Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Department of Ecology

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*?

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Photo: Lina Wu

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Abstract

The coffee industry in Uganda employs over 3.5 million families, and the exportation of coffee generates about 20 % of the foreign exchange earnings. Over the course of the past two decades a pest called the Black Coffee Twig Borer, *Xylosandrus compactus* (Eichhoff), has invaded the coffee plots. Since this pest attacks economically important plants it can cause serious damage to the farmers' and Uganda's economy. This study focuses on comparing the knowledge about this pest, and how the information is transferred amongst three important groups in coffee production: coffee farmers, advisers and experts from different organizations and institutes. Furthermore, I specifically investigated the relationship between *X. compactus* and a tree often promoted to be intercropped with coffee: the Natal fig (*Ficus natalensis*). The results were derived from conducting interviews and a field survey of *X. compactus* attack rates. The field data was collected in Kalungu and Bukomansimbi district and the interviews were conducted in the same districts, as well as in Mukono and Kampala. The views differed amongst the three groups. The farmers reported greater yield losses than the advisers estimated. Furthermore, the symptoms of the pest did not seem to be completely understood amongst the farmers showing that more information is needed. Despite being the main source of information concerning this pest for the farmers, the agricultural/production officers sometimes gave contradictory advice. Therefore a more thorough education for the officers is needed. The most common method to control *X. compactus* was phytosanitary (cutting off affected twigs and burning them). *Ficus natalensis* was perceived as a host tree for the pest by at least one in each of the three groups. The field data showed a significantly greater infestation degree when there were more than one *F. natalensis* within a five meter radius of the coffee tree. Hence, planting *F. natalensis* close to coffee should not be advised. To control the pest one could use an IPM approach, which reduces the use of chemical control, and instead uses methods which minimizes the effect on the ecosystem. Ways forward could include i.e. favoring natural enemies and intercropping with, repellent trees or non-host trees. This study could give a holistic picture of the impact of *X. compactus* and prevent farmers from planting potential host trees among the coffee.

Keywords: Xylosandrus compactus, Black coffee twig borer, robusta coffee, Coffea canephora, Uganda, Ficus natalensis, Natal Fig

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Abbreviations

NaCORI - National Coffee Research Institute
NaFORRI - National Forestry Resources Research Institute
NUCAFE - National Union of Coffee Agribusinesses and Farm Enterprises
UCDA - Uganda Coffee Development Authority

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1. Introduction

1.1 Background

Agriculture is of utmost importance to Uganda's economy where about 71% of the land is used for agriculture (CIA, 2013). The majority of the farms are small-scale, which produce enough food for both self-supply and selling. About half a million of these small scale farms receive the chief portion of their income from coffee export (Karlsson, 2015). Officially, there are 500 000 smallholder coffee farmers (most farms range between 0.5-2.5 hectares) and the entire coffee industry employs over 3.5 million families. Coffee exportation generates about 20 % of the foreign exchange earnings in Uganda (UCDA, 2012). Two types of coffee are grown in Uganda: arabica (*Coffea arabica)* which is grown in the highland areas and the more common robusta (*Coffea canephora*) which is grown in the area around Lake Victoria (up to 1200 meters above sea level) (UCDA, 2012). However, many of the coffee trees are old and need to be replaced in order to keep a high productivity (Karlsson, 2015), since coffee yields at its maximum during its first 40 years and most of the Ugandan coffee trees are more than 50 years old (UCDA, 2012).

Coffee trees are often intercropped with food crops and shade trees, which creates both a suitable environment for the coffee and provides a diversified income for the farmer (UCDA, 2012). This is an example of agroforestry, which is a form of intercropping where trees and shrubs often are integrated in the crop fields. Intercropping trees with regular food crops yields many benefits. Firstly, the leaves from the trees enrich the soil, the trees increase biodiversity, give shade and can have multiple purposes such as giving fruits or providing timber (Wekesa and Jönsson, 2014). Furthermore, an agroforestry system can reduce both soil erosion and leakage of nutrients (Lwakuba et al., 2003). Agroforestry systems with robusta coffee and non-fruit trees have a higher soil organic carbon content than monocultures with only coffee trees and systems with robusta coffee and fruit trees (Tumwebaze and Byakagaba, 2016). Agroforestry systems with coffee trees are furthermore a credible way of reducing the impact on the climate because of its carbon sequestration (Tumwebaze and Byakagaba, 2016). Moreover, agroforestry can also result in reduced numbers of parasitic and non-parasitic weeds, as well as an increased number of natural enemies (Pumariño et al., 2015). Even if the effect of agroforestry systems on invertebrate pests and diseases are dependent upon crop type, overall it can be said that agroforestry is advantageous regarding pest, disease and weed management (Pumariño et al., 2015). However, some pests, including the white stem borer *Monochamus leuconotus* Pascoe in Uganda, may benefit

from the shaded conditions that agroforestry provides, and multiply (Jonsson et al., 2015).

Ficus natalensis (Natal fig) is an indigenous tree in Uganda and one of the tree species promoted by Vi-Agroforestry to be intercropped with coffee (Kagezi et al., 2014). It is a culturally important tree since it is the major source of bark cloth (Oluka-Akileng et al., 2000) which is used for bedding and clothing amongst other things (Robertson, 2014). It is termite resistant and provides good shade (Wekesa and Jönsson, 2014); using shade can considerably reduce the labor input and weeding costs (Silva and Tisdell, 1990). *Ficus natalensis* is furthermore used as a wind break, shade tree for other crops, it conserves moisture, improves soil fertility and creates a favorable microenvironment for the crops (Oluka-Akileng et al., 2000). However, farmers have been reported to cut down trees due to the belief that too much shade favors *X. compactus* (Komakech, 2016). Some farmers also suspect that some shade trees are hosts to *X. compactus*.

Since 1993 the Black Coffee Twig Borer, *Xylosandrus compactus* (Eichhoff), has been a problem for coffee production in Uganda (Kagezi et al., 2014). It has over 200 hosts across the world (Ngoan et al., 1976) including tea, cocoa and avocado trees (Waller et al., 2007) and it can for example be found in tropical Africa, China, India and on many pacific islands (Waller et al., 2007). Of the two coffee species it is primarily the robusta coffee that is attacked by *X. compactus* (Waller et al., 2007). The female of *X. compactus* is less than 2 mm long and black while the males are smaller and reddish-brown (Figure 1). It takes about 30 days to complete the cycle from egg to mature adult. The female bores a hole into the underside of the twig and when she reaches the pith she chews a tunnel to make a brood chamber where she lays her eggs (Ngoan et al., 1976). White, fine saw dust can be seen around the entrance hole (Waller et al., 2007). The female carries fungal spores (‘ambrosia’ fungi) in mycangia (special structure on the head) which she places on the walls of the tunnel when she is preparing the nest (Waller et al., 2007). One fungus found in the mycangia is *Ambrosiella xylebori* (Hayato, 2007) which creates a 0.1 to 0.5 mm thick lining inside the brood chamber and serves as food for both larvae and the adults of *X. compactus*. After *X. compactus* attack the leaves wilt and then turn brown within a week or two (Ngoan et al., 1976).

Figure 1. To the left *Xylosandrus compactus* adult female and to the right an adult male. Photo: Gerard Malsher.

The pest hence causes two types of damage; mechanical damage when boring into the twig and xylem damage, via the introduction of ambrosia fungi. Severe attacks by *X. compactus* can even kill small trees (Hayato, 2007). There are different types of control methods being used to combat the pest, for example chemical control, sanitary methods (cutting off affected twigs and burning them) and improving the soil (Waller et al., 2007). To this day, a thorough understanding of how agroforestry practices affect *X. compactus* infestations is still not known.

1.2 Aim

This study aims firstly to determine and compare the level of knowledge about *X. compactus* among farmers, advisers and experts. Secondly it aims to clarify if there is a higher or lower degree of infestation of *X. compactus* when the robusta coffee is planted close to *F. natalensis* trees.

2. Materials and methods

The study was divided into two parts: interviews and a field study. All field work was performed collectively with Lina Wu and Christina Hultman. Both the interviews and field visits were conducted during February and March 2016. The study was carried out in the area surrounding Masaka (Kalungu and Bukomansimbi districts), in Central Uganda. Masaka is situated in the Banana-Coffee zone of Uganda which is a crescent shaped zone around Lake Victoria. In this zone bananas and coffee are common crops (Oluka-Akileng et al., 2000).

2.1 Interview method

The aim of the interviews was to gather information about *X. compactus* and to get a holistic picture of the perception of the pest as well as to locate the different sources of information for the three groups. The interview part of the study comprised in total 20 farmers, four officers in agriculture/production from Kalungu and Bukomansimbi district (two from each district), a development director from a public authority (Uganda Coffee Development Authority, UCDA), two representatives from a farmers' union (National Union of Coffee Agribusinesses and Farm Enterprises., NUCAFE) (the two representatives shared the interview), a consultant from NaFORRI (National Forestry Resources Research Institute), a research officer (National Coffee Research Institute, NaCORI) and an associate professor at a university (Makerere University). These particular organizations and institutes were chosen as they all had a connection to the pest, through working with coffee, trees or pest management. The representative from NaFORRI will be referred to as expert (a), the representative from NaCORI as expert (b) and from Makerere University as expert (c) in the text. The representatives from UCDA and NUCAFE are henceforward included in the group of officers and referred to as advisers (in total six people). The two agricultural officers from Kalungu district will be referred to as adviser (a) and (b), the representative from UCDA will be referred to as adviser (c) and from NUCAFE as adviser (d). The agricultural officer from Bukomansimbi will be referred to as adviser (e) and the production officer from Bukomansimbi as adviser (f). The farmers to be interviewed were chosen by the farmers' cooperatives' managers in dialogue with our supervisor at Vi-agroforestry. Our expressed wish was to interview farmers that were affected by *X. compactus* and had knowledge about the symptoms of the pest. The interviews began with a presentation of ourselves in order to clarify the aim of the study, diminish cultural misunderstandings and stress the importance of objective answers. The interviews were conducted in English and Luganda with the help of a translator. The answers were noted and later all

the answers were summarized (Appendix 1) for analysis. The questions were divided into general questions and specific questions for each of our studies. The questions used in this paper are listed in Table 1. They were chosen to highlight the views of farmers, advisers and experts about *X. compactus,* its impact on coffee growing, what control methods are recommended and used, what sources of information the three groups had, and to investigate the view of intercropping trees, especially *F. natalensis,* and the effects of shade on the pest.

Table 1. Questions from the different questionnaires that were used in this thesis. The questions concern coffee growing, *X. compactus* and trees

Appendix	Questions
1 Farmers	5, 9, 11-15, 17-21, 23-25, 27-29
2 Advisers	4, 7, 9-14, 17-21
3 Experts	2, 4, 7, 9-11, 13-18, 20, 21, 23-26

The interviews with the advisers and experts were conducted in English, hence no translation was needed. These interviews also started with a presentation similar to the one in the farmers' interviews. The answers were noted and summarized in Appendix 2 and 3, and then analyzed through comparing them with each other and concluding which views were most common.

2.2 Field study

Coffee trees were studied in order to determine the degree of infestation of the pest *X. compactus* in relation to shade and the abundance of surrounding tree species (the focus of this study was on *F. natalensis*). The field study comprised the same 20 farms where the interviews were conducted. On each farm 30 coffee trees on the coffee plot closest to the homestead was examined, meaning ten coffee trees studied per person and farm (i.e., in all 600 coffee trees were selected). The location of the 20 coffee plots were recorded by a GPS to know where they were situated if further studies will be conducted (Figure 2).

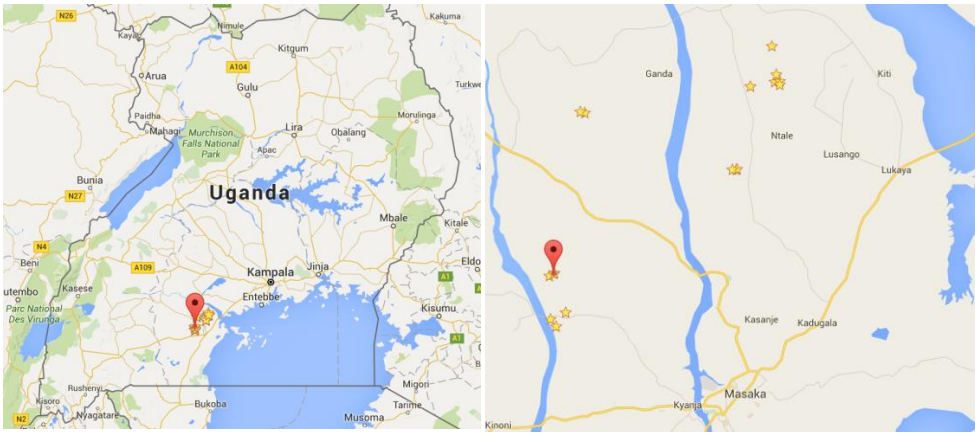


Figure 2. To the left a map showing an overview of the location of 17 of the investigated coffee farms and to the right a more detailed view. The remaining 3 farms could not be located due to using an alternate coordinate system when recording the locations.

Three parallel lines were selected, as shown in Figure 3; two of them ran along two borders, with a distance of five meters to the plot border. The third line went midway between the two other lines. The starting points of all lines were located five meters from the border. Depending on the size of the coffee plot, every or every second coffee tree was examined. If the coffee had no twigs on the middle third part then that tree was excluded and the next tree was examined instead.

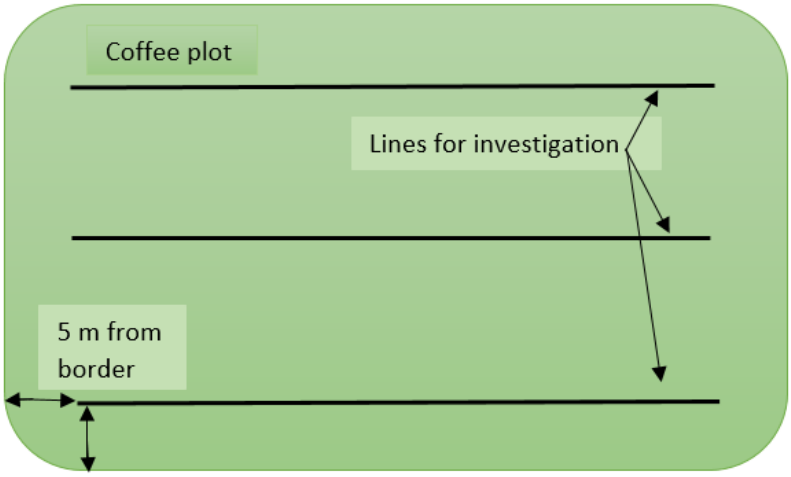


Figure 3. The three transect lines along which the coffee trees were investigated for *X. compactus*.

The sampling protocol for the field study method can be found in Appendix 4. Four twigs per coffee plant were examined, one twig in every cardinal direction on the middle third part of the coffee plant. This part was chosen because it was a practical height to work with and most trees had twigs in

this part and they could therefore be included in the survey. The pest has been reported to fly less than two meters above ground (Chong et al., 2009) and the middle third is thus where the highest percentage of the infested twigs can be found (Kagezi et al., 2013). The number of entrance/exit holes of *X. compactus* was counted on the four twigs.

We furthermore surveyed the surroundings of each coffee tree. The shade level was estimated by eye through evaluating the coverage of the canopy of other trees and crops, above the coffee tree in a radius of one meter around the coffee's crown. The degree of shade was divided into five groups: 0-20%, 21-40%, 41-60%, 61-80% and 81-100% canopy coverage. Lastly, all the different tree species and banana crops in a radius of five meters around the coffee tree were noted.

The field study data used for analysis in this thesis was the infestation degree in relation to the prevalence of *F. natalensis*, as well as coffee trees with no surrounding trees. Hence, the entire dataset collected was not used in the analysis.

2.3 Data analysis

To analyze the number of holes per twig in relation to the number of *F. natalensis* within five meters, we performed linear mixed effects models, using the lme function in the nlme package in R 2.14.0 (R Development Core Team 2011). We used such a GLM-approach instead of an Anova since the number of observations within each level of the fixed factor (see below) was strongly unbalanced. Prior to analysis, the data was log10 (x+1)-transformed to ensure that residuals of the model were approximately normally distributed. Due to a generally low number of trees present within five meters we could not analyze our data with number of trees expressed as a continuous variable. Thus, the fixed model included the number of *F. natalensis* summarized into a categorical variable with three levels (zero trees, one tree and more than one tree within five meters radius). The random model included plot to account for non-independence of trees sampled within each plot. To compare the effect of *F. natalensis* presence and abundance on means, Tukey contrasts were performed with the glht function in the multicomp package in R 2.14.0.

3. Results

3.1 Results from interviews concerning *X. compactus*

All of the questions asked in the interviews were not relevant for my research question. The questions that were chosen as a basis for this thesis are focused on how *X. compactus* have affected the coffee farming, what people know about the pest, symptoms, control methods, intercropping of *F. natalensis* and how that specific tree species, affects the pest. The material below is taken from Appendix 1, 2 and 3 summarizing the answers from the farmers, advisers and experts respectively.

3.1.1 Impacts of *X. compactus* on coffee yield

Every interviewee agreed that *X. compactus* is a major problem in Uganda. However, the view of the severity of the pest varied. The farmers reported yield losses ranging from 20-75%, but mostly (15/20 farmers) it ranged between 40-67%. The advisers' estimated yield losses varied between 5-40%. Adviser (c) said that *X. compactus* causes Uganda a loss of up to 40 million dollars which is 10% of the coffee export. Expert (a) estimated the yield loss to be up to 50% in organically grown coffee; and expert (b) estimated it to be 9% in whole of Uganda.

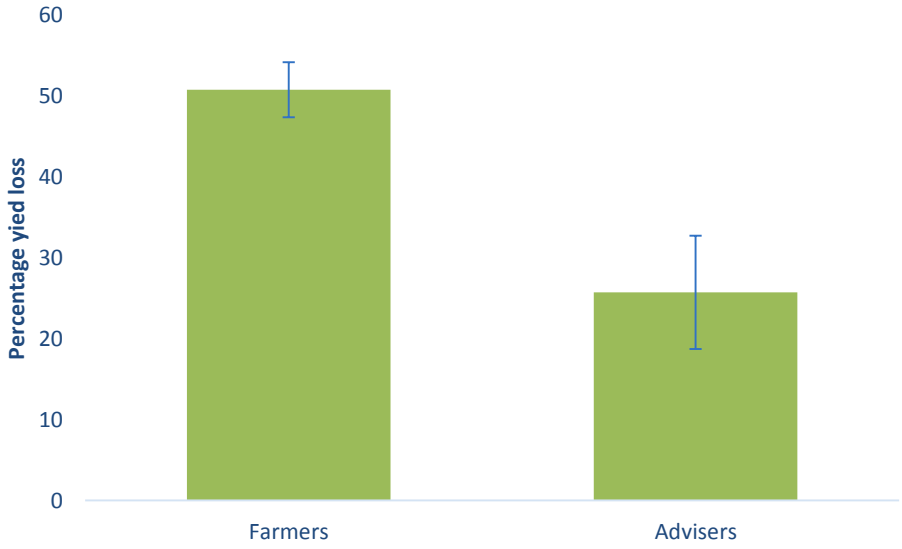


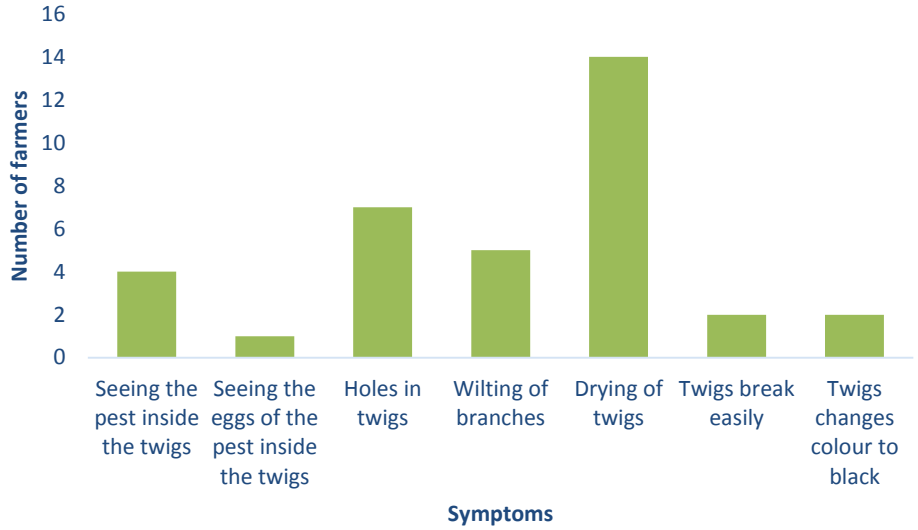
Figure 4. The mean coffee yield loss estimated in percentage by farmers and advisers, with standard error.

The advisers generally estimated lower yield losses than the farmers, as can be seen in Figure 4 (especially adviser (c) and (d) who are working at a national level rather than district level). The average yield loss among the

farmers was 51% and among advisers it was estimated to be on average 26%.

3.1.2 Symptoms and general information about *X. compactus*

Most farmers (14/20) pointed out dried twigs as a symptom of *X. compactus* infestation, only seven mentioned holes in the twigs. Other symptoms mentioned were wilting and yellowing of leaves, as well as discoloration of twigs (Figure 5). These varying symptoms might cause confusion when determining the cause of the yield loss, since drying twigs or yellowing leaves might be due to something else than *X. compactus*.



Figur 5 The farmers' descriptions of the symptoms of *X. compactus*.

Three fourths of the farmers did not know how the pest had arrived to their farm. Only two farmers said that the pest had flown there. All advisers agreed on the fact that the pest moved from farm to farm through flight. Expert (b) mentioned infected plant materials, while expert (a) mentioned shared tools and expert (c) said that short distances between field borders which enables the pest to fly from farm to farm were likely ways of pest dispersal.

More than half of the farmers had been growing coffee for the past 20 years or more. The majority of the farmers had experienced problems with *X. compactus* only during the past two to three years, while for some the problems with the pest had lasted for a longer period. The experts agreed that the pest is a fairly new problem. Thirteen out of 20 farmers answered that they had a specific area of their coffee plots that was more severely

affected and seven out of 20 that it was because there was too much shade at these sites.

The majority of the farmers believed that the pest is most active during the rainy season. Two thirds of the advisers said that *X. compactus* is most active during the dry season which stands in stark contrast to the belief of the farmers. Expert (b) (whose institute is the only one currently involved in research concerning *X. compactus*) said that the population was biggest during the dry season since it was suppressed during the rainy season. The opinions were, as shown in Table 2, mixed.

Table 2. Answers to when *X. compactus* is most active during the year

	Dry season	Rainy season	Other factor than season	Don't know
Farmers	20.0%	70.0%	5.0%	5.0%
Advisers	66.7%	33.3%	-	-
Experts	33.3%	-	33.3%	33.3%

3.1.3 Control methods

Chemical control is not widespread among the farmers, only seven out of 20 used insecticides. The chemicals used varied between the different farms, as well as the amounts and intervals, even when the chemical was the same. The most common control method used by the farmers was coffee tree management; primarily by removing and burning affected twigs (17/20) but also by removing sprouts on the coffee trees and by weeding (removing potential host plants). Tree management, by pruning shade trees, was also used. Felling of shade trees was a method used by the farmers to control *X. compactus* even though neither the advisers nor the experts had advised it (Figure 6).

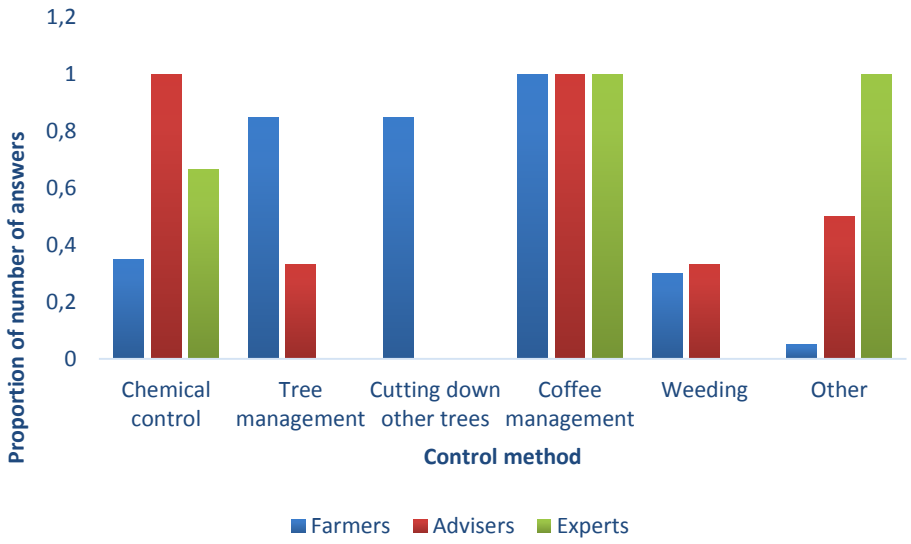


Figure 6. The proportion of number of people using or recommending different control methods.

All farmers answered that they had received advice concerning *X. compactus* and most of them had gotten advice to remove the affected twigs and burn them, only one had been advised to reduce the shade. All advisers mentioned burning of affected twigs as a method to control *X. compactus*, as well as chemical control but they referred to different chemical substances. A few of the advisers recommended weeding and alternative control methods (labeled "Other" in Figure 6) such as stumping (cutting down the entire coffee tree) and having a proper spacing between plants. All experts also recommended cutting off and burning affected twigs. Chemical control was also recommended. Expert (b) claimed that a combination of sanitary methods and chemical control would be necessary to control the pest, and that the chemicals ought to be systemic in order to be effective. Expert (b) also stressed that the coffee itself should not be too bushy since that attracts *X. compactus* and that the sprouts should be removed for the same reason. Expert (c) emphasized the importance of having strong coffee trees with enough nutrients to cope with the attacks.

The majority of the farmers had not seen any natural enemies of *X. compactus*, but three had seen an ant (*Plagiolepis sp.*) feeding on *X. compactus*. One adviser had heard of an insect that is a natural enemy to the *X. compactus* called "Munyera", which also is an ant. The natural enemies mentioned by the experts were a parasitoid (*Phymasticus coffeae)*, two pathogenic fungi (*Beauveria bassiana* and *Metarhizium anisopliae)* and an ant.

The experts were asked which life stage of *X. compactus* is the most vulnerable. Expert (b) said that it is believed to be the penetration stage, when the female bores into the twig and is exposed to attacks by for example parasitoids. Expert (c) claimed that the climate in Uganda is favorable for the pest which makes the generations overlap and therefore there is no time period that is particularly vulnerable.

3.1.4 Intercropping trees, specifically *Ficus natalensis*, with coffee

Nineteen out of 20 of the interviewed farmers did intercrop trees with their coffee, for various reasons such as to provide shade, green manure, fruits etc. Ninety percent of the farmers intercropped *F. natalensis* with their coffee. Mostly it was used for shade, firewood, green manure and bark cloth. It was most common to have about two to twelve *F. natalensis* per hectare, but some had more with the highest being 62 per hectare. *Ficus natalensis* was recommended by all the advisers and was rated as rather common (the advisers believed that 30-80% of farmers had this tree). One adviser stressed that the recommended trees depend on the region and vary between districts. *Ficus natalensis* was recommended for the same reasons as the farmers mentioned such as shade and bark cloth. One adviser mentioned *F. natalensis* having a symbiotic relationship with a mycorrhiza fungus which makes potassium available for coffee, however, no scientific articles were found to support this claim. One of the advisers said that *F. natalensis* could be a preferred host for *X. compactus* over coffee. The experts confirmed that *F. natalensis* is one of many trees recommended for intercropping. Other trees are for example *Albizia chinensis* and *Maesopsis eminii*. Expert (a) and (b) recommended *F. natalensis* as it provides shade, fodder and is used for bark cloth. Expert (c) recommended native trees to be intercropped with coffee, which *F. natalensis* is (Eggeling, 1951).

3.1.5 Hosts, repellant plants and *X. compactus*

Out of the 20 farmers that were interviewed 17 reported to have cut down trees in order to control *X. compactus*, out of which twelve had cut down *F. natalensis*. Four farmers suspected that *F. natalensis* was a host tree. Four of the advisers knew that *X. compactus* had alternative hosts and the potential host trees they mentioned were all common trees in the agroforestry landscape such as *Albizia* and avocado. Half of the advisers mentioned plants that were believed to be repelling plants: *Tagetes minuta* (Mexican marigold; repels the banana weevil (Blomme et al., 2003)), *F. natalensis*, *Allium sativum* (garlic) and *Nicotiana spp.* (tobacco). However, two of the advisers based the knowledge on word of mouth. Expert (a) and (b) pointed out that *F. natalensis* is a host tree for *X. compactus.* However, expert (b) said that it at the same time produces a sap which kills the pest. The repellant trees or plants named by the experts were *Azadirachta indica*

(Neem tree), *Cannabis sativa* (Cannabis), *Papaver somniferum* (opium) and *Piperaceae spp.* (pepper).

About half of the farmers said that there is a relationship between trees and *X. compactus*. When asked to elaborate they mentioned different suspected host trees (*F. natalensis*, jackfruit and avocado) and excessive shade. Most of the farmers were convinced that there is no relationship between crops and *X. compactus*.

3.1.6 Shade and *X. compactus*

The reasons for shading coffee trees are many, for example it was said to improve the taste, and contribute to a better microclimate. The shade trees act as wind-breakers and conserve soil moisture. The recommended shading varied between 30-70% among advisers. Two of the experts agreed that shade improves the quality of the coffee. Among the advisers the opinions were clearly divided concerning the effect of shade on the infestation degree; two advisers considered shaded coffee trees to be more infested and equally many considered sun exposed coffee trees to be more infested. Expert (b) argued that it is the stress caused by drought or too much shade that causes the attack rate of *X. compactus* to increase. Expert (a) had the same view as many farmers that shade provides a suitable environment for the pest and therefore shaded coffee is more affected. These two experts had somewhat overlapping views in this question. Table 3 shows the different opinions of the three groups.

Table 3. Comparison between answers concerning shaded or sun-exposed coffee being more affected by *X. compactus*

	Shaded coffee	Sun exposed coffee	Does not matter	Do not know	Comment
Farmers	70.0%	15.0%	5.0%	5.0%	-
Advisers	33.3%	33.3%	16.7%	16.7%	-
Experts	33.3%	-	-	33.3%	Stressed coffee (shade/drought) increases the hit rate by *X. compactus*

3.1.7 Spreading of information

All of the farmers had received advice concerning *X. compactus*. Three fourths of the farmers reported that this information was acquired from agricultural extension officers. However, some of the farmers expressed

resignation when it came to control methods. The phytosanitary methods resulted in many twigs being cut off and thereby reduced yields. The advisers primarily spread information through meetings and training of farmers. All of them said that at least some of the farmers followed the advice concerning *X. compactus* but that more is needed to be done if the pest is to be managed. Their sources of information were mainly research stations and farmers. The experts got their information from other research institutes (ex. a university in Hawaii), field studies and by reading publications. Two of the experts said that they spread information by visiting farmers or farmers' groups. Expert (a) said that its organization passes on information to agricultural extension officers who in turn advice the farmers.

3.2 Results from field study

Results from a linear mixed effects model (lme) analysis showed that the number of *F. natalensis* trees close to the coffee tree significantly affects the number of entrance/exit holes on the coffee twig ($p<0.05$). Figure 7 shows that having more than one *F. natalensis* leads to an increase in number of holes per twig compared to having no or one *F. natalensis*. However, the standard error increases with each category since there were not as many observations with many *F. natalensis* as with no or one *F. natalensis* (no surrounding *F. natalensis* with 475 observations, one *F. natalensis* with 104 observations and more than one with 21 observations). The posthoc Tukey test showed that there were significantly more entrance/exit holes when there were more than one *F. natalensis* within five meters radius compared to when no trees were present ($z=-2.761$, $p=0.0146$), but there were no significant differences between zero and one *F. natalensis* ($z=-2.065$, $p=0.0907$) and between one and more than one *F. natalensis* ($z=-1.647$, $p=0.2150$).

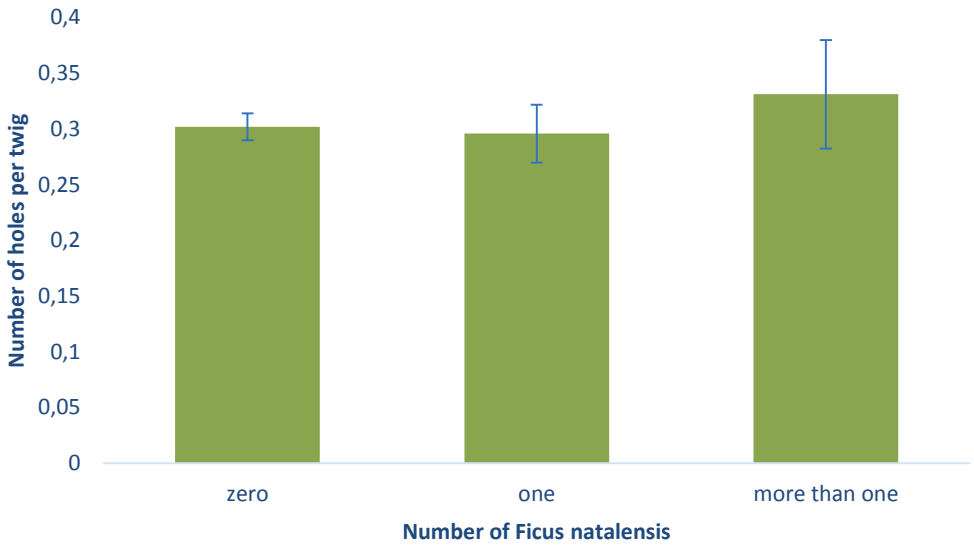


Figure 7. Average number of entrance/exit holes per twig on the coffee when surrounded by zero, one or more than one *Ficus natalensis*. Including the standard error.

4. Discussion

More than half of the farmers have been growing coffee for more than 20 years which makes their answers especially relevant concerning infestation degree. Furthermore, the farmers are out in the fields every day noting the damages and have seen the changes through the years. The interviewees in the districts and the institutions were not all equally well-informed concerning the pest. This resulted in varied, sometimes even contradictory, answers. For example, the production officer was more involved in veterinary matters and might not have had sufficient knowledge about *X. compactus.* Furthermore, two of the experts were not directly involved in any research concerning the *X. compactus*. NaCORI (where expert (b) worked) had done research specifically on the pest, and research on *X. compactus* had been carried out at one of the departments of Makerere University (however, not by the Associate Professor, expert (c), that we interviewed). However, the varying answers could also be due to the different scales they looked at; agricultural/production officers looked at a regional level while the institutions looked at a national level.

4.1 Impact and control methods of *X. compactus*

Wang et al. (2015) concluded that the three most limiting factors to robusta coffee production in Central Uganda are low coffee density (less than 1200 trees per ha), *X. compactus* damage, and high coffee tree age. *X. compactus* being a major problem is supported by the interviews with the three groups. However, the perception of the impact of the pest seemed to differ between the groups. Overall the farmers estimated the yield losses to be greater than the advisers' and the experts' estimates. This might be because the farmers interviewed in our study were chosen for being heavily affected by the pest while the advisers and experts referred to damage levels at the average farm. Alternatively, the impact of the pest might be increasing fast and this is noticed first by the farmers. The experts said that the pest is a fairly new problem which is in accordance with the farmers experiencing most problems with *X. compactus* during the past two to three years. When asked about the most active season of the pest the answers differed greatly between the groups. Most farmers were convinced that the pest was most active during the rainy season while one third of the advisers, along with expert (b), said that it is most active during the dry season. However, if one interprets the most active time as the time when the pest flies, bores, when the biggest population can be found or when the most symptoms can be seen the answers will inevitably differ. Since no distinction was made in the interviews as to what kind of activity was considered and no scientific articles were found to support either of them in Uganda, no conclusions can be drawn from this question. By asking a more specific question, as to what

was meant by active time, one could have gotten more easily interpreted answers. The farmers seemed to be fairly familiar with the symptoms of the pest but all did not seem to be aware that it flies and therefore easily spreads from farm to farm. The advisers seemed to deem the current effort by the farmers to manage this pest as insufficient. Therefore, stressing that *X. compactus* is a flying insect that easily disperses between farms could be of use when arguing for a collective management solution. The farmers expressed resignation for the amount of twigs that were cut off and the reduction in yield it resulted in. New methods are needed to battle *X. compactus* as phytosanitary methods are labor intensive, uneconomical and need a community-based approach (Kagezi et al., 2014).

4.2 The effect of *Ficus natalensis* and shade on infestation degree

Ninety percent of the farmers intercropped *F. natalensis* with their coffee making it a very common tree. *Ficus natalensis* was described as both a repellant and a host tree in the interviews, though most often it was thought to be a host tree. Another tree from the *Ficus* family has been reported to be a host tree - *Ficus carica L.* (Chong et al., 2009) suggesting that the *F. natalensis* could also be a host for the pest. The results from the field study show that having many *F. natalensis* trees close to the coffee leads to higher infestation degree. These results are in accordance with the findings of Kagezi et al. (2013) which stated that coffee trees shaded by *F. natalensis* had the highest infestation rates among eight common agroforestry trees. Thus both the interviews and the field study indicate that *F. natalensis* could be a host tree for *X. compactus*. However, it is also possible that *F. natalensis* merely contributes to increased shade which leads to higher infestations.

Christina Hultman's analysis of our joint data showed that having more than 20% shade could result in higher infestation rates by *X. compactus* (Hultman, 2016). To achieve a high coffee yield intermediate shade is recommended (Muschler, 2001), which is in concordance with the advisers' recommendations. However, as previously stated intermediate shade might not be optimal from a pest management point of view. A study from Malaysia showed that shaded coffee experienced significantly more damage by *X. compactus* than sun exposed coffee (Anuar, 1986). In that study the most affected trees were found in the middle of the plot where the shade levels were the highest (Anuar, 1986). This also correlates with some of the farmers' view that the most affected areas were the ones with most shade. However, only one third of the advisers shared the view that shaded coffee is more affected by *X. compactus* which can result in incorrect advice. Three fourths of the farmers got their information from the agricultural extension workers underlining the importance of having correct

information through these channels. In the present situation advisers have different opinions on rather important aspects, such as if sun-exposed or shaded coffee is more affected by *X. compactus.*

4.3 Control methods

Integrated Pest Management (IPM) is an approach which aims to minimize the use of pesticides and combines different management strategies to grow healthy crops. It encourages natural enemies as a control mechanism (FAO, 2016). Since the chemicals used by/recommended to the farmers in this study varied in both amount and application interval (Appendix 1, 2 and 3) and there seemed to be no clear damage threshold for when to spray, one could argue that a more IPM oriented approach should be advocated. The ant *Plagiolepis sp.* was mentioned by at least one in each of the three groups and has been proven to be an indigenous predator of *X. compactus* (Egonyu et al., 2015). Thus, favoring this natural enemy could be a way of controlling the pest. *Beauveria bassiana*, which was also mentioned in one interview, is a pathogenic fungi and also a natural enemy of the pest (Balakrishnan et al., 2011). *Xylosandrus compactus* is attracted to ethanol which makes it a good bait for traps to monitor the pest (Burbano et al., 2012). Limonene (a citrus-based terpene (Toplisek and Gustafson, 1995)) and verbenone (an anti-aggregation pheromone (Huber and Borden, 2001)) act as repellants to *X. compactus* and can reduce the severity of the attack (Burbano et al., 2012). Application of these substances could thus help to protect the coffee plots from *X. compactus* infestation. The input of fertilizers is often insufficient in central Uganda (Sseguya et al., 1999) and one way to mitigate the impact of the pest is by creating strong and healthy plants that can withstand an attack, for example by conserving moisture through mulching (Bambara, 2011). None of the farmers thought there was a relationship between food crops and the *X. compactus*. However, the pest is known to attack crops such as egg plants (NSC, 2014). Since expert (c) claimed that there is no specific time which is more vulnerable for the pest these control methods mentioned above, which are not time-specific, could be advised. However, expert (b) said that the period when the female penetrates the twig is the most vulnerable. Expert (b) also said that there currently is research being done in this area to prolong the penetration time, using chemical sprays, to favor parasitoids.

4.4 Limitations of the study and suggestions for further research

The farms that we visited were chosen with the aim of finding affected coffee plots which may have resulted in a rather negative impression of the pest situation. It might also have resulted in the advisers and experts appearing less informed since they were referring to the average farmer. Nevertheless, it likely resulted in us receiving trustworthy answers from the

questionnaires since the farmers had a thorough experience of the pest. One source of error that was noticed was that in some coffee plots trees had been recently cut down and were lying around. They might have had an impact on the coffee and *X. compactus* before they were felled and that impact (if it was shade-, or host tree-related) could have confounded our results. Furthermore, when the farmers answered that they cut down or pruned their shade trees they might have done it for more reasons (such as firewood etc.) than solely to control *X. compactus*. Through adding a question about the reasons for pruning or cutting down the trees the answers could have been clearer. Another limitation was the few observations in the field study, especially with more than one *F. natalensis*. In further study more observations should be conducted to achieve trustworthy results in all categories. If further research would be conducted one could instead choose agroforestry farms with or without *F. natalensis*.

5. Conclusion

Having *F. natalensis* trees intercropped with coffee and having more than 20% shade can increase the attack rate of *X. compactus*, which correlates with the view of the farmers. However, from this study no conclusions can be drawn as to whether *F. natalensis* is a host tree or not, or if it simply is the shade it provides that is beneficial for *X. compactus*. It is clear that *X. compactus* is causing a lot of damage to robusta coffee in Uganda and one apparent problem is the varying advices from advisers given to farmers. Furthermore, the advice given sometimes lack scientific support. One way forward is better education for the advisers concerning this pest and how to handle it. Agroforestry can be beneficial when it comes to pest control since natural enemies are more abundant in such systems (Pumariño et al., 2015). IPM walks hand in hand with this through promoting natural enemies etc. (FAO, 2016). Since having more than one *F. natalensis* surrounding coffee trees increases the infestation of *X. compactus* other trees should be considered for intercropping. From our study Lina Wu (2016) concluded that the status of *Albizia chinensis* being a host tree or not is unclear at this point. The recommended shade levels of the coffee trees varied between the interviewees. There are studies on shade affecting the yield and quality of coffee (Muschler, 2001, Nzeyimana et al., 2013) and on shade affecting *X. compactus* (Anuar, 1986, Hultman, 2016). A study finding the balance between shade, infestation of *X. compactus* and yield could be the next step. Another example of further study in this specific field could be comparing the infestation degree of *X. compactus* on coffee plots with no intercropped trees with coffee plots intercropped with trees (in our work all except one farm had trees).

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Appendix 1
Questions for the coffee farmers

Note: BCTB = Black Coffee Twig Borer
Note: 1 feet = 30,48 cm

General information

1. How many acres is your land around the homestead?
   (Ranging from 0,06-8 ac.)

Size of land	Number of farmers
X < 1 ac	2
1 ≤ X < 2 ac	2
2 ≤ X < 3 ac	4
3 ≤ X < 4 ac	4
4 ≤ X < 5 ac	1
5 ≤ X < 6 ac	4
6 ≤ X < 7 ac	2
7 ≤ X < 8 ac	1

2. How many acres is occupied by coffee around the homestead?
   (Ranging from 0,06-5 ac.)

Size of land	Number of farmers
X < 1 ac	2
1 ≤ X < 2 ac	4
2 ≤ X < 3 ac	5
3 ≤ X < 4 ac	3

$4 \leq X < 5$ ac	3
$5 \leq X < 6$ ac	3

3. How many coffee plants do you have?
(When an interval was given the mean of this interval was used in the calculations. Ranging from 117-1667 coffee plants/acre.)

Number of coffee plants	area (acres)	coffee plants/acre
1) 450	1	450
2) 1800	3,5	514
3) 800	2	400
4) 2000	4,5	444
5) 1500	4	375
6) 1200	2,5	480
7) 450	1	450
8) 175	1,5	117
9) 2500	5	500
10) 1000	2	500
11) 200	0,25	800
12) 1200	3	400
13) 2500	5	500
14) 100	0,06	1667
15) 900	5	180
16) 2000	3	667
17) 1680	4	420

18) 450	1	450
19) 800	2	400
20) 1000	2	500

4. How did you space your coffee when planting them? Why?
(Ranging from 6-12 feet and for various reasons.)

Spacing (feet)	Number of farmers	Reasons (number of farmers)
6	1	If one coffee dies other coffee trees will compensate the yield loss (1)
9	1	Many died of drought, wanted less spacing to secure coffee production (1)
9-10	1	enough light and space (1)
10	15	recommended spacing from extension officer (6), no reason (1), reduce competition for light (1), to give enough space for the coffee (4), to get more yield (1), if closer - negative impact on production (1), when replacing died/dried coffee no spacing is used (2), less fertilizer needed (1), If one coffee dies other coffee trees will compensate the yield loss (1), gives enough space for intercropping (1)
10-12	1	enough space for the coffee (1)
12	1	avoid competition between coffee trees (1)

5. How long have you been growing coffee?

Years	Number of farmers
3	1
5	2

10	2
15	1
20	7
25	1
30	2
>30	4

6. Do you work on the coffee farm by yourself, with your family or do you hire someone else?

Who works on the coffee farm	Number of farmers
Myself	2
Myself and family	8
Myself, family and hired workers	7
Myself and hired workers	3

7. Do you intercrop any crops with your coffee? If so, which crops?

Crop	Number of farmers
Banana	18
Beans	5
Sugarcane	1
Maize	4
Irish potatoes	1
Cassava	5
Jams	2

Pumpkin	1
No intercropping	1

8. What spacing do you use between the crop and the coffee?

Spacing (feet)	Number of farmers
1	1
3	3
Crop in the middle of 4 coffee plants, about 5 feet in distance	8
10	1
>20	1
Depending on crop	1
No standard spacing	5

9. What trees do you intercrop with your coffee?

Tree species	Number of farmers	Number of trees per farmer	Reason for planting it (number of farmers)
Ficus natalensis (Mutuba or Natal fig)	18	1 tree/acre (4) 2 trees/acre (2) 3 trees/acre (1) 4 trees/acre (2) 5 trees/acre (2) 6 trees/acre (1) 7 trees/acre (1) 8 trees/acre (1) 10 trees/acre (1) 20 trees/acre (1) 25 trees/acre (1)	Shade (14) manure (5) firewood (8) stakes for supporting banana (1) poles for building (1) barkcloth (5) timber (2) protection of environment (1) reduce soil erosion (1) native tree (1) bringing in money (1)

		"Don´t know, but many" (1)	recommended (1) Was there when he/she moved there (1)
Albizia chinensis (Mugavu or Silk tree)	5	<1 tree/acre (1) 3 trees/acre (2) 4 trees/acre (1) 10 trees/acre (1)	Shade (2) Increase soil fertility (1), Shade and increase soil fertility (1) Shade and firewood (1)
Maesopsis eminii (Musizi or Umbrella tree)	6	1 tree/acre (1) 2 trees/acre (2) 3 trees/acre (1) 5 trees/acre (1) 8 trees/acre (1)	Shade (1) Timber (1) Timber and firewood (1) Increase soil fertility and timber (1) Timber and selling of timber (1) Firewood, timber and shade (1)
Jackfruit	14	<1 tree/acre (3) 1 tree/acre (2) 2 trees/acre (3) 3 trees/acre (2) 4 trees/acre (2) 6 trees/acre 8 trees/acre (2)	Fruits (14) Fodder (2) Firewood (2) Shade (2)
Guava	2	>1 tree/acre (1) 1 tree/acre (1)	Fruits (2)
Mango	4	1 tree/acre (2) 4 tree/acre (1) 5 tree/acre (1)	Fruits (2) Fruits and shade (1) Firewood and shade (1)
Avocado	6	1 tree/acre (3) 2 tree/acre (1) 3 tree/acre (1) 4 tree/acre (1)	Fruits (6) Medicinal leaves (1)
Oranges	1	3 trees/acre (1)	Cashcrop (1)
Neemtree	1	<1 tree/acre (1)	Medicinal (1)

Spathodia narotica	1	<1 tree/acre (1)	Medicinal (1)
Macamia	2	4 trees/acre (1) 7 trees/acre (1)	Timber (1) Firewood (1) Building material (1) Shade (1)
Papaya	1	1 tree/acre (1)	Fruits (1)
Podo-podocarpus	1	<1 tree/acre (1)	Timber (1)
Loquat	1	1 tree/acre (1)	Fruits (1)
No trees intercropped	1		

10. To secure a long-term coffee production, what do you think would be the appropriate distance between trees and coffee? And also between the trees themselves?

Tree-coffee		Tree-tree	
Answer (feet)	Number of farmers	Answer (feet)	Number of farmers
About 5	15	About 20	4
About 10	3	About 30	6
Don´t know	1	About 40	3
		About 50	3
		100	1
		150	2

Comment: 1 farmer no answer since no trees intercropped.

Black coffee twig borer, in Luganda: ”Akawuka akakazza amatabi agemwanyi” (descriptive term)

11. Have you noted any pests on your coffee? Can you describe the effect of these pests on your coffee?

Symptoms or pest	Number of farmers
Wilting and drying of leaves	3
Dried branches/twigs	8
Wilted and dried branches	2
Drying of the whole coffee	4
Young plants wilt	1
Discovering of holes when dried branches are removed	1
Destruction of productive branches	1
Black pest that makes holes in twigs and lay their eggs inside	1
Coffee wilt disease	3
BCTB	11
Formicid ant (*plagiolepis*)	3

Comment: Many said symptoms that seems to be the BCTB, but they didn´t know the name. But when we asked the following question about if they have the BCTB on their farm they said "yes". That is probably because it´s translated into Luganda where the name of BCTB is like a description of the symptoms.

12. Do you have problems with the Black Coffee Twig Borer on your farm? Estimation of yield/quality loss (kg/ha).

	Yes (Y)/ No (N)	Before BCTB (kg/ha)	After BCTB (kg/ha)	% yield loss
1	Y	556	324	58
2	Y	2254	1690	75
3	Y	3198	1426	45

4	Y	2198	1374	63
5	Y	312,5	124	40
6	Y	2224	927	42
7	Y	2471	494	20
8	Y	1149	383	33
9	Y	2728	1535	56
10	Y	2857	571	20
11	Y	3459	2076	60
12	Y	3180	2052	65
13	Y	1483	741	50
14	Y	8750 kg/ha	5832,5 kg/ha	67
15	Y	But the BCTB might not be the only problem, ex declining soil fertility could be the reason.		
16	Y	1750	875	50
17	Y	1297	757	58
18	Y	2502	1334	53
19	Y	1812,5	906,25	50
20	Y	2669	1631	61

Yield loss (%)	Number of farmers
≤ 40	4
41-50	5
51-60	5
61-70	4
71-75	1

Comment: one farmer couldn't give us an approximate number of yield loss only caused by the BCTB.

13. What symptoms does the BCTB have?

Symptom	Number of farmers

Seeing the pest inside the branches	4
Seeing the eggs of the pest inside the branches	1
Holes in branches	7
Wilting of branches	5
Drying of branches	14
Branches break easily	2
Branches changes colour to black	2
Wilting of leaves	3
Drying of leaves	3
Yellowing of leaves	3
Falling of leaves	4
Decrease of yield	1

14. How do you think the BCTB came to your coffee farm?

Reason	Number of farmers
I don´t know	15
They fly	2
Brought by other people	3
Spread by husks	2
By wind	2
Birds	1
“As insects move”	1
Because of some trees	1

15. For how long have you had problem with BCTB?

Years	Number of farmers
2	7
3	6
4	3
5	3
>5	1

16. How has the intensity of the problem changed over time?

2015	
% damage	Number of farmers
0-20	5
21-40	4
41-60	4
61-80	0
81-100	7
2014	
0-20	10
21-40	1
41-60	3
61-80	1
81-100	5

2013	
0-20	8
21-40	1
41-60	0
61-80	0
81-100	3
Don’t know, it was unknown at the time	1

17. Do you have a special area in your coffee plantation where you experience most problems with the BCTB?

Answer	Reason
Yes (13)	Young plants (2) Too much shade (7) Don’t know why (4) Where it started spreading from (1) Depending on management (1)
No (7)	It’s spread everywhere (4), no special area (1), no (2)

18. When is the BCTB most active? (Time of year/day?)

Period of year	Number of farmers
Rainy season	14
Dry season	4
In the end of the rainy season	1
Don’t know	1

Time of day	Number of farmers
At night	9
In the afternoon when it´s a lot of sunshine	1
Don´t know	10

19. Do you use any chemicals to control the BCTB? If yes, name, how much/often?
(13 answered no, 7 yes)

(RS = rainy season, DS = dry season)

	Yes (Y)/ No (N)	Name	Amount	Enough for	How often
1	N				
2	N (but neighbours bought. Plans to use self)				
3	Y (but didn't work)	Black-off	100ml/20l	30 plants	Once/week RS
		Malathion	100ml/20l	30 plants	Once/week RS
4	Y	Dursban	20ml/20l	50 plants	Once/1,5-2 weeks RS (total: 4 times)
5	N				
6	N				
7	N				
8	N				
9	Y	Rocket	50 ml/15l h2o	30 plants	twice a month during dry season

10	Y	Dursban	25 ml/20 l vatten	20 coffee plants	Once a week in the rainy season.
11	Y	Ambush	10 ml/15 l H20	10 plants	Once a month/12 times a year
12	Y	Striker	100 ml/15 l of water	20 coffee	2 times a week (Monday and Thursday) when it´s too much infestation.
13	N				
14	N				
15	N				
16	Y, not very much	Striker	20-40 ml/20 l water	1 ac ~ 666,67 coffee	3 times/month (just tried once)
17	N				
18	No				
19	no				
20	No				

20. Do you manage your trees to control the BCTB? If yes, how? (Pruning, reducing roots etc.)

Answer	Number of farmers
Yes, pruning	17
No	3

21. Have you cut down any trees in order to control the BCTB?

Answer	Number	Reason and which trees (number of farmers)

	of farmers	
Yes	17	Ficus (12), Jackfruit (1), Maesopsis (2), reduce shade (4), other reasons (2)
No	3	no reason (2), reduce shade (1)

22. Do you manage your coffee to control the BCTB? If yes, how? (Pruning etc.)

Answer	Number of farmers	Method
Yes	20	Removes affected branches and burning them (17) Remove affected branches (1) Applying manure (1) Removing sprouts (8) Pruning (3) Have given up the control methodes because the coffee dies anyway (2) Cut down the whole coffee tree (1)
No	0	

23. Have you seen anything feeding on the BCTB? (Enemies of the BCTB: insects, birds, lizards…)

Answer	Number of farmers	Comment (number of farmers)
Yes	3	Formicid ant (4), Entalumbwa (1)
No	17	only sunshine (1)

24. Do you use any other methods to control the BCTB? (other than chemical, tree management, coffee management)

Answer	Number of farmers
No	14
Yes, Weeding	6
Yes, and removes dry leaves on ground	1

25. Do you think there is a relationship between trees and the BCTB? If yes, in what way?

Answer	Number of farmers	In what way (number of farmers)
Yes	11	Avocado works as a host tree (4) Jackfruit as a host (1) Ficus as a host (4) Trees that gives too much shade (5) Random tree work as a host (1)
No	7	Feeds only on coffee (1) Have not observed any relationship (6)
Not sure	2	

26. Do you think there is a relationship between crops and the BCTB? If yes, in what way?

Answer	Number of farmers	In what way (number of farmers)
Yes	1	Too much dry leaves contributes to the BCTB infestation (1)
No	13	Only on coffee (1)
Not sure	6	

27. If you compare a coffee in the shade and one in the sun – which has most problem with BCTB?

Answer	Number of farmers
Shaded coffee	14
Sun exposed coffee	3
Not sure	1
It affects all coffee	2

28. Have you gotten any advice concerning the BCTB?

Answer	Number of farmers	What advice? (number of farmers)
Yes	20	Remove affected branches and burn them (12) Removing affected branches (2) Coffee management (4) Chemical control (3) Weeding (1) Reducing shade (1)

29. From whom/where?

Answer	Number of farmers
Agricultural extensional officers	15
Subcounty office	2
Radio program	1
Cooperative office	2
Local government office	3
Chemical company	1
Organisations (for example UCDA)	2
Friends	1

Appendix 2
Questions for the officers in Kalungu and Bukomansimbi districts and to UCDA and NUCAFE

Key to the letters:

a. Agricultural officer, Kalungu
b. Assistant agricultural officer, Kalungu
c. Development director, UCDA
d. Production and Marketing Assistant, and Entreprenuership Services Manager, NUCAFE (shared interview)
e. Ag. District Agricultural Officer, Bukomansimbi
f. Agriculture District production coordinator, Bukomansimbi

Alternative questions for UCDA and NUCAFE, since these "big" organisations are responsible for an overall view and doesn't answer for a certain district.
Note: BCTB = Black Coffee Twig Borer
Note: 1 feet = 30,48 cm

1. How many coffee farmer households are there in the district?

a) 25 000 households, in total 7514 ha is being used for coffee production.
b) About 7000 household, in total 7514 ha is being used for coffee production.
c) Not asked. Number of total coffee farmer households in Uganda is searched for on Internet.
d) Not asked. Number of total coffee farmer households in Uganda is searched for on Internet.
e) Totally there are 38 000 farmer households in this district, 34 000 of those have coffee.
f) Don´t know, but 70 % of the total farmers in the district grows coffee.

2. What kind of coffee is grown in this district?

a) Traditional Robusta
b) Traditional Robusta, Clonal, Arabica (50/50)

c) *Not asked since no responsibility for a certain district.*
d) *Not asked since no responsibility for a certain district.*
e) *Traditional Robusta. It's a mixture, some has been improved over time*
f) *Traditional Robusta*

3. What coffee pests are common in this district?

a) Coffee wilt disease, coffee berry borer and coffee twig borer.
b) Coffee twig borer and the coffee berry borer.
c) in Uganda: Black Coffee Twig Borer, stemborers, root mealy bugs, scales
d) in Uganda: Coffee mealy bug, ants, the Black Coffee Twig Borer is the most common pest after the ants, Coffee Berry Borer, root mealy bugs. Stemborers are not that common.
e) Black coffee twig borer, berry borer, aphids and black ants
f) Black Coffee twig borer, ants around the roots, Munyera/ant and mealybugs.

4. Is the BCTB a major problem in your district? Estimate yield & quality-loss?

a) *Yes it is, it affects about 50% of all coffee plantations here in Kalungu. The estimated yield loss is about 20%.*
b) *Yes it is, approximately 50% is being lost of the yield due the coffee twig borer.*
c) *Yes, we believe it is about 5-10% yield loss. The CTB has affected up to 10 % of the farmers homes, but the output has only been affected up to 5%. In the long run it will have a big impact. Nearly 80% of fields are affected, about 20% of the trees on these farms are affected by CTB. Affected trees are still yielding. The CTB causes a loss of up to 40 million dollars for Uganda which is 10 % of the coffee export.*
d) *Estimation: at average 14% of the coffee are affected on each farm. Average yield is 5 kg per tree. With this formula it gives us yield loss in terms of shilling and kg: 450 (# coffee trees per acre) x (14/100)(%) x 5 (yield per coffee in kg) x 5000 (payment in Shilling/kg) = 1,5 million shilling in yield loss = 315 kg/ha yield loss.*
e) *Yes, 30-40%*
f) *Yes, 30-40%*

5. How big is the problem with the BCTB compared to other pests on coffee? (%)

a) *The problems with coffee twig borer is the second worst pest after the coffee wilt disease. The coffee wilt disease causes a yield loss of about 50% and big fields had to be cleared in order to reduce the problems.*
b) *60%, because it is spread easily.*
c) *70%*
d) *(See question 1) BCTB is the second biggest pest on coffee after ants.*
e) *BCTB is the biggest problem, about 60 %.*
f) *80 %.*

6. When did the problems with the BCTB start?

a. Year 2010.
b. 4 years ago, meaning in 2012.
c. It was discovered before 2008 but did not become a problem until then, but the real impact was seen in 2010.
d. First recognized 1995. Serious problem around 2000.
e. *It has been around for some time but recently (2012-2013) it has reached epidemic levels.*
f. *Since 2010 I´ve heard, but it might have started earlier.*

7. How is the BCTB spread?

a. Before the coffee twig borer pest started we already had the coffee wilt disease causing the coffee to be much weaker. Otherwise the coffee twig borer is being spread by the natural means, meaning with infected materials specially those clonal coffee are already infected when they are planted and from there it is spreading the pest. The pest is being spread as pests normally move.
b. Through the air, the BCTB lay eggs in the branches and then they fly away to another host… it is always coming back to the coffee.
c. They fly from coffee to coffee or alternative hosts. They take refugee in alternative hosts and then they come back. The BCTB can fly up to 200 m. There are many alternative hosts (mango, avo, albizia etc).
d. A branch with eggs could have broken off and been left in the garden, this will spread the pest. It can be spread through mulch

(containing eggs/larvae from other farms, foreign material). It also flies from garden to garden.

e. *It's a beetle so it flies. And it lays eggs after boring into the twigs and then it takes off.*
f. *It flies from a tree to another. Maybe by wind.*

8. How has it changed over time?
c. *We don't have the statistics. But we noticed that it had gone down during last half year but now it has come back.*
d. It has been declining for the last years because of the continued use of chemicals by the farmers. There are no chemicals for Coffee Wilt Disease, but other methods that are used which work somewhat for suppressing the BCTB as well. Last 2 years: declination from 17% to 13%.

	How many of the farms have been affected each year?
2015	*a. 50% = 12 500 farms* *b. 50%* *c. Answer above.* *d. 13%* *e. All of them (a little lower than 2014)* *f. 100 %*
2014	*a. 35 % = 8750 farms* *b. 55%* *c. Answer above.* *d. 17%* *e. All of them (the highest)* *f. 100 %*
2013	*a. 20 % = 5000 farms* *b. 70%* *c. Answer above.* *d. -* *e. All of them* *f. 100 %*

9. What changes in infestation have you noted based on time of year, climate and time of day in the field?

a. *There is more infestation during the dry season since the pest is more available for noticing during the management period. During*

the dry season the plants are water stressed and is more affected by the pest. The pests are not very active during the morning, more during midday-evening.

b. *There is less problem during the dry season. During the rain season it is spread widely. When it is hot outdoors, the coffee twig borer moves out from the branches, in low temperatures they stay inside the branches.*
c. *We don't see the BCTB during the rainy season. It comes out during the dry season. The BCTB attacks the plant during the plants weakest point, which is during the dry season, but it doesn't affect the coffee when the plant is vigorous. We haven't seen any change in infestation during day; but there are more in the shade, where humidity etc. is more suitable for BCTB.*
d. *More identifiable during the off-season (when the farmers are not harvesting during the dry seasons). From January - March, and in some areas until April. Also from July- October.*
e. *The infestation changes with the seasons. It is worse during the dry season. I have not noticed any changes in infestation based on time of day. But research has shown that it is more active during the evening and night.*
f. *During the rainy season. They bore through the twigs.*

10. What control-methods can be used in order to reduce the problems with BCTB?

Cut off affected coffee branches (a, b, d, e, f)
When? When you see that the twigs are affected. (b, e, d, f) Dry season (a)

Burn affected coffee branches (a, b, c, d e, f)
When? When you see that the twigs are affected (b, c, d, e, f) Dry season (a)

Remove coffee leaves (c,)
When? When you see that the twigs are affected (c,)

Reduce shade from trees and crops (c, e)
When? Whenever (c,) When needed (e)

Chemical control	Quantity (per acre)	How often	When?
Striker (b, f)	*Is not used because of too costly (b)* *40 ml/15 l water (f)*	*Every 2 weeks (f)*	*When there is a problem (b)*
Decis (e)	*200ml/20l H2O (e)*	*Every 2 weeks (e)*	*Dry season or when you see it (e)*
Black off (e)		*Every 2 weeks (e)*	*Dry season or when you see it (e)*
Acterra (a, b, f)	*200g (a)* *Is not used because of too costly (b)*	*6 times/season (a)* *Every 2 weeks (f)*	*Dry season (a)* *When there is a problem (b)*
Dursband (b, f)	*Is not used because of too costly (b)*	*Every 2 weeks (f)*	*When there is a problem (b)*
Copper Nordox (d)	-	-	*When they see the pest. Avoid spraying during rainy season. (d)*
Systemic chemicals Imidacloprid (King quenson industry) (c)	*½ l active substance per acre (c)*	*4 times per year, twice per season (c)*	*If coffee plantation is severely affected (30%). It's applied during dry season, and not when flowers and berries are on the twigs which creates a short window - about 4 months: feb, mar, jul, aug. (c)*

Weed control of host plants (b, d)
BCTB wants to hide in weed/dark places. (b)
Regular weeding. Slashing or chemical methods prevent the pest from breeding in the weeds. (d)

Other (a, b, c)
Bury the infected coffee branches (a)

Spacing between coffee plants, BCTB thrives when there is a lot of leaves. (b)
Cut off whole coffee tree if 70% (“stumping”) (c)
Soil management (fertilizers etc. gives a vigorous coffee), org. fertilizers. (c)

11. Do you know of any natural enemies to the BCTB? If yes, which?
    a. *No.*
    b. *No.*
    c. *No*
    d. *No, not adapted yet in large scale farms. Maybe spiders.*
    e. *No*
    f. *Munyera (attracted to come to the garden if you put bones with remaining meat on it).*

12. Do you know of any host trees/plants for the BCTB? If yes, which?
    a. *No, only coffee, but there should be some.*
    b. *Yes, but forgot the names.*
    c. *Albizia, Mango, Avo, all shade trees*
    d. *No*
    e. *Avocado and Macamia mainly, and also a shrub that resembles coffee.*
    f. *Any other trees can be affected!*

13. Do you know of any plants/trees that repels the BCTB? If yes, which?
    a. *No, but there was some farmers who told us about Tagetes minuta, that was repelling the coffee twig borer. It is also known for repelling banana weevils.*
    b. *No*
    c. *Ficus .*
    d. *I heard of a study that used garlic on coffee farms, but it is still being researched so this information has not went out to the farmers yet.*
    e. *No, but I have heard that tobacco can repel for example the banana weevil so maybe intercropping tobacco with coffee could be an alternative, or use tobacco husks as mulch, or use tobacco smoke to repel the BCTB.*
    f. *Don´t know.*

14. What trees do you recommend to intercrop with coffee and why? How common are these trees? (How many farmers have these trees out of all farmers in the district?)

c. The trees vary depending on the region. Shade is important for coffee. And the trees provides food security.

d. Don't recommend so much trees, mainly banana. Try to avoid alternative hosts by not recommending trees.

Species	Why?	% of farmers having the tree
Ficus natalensis	*a. Shade tree and also attract pests – can be used as a preferred host to coffee. It is also well-known for being resistant to all kind of weather.* *b. Good leaves for decomposition. Good timber.* *c. Shade (coffee needs shade)* *d. Gives shade, adds manure in form of leaves and protects the soil. Less competitive than other trees, because their root systems are small and deep. Makes potassium (K) available for the coffee. In symbiosis with a fungi called mycorrhiza.* *e. Bark cloth, firewood, shade, it keeps water in the soil and its leaves decomposes faster than leaves from other trees.* *f. Historical background – to make barkcloth. For shade… but now they have realized that shade is not good when it comes to the BCTB, because it makes them thrive. The leaves decomposes easily and adds nutrients to the soil.*	*a. 60* *b. 30* *c. -* *d. -* *e. 80* *f. 80*
Albizia chinensis	*a. -* *b. -* *c. Albizia can be used for fodder, firewood and is nitrogen-fixing as well as fast growing, but is the most affected by BCTB. It is its number one alternative host in some areas, so that tree is recommended for only some areas in Uganda.* *d. -* *e. -* *f. For shade, medicine (cook it and make bath for babies and use it for cough), contributes with good nutrients for the soil for the coffee.*	*a. -* *b. -* *c. -* *d. -* *e. -* *f. 40*

Maesopsis eminii	*a. It's used for coffee boundaries and shade.* *b. Good leaves for decomposition.Good shading.* *c. -* *d. Gives shade, adds manure in form of leaves and protects the soil. Less competitive than other trees, because their root systems are small and deep.* *e. Its roots go deep and picks nutrients from deep down. Its leaves quickly decomposes and the shade is big* *f. -*	*a. 2* *b. 1* *c. -* *d. -* *e. 2* *f. -*
Grevillea Robusta	*a. -* *b. -* *c. -* *d. -* *e. Shade, firewood and the leaves decomposes easily.* *f. -*	*a. -* *b. -* *c. -* *d. -* *e. 1* *f. -*
Macaemia Rutea	*a. -* *b. -* *c. -* *d. Yes* *e. -* *f. -*	*a. -* *b. -* *c. -* *d. -* *e. -* *f. -*
Fruit trees Ex Mango, jackfruit, avocado	*a. -* *b. -* *c. -* *d. -* *e. Shade (but all are not good for intercropping because the leaves takes a long time to decompose), and for giving balance to the garden.* *f. -*	*a. -* *b. -* *c. -* *d. -* *e. 1* *f.*
Banana	*a. -* *b. Good shade, but also the roots of banana do not affect the coffee.* *c. -* *d. Yes* *e. -* *f. -*	*a. -* *b. 6* *c. -* *d. -* *e. -* *f. -*

15. Are there any recommendations for how many trees there should be in an acre to support the coffee trees in an agroforestry system?

a. *Coffee to coffee: 10 feet. Maesopsis eminii: since it's being used at the boundaries it could fit about 40 trees. Ficus natalensis: 10-20 trees.*
b. *50 trees.*
c. *It depends on the type of trees. The distance between coffee plants is 9 by 9ft or 10 by 10 ft. There should be about 10-12 trees per acre.*
d. *11-15 trees*
e. *No. There is no proper recommendation, but we recommend to put a shade tree every 40ft (especially Ficus).*
f. *No recommendations.*

16. What is the recommended spacing between the tree and the coffee? And also between the trees?

a. *The Maesopsis eminii should be 20 feet apart from each other on the boundary. There is no agreed recommendation of the spacing for the Maesopsis and coffee. The agroforestry methods came in late 90s and has been very slowly adopted. This is because the advisers are still giving different advice so the farmers are all doing differently.*
b. *40 feet between coffee and tree (can vary). 40 feet between trees. 10 feet between coffees.*
c. *The trees are put between the coffee plants so there would be 10ft between the coffee and the tree. There should be 40 ft between trees. And 20ft between Bananas.*
d. *It doesn't vary too much: 10-15 feet between a coffee and a tree like Ficus natalensis. A tree is placed in the middle of four coffee trees. Between the coffee trees a spacing of 10 feet is recommended. Between one tree (ex. Ficus natalensis) and another tree 15 m spacing is recommended.*
e. *Between a tree and a coffee, you decide for yourself but ideally it should be 10ft. And between trees it should be 40ft.*
f. *No specific recommendations because a coffee and a Albizia can be very close in the gardens…*

17. Why is it important to shade the coffee? What is recommended shading in percentage?

a. *1) Windbreakers, 2) Weather – to reduce sunburn. The recommended shading is about 40% so that the plants can cope with the extreme weather sometimes.*
b. *Helps the coffee to keep its moisture. Reduces sunshine during drought period. A 50% of shade is needed.*
c. *The coffee doesn't need a lot of sunshine, but it needs a good microclimate. There should be 70% light and about 30% shade.*
d. *Coffee is a shade loving tree. The shade helps to maintain moisture. It helps to give more foliage growth. Shading trees helps to conserve a below and above ground diversity for a sustainable coffee production. They contribute with a proper balance of nutrients thanks to their small leaves, which decomposes and gives food to microorganisms. The coffee develops a better taste (aroma and flavour) and quality. Ficus has a good balance of nitrogen which is very critical to the growth of coffee. The amount of shade that is recommended varies a bit, but in average 65% shade is sufficient. The coffee needs proper lighting too. If the degree of shade is too much the coffee grows too much vegetative, without flowering and consequently gives no coffee beans.*
e. *There are multiple reasons: 1) the beans taste better (it resembles Arabica in taste)*
   2) It conserves the soil moisture and cools down the whole garden.
   3) They act as wind-breaker. About 40% is the recommended shading.
f. *Keep moisture in the soil. 10 trees in 1 acre.*

18. If you compare a coffee in the shade and one in the sun – which has most problem with BCTB?
    a. *Do not know the answer.*
    b. *The coffee in sunshine has more problem.*
    c. *The one in the shade has more problem with the BCTB.*
    d. *The one in the sun. The BCTB female beetle bores tunnels in the twigs. Searches for water/sap.*
    e. *It's the same, there is no difference in infestation.*
    f. *Shaded coffee. Think that the twigs become softer there and are easier to penetrate for the BCTB.*

19. How do you spread the information to the farmers? (More challenges?)

a. *Through extension work, meeting and trainings. We educate local leaders. The challenges we face are that the farmers take time to realize the problem, the interest for taking control measures are very low. They only need information when the problems are too big and too hard to handle.*
b. *Farm visit and through training programs.*
c. *We have extension staff who organise seminars, workshops and educates farmer leaders. We also have radio stations and make demonstrations. One challenge we face is how to change the attitude of farmers. They will not cut of branches, instead they want to wait until they have picked the berries but then the bug has already spread. There is low attendance at the demonstrations on the farms. Chemical pesticides are expensive (1l = 80 000 Ush). The insect flies so it can spread easily which calls for a communal approach – individual approach doesn't work. Everyone needs to do the same thing in order to control the BCTB.*
d. *Trainings on farms and farmers groups, radio broadcasts, TV-programs on how to manage coffee pests etc, shows and exhibitions, national coffee festival, coffee value chain - a site to share information, messaging (bulk sms and phones) – more and more farmers have phones and internet, media. The farmers are embracing new technology for example whats app, facebook, etc. They share information with other farmers. Not everyone is reachable though if they don't have a phone. We don't have clear line of how to deliver the information. Extension work needs a boost of human resources (more people need to spread the information). Easier to reach groups instead of individual farmers. Most of the information is available in English, but it need to be accessible in different languages, like Luganda. Also the information needs to be in simplified forms, for example with pictures so the information needs to be processed before reaching the farmers.*
e. *Executive Officers in the subcounties spreads information. We also link up with research, for example are given brochures and charts which are distributed to farmers' groups. We also do radio broadcasts.*
   The number one challenge we face is the lack of commitment from farmers. Everybody needs to do their part to make a difference. There are also a lot of misconceptions. For example people make

their own decoctions and sells them – they might not be effective but they are cheap. Ambush is a chemical that is no longer imported, it contains cypermethrin.

f. *Through radio program, agricultural partners and extensional staff who trains the farmers on the ground. Need more research. More collaboration between the farmers so the infestation doesn't spread between neighboring gardens. Maybe introducing a punishment for those who don't follow the advice.*

20. Is the technical advice for controlling the BCTB being used by the farmers? What more could farmers do?
    a. *Yes they are. What they could do more of is to do the right agronomic methods in order to grow strong plants, since the common farmer don't have the money for buying chemicals.*
    b. *Yes, most of the farmers follow the advice about weeding, cut off branches and burn them when needed. They also remove the old stems that could be weaker because of diseases. We would like more farmers to come for the trainings (but the cost for fuel is too much for them?), we would like more farmers to do right pruning when they observe pests and that they follow the recommended spacing for their coffee (many wants as many coffee as possible so that when the pest comes they wouldn't get that affected and lose so much).*
    c. *Most of the farmers follow the advice. 100% of the farmers are aware of the BCTB, but they are not all practicing the advice given. They don't want to prune when there is coffee on the branch, and doesn't want to spray pesticides because it is expensive. And the farmers are lazy.*
    d. *Yes it is. That is the reason for the continuing decline. But some farmers neglect the pest.*
    e. *Yes and no. Farmers want a quick solution and there is some resistance to the advice given.*
    f. *Some do, some don't which is a problem because it flies from one garden to another.*

21. What is your source of information about the BCTB? (Field study, University, organization)
    a. *Research institutions and farmers.*

b. *Radiostations – central broadcasting services with experts and UCDA. TV. Bosses from field studies. Internet.*
c. *Mainly we get our information from coffee research and international conferences. We are a member of International Coffee Organization (ICO) and also of Inter African Coffee Organization (IACO). We are linked to many coffee producing countries whom shares information. And we also get information directly from the farmers.*
d. *Authority (UCDA), NaCORI, our own research, other partnerships, agribusiness initiatives, Vi-agroforestry, adopt information from other coffee growing countries.*
e. *Research station, UCDA, Ministry of agriculture and friends.*
f. *I read on internet, I get information from UCDA and from farmers and their experiences.*

Appendix 3
Questions for NaFORRI, NaCORI and Makerere University

Key to the letters:

a. Consultant, NaFORRI
b. Research officer and entomologist, NaCORI
c. Associate Professor, Makerere university school of Agricultural sciences

Note: BCTB = Black Coffee Twig Borer
Note: 1 feet = 30,48 cm

1. What pests affect the robusta coffee in Uganda?
    a. *Coffee twig borer, Coffee berry borer, Coffee leaf rust, Red coffee blister, Brown eyespots*
    b. *There are many. We have the coffee twig borer, coffee berry borer, coffee root mealy bugs, tale caterpillar and minibugs.*
    c. *Coffee twig borer, coffee berry borer, mealybugs, leaf miner, scale insects, antestia bugs.*

2. Is the BCTB a major problem in Uganda in comparison with other coffee pests? If yes, to what extent (%)?
    a. *Yes, it is a severe problem. Some farmer don't know how to manage it. The BCTB can give up to 50% yield loss in organically grown coffee. Among the coffee pests the BCTB is the biggest one; it constitutes 60% of the pest damages.*
    b. *Coffee twig borer is our biggest challenge, the damage its causing affects a total loss of 9% here in Uganda. If I estimate then the coffee twig borer contributes to about 60% of all pests.*
    c. *Yes, since 1990 when it started, the problem has increased in intensity. Now about 30 % of the coffee trees are affected by the coffee twig borer.*

3. Are there any specific districts or regions that are more severely affected?

a. Yes, mainly in the far west region of Uganda (Districts: Kasese, Kamwenge). But other regions are also affected: Central – Luwero, Mityana, East – Mbale, Kapchorwa, Manatwa.
b. Yes, the worst infestations are in Masaka, Mpigi, Rakai and Butambala where all (100%) of all farms were hit by the coffee twig borer.
c. (Short of time for this interview, this question was excluded.)

4. For how long has the BCTB been a problem on coffee farms in Uganda?
    a. *In my own judgement it has been severe for the past 5 years.*
    b. *It appeared the first time in 1993 in Bundibugyo, Western Uganda. At that time the coffee wilt disease was already infecting and weakening the coffee. In 2010 the big spread of the coffee twig borer began.*
    c. *Since the 1990s*

5. Where did the BCTB originate from?
    a. *Don't know*
    b. *We know that it was an epidemic in Asia and it might have originated from the tea plantations in China.*
    c. *It is rumored that it came from the Democratic Republic of Congo to Uganda, but it wouldn´t be fair to say so.*

6. How did it come to Uganda?
    a. *Don't know*
    b. *We don't know, but we suspect that it came from the west, maybe the Democratic Republic of Congo through flight and bacterias.*
    c. *I don´t study the coffee twig borer specifically, I don´t know.*

7. How did it spread within Uganda?
    a. *Farmers share tools. Coffee farms are often in the same areas and are often close to each other so the pest crosses to other plantations.*
    b. *The planting materials got infected and in that way it spreads very fast. And also from farm to farm by flight. It has 48 host plants, ornamentals included, in Uganda.*
    c. *It flies, moves from field to field.*

8. What changes in infestation have you noted based on time of year, climate and time of day in the field?
    a. *Don't know.*
    b. *You find the biggest populations during the dry seasons. The coffee twig borer is being suppressed during the wet, raining season. (The coffee twig borer and the coffee berry borer both belong to Coleoptera, so they are very similar.)*
    c. *Increase in infestation since 1990 because of lack of effective control methods. During a period of one year it´s always there. It depends more on how farmers manage the problem than which time of the year it is.*

9. What type of methods can be used to reduce the problems with the BCTB?

Cut off affected coffee branches (a, b, c)
When? Dry season (a), Not specified, as soon as needed (b) Did not have time to ask (c)

Burn affected coffee branches (a, b, c)
When? Dry season (a), Not specified, as soon as needed (b), Did not have time to ask (c)

Chemical control (a, b)	Quantity (per acre)	How often	When?
Imaxi (b)- Comment from b: neonicotinoid (trust the recommendations from manufacturer)	*600 ml (4ml=1litre)*	*twice a year, once/season*	*Max flight of females beginning of season, when rain sets – triggers the flight*

Comment (b): We rely mostly on sanitation but a combination with the chemicals is necessary to control the coffee twig borer. We use the chemicals approved by EU and USA. They need to be systemic so that the plant absorb it and affect within the branch, this way we can reach the eggs, larvaes and the males. We follow the recommendations coming from Hawaii.

Traps with ethanol are on testing level and it works (c)
Biological control on testing level (c)

10. Beside these control methods, what other recommendations concerning the control of the BCTB do you have for the coffee farmers here in Uganda who implements agroforestry?
    a. I have heard about farmers who pours ash around the coffee shrubs, but I don't know why or if it helps. They do it during the rainy season. And there are supposed to be natural enemies to the BCTB. There are also organic sprays that can be used.
    My own recommendation would be to remove the whole affected plant from the plantation because you don't now how far the BCTB has entered. But farmers really value their coffee and they don't want to cut them down.
    b. The farmers need to remove the sprigs because they tend to attract the coffee twig borer more, and also the sprigs reduce the coffee yield since they don't give that much coffee. We also give the farmers the recommendation to not to have more than 3-4 stems because the more bushy the coffee becomes the more coffee twig borer it attracts. We also recommend to avoid alternative hosts so that the coffee twig borer doesn't come back. Shade is OK but too much also gives problem. The shade trees chosen need to not be alternative hosts and they require good management.
    c. It´s important that the coffee trees gets enough nutrients so they are not stressed and thanks to that less vulnerable for pests.

11. Is there a period in the lifecycle of the BCTB, when it is the most vulnerable?
    a. Not sure, but think larvae stage is more vulnerable.
    b. Referring to a various number of publications on this theme, the coffee twig borer seems to be most vulnerable when the females are penetrating the twigs. We see the similarity with the coffee berry borer because as the coffee berry borer is not vulnerable in flight it becomes more exposed during the entering stage of the berry.
    c. In our temperate climate it's always good conditions for the coffee twig borer and the generations are overlapping.

12. If yes, which method could be used to control it at this stage?
    a. Natural enemies or maybe spraying.

b. At the moment they are looking at a chemical spray that would prolong the penetration time (on the twig) so that parasitoides would have sufficient time to attack the coffee twig borer.
c. -

13. Do you know of any natural enemies to the BCTB? If yes, which?
    a. Yes, an insect but don't know which.
    b. Yes. We have the parasitoid Phymasticus coffeae (Hawaii), the fungus Beauveria bassiana and Metarhizium anisopliae (fungal pathogens, entomopathogens), and also the ant predator Plagiolepis sp. That eats mealybugs, lace and the coffee twig borer. They disseminate this knowledge on how to increase these populations of natural enemies to the farmers.*
    *note: could be lacebugs, however we are not sure what b meant.
    c. Ants who goes into the tunnels made by the coffee twig borer.

14. What trees do you recommend to intercrop with coffee? Why? Recommended spacing?

c. She said that she recommend native trees and referred to this article for all the names: Impact of the black twig borer on Robusta coffee in Mukono and Kayunga districts, Central Uganda.

Species	Why?	Spacing (m)
Albizia chinensis	*a. -* *b. Yes (check brochure)*	
Albizia coriaria (mostly in the west)	*a. It branches out a lot which provides good shade. It has small leaves that still lets some sunlight though. Firewood.* *b. Yes (check brochure)*	*a.20*
Maesopsis eminii (mostly in the west)	*a. Grows tall, so they need to be closer to each other, and has heavy branches. The branches don't cause a lot of damage when falling off. It is good for timber which diversifies the income of the farmer. It grows faster than Albizia.*	*a.10*
Ficus natalensis	*a. It provides shade, and fodder. It is used for barkcloth (cultural clothes). A problem with it is that it has big leaves so it can give too much shade and must be pruned.* *b. Yes (check brochure)*	*a.15*

Ficus ovata *Ficus viocosa*	*b. Yes* *b. Yes*	
Grevillea Robusta and Yakoranga 15 m	*b. Not recommended for agroforestry since the rootsystem is too close to the soilsurface and therefore it feeds from the same level as the coffee.*	
other *Cordia africana (mostly in the east)*	*a.Fast growing. It is good for timber and firewood. It doesn't grow so tall. A local type of Ground nut climbs in the Cordia.*	*a.12*
Melicia excelsa	*a. It is used for timber. It has broad leaves which it sheds and allows light in the plantation. The leaves are easily degradeble and adds manure.*	*a.20*

15. Do you know of any host trees/plants for the BCTB? If yes, which?
    a. *Yes, Ficus natalensis*
    b. *Yes, we have about 48 host plants, please read more in the brochure. The Albizia chinensis and coriaria are minor hosts for the BCTB. Ficus also a little but this tree also produces some sap that kills the BCTB.*
    c. *Some trees that are commonly found, not scientifically confirmed*

16. If yes, how does the plant/tree attract the BCTB?
    a. *Don't know, maybe pheromones.*
    b. *Chemoecology, through substances. We are separating the attractors but these are not yet analyzed. We have been using ethanol in our traps that works as a very good attractant.*
    c. *Coffee is one of the coffee twig borer´s preferred hosts. Pests are specific when looking for hosts… looking for "chemicals"…*

17. Do you know of any plants/trees that repels the BCTB away? If yes, which?
    a. *Yes, Neem tree.*

b. *Yes, Cannabis sativa, opium, pepper and neem.*
c. *I don´t know.*

18. If yes, how does the plant/tree repel the BCTB?
    a. *I don't know how, maybe smells. I wouldn's recomend it in a coffee plantation but maybe on the boarders. It is the same height as the coffee so it wouldn't provide any shade.*
    b. *Chemoecology, through substances. We are separating the attractors but these are not yet analyzed. We have been using ethanol in our traps that works as a very good attractant. (same as answer 16).*
    c. *-*

19. What is the recommended spacing between the tree and the coffee? And between coffee and coffee plant?
    a. *Between tree and coffee the recomended spacing is 6 ft. Between a coffee and another coffee plant it is recomended to have 8 ft.*
    b. *We recommend a triangular pattern of the trees to get optimum shade. The coffee should be interspaced with 3 meters apart from each other.*
    c. *3 feet between one coffee and another coffee. Changes a bit depending on the coffee variety. The distance between a coffee and a tree has no impact on the infestation of the coffee twig borer, because they can fly far…*

20. Why is it important to shade the coffee? What is recommended shading in %?
    a. *There are three reasons:*

1. *Shaded coffee has higher quality with bigger and heavier beans. The micro-environment is more suitable under shade.*
2. *REDD+: Reducing Emissions from deforestation and forest degradation. Coffee farmers must also benefit from reducing emissions. The farmers are linked to the carbon market and earn more money by having more trees.*
3. *There are multiple uses for trees, for example fruits, firewood etc. And also distributing the risks.*

There should be no more than 40% shade above the coffee.
b. It increase the yield and quality (if you use Ficus it also improves the soil). Today it's also *very important to mitigate the climate challenges. The dry areas need more shading than the banana trees can provide. But too many bananas at other places can cause too much shade. This also depends on the season and is not fixed. It's very difficult to give the exact number in percentage.*
c. Not more than 40 % shade in the gardens.

21. If you compare a coffee in the shade and one in the sun – which has most problem with BCTB?
    a. *The shaded coffee.*
    b. *Please have a look on the publications made on this. The amount of shade and as well drought can cause stress for the coffee and weakening and increase the hit rate of BCTB.*
    c. *I don´t know.*

22. Why?
    a. *Trees provide a suitable environment for the pest.*
    b. *(same as answer 21).*
    c. -

23. What is your source of information on the BCTB?
    a. *Field studies where we interact with farmers, farmers groups and coffee cooperatives. And also by reading online.*
    b. *We started from scratch. We got some information from India (BCTB reduce the coffee production by 8% in India), we have a partnership with University in Hawaii and the university of California (they got problem on Cola, an ornamental plant).*
    c. *Patrick Kucel from NaCORI, From the NaCORI group, Sometimes from students in Makarere University when they do publications, Reading publications.*

24. What specific research have you done concerning the BCTB?
    a. *I have not done any research on the BCTB myself but I have done 3 consultations.*
    b. *None.*

c. *None, I study Arabica in high altitudes where the BCTB isn´t a problem.*

25. How do you disseminate these research findings concerning the BCTB to the farmers?
    a. *Generally NaFORRI sets up demonstrations, for example how a pest attacks crop. We work with district local governments and work directly with Extension Officers. We also file reports and distribute to the Extension Officers.*
    b. *Through extension work, sometimes directly to the farmer groups. We attend to conferences all over the world.*
    c. *I go out to the farmers and do farm trials and demonstrations.*

26. Any other comments/what challenges do you face in your research?

a. 1) *Negative attitudes toward trees among the farmers, which is hard to change. 2) The organization have a lot of knowledge but it is not distributed – the extension arm is weak. Before NADS was the extension but now it has been changed to Operation Worth Creation which only supply input but no extension. There is no record keeping or tracing. 3) What researchers discover stays with them – it doesn't reach the people.*

b. B*CTB is a quite new phenomena, we face a lot of work since it's a new area for us. We have big pressure on us from the government and our resources are limited as well for the personnel. We got some finances from EU but at the same time we are limited to buy chemicals by the World bank which puts restrictions on us.*

c. *The farmers are in very different social- and economic situations and their cropping systems vary. Therefore it´s difficult with the communications. The small scale farmers don´t listen to the advice, they are not willing to change.*

Appendix 4
Field study protocol

Tree number		**Cardinal direction**			
1		**North**	**East**	**South**	**West**
Coffeetwigs (Middle third part of the coffee plant)	Number of holes in twig				
	Wilting degree	0 L M H	0 L M H	0 L M H	0 L M H

	0-20%	21-40%	41-60%	61-80%	81-100%
Shade					

	Ficus natalensis	*Grevillea robusta*	*Maesopsis eminii*	*Polyscias fulva*	*Albizia chinensis*	Banana	Other
Number of trees (5m)							