashida, N., Mildred, M., 2014. The coffee year book 2013/2014. Access to land: Is it the main obstacle to active women participation in coffee production? 15th Edition. ed. Uganda Coffee Federtion., Kampala, Uganda.

National Coffee Strategy, 2015. Uganda National Coffee Strategy 2040 Plan for 2015/16 - 2019/20.

Nyasimi, M., Radeny, M., Kimeli, P., Mungai, C., Sayula, G., Kinyangi, J., 2016. Uptake and Dissemination Pathways for Climate-Smart Agriculture Technologies and Practices in Lushoto, Tanzania.CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS).

Ochago, R., 2018a. Gender and pest management: constraints to integrated pest management uptake among smallholder coffee farmers in Uganda. Cogent Food & Agriculture 4. https://doi.org/10.1080/23311932.2018.1540093

Ochago, R., 2018b. Gender and pest management: constraints to integrated pest management uptake among smallholder coffee farmers in Uganda. Cogent Food & Agriculture 4. https://doi.org/10.1080/23311932.2018.1540093

Ochago, R., 2018c. Gender and pest management: constraints to integrated pest management uptake among smallholder coffee farmers in Uganda. Cogent Food & Agriculture 4. https://doi.org/10.1080/23311932.2018.1540093

Ochago, R., 2017. Barriers to women's participation in coffee pest management learning groups in Mt Elgon Region, Uganda. Cogent Food & Agriculture 3. https://doi.org/10.1080/23311932.2017.1358338

Ogato, G.S., Boon, E.K., Subramani, J., 2009. Gender Roles in Crop Production and Management Practices: A Case Study of Three Rural Communities in Ambo District, Ethiopia. Journal of Human Ecology 27, 1–20. https://doi.org/10.1080/09709274.2009.11906186

Okiror, F.A., 2018. Improving smallholder coffee productivity one step at a time | CCAFS: CGIAR research program on Climate Change, Agriculture and Food Security [WWW Document]. URL https://ccafs.cgiar.org/news/improving-smallholder-coffee-productivity-one-step-time#.XXuJligzbIU (accessed 9.13.19).

Ousmane, D., Nafiou, M.M., 2019. Determinants of agricultural technology adoption: Farm households' evidence from Niger. J. Dev. Agric. Econ. 11, 15–23. https://doi.org/10.5897/JDAE2018.0998

Phiri N. and Baker, P.S., P.N. and B., P.S., 2009. Coffee Wilt in Africa Final Technical Report. Farms and Farmers: Agronomic and Socio-economic Surveys. CAB International, Meddy Mulisa in Bukoba.

Pinard, F., Makune, E.S., Kampagne, P., Mwangi, J., 2016. Spartial distribution of Coffee Wilt Disease Under Roguing and Replanting Conditions: A Case Study from Kaweri Estate in Uganda. Phytopathology 106, 1291–1299.

Rutherford, M.A., 2006. Current Knowledge of Coffee Wilt Disease, a Major Constraint to Coffee Production in Africa. Phytopathology 96, 663–666. https://doi.org/10.1094/PHYTO-96-0663

Rutherford, Mike A, Phiri, N., 2006. Pests and Diseases of Coffee in Eastern Africa: A Technical and Advisory Manual 70.

Rutherford, Mike A., Phiri, N., 2006. Pests and diseases of coffee in Eastern Africa: a technical and advisory manual. Wallingford, UK: CAB International.

Shita, A., Kumar, N., Singh, S., 2018. AGRICULTURAL TECHNOLOGY ADOPTION AND ITS DETERMINANTS IN ETHIOPIA: A REVIEWED PAPER 7.

Stewart, R., Rebelo, D.Silva.N., Langer, L., Muchiri, E., Zaranyika, H., Erasmus, Y., Randall, N., Rafferfy, S., Korth, M., Madinga, N., de Wet, T., 2015. The effects of training, innovation and new technology on African smallholder farmers' wealth and food security: a systematic review. 3ie Systematic Review. London: International Initiative for impact evaluation (3ie).

Tessema, Y.M., Asafu-Adjaye, J., Kassie, M., Mallawaarachchi, T., 2016. Do neighbours matter in technology adoption? The case of conservation tillage in northwest Ethiopia 11, 15.

THE NATIONAL COFFEE POLICY, 2013. MINISTRY OF AGRICULTURE, ANIMAL INDUSTRY AND FISHERIES. THE NATIONAL COFFEE POLICY.

UCDA, 2019. Robusta Coffee Handbook. Uganda Coffee Development Authority, Kampala, Uganda.

UCDA, 2016a. UCDA Annual Report July 2015-June 2016, Volume 25. UCDA, Uganda.

UCDA, 2016b. Uganda Coffee Development Authority. Annual Report 2015/2016. Uganda Coffee Development Authority, Kampala.

UCDA, 2015. Uganda Coffee Development Authority. 2014-2015 Annual Report. Uganda Coffee Development Authority, Kampala.

UCDA, 2012. UCDA Annual Report 2011-2012. Uganda Coffee Development Authority, Kampala.

UNDP, 2012. Development of Inclusive Markets in Agriculture and Trade (DIMAT). Value Chain Analysis (VCA) of the Coffee Sub-sector in Uganda. The Market and Nature of Coffee Value Chains in Uganda. UNDP, GoU, Kilimo Trust, Uganda.

Unger, J., 2014. Evaluation of local knowledge applied by farmers towards management of crop pests and diseases in the Masaka region, Uganda 100.