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Department of Ecology

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– Impact of shade level on abundance of BCTB and knowledge levels about BCTB

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Abstract

The Black Coffee Twig Borer (BCTB), (*Xylosandrus compactus* (Eichhoff)) is a devastating pest on robusta coffee in Uganda. The coffee in Uganda grows mostly in agroforestry systems where trees and crops are combined and interact with each other. Farmers believe they have to cut down other trees in order to reduce the problem of the BCTB, because they think the trees increase the risk of receiving the pest on their farm. This is against the vision of Vi Agroforestry, who plant and preserve trees in order to increase stability within the farming systems. This study investigated if abundance of the BCTB increases with increased amount of shade on robusta coffee. Another aim of the study was to investigate if the knowledge level and opinion about BCTB and shade for coffee, vary between farmers, officers and researchers. The study was mostly conducted in Kalungu and in Bukomansimbi districts in the central region of Uganda. This included the observational field study as well as interviews with the farmers and officers working in these districts. Other interviews with researchers and officers working with the whole country were conducted in the surroundings of the capital, Kampala. We measured amount of shade in relation to degree of infestation by the BCTB by counting their entrance/exit holes on coffee trees in each farmer's coffee plantation.

The opinions and knowledge between the three groups of people (farmers, officers and researchers) differed in some questions. One question that resulted in various answers, especially among the officers and researchers, was if shaded or sun-exposed coffee is most affected by the BCTB. Most of the farmers said it is the shaded coffee that is most affected by the BCTB. Our observational study showed a significant ($P<0.05$) increase of infestation by the BCTB between two categories of shade, from 0-20 % to 41-60 % shade. The increase of infestation was close to significant ($p=0.075$) also between two other shade categories 0-20 % and 61-80 % shade. The shade by trees may not be the only reason for more infestation close to other trees, since they can be alternative host trees for the BCTB. However, there were different opinions among farmers, officers and researchers about possible host trees and this disagreement can be explained by a lack of research or that new information has not reached out. There is literature supporting that *A. chinensis* is a host for BCTB, but no such evidence is found for *F. natalensis*. These findings are interesting for future design of coffee agroforestry systems, but still more research is needed to be able to take the right measurements when it comes to BCTB, shade and effects of possible host trees intercropped with coffee. The interview results indicate that officers need more training so that they can provide consistent and relevant advice regarding shade. An interesting approach for further research would be to investigate if there is a host tree that is more attractive than coffee and thus could work as an attractant (trap crop) for BCTB. The infested twigs of this host tree could then be harvested and used as cooking fuel. As an extension of our study it would be interesting to sample more coffee trees within the three higher shade categories (41-60 %, 61-80 % and 81-100 %), to see if there is a significant increase of BCTB even for these higher shade categories.

Keywords: Agroforestry, canopy cover, *Coffea canephora*, host trees, natural enemies, shade trees.

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Abbreviations

BCTB	Black Coffee Twig Borer
NaCORI	National Coffee Research Institute
NaFORRI	National Forestry Resources Research Institute
NUCAFE	National Union of Coffee Agribusiness and Farm Enterprises
UCDA	Uganda Coffee Development Agency

1 Introduction

Coffee production is an important source of income for about 1.2 million Ugandan households, and for the country as a whole (Uganda Coffee Development Authority, UCDA, 2008). Uganda is the 7th biggest coffee producer in the world (UCDA, 2008). Arabica- (*Coffea arabica)* and robusta coffee (*Coffea canephora)* are the two different types of coffee grown in Uganda (Bekele-Tesemma ed. 2007). The robusta coffee gives 30 % higher yield than the arabica coffee, while the prices are 30 % lower, because of its inferior taste and flavor (Bekele-Tesemma ed. 2007). The coffee focused on in this study is the robusta coffee, which is native to the country and grows wild around the Lake Victoria Basin for instance. The robusta coffee is the most common coffee in Uganda, growing on 80 % of the total coffee area, and has been commercially grown since the 1920´s (UCDA, 2008). Robusta coffee grows at altitudes of 900-1200 m and it is common in all lowland regions of Uganda, especially in the lakeshore region close to Lake Victoria (UCDA, 2008; Bekele-Tesemma ed. 2007). Pests and diseases are important constraints to coffee production. In particular, Coffee Wilt Disease has been a problem for the coffee farmers in Uganda, since 1993 (UCDA, 2016-04-11) and more recently they are facing another severe problem, the Black Coffee Twig Borer (BCTB), (*Xylosandrus compactus* (Eichhoff)) (Egonyu et al. 2009).

Most coffee in Uganda is grown in an agroforestry system, where crops and trees are intercropped. In such systems, coffee is grown together with shade trees and also with food crops such as bananas and beans (UCDA, 2016-02-22). An agroforestry system for food production is more similar to a natural ecosystem than to an intense agroecosystem with monocultures. The latter one is highly dependent on outside inputs such as fertilizers and pesticides, while an agroforestry system is less dependent on outside inputs (Gliessman, 2007). Food production in an agroforestry system that includes many different species, in different successional stages, enhances food security as well as a regular income throughout the year, for the farmers (Gliessman, 2007). An agroforestry system including both perennials and annuals, as well as trees, shrubs and crops of different root depth and above ground height contains a lot of biodiversity (Gliessman, 2007). The canopy layers provide habitat for a diversity of birds and insects which can enhance biological control, pollination and other ecosystem services in the system (Gliessman, 2007). Agroforestry can also increase a system´s resilience and ability to withstand violent weather conditions in a changing climate (Rockström et al. 2012).

In the coffee growing areas of Uganda there is a great need for tree products, such as firewood, poles and timber. Despite a shortage of land it is possible to provide these tree products, thanks to the allowance for intense production of crops and trees within an agroforestry system (Bekele-Tesemma ed. 2007). Furthermore, shade

trees have many positive effects on coffee production (Bekele-Tesemma ed. 2007). Their leaves contribute with organic matter and nutrients to the soil. Thanks to their deep root systems they can pump up nutrients from soil horizons below the coffee root systems and therefore contribute to a higher amount of circulating nutrients in the agroforestry system (Bekele-Tesemma ed. 2007). Leguminous trees even contribute the system with nitrogen derived from the air thanks to their association with nitrogen-fixing bacteria. Trees limit soil- and wind erosion as well as evapotranspiration (Gliessman, 2007). The shade provided by the trees also regulates the photosynthesis rhythm of the coffee, which gives a more long-lasting and high yielding coffee production. Further benefits from shade are improved coffee bean quality and reduced weed growth (Bekele-Tesemma ed. 2007).

Nevertheless, too much shade during the wet-season can create humidity levels of up to 100 % within the coffee intercropping system, which favors fungal diseases (Gliessman, 2007). It is therefore common to heavily prune the branches of the shade trees at the beginning of the wet-season. Another aspect of trees that can be negative are allelopathic interferences, with excretion of chemical compounds by one tree that harm growth or development of other surrounding plants or trees. Competition for water or nutrients etc. can also occur. To avoid potential negative effects it is important to choose trees for intercropping carefully and also to use the right spacing, for the coffee as well as for the trees and other crops such as banana (Gliessman, 2007). Tree management such as pruning is also important to keep some sun light into the coffee plantation and consequently avoid the negative effects of too much shade (Bekele-Tesemma ed. 2007).

Trees for intercropping with coffee recommended by Vi Agroforestry include *Ficus natalensis, Cordia africana, Maesopsis eminii, Albizia chinesis, Albizia coraria* and *Polyscias fulva* (personal communication, Komakech, 2016-03-17). These trees are recommended since they have leaves that decompose easily and their root systems are deep enough to not compete with the coffee for water and nutrients (personal communication, Komakech, 2016-03-17). These trees, which provide permanent shade, should not be planted closer than a distance of 12 meters (40 feet) to each other (UCDA, 2008). Fruit trees for example, such as mango and avocado are not recommended within a coffee plantation. They should rather be placed on the borders. The main reason for that is that their leaves do not decompose easily (personal communication, Komakech, 2016-03-17).

Overall the abundance of natural enemies has been shown to be higher in agroforestry systems and pest abundance lower, than in agroecosystems with intense crop production (Pumariño et al. 2014). Shaded coffee has been shown to be positively correlated with pest control by natural enemies such as ants and birds (Milligan, 2014). Another study reveals that shaded coffee becomes less infested by mealy bugs and scale insects (Karungi et al. 2015). Coffee Berry borer, (*Hypothenemus*

hampei) is another pest that has repeatedly been shown to be less common in shady plantations (Jonsson et al. 2015; Jaramillo et al. 2013). However, for some pests increased shade levels can increase their infestations. The White Stem Borer, (*Monochamus leuconotus*) (Jonsson et al. 2015) and lace bugs, (*Hemiptera ghesquierei and H. placida*) (Backlund, 2012) have been shown to be more common where there is more shade.

Farmers in Uganda are experiencing great challenges with the BCTB, an insect pest that has been an increasing problem the last years, also on the agroforestry farms (personal communication, Komakech, 2015-10-07). Many farmers believe they have to cut down all other kinds of trees (except *F. natalensis*) on their agroforestry farms because they think the trees increase the risk of receiving the pest on their farm (personal communication, Komakech, 2015-10-07). Some surveys have already been done on this subject. One study performed in Uganda, showed that the BCTB appears in higher quantities where the shade tree *A. chinensis* is found (Kucel et al. 2011). Two potential explanations for these patterns are, i) *A. chinensis* provides a, for the pest, favorable microclimate, or ii) *A. chinensis* is a host tree for the BCTB (Kucel et al. 2011). Another study executed in Uganda, on farmers' plantations in Kyampisi sub-county, east of Kampala, investigated the effects of shade level on abundance of BCTB. Three different shade categories were used: full shade (1 m from tree trunk), minimal shade (edge of shade tree canopy) and full sun (3 m from canopy edge). Full shade varied from 11.7±7.6% to 60.0±26.5% canopy cover. They found that the degree of infestation by BCTB was higher in full shade than in full sun, when the shade tree species were *A. coriaria*, jackfruit or mango (Kagezi et al. 2013). The highest percentage of infested coffee trees and twigs was found in full shade and the lowest percentage of infested coffee trees and twigs was found in full sun (Kagezi et al. 2013). Another study executed on three year old coffee, showed that shade significantly increased (P=0.05) the damage by BCTB on robusta coffee (Anuar, 1986). Damage was measured as percentage black twigs per coffee tree. The shade category in this study was in average 64.3 % during the time of the day when the study was conducted. The non-shaded category had accordingly no shade (Anuar, 1986).

In relation to Kagezi et al. (2013) and Anuar (1986) one new thing about our study is that we have been looking at shade in a different way. We have been working with 5 categories of shade depending on the canopy cover above each investigated coffee tree. Another thing is that we have been looking at different farms, with a variety of coffee intercropping systems and management. These farms are situated in two other districts than the study by Kagezi et al. (2013) made on shade and BCTB. Similar to Kagezi et al. (2013) we have been looking at entrance/exit holes in twigs. However this differed from the study by Anuar (1986), where they looked at blackened twigs to quantify the infestation by BCTB. Therefore it is interesting

to see if our results of shading level and degree of infestation by the BCTB are in line with previous results. Our study contains interviews as well, to see how the view and knowledge about the BCTB differs between researchers, officers and farmers. Accordingly we hope to broaden the knowledge about the BCTB between different groups of people.

Many coffee farmers in Uganda cut down trees because they think trees contribute to the infestation of BCTB (personal communication, Komakech, 2015-10-07). To cut down trees is against the ideas of Vi Agroforestry, who promotes planting and preservation of trees in order to increase stability within the farming systems. That is why the impact of shade, as well as the impact of two different tree species promoted within coffee plantations (*A. chinensis* and *F. natalensis*), on the BCTB on robusta coffee *(Coffea canephora)* was examined in this study. In my thesis I focus on the effects of shade level on BCTB, whereas Julia Dahlqvist focuses on *F. natalensis* (Dahlqvist, 2016) and Lina Wu on *A. chinensis* (Wu, 2016).

1.1 Aim

The primary aim of my study was to investigate if there is a relationship between the level of shading of coffee trees and the abundance of BCTB. Another aim was to see if the knowledge and opinions about BCTB vary between researchers, officers and farmers.

According to the information given by Vi Agroforestry in Masaka and two other studies (Kagezi et al. 2013; Anuar, 1986) made on this subject, a hypothesis was formulated. The hypothesis was that the abundance of the BCTB is higher in shaded coffee, which is the reason why farmers´ believe they have to cut down their shade trees in order to decrease the problem of this pest (personal communication, Komakech, 2016-03-04).

1.2 Research questions

1) Is the abundance of the Black Coffee Twig Borer increasing with increased level of shade on robusta coffee?

2) Does the knowledge level and opinion about BCTB and shade for coffee vary between farmers, officers and researchers?

1.3 Black Coffee Twig Borer (BCTB)

The BCTB is a small beetle. The female is black, it is 1.55-1.88 mm long and 0.68-0.83 mm wide. The male is smaller (length 0.76-1.14 mm and width 0.37-0.45 mm) and reddish-brown (Figure 1). The eggs are 0.55 mm long and 0.33 mm wide. They are whitish translucent (Ngoan et al. 1976). Development from egg, through larval and pupal stage into a mature adult requires about 30 days. It is only the adult beetles that damages plants and the males are flightless, thus it is only the females that emerge from a twig as they become adult beetles (Ngoan et al. 1976). The female bores through the xylem of a twig and chews through the pith of the twig to create a common brood chamber in which she lays eggs. The entrance holes are most commonly made on the underside of the twigs. She inoculates a fungus, (*Fusarium solani*) in the brood chamber which spreads and creates a thin film (0.1-0.5 mm thin) inside the chamber. The fungus is the only food for the larvae and the adult beetles (Ngoan et al. 1976). After a coffee tree gets infested the leaves turn dull green and wilt within one week. The following week the leaves turn brown (Ngoan et al. 1976). There are over 200 host trees for the BCTB including robusta coffee (*Coffea canephora*), macadamia nut (*Macadamia ternifolia*), litchi (*Litchi chinensis*), avocado (*Persea americana*) and *Eucalyptus* spp. (Hara et al. 1979).

Figure 1. A female BCTB on the upper row and a male on the bottom row. The photos are not proportional to their real life size. BCTB from Uganda. (Photo: Gerard Malsher, SLU).

2 Materials and methods

Two different methods were implemented in this study: interviews of different stakeholders and observations of pest abundances in the field. All field work was carried out together with Julia Dahlqvist and Lina Wu. The observational field study and most of the interviews (with farmers and officers) were conducted in Kalungu and Bukomansimbi districts, situated north of Masaka, in the central region of Uganda (Figure 2). A few interviews with researchers were conducted in the surroundings of the capital of Uganda, Kampala. All the practical work was performed during a period of eight weeks, from January to March 2016. To start up the project in Uganda a few farmers were visited in Lwengo and in Mubende districts. These visits were conducted to give a better idea of what the small scale coffee farming systems look like, too see the symptoms of the Black Coffee Twig Borer (BCTB), (*Xylosandrus compactus* (Eichhoff)) in reality and to decide how to design the field study.

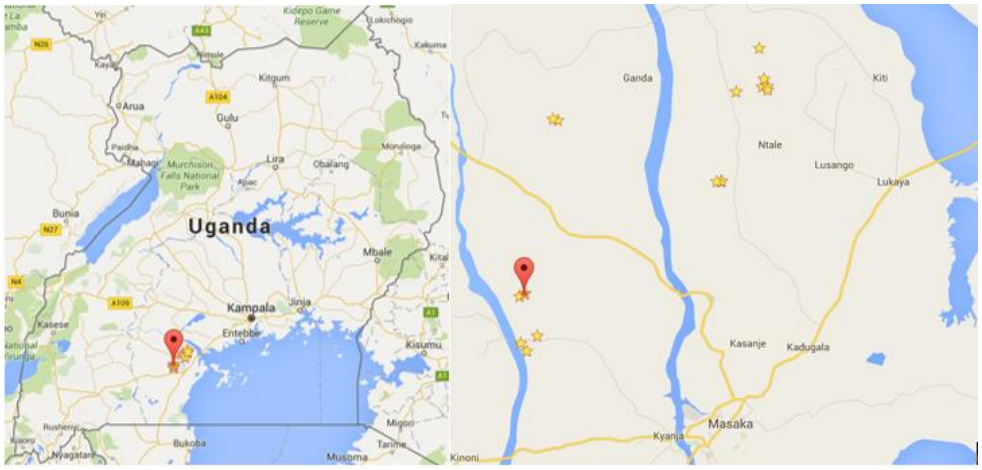


Figure 2. A map of Uganda to the left and a map of the surroundings of Masaka to the right. Stars show the location of 17 of the coffee farms participating in this study, (the remaining 3 coordinates were not found in Google maps).

2.1 Field study observations

We studied infestation levels of the BCTB, on robusta coffee, at 20 different farms belonging to the interviewed farmers. In total 30 coffee trees on the coffee plot closest to the homestead was examined, meaning 10 coffee trees studied by each person (Christina Hultman, Julia Dahlqvist and Lina Wu) per farm. The whole study thus comprised 600 coffee trees. Three parallel lines were defined in the coffee plot. Two of them ran along two borders, with a distance of 5 meters to the border. The third line went mid-way between the two other lines. The starting point of each line was

5 meters from the border at the end of the long side of the plot (Figure 3). Depending on the size of the coffee plot, every, or every second coffee tree was examined, unless the coffee tree did not have any twigs on the height of examination, then it was excluded from the study.

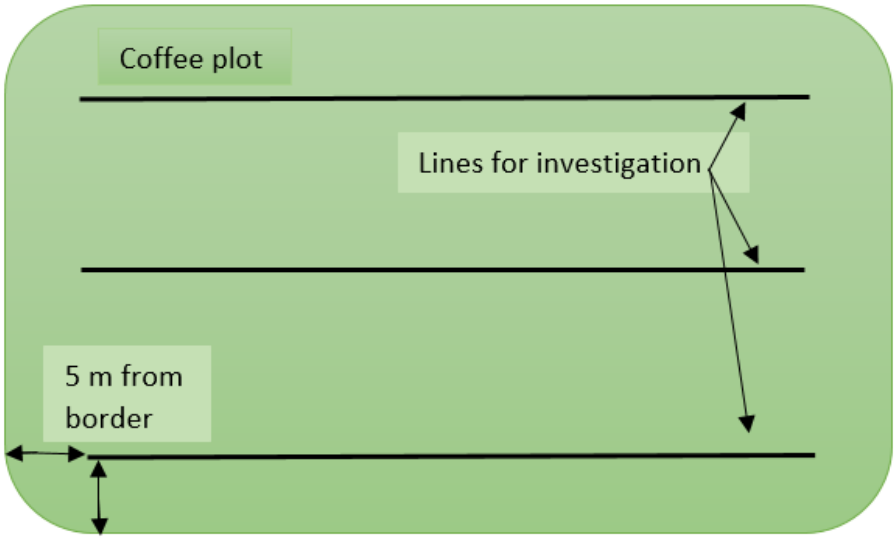
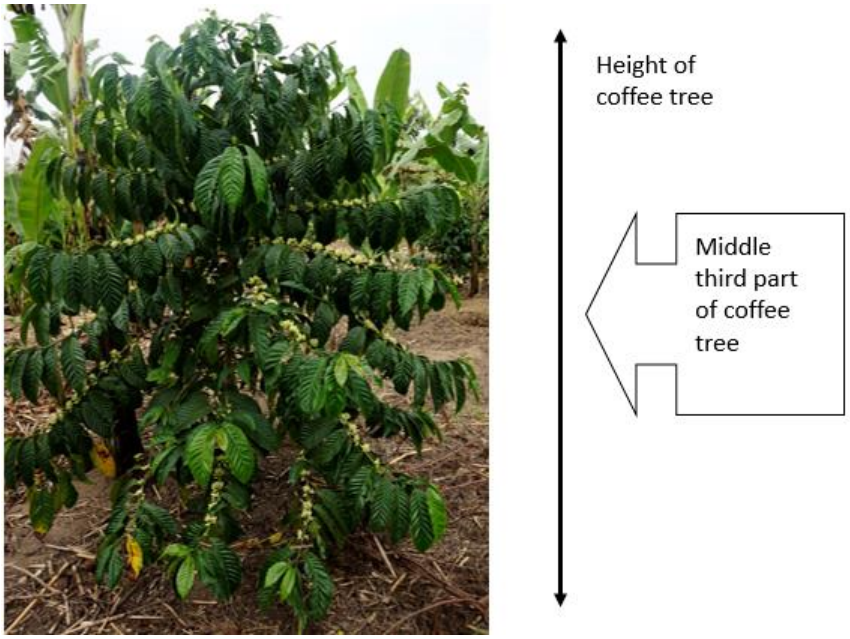


Figure 3. Coffee plot representing one farm with three parallel lines for investigation. Ten coffee trees were investigated per line on each farm.



Figur 4. The total height of a coffee tree divided into three parts, where 4 twigs in the middle third part of the coffee were chosen for investigation. (Photo: Christina Hultman).

Four twigs per coffee tree were examined, one twig in every cardinal direction. These twigs were situated somewhere at the middle third part of the coffee trees height (Figure 4). We wanted to define a height that could include almost all differently looking coffee trees, resulting from different age and/or management. That is the reason why we chose to look at twigs somewhere at middle third part of the coffee trees. The number of entrance/exit holes were counted on each twig.

A survey of the surroundings of the coffee tree was thereafter conducted. The shade was estimated by the cover of the canopy of other trees and crops, above the coffee tree. The estimation was done in a radius of one meter around the coffee crown and was done by eye. To reduce the risk of making different assessments of the same level of shade above a coffee tree, we looked together at some coffee trees beforehand to discuss and agree on the shade level of these coffee trees. The level of shade was divided into 5 categories: 0-20 %, 21-40 %, 41-60 %, 61-80 % and 81-100 % canopy coverage. See appendix 4, for the data sheet of the field study observations.

To analyze the number of holes per twig in relation to the shade level of a coffee tree, we performed linear mixed effects models, using the lme function in the nlme package in R 2.14.0 (R Development Core Team 2011). Shade level was analyzed as a categorical variable with 5 levels (0-20 %, 21-40 %, 41-60 %, 61-80 % and 81-100 % canopy coverage). We used a GLM-approach instead of an Anova since the number of observations within each level of the fixed factor was strongly unbalanced. Prior to analysis, the data was log10 (x+1)-transformed to ensure that residuals of the model were approximately normally distributed. The random model included plot to account for non-independence of trees sampled within each plot. To compare the effect of shade level on means, Tukey contrasts were performed with the glht function in the multicomp package in R 2.14.0.

2.2 Interview method

The interview part of the study comprised in total 20 farmers, 6 officers and 3 researchers to compare their views and knowledge about BCTB. We interviewed 10 farmers from Kalungu and 10 from Bukomansimbi districts, 2 agricultural officers from Kalungu district, 1 Agricultural Officer and 1 Agriculture production coordinator from Bukomansimbi district, 1 development director from UCDA (Uganda Coffee Development Agency), 1 Production and Marketing Assistant Entrepreneurship Services Manager from NUCAFE (National Union of Coffee Agribusinesses and Farm Enterprises) and 3 researchers, one from NaFORRI (National Forestry Resources Research Institute), one from NaCORI (National Coffee Research Institute) and lastly one from Makarere University school of Agricultural sciences. The interviewees categorized as officers in this thesis include the four officers advising

farmers in the two districts and the two persons, from UCDA and NUCAFE, which are advisers in the whole country.

The farmers to be interviewed were chosen by the cooperatives' managers in dialogue with the facilitator at Vi-agroforestry. The expressed wish was to interview farmers that were affected by the BCTB and had knowledge about its symptoms, which the facilitator and cooperative managers had in mind when choosing the interviewees. The officers in each of the two districts were chosen according to their experiences in the field and with farmer extension work, thus preferably agricultural officers, but it depended also on who was available when we had time to conduct the interviews. The researchers were chosen according to their experiences of the BCTB or, to their experiences of coffee and agroforestry. The interviews began with a presentation by the interviewers in order to clarify the aim of the study, to diminish cultural misunderstandings and to point out the importance of objective answers to get as reliable answers as possible. The farmers' interviews were conducted in English and Luganda with the help of a translator. The answers of the farmer interviews were noted and later all the answers were summarized in appendix 1 for analysis. The interviews with the agricultural and production officers, as well as the officers and researchers at organizations and universities were conducted in English and no translation was needed. The answers were noted and summarized in appendix 2 for the officers and appendix 3 for the researchers.

The interview questions of importance for my two research questions are 9, 12-15, 20-22, 25 and 27-29 in the farmers questionnaire (appendix 1), 4-6, 10 (parts of it), 12, 14 (parts of it), and 17-20 in the officers questionnaire (appendix 2) and 2, 4, 9, 14 (parts of it), 15, 19-22 and 25-26 in the researchers questionnaire (appendix 3). For the second research question, whether knowledge level and opinion about BCTB and shade for coffee varies among stakeholders, I chose to compare answers from the questions about shade, shade trees and/or BCTB, between the three groups (researchers, officers and farmers). Also the questions about challenges for distribution of information about BCTB were discussed.

3 Results

3.1 Observational field study

I studied the effects of different shade levels on the abundance of BCTB. The number of sampled coffee trees for each shade category varied noticeably. Most of the investigated coffee trees (414) were in the category with least shade. For the shade category: 21-40 % there were 98 coffee trees, for 41-60 % shade there were 40 coffee trees and for the two categories with most shade (61-80 % and 81-100 %) there were 28- and 20 coffee trees respectively.

Results from a linear mixed effects model (lme) analysis showed that the shade level significantly affected the number of entrance/exit holes on the coffee twigs ($p<0.05$) (Figure 5). The posthoc Tukey test showed that there were significantly more entrance/exit holes when the shade level was 41-60 % compared to when it was 0-20 % ($z=2.930$, $p=0.0253$), and that there were nearly significantly more holes when the shade level was 61-80 % compared to 0-20 % ($z=2.534$, $p=0.0754$). All other comparisons were non-significant.

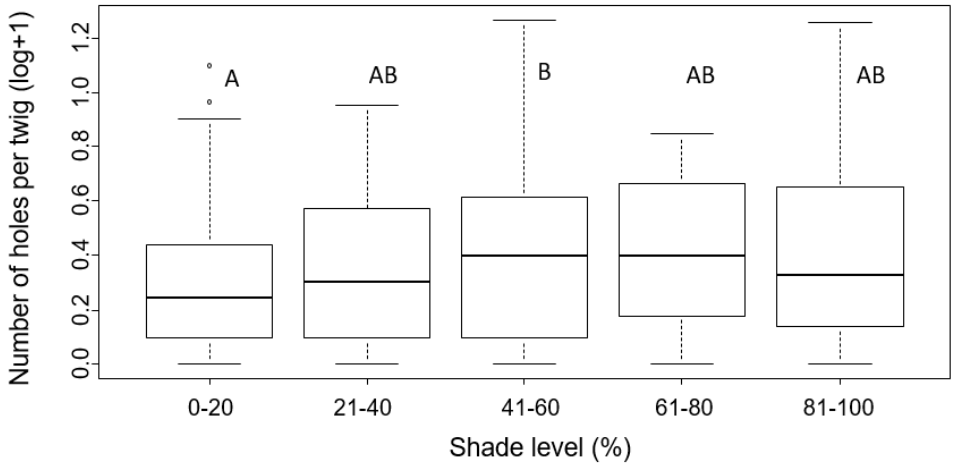


Figure 5. Level of shade above coffee tree (divided into 5 categories) in relation to average amount of holes per twig. The line in the middle of each box represents the median of the amount of holes per twig, the ends of the boxes represent the first and third quartiles, and the horizontal lines outside the boxes (whiskers) represent the extreme values found within 1.5 times the length of the box outside the closest end. Even more extreme values (outliers) are shown as dots. Different letters above boxes indicate significant differences.

3.2 Results from the interviews

My second research question was whether the knowledge level and opinion about BCTB and shade for coffee vary between farmers, officers and researchers. The results from the interviews contain only answers from the questions of relevance for my two research questions, thus they have to do with shade, shade trees and/or BCTB.

3.2.1 Recommendations about shade for coffee in general, by officers and researchers

The recommended shading for coffee was similar between officers and researchers and the reasons for why shade is important for coffee were also quite similar, see table 1 below for more details.

Table 1. *Recommendations about shade for coffee in general, by officers and researchers.*

Group of interviewees	Recommended shade level for coffee	Reasons why shade (and trees) is important
Officers	30 - 65 %	Shade helps to maintain moisture and reduce sunshine, which is especially important during the dry season. Helps to cool down the coffee plot and contribute to a good microclimate. Shade also contributes to more foliage growth and it gives the coffee a better taste (aroma and flavor). Other aspects mentioned were that trees increase the biodiversity for a sustainable coffee production, they add nutrients to the top soil and act as wind-breakers which helps the coffee to cope with extreme weather conditions.
Researchers	Not more than 40 %. The optimal percentage of shade varies with seasons.	Shade helps to increase the quality and weight of the beans. The micro-environment is more suitable under shade trees and the farmers could earn more money by having more trees thanks to UN-REDD program (Reducing Emissions from Deforestation and forest Degradation). Other positive aspects of having trees are that they have multiple uses and they help to spread the risks for the farmers, also thanks to their mitigation of climate challenges.

3.2.2 Tree species intercropped with coffee

The recommended shade trees to intercrop with coffee were similar between the officers and the researchers, and these trees were also the most commonly planted by the farmers. However some of these tree species were mentioned to be host trees for the BCTB, by some people from the three groups (farmers, officers and researchers).

Some farmers mentioned that some trees (*F. natalensis, M. eminii, A. chinensis,* jackfruit and mango) were intercropped with their coffee to give shade. As many as 14 farmers mentioned shade as one of the reasons for planting *F. natalensis* within

the coffee plot. Other reasons for having trees intercropped with coffee were to get timber, firewood, increased soil fertility thanks to the leaves and of course fruits for the jackfruit and mango. The officers recommended especially *F. natalensis, A. chinensis* and *M. eminii* to be intercropped with coffee. *Ficus natalensis* was recommended by all officers except one and they mentioned that it gives good shade for the coffee and some also said it gives important nutrients to the soil and that it has a historical background for making bark cloth. *Albizia chinensis* and *M. eminii* were mentioned by some officers and a few also pointed out shade and nutrients as good properties given by those species. One officer did not normally recommend any trees for intercropping with coffee because they can be alternate hosts for the BCTB. This officer mainly recommended bananas for intercropping with coffee. One researcher (a) recommended *F. natalensis* and *M. eminii* to be intercropped with coffee, but at the same time admitting that *F. natalensis* with its big leaves can give too much shade and need to be pruned. *Maesopsis eminii* was said to be good for a diversified income from timber since it is a fast growing tree. Another researcher just recommended native trees, but did not specify which species. The third researcher (b) referred to a publication from their institute: *Recommended shade-tree species for various coffee agro-ecologies of Uganda (*Kagezi et al. 2015), where *F. natalensis, F. mucuse* and *A. coriaria* were recommended for the central region of Uganda. This researcher on the other hand did not recommend *A. chinensis* in coffee agroforestry systems since it was considered an alternative host for the BCTB and is sensitive to strong wind. Some farmers mentioned *F. natalensis* and avocado as alternative hosts for the BCTB.

3.2.3 Magnitude of the BCTB-problem

All farmers, officers and researchers answered that the BCTB is a major pest in Uganda. All 20 farmers have problems with the BCTB on their farm and half of the farmers experienced the yield loss of the BCTB to be somewhere between 40-60 %. They have had problems with the BCTB during the last 2-5 years, most of them during the last 2-3 years. All officers stated the BCTB to be a major problem in their district or in Uganda as a whole. All except one officer said that it is the biggest of all pests on robusta coffee. The opinions or knowledge about when the BCTB was first discovered in Uganda were divided also within a district. In Kalungu the different officers said that it came either in 2010 or in 2012. In Bukomansimbi one officer said it reached epidemic levels in 2012-2013, but it arrived some years earlier. Another officer had heard it arrived in 2010 or earlier. According to the information about Uganda as a whole BCTB was first detected in 1995 and became a serious problem in 2000 according to one officer, or arrived before 2008 and became a serious problem in 2010 according to another officer. One researcher (b) said that

the BCTB came to western Uganda first, to Bundibugyo, in 1993 and it is widely spread since 2010.

3.2.4 Infestation of BCTB on coffee with or without shade

The answers about if shaded or sun-exposed coffee are most affected by the BCTB varied especially among the officers and researchers, see Figure 6. However most of the farmers said it is the shaded coffee that is most affected by the BCTB.

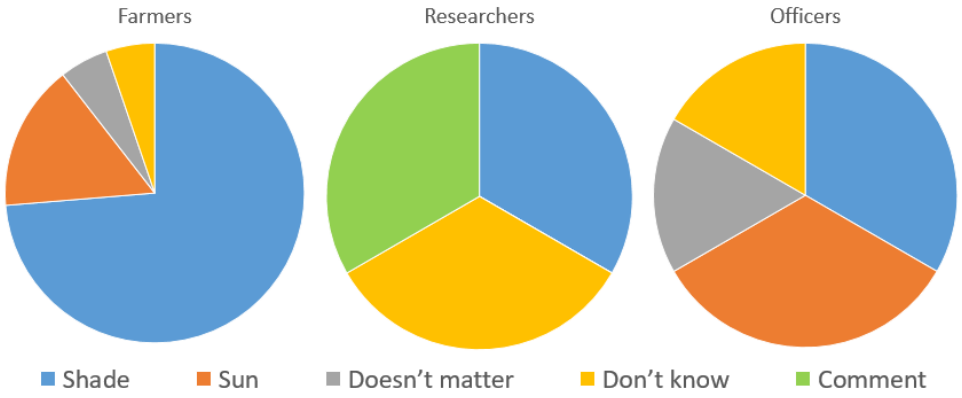


Figure 6. Proportions of the answers about if shaded or sun-exposed coffee is more infested by the BCTB, within the three groups (20 farmers, 3 researchers and 6 officers).

Fourteen out of 20 farmers said that it is the shaded coffee that is most affected by the BCTB. Among both officers and researchers the answers differed considerably. Two officers said it is the shaded coffee whereas 2 other said that it is the sun-exposed coffee and the other 2 did not know or said it does not matter. Among the researchers one (a) said it is the shaded coffee, because of the suitable environment for the pest, created under shade. One researcher (c) did not know and the third one (b) commented (Figure 6, in green) that it is not easy to say, because the amount of shade, as well as drought can cause stress for the coffee and weaken it, which increase the attack rate of BCTB.

3.2.5 Control methods for the BCTB

Regarding sanitary methods to control the BCTB the opinions were very similar between all researchers and officers who recommended these methods. These recommended methods were also implemented by the majority of the farmers. The sanitary methods implied to remove affected twigs and burn them. However, two farmers mentioned that they had given up the management and meant that the coffee dies anyway. Some farmers experienced that the coffee trees became naked, with no berry bearing twigs left.

One researcher (b) said that it is important to combine these sanitary methods with systemic chemicals that are absorbed by the coffee tree and transported to the twigs to kill eggs, larvae and adult males that live inside the twigs their entire life. Fifty percent of the officers also mentioned chemicals as a way to control BCTB, but this method was seldom used by the farmers.

One of the researchers (b) also recommended to remove young twigs from the coffee since they attract the BCTB and do not contribute much to the total yield. There were 8 farmers who mentioned that they implement this method as well. Other recommendations by this researcher (b) were to leave a maximum of 3-4 stems in order to avoid getting too bushy coffee which attracts the BCTB. Shade was stated as good for the coffee but for the same reason as mentioned before, it should not be too much. Most of the farmers also said that they prune their shade trees (e.g. *F. natalensis, M. eminii* and *A. chinensis)*, not only to control the BCTB, but as usual tree management, to reduce shade. Some mentioned that they have cut down trees to reduce shade as well. Two officers also recommended reducing the shade in order to control the BCTB.

3.2.6 Advice given and taken

The officers and researchers disseminated their information mostly through extension work, and this is how the farmers said they received their information as well. Almost all the farmers answered that they had gotten advice concerning the BCTB from district agricultural extension officers. All the officers mentioned that they spread information to the farmers through extension work in the field, including seminars, workshops and training programs. Four out of 6 officers mentioned radio programs as a way to reach out with information to the farmers. One of the officers, working with the whole country also mentioned TV-programs as a way of reaching out to the farmers, as well as through Facebook, What's App or with bulk SMS. Also the national coffee festival was brought up as a way of spreading information. Another officer said that they link up with research and spread their brochures and charts to the farmer groups. The research findings are distributed to the farmers through extension work and demonstrations.

3.2.7 Challenges

Challenges that the officers and researchers face in their work with the BCTB were especially lack of resources to reach out to the farmers and make them understand the importance of controlling the BCTB. Half of the officers said that it is important that everyone implements the control methods to suppress the dispersion of the pest to neighboring coffee plots. One officer even suggested that a solution for the lack of commitment by farmers to the recommended control methods that several of the officers experienced, could be to introduce some kind of punishment for the farmers

who do not follow the advice. Researchers mentioned challenges in their work, such as that the BCTB is a new phenomenon and that the resources are limited at the same time as the government puts pressure to develop solutions. They said that they see negative attitudes toward trees among farmers and that it is not easy to reach out with their research findings. Because the farmers are in very different socioeconomic situations and their cropping systems vary it is difficult to communicate.

4 Discussion

4.1 The influence of shade on BCTB

One of the main research questions in my thesis was whether the abundance of BCTB increases with increased level of shade on robusta coffee. The results show that infestation by BCTB increases with increased level of shade (Figure 5). My second research question was whether the knowledge level and opinion about BCTB and shade for coffee vary between researchers, officers and farmers. There were many divided opinions about if the shaded- or the sun-exposed coffee is most affected by the BCTB, especially among the officers and the researchers (Figure 6). However most of the farmers answered that shaded coffee is more affected by BCTB than sun-exposed coffee. This indicated that the knowledge level and opinion differs within- and between the groups (farmers, officers and researchers).

4.1.1 Observational field study - influence of shade on BCTB

I found support for the hypothesis that the amount of entrance/exit holes increases with increased level of shade (Figure 5). However it was only a significant increase of holes per twig between the shade categories 0-20 % and 41-60 % shade ($p<0.05$). Between the shade categories 0-20 % and 61-80 % shade the result was close to significant ($p=0.075$). These results are consistent with Anuar (1986), who showed a significant increase of BCTB from 0 % to 64.3 % shade. However, they used another measure of infestation degree, namely percentage of black twigs per coffee instead of entrance/exit holes. The results are also similar to those found by Kagezi et al. (2013) who also measured infestation rate as amount of entrance/exit holes in the coffee twigs. The study set-up of Kagezi et al. (2013) differed somehow from ours. They used 3 different categories of shade: full shade (1 m from tree trunk), minimal shade (edge of shade tree canopy) and full sun (3 m from canopy edge) divided among 8 different shade tree species. Thus actual shade levels of the shade categories differed considerably between the different tree species. Full shade differed from 60.0±26.5 % canopy cover for jackfruit (highest) and 11.7±7.6 % canopy cover for *A. chinensis* (Kagezi et al. 2013). Since full shade differed so much between the tree species in their study I think it is difficult to say that it is the percentage of shade that caused the increased infestation. Our study is more consistent when it comes to the specified shade categories.

We investigated 600 coffee trees in total. However most of the coffee trees, 414 had the lowest category of shade (0-20 %). For the 2nd lowest shade category (21-40 %) there were 98 coffee trees, but for the three higher shade categories there were only 40, 28 and 20 coffee trees respectively. Since there were so few replicates for

the three higher shade categories, this led to low explanatory power in the statistical analysis. This could be one explanation for why I did not find a significant increase of infestation by the BCTB for these higher shade categories. Preferably there should have been more coffee trees investigated within these three higher shade categories, to get a more reliable result.

4.1.2 Interview answers - influence of shade (or trees) on BCTB

The knowledge level and opinion differed within- and between the groups, (farmers, officers and researchers) on whether shaded- or sun-exposed coffee is most affected by the BCTB (Figure 6). Especially within the groups of officers and researchers the answers differ considerably. However most of the farmers (14/20) said that the shaded coffee is most affected, which is consistent with our field study and previous research (Kagezi et al. 2013; Anuar, 1986). This was also suggested by researcher (b) who has been involved in research concerning BCTB. This researcher (b) gave a comment instead of a fixed answer (Figure 6, in green) and said that the amount of shade, as well as drought can cause stress for the coffee and weaken it, which increases the infestation rate of BCTB. Another researcher (a) who said that it is the shaded coffee that is most affected, said that it is because of the suitable environment for the pest, created under shade. This is also suggested by Anuar (1986), who meant that the moisture created under shade can favor growth of the inoculated fungus. Since the officers had so many different answers on this question it is likely that they were not aware of previous research or they simply neglected these findings.

The shade may not be the only reason for more infestation close to other trees. *Albizia chinensis, F. natalensis* and avocado were mentioned to be host trees by some farmers, officers or researchers. Nevertheless these trees that were suspected host trees were also among the most common shade trees planted by the farmers and recommended by the officers and researchers to intercrop with coffee. The recommended trees were especially *F. natalensis, M. eminii, and A. chinensis*.

Avocado was shown to be an alternative host for the BCTB by Hara et al. (1979). One researcher (b) said that *A. chinensis* is an alternative host for the BCTB when referring to a brochure by Kagezi et al. (2015). *Albizia chinensis* is suggested to be a possible host tree for the BCTB also by Kucel et al. (2011). This researcher (b) has been involved in research concerning the BCTB on coffee for many years, which means there is a lot of experience behind this answer. However our study showed no significant relation between *A. chinensis* (Wu, 2016) and degree of infestation by BCTB. On the other hand, our study did find that there was a significant increase of infestation where there were more than one *F. natalensis* within a 5 m radius of a coffee tree (Dahlqvist, 2016). I have not found any research supporting that *F. natalensis* is an alternative host, but there are more than 200 plant species that are hosts for the BCTB (Greco et al. 2012). There was also one officer who did not

recommend trees for intercropping with coffee in general, because they can be alternate hosts, though without mentioning any specific species. Instead this officer recommended bananas for intercropping with coffee. It clearly is important to choose trees for intercropping very carefully (Gliessman, 2007). Accordingly there is a need to oversee which recommendations that farmers are given. There is a need for more information on this subject and therefore further research is required.

4.2 Other interview answers

4.2.1 Recommendations about shade for coffee in general, by officers and researchers

The level of shade recommended for coffee by the officers (30-65 %) and by the researchers (not more than 40 %. The optimal percentage of shade vary with seasons) were similar to the recommendations in Bekele-Tesemma ed. (2007). The arguments of why shade is important used by the officers and researchers were very similar to each other and in general agreement with Bekele-Tesemma ed. (2007) and Gliessman (2007). Both researchers and officers mentioned that shade provides a good microclimate for the coffee and that it increases the quality of the coffee (aroma and flavor). The officers and researchers also agreed that trees increase the diversity for a sustainable coffee production and they have multiple uses. Accordingly the right amount of shade contributes to coffee production.

4.2.2 Magnitude of the BCTB-problem

All farmers, officers and researchers agreed that the BCTB is a major pest in their working area. Farmers experienced problems with the BCTB in their coffee plots, officers in their districts and researchers as well as officers working in the whole country said that the BCTB is widespread in the whole country, which is consistent with Egonyu et al. (2009). All 20 farmers interviewed have problems with the BCTB on their farm. However this might not be the case for all farmers in these two districts, since we actively selected farmers affected by BCTB for this study. Therefore we probably investigated coffee farms more severely affected than the average in these two districts. The opinions or knowledge on exactly when the BCTB came to the farmers coffee plots, to the two districts or to Uganda differed. The researcher (b) who has been working with the BCTB said that it first came to western Uganda in 1993, to a district called Bundibugyo (Kagezi et al. [2016-04-30]) and that it is widely spread in the country since 2010. Therefore it is not surprising that most of the other researchers, officers and farmers experienced serious problems with the BCTB during the past 3-5 years or so, when the BCTB has had time to spread within the country.

4.2.3 Control methods for the BCTB

The opinions were rather similar between all researchers and officers regarding how to control the BCTB with sanitary methods, and these recommended methods were also implemented by the majority of the farmers. However the recommendations about chemical use were not commonly implemented by the farmers.

Sanitary methods in particular were both recommended and used. These methods are comparatively effective to decrease the number of BCTB, but are uneconomical since the amount of berry bearing twigs are reduced, thus reducing coffee yield (Egonyu et al. 2009). This was also confirmed by some farmers who said that their coffee trees have become totally naked after taking off the affected twigs. Two farmers had given up the management and meant that the coffee dies anyway and further farmers also expressed serious concerns about the BCTB situation. One researcher (b) pointed out that it is important to combine these sanitary methods with systemic chemicals that is absorbed by the coffee tree and transported to the twigs to kill eggs, larvae and adult males that live inside the twigs their entire life. The females fly to another tree or twig as soon as they have mated, to infest and lay more eggs (Egonyu et al. 2009). However, insecticides are not affordable for many farmers and they can be harmful to the humans and to the environment if they are not used in an appropriate manner (Egonyu et al. 2009). Therefore very few farmers implemented chemical control of BCTB, though it was advised by some officers as well.

4.2.4 Advice given and taken and challenges

The officers and researchers spread their information mostly through extension work, which is how the farmers receive their information as well. Almost all the farmers answered that they have gotten advice concerning the BCTB from district agricultural extension officers.

The challenges that officers and researchers face in their work with the BCTB were especially lack of resources on how to reach out to the farmers and make them understand the importance of controlling the BCTB. They mentioned that because BCTB spreads easily it is important that everyone takes the right measurements in order to control the problem. Since the sanitary methods are labor demanding and reduces the amount of berry bearing twigs (Egonyu et al. 2009) it must be hard to convince the farmers to put in all this labor. It is important to develop an effective integrated pest management program for the BCTB (Egonyu et al. 2009) and as researcher (b) pointed out to combine sanitary methods with systemic chemicals to make it more effective.

4.3 Limitations of the study

Since our expressed wish was to interview farmers that were affected by the BCTB and had knowledge about its symptoms, our results might have been affected accordingly. But the officers in these two districts said that the BCTB is a severe problem and widespread. This indicates that most farms there were affected, but maybe not to the same extent as the farmers we interviewed. The interviewed farmers had quite clear ideas about the symptoms of the BCTB, though some of the symptoms mentioned, such as wilting, could also have been caused by Coffee Wilt Disease for instance. We probably got more information about the BCTB than the average farmers in these districts could have given. In the same way, this also indicates that we sampled more coffee affected by the BCTB than what would have been sampled on an average farm in these two districts.

We got to interview one production officer, who works primarily with animals as a veterinary, and less with agriculture and coffee cultivation. This could have affected this person's knowledge level about the BCTB for instance. The background also differed between the researchers. One (a) is doing research on trees and has not been working directly with the BCTB. Another one (c) is doing research on arabica coffee and is an entomologist, but has not been working directly with the BCTB. The third researcher (b) has been involved in research concerning BCTB. This has probably influenced how reliable and how developed their answers were and for the researchers, this was probably the biggest reason for differences in the answers. However for the officers, the biggest reason for different answers and certainty of the answers was probably the low number of officers (6) interviewed in this study. As an example the officers gave very different answers on the question whether shaded or sun-exposed coffee is most affected by BTCB. If we would have interviewed a higher number of officers the conclusions about their answers would have been more representative for the officers in general.

My impression of the farmer interviews were that they were relaxed and did not hide or exaggerate anything in their answers, but it is difficult to know. We were seen as rich Europeans, from the academic world and they had not met us before, which could have made them feel uncomfortable or insecure. However, our Ugandan field mentor, Fred Mujurizi was always there to introduce us in their native language (Luganda) and also to tell them that we were not there to give them any money and that their answers would not have any consequences for them. We were simply there to get to know their real experiences with the BCTB. With this said I think we obtained as objective answers as possible.

For the observational field study we were three persons (Christina Hultman, Julia Dahqvist and Lina Wu) estimating the shade by eye, in a radius of one meter around the coffee crown. This was sometimes difficult to do with certainty, but since we

had 5 categories with quite broad ranges the amount of misjudgment should be relatively small. Furthermore we looked together at some coffee trees beforehand to discuss and agree on the shade level of these coffee trees in order to reduce the risk of making different assessments of the same level of shade. On some farms we also noticed that they had heavily pruned some shade trees recently. This indicates that a few of the investigated coffee trees recently had more shade, which could have influenced the results. Another challenge was to count the amount of holes per twig and we probably misjudged some holes. Since some of the holes had started to merge together they were difficult to recognize as a BCTB hole, rather than just another damage in the bark of the twig.

5 Conclusions

5.1 Principal findings and implications

The main result from this study was that infestation by BCTB increases with increased level of shade (Figure 5), with a significant increase between 0-20 % and 41-60 % shade. Between 0-20 % and 61-80 % shade the increase of infestation was close to significant. The shade influence by trees may not be the only reason for more infestation close to other trees, since they can be alternative host trees for the BCTB. However, there were different opinions among farmers, officers and researchers about possible host trees and this disagreement can be explained by a lack of research or that new information has not reached out. Another important result in this study was that the opinions about if shaded or sun-exposed coffee is most affected by BCTB, varied considerably among the officers and researchers, whereas most of the farmers answered that the shaded coffee is more infested by the BCTB (Figure 6). Combined with our results which show that the infestation was higher in 41-60 % shade than in 0-20 %, this indicates that especially the officers did not get the right information concerning BCTB and shade. These findings about the influence of shade on the BCTB are also found in the literature and they indicate the importance of pruning the shade trees regularly in order to control the amount of shade for the coffee. When designing a coffee agroforestry system or planting new shade trees for intercropping with coffee, these findings should be kept in mind, both regarding shade and possible host trees for the BCTB. Since shade trees have many good effects on coffee production and for the farmers´ livelihood it is critical to keep having trees within the coffee plots. However, it is important to be aware of the consequences of too much shade and if possible to avoid planting host trees for pests. It is important that these findings are distributed to the officers so that they can provide consistent and relevant advice regarding shade.

5.2 Further research

The BCTB is a main constraint for the coffee farmers in Uganda and further research is needed in order to find more effective control methods for this pest. Biological control with natural enemies would be an interesting topic for future research in order to control the BCTB. Traps with ethanol or other compounds, as well as possible volatile compounds that repel the BCTB would be interesting to investigate more. Control methods where the twigs are not removed enables the coffee berries to ripen on the coffee tree and are therefore more attractive to the farmers.

Since we investigated very few coffee trees within the three higher shade categories (41-60 %, 61-80 % and 81-100 %), investigating effects of higher shade levels more thoroughly could be a recommendation for future research of the same kind. This could be done by choosing transects differently or simply by selecting more coffee trees under shade trees. This could be done by choosing farms with many shade trees intercropped. It would be interesting to see if that would show a significant increase of infestation by BCTB even for these higher shade categories.

Further research about other host trees and plants is also needed, as well as to investigate the effects of having other host trees within a coffee plot. Is it really so that other host trees only would increase the number of BCTB or could it be possible to use other host trees as a control method? One such example could be a tree species that is more attractive than coffee for the BCTB. This tree might be used as a trap crop where infested twigs are cut off and burned for cooking.

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Appendix 1 – Answers from 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 re-placing 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) "Don´t know, but many" (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) 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)	Fruits (14)

		1 tree/acre (2) 2 trees/acre (3) 3 trees/acre (2) 4 trees/acre (2) 6 trees/acre 8 trees/acre (2)	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 twigs	8
Wilted and dried twigs	2
Drying of the whole coffee	4
Young plants wilt	1

Discovering of holes when dried twigs are removed	1
Destruction of productive twigs	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 twigs	4
Seeing the eggs of the pest inside the twigs	1
Holes in twigs	7
Wilting of twigs	5

Drying of twigs	14
Twigs break easily	2
Twigs 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 plot 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 sun-shine	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 of farmers	Reason and which trees (number 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 twigs and burning them (17) Remove affected twigs (1) Applying manure (1) Removing sprouts (8) Pruning (3) Have given up the control methods 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 twigs and burn them (12) Removing affected twigs (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 Entrepreneurships 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" organizations 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, stem borers, 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. Stem borers 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 twigs 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 refuge in alternative hosts and then they come back. The BCTB can fly up to 200 m. There are many alternative hosts (mango, avocado, Albizia etc).

d) A twig 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 is 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 rainy season it is spread widely. When it is hot outdoors, the coffee twig borer moves out from the twigs, in low temperatures they stay inside the twigs.

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 twigs (a, b, d, e, f)

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

Burn affected coffee twigs (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 be-cause 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 be-cause of too*	*6 times/season (a)* *Every 2 weeks (f)*	*Dry season (a)* *When there is a problem (b)*

	costly (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 twigs (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, Avocado, 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*	*a) -* *b) -* *c) -* *d) -* *e) -* *f) 40*

	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.*	
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) 20* *b) 10* *c) -* *d) -* *e) 20* *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, jack-fruit, av-ocado*	*a) -* *b) -* *c) -* *d) -* *e) Shade (but all are not good for inter-cropping because the leaves takes a long time to decompose), and for giving balance to the garden.* *f) -*	*a) -* *b) -* *c) -* *d) -* *e) 100* *f)*
Banana	*a) -* *b) Good shade, but also the roots of banana do not affect the coffee.* *c) -* *d) Yes* *e) -* *f) -*	*a) -* *b) 60* *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 an 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 flavor) 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 is 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 organize 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 twigs, 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 sub counties 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 twigs 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 twig, 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) Radio stations – 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 it is 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 bacteria.
   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 twigs (a, b, c)
   When? Dry season (a). Not specified, as soon as needed (b). Did not have time to ask (c)

   Burn affected coffee twigs (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 twig, this way we can reach the eggs, larvae 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 know 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 parasitoids 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 [OBS! Not sure about spelling]. They disseminate this knowledge on how to increase these populations of natural enemies to the farmers.*
    **note: could be lace bugs, 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	*b) Yes (check brochure)*	
Albizia coriaria (mostly in the west)	*a) It twigs 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	*a) Grows tall, so they need to be closer to each other, and has heavy twigs. The twigs don't cause*	*a) 10*

(mostly in the west)	*a lot of damage when falling off. It is good for timber which diversifies the income of the farmer. It grows faster than Albizia.*	
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	*b) Yes*	
Ficus viocosa	*b) Yes*	
Grevillea robusta and Yakoranga *15 m*	*b) Not recommended for agroforestry since the root system is too close to the soil surface 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 degradable 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't recommend 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 recommended spacing is 6 ft. Between a coffee and another coffee plant it is recommended 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 – Sheet for field study observations

Investigation per coffee tree

		North	**East**	**South**	**West**
Coffee twigs in middle third part of the coffee tree	Number of holes in twig				
	wilting degree	0 L M H	0 L M H	0 L M H	0 L M H

Estimation of shade (covering canopy) above the coffee tree in a 1 m wide circle around the coffee crown:

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

Counting of trees and/or crops around the coffee tree in a radius of 5 meters.

	Ficus natalensis	*Grevillea robusta*	*Maesopsis eminii*	*Polyscias fulva*	*Albizia chinnensis*	Banana	Other
# Trees (5m)							