Infestation and management of the Black coffee twig borer in Uganda - and the potential impact of the leguminous tree *Albizia chinensis* on robusta coffee

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Abstract

The Black coffee twig borer's (BCTB) impact on the robusta coffee production in Uganda is of major importance. A recent study showed that 69% of the coffee farms are infested by the pest of the 26 districts surveyed, with an average of 40% of the coffee plants being attacked. The national yield loss is estimated to be 9% because of BCTB.

In this survey farmers, extension officers and researchers were interviewed to compare the knowledge accumulated of BCTB on local, district and national levels and to discuss the management methods of the pest. Since the coffee plants are largely grown using agroforestry methods the utilization of shade trees is both common and recommended. A field study was conducted in the two districts in Central Uganda to investigate if shade trees can be potential hosts to the beetle. In this particular thesis the relationship between the BCTB and the promoted leguminous tree, *Albizia chinensis*, was examined. Although *A. chinensis* is recommended to be intercropped with coffee, it has been found to be an alternative host to the BCTB.

The results from the interviews show the different levels of knowledge accumulated by the groups considering the BCTB. The farmers experienced an increased infestation levels of BCTB over the last few years and estimated their yield loss to range between 20-75% because of the pest. The estimation by the officers were lower (5-50%) and two officers believed the infestation levels to be declining. The cutting down of shade trees wasn't recommended by any officer or researcher, however, four farmers cut down shade trees in order to decrease the levels of BCTB. There may be more cases though, since eleven farmers didn't give any reason to why they chose to cut down their trees. *A. chinensis* was mentioned to be a host to BCTB by one researcher and one officer, but the same researcher still recommended it for certain areas. Only one more officer recommended *A. chinensis* to be intercropped with coffee. The results from our field study showed no significant relationship between presence and abundance of this tree and BCTB attack rates. None of the farmers who had *A. chinensis* seemed to know the potential the tree inhabits as host to BCTB. The issue thus remain to be further investigated and include to what extent *A. chinensis* can be recommended.

This study gives indications on what can be done to further improve the situation for the coffee farmers in the two districts surveyed.

Keywords: Xylosandrus compactus, agroforestry, shade, *Vi agroforestry*

Sammanfattning

Kaffevivelns påverkan på robusta kaffe i Uganda är av stor betydelse. En färsk studie visade på att 69% av kaffegårdarna var drabbade av skadgöraren i de 26 undersökta distrikten. I genomsnitt var 40% av kaffeplantorna attackerade. Den nationella skördeförlusten på grund av kaffeviveln uppskattas till 9%.

I denna studie intervjuades bönder, rådgivare och forskare för att jämföra kunskapsnivåerna kring kaffeviveln på lokal, distrikt och nationell nivå, samt för att diskutera kontrollåtgärder. Eftersom det mesta av kaffet odlas i agroforestry system så är användandet av skuggträd både en vanlig och rekommenderad metod. En fältstudie genomfördes i två distrikt i centrala Uganda för att undersöka ifall skuggträd är potentiella värdar för kaffeviveln. I den här studien undersöktes sambandet mellan kaffeviveln och det rekommenderade leguminosa trädet *Albizia chinensis*. Fastän man uppmuntrar samodling med *A. chinensis* i kaffeodlingar så har man tidigare visat på att det är ett värdträd för kaffeviveln.

Resultaten från intervjuerna visar på de olika kunskapsnivåerna och uppfattningar som de skilda grupperna hade angående kaffeviveln. Bönderna upplevde ökade angreppsnivåer av kaffeviveln under de senaste åren och uppskattade sina skördeförluster till 20-75%. Rådgivarna i sin tur, uppskattade lägre angreppsnivåer (5-50%) och två av rådgivarna trodde att angreppsgraden höll på att minska. Fyra bönder högg ner sina skuggträd för att minska angreppen av kaffeviveln, en åtgärd som inte rekommenderades av varken rådgivarna eller forskarna. Ytterligare ett antal bönder kan ha tillkommit, då elva bönder inte uppgav någon anledning till varför de huggit ner sina träd. En forskare och en rådgivare uppgav att *A. chinensis* är ett värdträd för kaffeviveln, dock rekommenderade samma forskare fortfarande trädet för särskilda områden. Endast en rådgivare till rekommenderade *A. chinensis* för samodling i kaffe. Resultaten från vår fältstudie visade inte på något signifikant samband mellan närvaron och förekomsten av *A. chinensis* och kaffevivelangrepp. Ej heller tycktes de fem bönderna som hade *A. chinensis* medvetna om att trädet potentiellt kan vara ett värdträd för BCTB. Eftersom uppfattningarna skiljer sig om till vilken grad *A. chinensis* kan användas som skuggträd, så bör detta undersökas vidare.

Studien ger vidare indikationer på vad som kan göras för att förbättra situationen för kaffebönderna i de två undersökta distrikten.

Nyckelord: Xylosandrus compactus, agroforestry, skugga, *Vi skogen*

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Abbreviations

BCTB	Black coffee twig borer
NaCORI	National Agricultural Coffee Research Institute
NaFFoRRI	National Forestry Resources Research Institute
NUCAFE	National Union of Coffee Agribusinesses and Farm Enterprises
UCDA	Uganda Coffee Development Authority

1. Introduction

1.1 Coffee in Uganda

Agriculture is the most important economic sector in Uganda, accounting for 27% of the total GDP and employing about 82% of the labor force (CIA, 2013). Uganda ranks as the second biggest coffee producer in Africa and number ten in the world (UCDA, 2008). The coffee industry employs over 3.5 million families and the crop is still contributing 20-30% of the export incomes despite the efforts made by the Government to diversify the economy. The coffee production is dependent on 500 000 smallholder farmers, each having an average farm size ranging from less than 0.5 up to 2.5 hectares (UCDA, 2012). To ensure the households' food security the coffee is being intercropped with banana, cassava, sweet potato, beans and maize. The surplus is sold at the local markets. Uganda has for several years been an important producer of organic and fairtrade coffee (Karlsson, 2015). There are two types of coffee grown in Uganda: robusta (80%) and arabica (20%)(UCDA, 2008). Most of the coffee plants have exceeded the biological optimum of 40 years, and as a result is the Government replacing the old coffee with new genetically pure and high yielding varieties since 1991 through different programs (UCDA, 2012). Although the coffee production since then has been improved, there are new constraints emerging. After the yield peak of 4.2 million bags produced in 1998 the productions slowly began decreasing, because of the outbreak of the Coffee wilt disease that slowly destroyed 52% of the robusta coffee (UCDA, 2008).

1.2 Agroforestry – growing coffee under shade

To produce coffee in a sustainable way, including social, economic and environmental aspects, and with minimal inputs of agro-chemicals, it is recommended to grow coffee under shade (UCDA, 2012). As the climate change challenges are increasing, the need for mitigation of its effects is crucial for the coffee production's continuation. Growing coffee under shade can be of economic value to the farmers as it requires less input in terms of fertilizers and chemicals, but also essential to protect the coffee from climate extremes and water loss in the future (Lin et al., 2008). A study on arabica coffee in Costa Rica (Muschler, 2001) concluded that a higher quality of coffee beans is produced when the coffee is grown under shade. This is because shade promotes a slower and more balanced filling in the time of ripening of berries. The results from the study showed that both the fruit weight and bean size increased significantly when shade intensity was increased, from 0% to more than 80% shade underneath the forage legume tree *Erythrina peoppigiana*. This is not though, certain to apply for robusta coffee.

The Swedish development organization *Vi Agroforestry* is active around Lake Victoria in East Africa, and was founded in 1983. The organization promotes agroforestry methods to be used as agricultural practices, which implicates tree planting together with crops and livestock husbandry (Vi skogen, 2016). The benefits from agroforestry are many; the diverse crop production favors both the economy and supports the households' needs of medicine and timber (Wekesa and Jönsson, 2014). The soils are enriched when the fertility is improved by the agroforestry methods especially when nitrogen fixing plants are added to the production system. The trees also contribute to the reduction of soil erosion and to the carbon sequestration.

When adding trees to a coffee production system, the species interactions will become of a more complex nature than growing only coffee. As a result the ecological network may be able to more effectively buffer against pest outbreaks (Vandermeer et al., 2010), because the populations of natural enemies has been observed to increase in agroforestry systems (Pumariño et al., 2015). The responses on the pest varies though, with the complexity of the landscape: Chaplin-kramer et al. (2011) found that the generalist responded consistently to all scales, whereas the specialist enemy replied more strongly to landscape complexity on smaller scales. However, the reduction of pest abundance in perennial crops (e.g. coffee) contributed to the general idea that higher habitat complexity leads to better pest control (Pumariño et al., 2015). But at the tree-crop interface in agroforestry systems an increased pest and disease incidence was observed by Schroth et al. (2000). The causes are the humid microclimate generated by the trees, the physical protection the mammal and bird pests get from the trees, and the possibility that the crops are more competition-stressed by the intercropping methods. Coffee plants grown under shade trees can become more exposed to competition for growth resources, as well have reduced risks of getting stressed by improved micro-climate and a balanced nutrient provision (Beer et al., 1998). Stressed coffee plants may look healthy although it is emitting stress-related volatile compounds, signalling the status of the plant and further attracting host-seeking ambrosia beetles (Ranger et al., 2010).

The impact of shade on pest abundances has been investigated by Jonsson et al. (2015), and the study indicated that the effects depended on the identity of the pests in the area and the environmental conditions. For example, the coffee berry borer populations were more common in sun-exposed plots whereas the opposite applied to the white stem borer. The agroforestry system can be adapted to more effectively manage pests, diseases and weeds if the importance of the identity of the pest and environmental context is understood (Pumariño et al., 2015).

1.3 The black coffee twig borer (BCTB)

The Black Coffee twig borer, *Xylosandrus compactus* (Eichhoff) is an ambrosia beetle belonging to the Scolytidae family and tribe Xyleborini (Greco and Wright, 2012). The BCTB is an invasive pest that is probably native to south-east Asia (Ngoan et al., 1976), but has spread to most of tropical Africa, Asia, the Pacific islands, Latinamerica and the US (CABI, 2016). The hosts of BCTB includes 225 plants worldwide, for example tea, cocoa and several species of ornamentals. A recent survey from 2013 revealed that 69% of the surveyed coffee farms in 26 districts in Uganda were infested by BCTB with an average of 40% of the coffee trees being attacked. This lead to the death of 9% coffee twigs, why 9% of the coffee production is estimated to be lost due to the BCTB (Kagezi et al., 2013). The worst hit districts included Masaka, which is only 30-40 km away from Kalungu and Bukomansimbi.

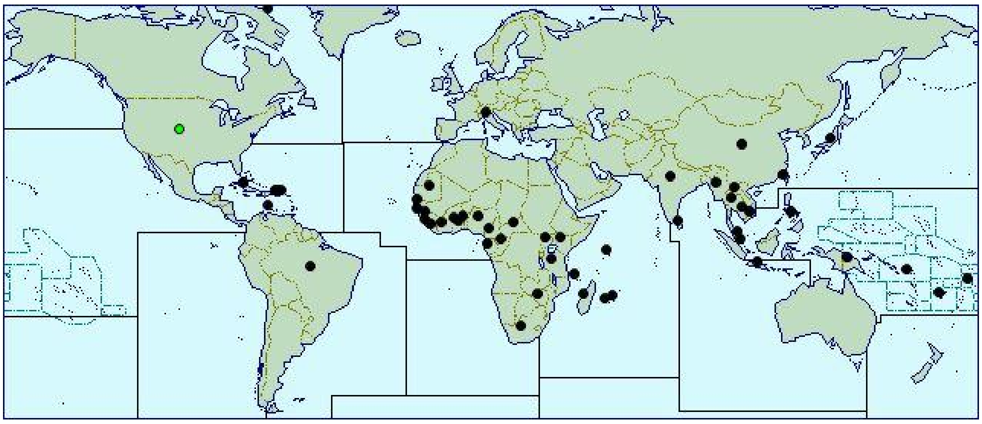

Figure 1. Distribution of BCTB. The black dots show the presence of the pest in the area, while the green dot indicates the presence for the region (CABI, 2016).

The adult females of BCTB are 1.4-1.8 mm long and 0.7-0.8 mm wide, shiny-black in color, while the males are reddish-brown, 0.8-1.3 mm long and 0.42-0.46 mm wide (figure 1). The males live only up to 6 days and are flightless, while the females live up to 58 days (Ngoan et al., 1976). The complete life cycle from egg to mature adult requires about 28.5 days at 23-27ºC with 50-60% relative humidity, so on the 29th day the new females exit the parental galleries to establish new ones (Greco and Wright, 2012).

Figure 2. BCTB females are seen in the left column, the males to the right. (Photo by Gerard Malsher).

It is only female beetles that cause damage to the plants by boring into the plant tissue of the host. Females make their entrance holes of 0.71-0.89 mm diameter into living twigs up to 5 mm in diameter. They bore through the xylem into the twig pith, and when having reached the pith they chew along the axis of the twig to make a common brood chamber for the eggs (Ngoan et al., 1976). Once the ambrosia fungus *Fusarium solani* is inoculated into the galleries by the female beetles, the eggs are laid in loose clusters (Ngoan et al., 1976). Each female hatch between 10 and 30 eggs (Greco and Wright, 2012). The larvae and adults of BCTB get food from the symbiosis developed with the ambrosia fungus (Ngoan et al., 1976). The introduction of the ambrosia fungus leads to necrosis and desiccation of the host's twigs. Both the nutrition and water flow through the xylem is obstructed up to 5 cm in length of the twigs from the entrance hole (Ngoan et al., 1976). The BCTB attacks both healthy as well as stressed plants (GISD, 2015) and can rarely even attack twigs as thick as 20 mm in diameter, which can lead to the death of small trees (Hayato, 2007). The host trees includes the pear, avocado and cacao (Ngoan et al., 1976). Both the tunneling activity of BCTB and the infection of ambrosia fungus might contribute to the physical and economic damage to the infested plants (Greco and Wright, 2015). One week after the initial entry of a female BCTB, the leaves on the infested twigs turn dull green, curl inward and wilt. After another week the leaves turn brown (Chamberlin, c1939). Shaded robusta coffee has been observed to be more frequently attacked by the BCTB than non-shaded coffee plants (Anuar, 1986), probably because of the favorable micro-climate generated by the coffee plants. The study from Anuar (1986) showed that the damage by the BCTB on shaded coffee robusta plants also was more severe, giving twice as many wilted branches.

Figure 3. The drying of branches and leaves at the left photo, entrance holes on the right. (Photo by author)

1.4 The symbiosis between BCTB and ambrosia fungi

The ambrosia fungus *Fusarium solani* serves as the sole food source for both larvae and adults of BCTB (Ngoan et al., 1976). BCTB stores and transfers this fungus in specialized organs called mycangia, which the offspring gets as soon as they leave the gallery to colonize new plants from their mother (Hulcr and Dunn, 2011). A mutualistisc symbiosis between the ambrosia fungi and BCTB is established and the fungus benefits from the insect because: (1) it is transported and inoculated into a good environment with suitable moisture and nutrients, (2) hyphae growth is facilitated since the injury caused in the wood enables faster penetration, (3) the feces from the BCTB provides nitrogen, (4) the fungus is protected in the mycangia organs of the beetle during flight and (5) the fungus is able to multiply in the mycangia (Batra, 1967). BCTB benefits through this association because: (1) the fungus weakens the wood which makes the excavation easier for the developing larvae, (2) the BCTB is protected from the defense mechanism that exists in the phloem and (3) the predigestion of host tissue by the fungus extracts nutrients which serves as the sole source of food for both larvae and adult beetles (Batra, 1967). Other non-ambrosia fungi (the oak wilt pathogen *Endoconidiophora fagacearum* and the dutch elm pathogen *Ceratocystis ulmi*) has been found in the mycangia of 20 (other than *Xylosandrus compactus*) ambrosia beetles studied by Batra (1963) who concluded that the ambrosia beetles are capable of carrying plant pathogens, that might add to the dissemination of pathogens.

1.5 The agroforestry tree *Albizia chinensis*

One of the aims of this study is to investigate whether the nitrogen-fixing tree, *A. chinensis*, which is recommended for intercropping with coffee, has any relationship to the infestation degree of BCTB. It has been shown that *A. chinensis* is a host by Kagezi et al. (2014a, 2014b), why it is recommended to reduce the number of *A. chinensis* in coffee production systems. However, in the training material from Ugandan coffee Development Agency, *A. chinensis* is one of the recommended shade trees (NSC, 2014). In the same material it states that *A. chinensis* is commonly known to be a host to BCTB, why the farmers are advised to consult their extension officer for further information concerning the management methods. A study on eight different shade trees, conducted by Kagezi et al. (2013) in Mukono (Central Uganda), showed that an increased infestation level of BCTB was related to tree specific shading degree. The shading properties varied significantly between different shade tree species, with the lowest shading percentage for *A. chinensis* and the highest for jackfruit. The study concluded a higher infestation degree of BCTB if grown at the edge of *A. coriaria*, jackfruit and mango, but no significance was shown in relation to *A. chinensis*.

Albizia chinensis was introduced to Uganda from tropical and sub-tropical Asia where it originated (White, 2015). It is a deciduous and evergreen tree, growing up to 30 meter tall (Orwa et al., 2009). According to the *National Agricultural Coffee Research Institute* in Uganda the tree gives good shade to the coffee since the crown is flat and outspread but also because of the small leaves that still let some sunshine to go through. The tree is nitrogen-fixing and recommended to be intercropped with coffee in East Africa as it improves the soil fertility, provides fodder and bee forage (Wekesa and Jönsson, 2014). Because of its properties as a fast growing legume, *A. chinensis* is used for the reforestation of degraded land and for slope stabilization, decreasing the erosion. Unfortunately, the tree produces low quality firewood, and the wood is lightweighted; soft and not very durable, but resistant to termite attack. In Bangladesh *A. chinensis* is grown in Garo agroforestry systems for weed growth suppression (Orwa et al., 2009). *Vi Agroforestry* also recommends *A. chinensis* for its degradable leaves which adds nutrients to the soil, but also because it is not a competitive tree since its root system develops at deeper level than the coffees' (Komakech, 2016).

1.6 Aims of the study

This study had two aims. The first aim was to compare the knowledge about the BCTB in Uganda between three different target groups: researchers, agricultural- and production officers and farmers. The objective was to get a picture of the situation today and how the BCTB is managed. The second aim was to determine whether the leguminous tree, *A. chinensis*, has an impact on the infestation rate of the BCTB on robusta coffee.

1.7 Research question

- How does the picture of BCTB considering the infestation level and management methods differentiate between the different target groups, and does the degree of infestation vary with the amount of *Albizia chinensis* growing near the coffee plant?

2 Material and method

The project consists of an interview part and a field study part. All work in the field was performed in collaboration with two study mates and a translator from *Vi agroforestry*. The fellow students Christina Hultman and Julia Dahlqvist have their own specific objective and will handle the relationship between the BCTB and shade, and BCTB and the tree *Ficus natalensis,* respectively.

2.1 Interview method

The interviews aimed to find out more about the severity of the problem with BCTB today for the Ugandian coffee farmers. The researchers and officers were asked to estimate the infestation degree at national respectively district level, we had questions considering the management methods recommended and also regarding the agroforestry methods of intercropping shade trees with the coffee. The farmers were interviewed in order to get a picture at local level of the coffee production strategies for the management and intercropping methods, and their experience of BCTB.

The interview part of the study comprised in total 20 farmers, ten from each district. In Kalungu district two agricultural officers were interviewed, and in Bukomansimbi our questions were answered by one agricultural and one production officer. The group I call "officers" in the analysis was also represented by the Development director at *Uganda Coffee Development Authority* (UCDA), and the Production and Marketing Assistant and Entreprenuership Services Manager (shared interview) from *National Union of Coffee Agribusinesses and Farm Enterprises* (NUCAFE). The researchers included a research officer and entomologist from *The National Coffee Research Institute* (NaCORI), an Associate Professor at *Makerere University* and a consultant at *National Forestry Resources Research Institute* (NaFoRRI).

The farmers to be interviewed were chosen by the cooperatives' chairman in dialogue with the facilitator at *Vi Agroforestry*. The expressed wish was to interview farmers that were affected by BCTB and had knowledge about its symptoms, which both the facilitator and cooperative managers had in mind when choosing our interviewees. All interviews began with a presentation by us in order to clarify the aim of the study, diminish cultural misunderstandings and emphasize the importance of objective answers. The interviews were conducted in English and Luganda (the major language in Uganda) with the help of a translator. No translation was needed for the interviews with the agricultural and production officers, organizations and university since the language spoken by them was English. The answers to all questions were noted and summarized in appendices 1 (farmers), 2 (officers) and 3 (researchers), and then sorted into groups depending on the answers. The questions were divided in general and specific related questions regarding our own specialized objective with the study. As my study focused on the impact of the shade tree *Albizia chinensis* on coffee, these questions (table 1) from each questionnaire was in particular analyzed.

Table 1. Relevant questions for the study of shade trees impact on BCTB, derived from each questionnaire.

Questionnarie	Question number
Appendix 1: Farmer	9, 10, 20, 21 and 25
Appendix 2: Officer	10, 12, 13, 14, 15 and 16
Appendix 3: Researcher	13, 14, (15, 16, 17) and 18

2.2 Field study method

The effects of shade trees on the number of entry/exit holes by BCTB was studied in a field survey. In total 20 coffee plots were surveyed in Kalungu and Bukomansimbi district 30-40 km from Masaka city in Central Uganda (Figure 3). The visits in the field were performed during four weeks in the dry season of January-March.

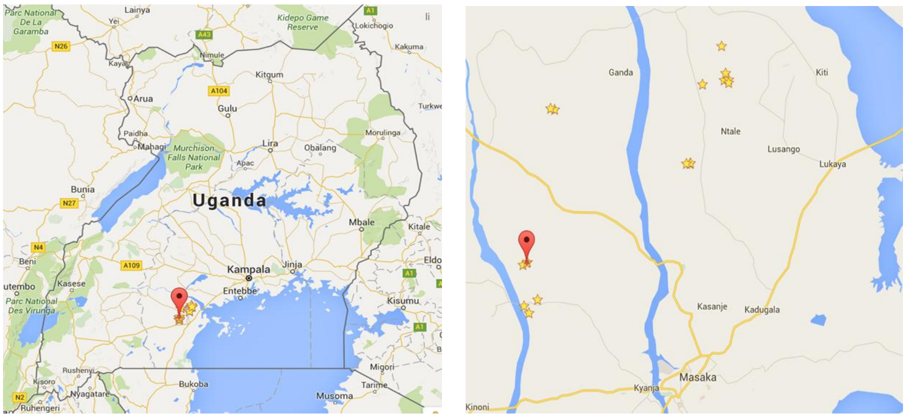

Figure 4. Maps of the farms' location in Uganda.

On each farm, one of the coffee plot closest to the homestead was chosen. In every coffee plot, 30 coffee plants were examined, meaning 10 coffee plants per person. Thus, the whole study comprised 600 coffee plants. The coordinates for the location of the coffee plot was registred with a GPS. Three parallel lines were selected; two of them ran along two borders, with a distance of 5 meters to the border. The mid-way line went between the two other lines. The starting points were located 5 meters from the border (figure 4). Depending on the size of the coffee plot, every or every second coffee plant was examined for number of entrance/exit holes. The too old, mainly distinguished by a height of more than 2 meter were excluded in the study of practical measures.

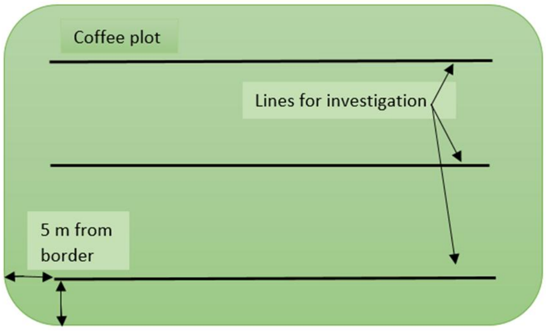

Figure 5. Location of the transects chosen to investigate damage of BCTB on coffee plants.

The sampling protocol presented in appendix 4 was executed for the field study. On every coffee plant, four twigs were examined, one twig in every cardinal direction on the middle third part of the coffee plants height. The height was chosen because this would include the majority of the coffee plants, and also because BCTB has the tendency to fly about 1.5m above ground. The number of entrance/exit holes by BCTB was counted on each twig. A survey of the surroundings of each coffee plant was thereafter conducted. The shade level was estimated by the canopy cover of other trees and crops, in five categories: 0-20%, 21-40%, 41-60%, 61-80% and 81-100% canopy coverage. The estimation was done in a radius of one meter around the coffee crown. Lastly, the different trees and bananas within a radius of 5 meters of the coffee plant were counted.

2.3 Statistical analyze method

To analyze the number of holes per twig in relation to the number of *A. chinensis* within 5 m radius, we performed linear mixed effects models, using the lme function in the nlme package in R 2.14.0 (R Development Core Team 2011). We used such a GLM-approach instead of an Anova since the number of observations within each level of the fixed factor was strongly unbalanced. Prior to analysis the data were log10 (x+1)-transformed to ensure that residuals of the model were approximately normally distributed. Due to a generally low number of trees present within 5 m radius we could not analyse our data with number of trees expressed as a continuous variable. Thus, the fixed model included the number of *A. chinensis* summarized into a categorical variable with three levels (zero trees, one tree and more than one tree within 5 m radius). The random model included plot to account for non-independence of trees sampled within each plot.

3 Results

These results are extracted from the interviews with the 20 farmers to give a general overview of the coffee plots' appearance and the coffee production management methods (appendix 1). The six officers' and three researchers' perception on BCTB and the recommended management methods are thereafter presented (appendix 2 and 3).

3.1 Appearance of the coffee plots

The surveyed coffee plots around the homestead ranged from 0.02-2.02 ha. The density of the coffee plants varied between 47 and to 673 coffee plants/hectare. Intercropping was popular, only one farmer had coffee as the only crop at the coffee farm. The others intercropped their coffee, and the majority had chosen banana, beans and cassava but also other crops (diagramme 1).

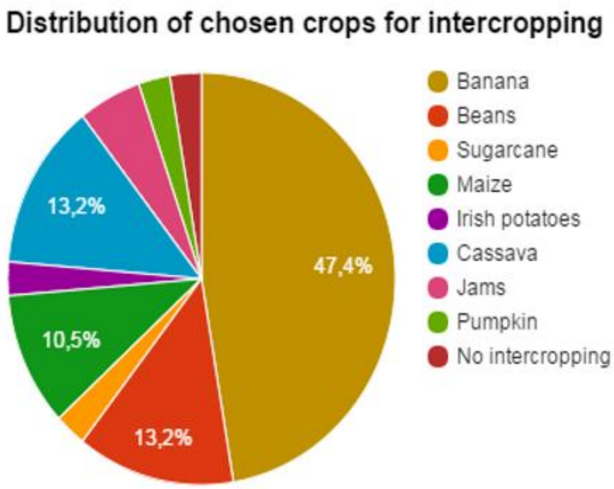

Diagramme 1. Intercropped crops at the coffee plots.

Banana was the most frequent crop that was intercropped with the coffee plants. A key advantage with banana, according to both farmers and officers, is that it provides good shade and plenty of water, without competing for nutrition with the coffee plant. A banana plant was recommended to be planted in the middle of four coffee plants especially in the establishing phase of the coffee plants (the coffee plants are boosted by the banana plants because of the provision of shade and water). With the coming succession of the plot, the coffee would slowly outgrow the banana plants, if the new banana shoots were carefully and regularly distributed in the plot. As a result of the plentifulness of banana plants, the most common spacing between coffee and other crops was roughly 1.5 meters.

3.2 Black coffee twig borer - an abstract from the interviews

BCTB attacks more than 48 plant species in Uganda. The first report of the infestation of the BCTB was from the Western district of Uganda, called Bundibugyo in 1993 (appendix 3). It is however, a relatively new phenomenon in the two districts surveyed. According to most farmers it emerged only 2-5 years ago, only one farmer had more than 5 years of experience with BCTB. Of all current pest damage on coffee it was estimated to be responsible for 60% by the researchers, while the officers reckoned it to have an even bigger impact of 80%. They reported the damage BCTB as wilting and drying of both branches and leaves of the coffee plants. Four farmers also mentioned the drying of the whole coffee plant to be a symptom of the BCTB. The farmers' overall experience is that the problem has increased over the last years, since the damage by the BCTB (%) is increasing and is observed more frequently (Diagramme 2).

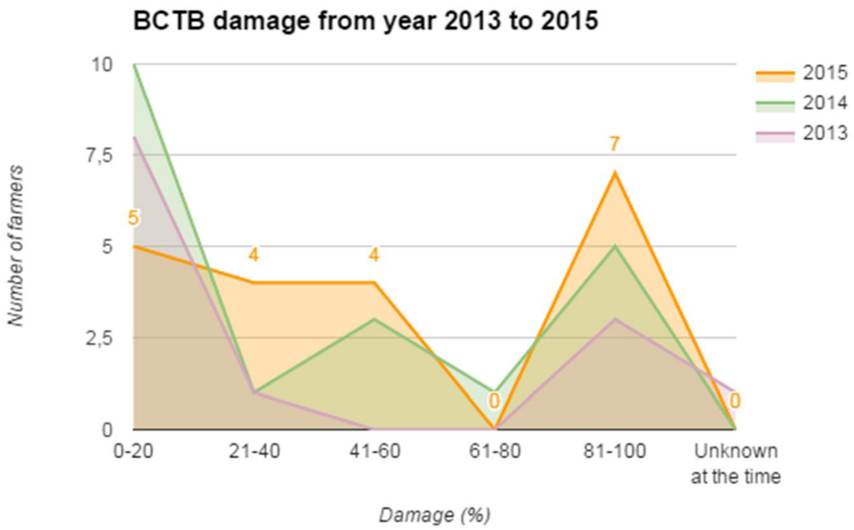

Diagramme 2. The farmers' experience of increased infestation based on the BCTB damage (estimated in percentage) over the last three years.

At district level the officers estimated 50-100% of the coffee plots to be affected by BCTB. They had different opinions about how the infestation rate had changed over the last few years. Two officers said that 100 % of all coffee plants were infected in every coffee plot in their district, and this had been the case during the last three years. Only one officer confirmed the farmers' assumption of an increased BCTB infestation, while two officers indicated a trend towards a lower infestation rate. The decreased infestation rate was explained by the persistent use of chemicals that had suppressed the BCTB. One officer made a comment that there is a lack of statistics concerning the

BCTB, but he thought that BCTB had first been suppressed during the last half year but now is on its way back.

The interviewees said that BCTB is a major problem for the national coffee robusta production, as the researchers estimated the national yield loss to be approximately 50% in organic coffee and 9% in conventional grown coffee in Uganda. The officers' estimation of the average yield loss in their district ranged from 5% to 50%. The actual yield loss reported by the farmers was between 20% and 75% (diagramme 3). One farmer couldn't approximate the loss due to only the BCTB, saying that several other aspects had to be taken into account.

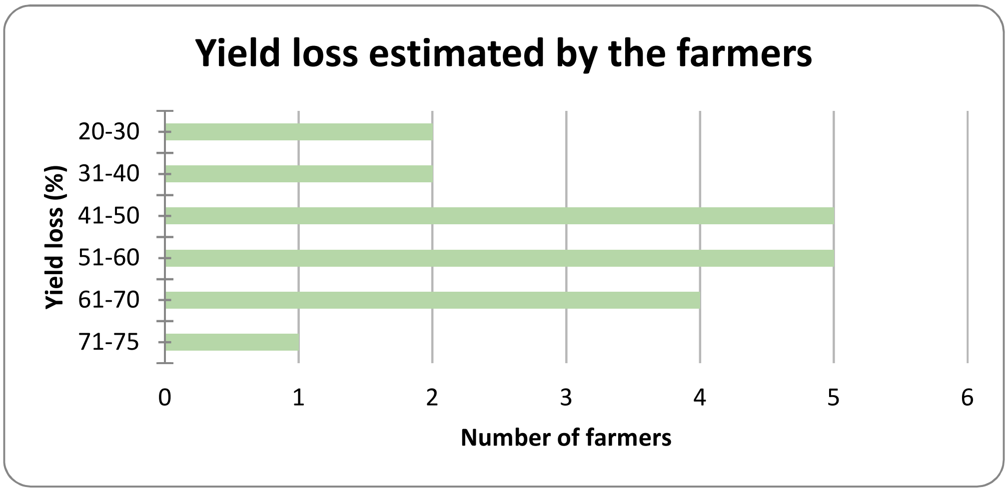

Diagramme 3. The yield loss in percentage due to BCTB estimated by the farmers.

Thirteen out of 20 farmers had identified a special area in their coffee plot where the coffee was more severely affected by BCTB. The stated reasons, could be more than one per person, were: too much shade (7 farmers), young coffee (2 farmers), management-dependent (1 farmer), the location where BCTB had first colonized (1 farmer) and don't know (4 farmers).

3.3 Pest management methods used and recommended

The researchers and officers recommended mostly sanitation (cut off and burn affected branches) but said that a combination with systemic chemicals is necessary to control BCTB. Only about 35% of the farmers used insecticides, but almost all (80%) did cut down and burn the affected branches (diagramme 4).

Both officers and researchers recommended several tree species to be intercropped with coffee. The recommendations of shade trees varied with region in the country. One researcher urged the farmers to avoid any alternative host to the BCTB by suggesting the sole intercrop to be bananas. This matter was also discussed with one of the researchers who said that the BCTB might be able to fly at least a distance of 200m, and obstruct the attempts of isolating the BCTB by not growing any potential hosts nearby. Three of 9 officers and researchers recommended the farmers to prune the shade trees but none recommended to cut them down. Nearly all the farmers (17/20) pruned and had cut down some of their shade trees: *Ficus natalensis*, *Maesopsis eminii* and jackfruit. The reasons behind the cutting of trees were according to four farmers to reduce the shade, two farmers named "*other*" reasons (firewood, timber etc.) and the remaining 11 farmers didn't give a reason for cutting them down.

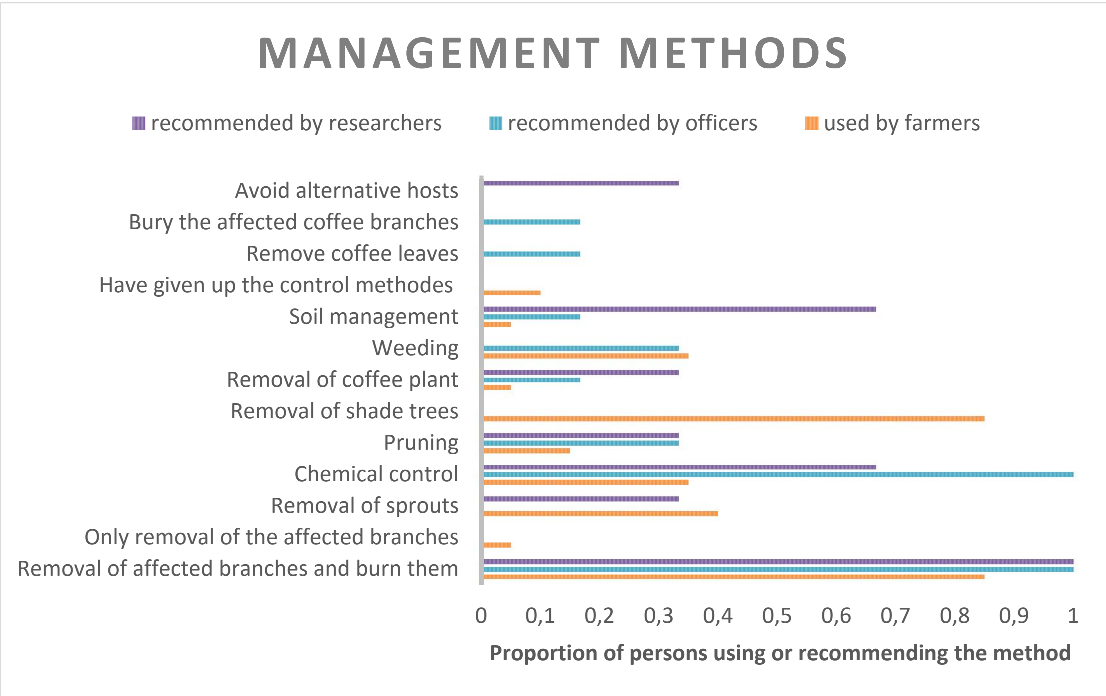

Diagramme 4. The management methods used by the farmers and the recommended from the researchers and officers in order to control the BCTB.

The reported potential BCTB hosts are seen in diagramme 5. Seven of the interviewees hadn't observed any specific host shade tree, whereas the trees *F. natalensis* and avocado were believed to increase the BCTB infestations by six persons each. An additional five farmers believed that any shade tree that cause too much shade is an alternative host to BCTB.

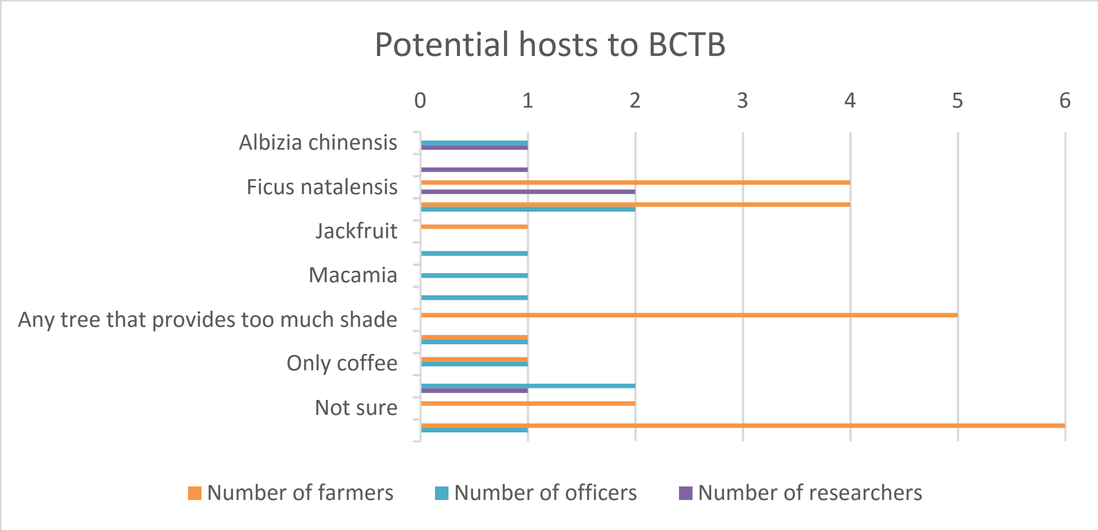

Diagramme 5. The reported potential hosts to BCTB by the different interviewed groups.

The majority of the farmers (15) thought that the appropriate distance (in a longterm coffee production) between shade trees and coffee was 1.5m, whilst the majority of the officers suggested the doubled spacing of 3m. The only researcher giving an opinion about this recommended 1.8m. Between shade trees a spacing of 6-46m were used by the farmers, the majority of the officers advised it to be 12m (ranging between 3-12m). The spacing recommendations by the officers varied a lot depending on tree specie and one researcher believed that having trees in a triangular pattern would provide optimum shade for the coffee plants.

One officer mentioned that the spacing used between coffee plants was important since BCTB thrives when there is a lot of leaves. The researchers' suggestion was to not have more than 3-4 stems on every coffee plant, because the bushier the coffee plant becomes the more coffee twig borer it attracts. This recommendation was followed by 40% of the farmers, who removed the sprouts regularly. When the coffee plant gets severely affected (over 70%), one researcher and one officer recommended to remove the whole coffee plant, because of the difficulty in knowing how far the BCTB has entered. This recommendation was followed by only one farmer. Half of the officers also recommended weeding as a control method, a measure adopted by 35% of the farmers. Soil management and the usage of fertilizers was also endorsed by both researchers and officers, but was only done by one farmer. Two farmers confessed to have given up the control methods since "*the coffee plant dies anyway*".

The natural enemies that have been observed by 4 farmers, one officer and two researchers include an ant (Hymentoptera: Formicidae). One researcher also mentioned the parasitoid *Phymasticus coffae* (Hawaii), the fungus *Beauveria bassiana* and the fungal pathogen *Metarhizium anisopliae* to be natural enemies. The plants mentioned to repel BCTB included: *Azadirachta indica, Nicotiana tabacum, Cannabis sativa, Papaver somniferum, Piper nigrum, Tagetes minuta, Ficus natalensis* and *Allium sativum.*

3.4 Shade and BCTB

The coffee plots differed in degree of shading. The shade was said to improve the quality of beans and aroma by one researcher and one officer. The opinion about shading degree varied: the researchers suggested maximum 40% shade, whilst the officers approved 30-65% shade. On the other hand, the researchers meant that this also depends a lot on the season and therefore no fixed shading degree can be recommended.

The different groups had different views of whether there is a relationship between the infestation degree of BCTB and shade level. Across all groups 17 thought that shade increased the infestation rates of BCTB, whereas 5 thought that sun-exposed coffee plants were more frequently attacked (diagramme 6).

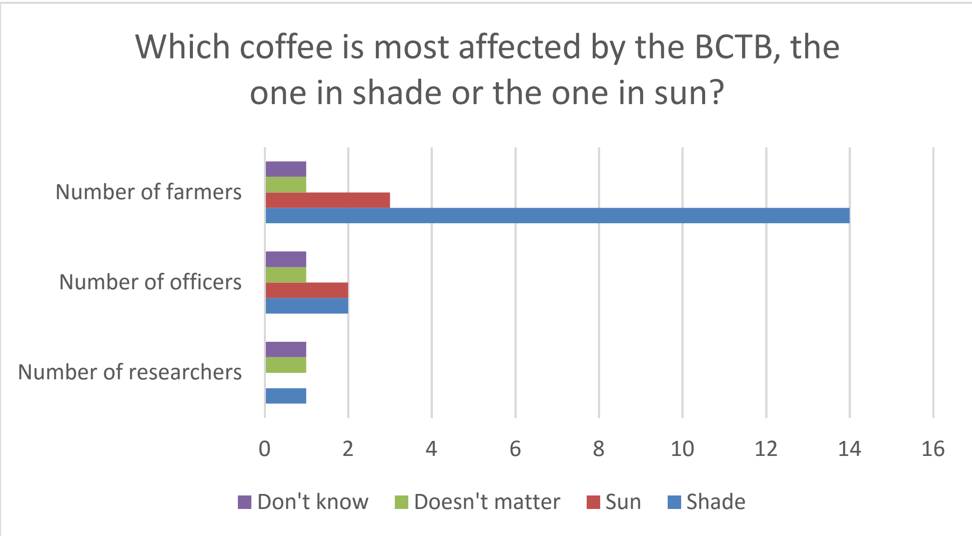

Diagramme 6. The votes on which coffee: shaded or sunexposed, that gets more affected by BCTB.

The majority of the farmers (14 farmers), believed that shading the coffee caused more trouble with the BCTB, whereas only 3 believed that it was the sun-exposed coffee that had higher BCTB populations. The opinion among the officers were more variable: two thought that infestation was higher in shade, whereas two thought that it gets worse in the sun-exposed coffee. Of the remaining officers, one were of the opinion that it does not matter, that both are equally infested, and the last one said that he didn't know. One more researcher added to the "*don't know*"-comment, while an another researcher proclaimed the shade to be of crucial importance to the hit rate of BCTB. The last researcher's comment to this was that too much shade, as well as drought, can cause stress and weaken the coffee plant and thereby increase the infestation level of BCTB.

3.5 The impact of *Albizia chinensis*

One officer and one researcher mentioned *A. chinensis* as a potential host for BCTB, whereas none of the farmers mentioned it as a host or had chosen to cut it down. The officer from UCDA mentioned *A. chinensis* to potentially be BCTB's number one alternative host why it should only be recommended for certain areas with low risk of BCTB infestation. The researcher from NaCORI however, thought *A. chinensis* to be a minor host.

Five farmers had *A. chinensis* intercropped with their coffee plants. The distribution varied and ranged from less than 2,5 up to 0.2 trees per hectare. It was planted to contribute good shade, increase soil fertility and provide the households with firewood and fodder according to the farmers. The analysis made by the researchers is that *A. chinensis* provides good shade since it has small leaves and branches out a lot which allows sunlight to go through.

The data gathered on how many *A. chinensis* that surrounded the total number of 600 coffee plants from the surveyed 20 coffee plots were sorted into three different categories: zero, one and more than one. We found 517 coffee plants surrounded with no (e.g. zero) *A. chinensis,* 66 coffee plants with one *A. chinensis* and 17 coffee plants with more than one *A. chinensis* within a radius of 5 m from each coffee plant. The average number of *A. chinensis* that surrounded the 600 coffee plants was 0.0017. Results from a linear mixed effects model (lme) analysis showed no significant result ($p>0.05$) on the relationship between *Albizia chinensis* and the infestation rate of BCTB thus saying that, from the data gathered from the 20 farmers conducted in this survey, the *A. chinensis* is neither increasing *nor* decreasing the infestation rate of BCTB (diagramme 7).

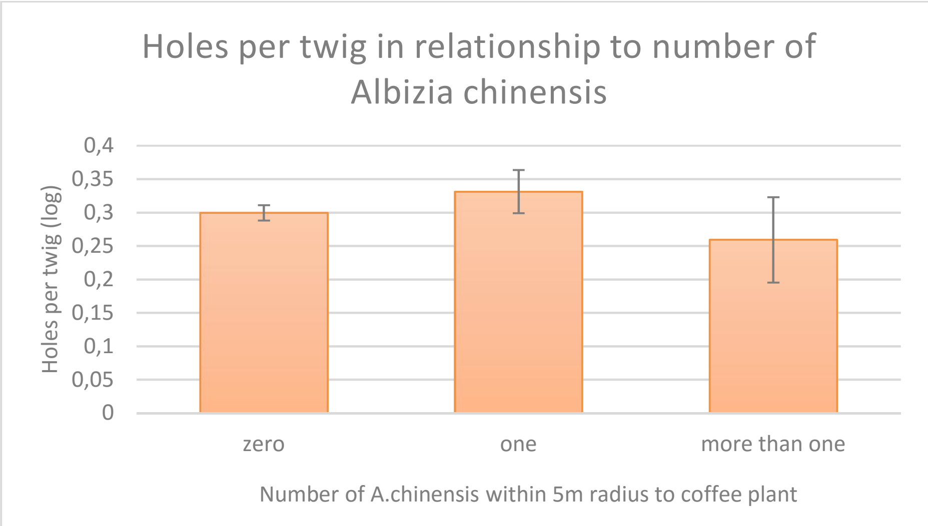

Diagramme 7. The infestation rate of the BCTB in relation to number of Albizia chinensis within 5m radius. Values presented are mean +- SE of mean.

3.6 Distribution of information and source of information

The majority of the farmers got their information from the agricultural extensional officers, but also from the subcounty-, cooperative-, local government offices and organisations (UCDA). The agricultural officers in their turn got mainly information from research institutions, UCDA, radiostation with central broadcasting services involving experts, the Ministry of Agriculture, internet and farmers. The only production officer mentioned UCDA and farmers as his source of information. The officers' from NUCAFE reported their source to be UCDA, NaCORI, their own research and the partnerships with the agribusiness, Vi-Agroforestry and other coffee producing countries. UCDA got their information from coffee research presented on international coffee conferences (member of ICO and IACO) and farmers. None of the researchers had themselves been involved in specific BCTB research, instead the researcher from Makerere University got information from student publications and NaCORI. NaCORI as an institution have done research and collaborates with the Universities of Hawaii, California and India. Also the consultant from NaFFORI mentioned that he had been part of three BCTB consultations with farmers, farmer groups and cooperatives. The NaFFORI disseminated their knowedge to local government and agricultural extension officers, whereas the researcher from Makerere University demonstrated directly to farmers, and NaCORI spread their knowledge on all levels: globally (conferences), through extension work and sometimes directly to farmers.

4. Discussion

Albizia chinensis is commonly known to be an alternative host to BCTB in the literature, why it is recommended to reduce the number of *A. chinensis* in coffee production systems. However, of our interviewees only the researcher from NaCORI and the officer from UCDA stated *A. chinensis* to be an alternative host to BCTB. The researcher from NaCORI, however, seemed to recommend *A. chinensis* to be intercropped with coffee only in certain areas (with low BCTB infestation) since it it a minor host to BCTB. The officer from UCDA didn't recommend *A. chinensis* to be intercropped with coffee at all as it potentially can be BCTB's number one alternative host. Further investigation is needed to confirm on to what extent *A. chinensis* is a host to BCTB and if it should be recommended to the farmers if the BCTB infestation increases. Of our interviewees there was only one more officer, besides the researcher from NaCORI, who recommended *A. chinensis* for its good qualities. However, none of the five farmers seemed to recognise the increased risk of BCTB by having *A. chinensis* in their coffee plots, but this could also be a matter due to the low numbers of farmers who had *A. chinensis.* Furthermore, the farmers who had *A. chinensis* grew them in low abundances. If the density of *A. chinensis* had been larger its impact as an alternative host might have been observed by the farmers and in our field study, which points at no significant effect of *A. chinensis* on the infestation degree of BCTB.

Based on a study carried out by Anuar (1986), the shaded coffee plants get higher BCTB infestation levels because of the favorable conditions generated by the micro-climate beneath shade tree. In our field study a similar relationship between shade and BCTB was found. The infestation rate of BCTB was significantly lower when shade was 0-20% compared to 41-60% (Hultman, 2016). However, the opinions regarding whether it is the shaded or sun-exposed coffee plants that get more attacked by BCTB varied between the interviewed groups. The majority (14) of the farmers believed the shaded coffee to be more exposed to BCTB, which was affirmed by two officers and one researchers. Also, seven farmers recognized more infestation by BCTB in areas of their coffee plots with too much shade.

Kagezi et al. (2013) conducted a study in Mukono district and found an increased infestation level of BCTB on coffee under full shade, by investigating the the tree-specific shading properties of eight shade trees. The shading properties was investigated on *A. chinensis* and seven other shade trees. *A. chinensis* was concluded to have the lowest shading percentage, why no significant infestation degree of BCTB was found for this particular tree. The same study showed instead higher infestation degree of BCTB if grown at the edge of *A. coriaria*, jackfruit and mango, and even *F. natalensis* showed higher significance than *A. chinensis.* Dahlqvist (2016) also found more significance for *F. natalensis* than I did for *A. chinensis*, with data gathered from the same coffee plots. Therefore it is important to have in mind the shading properties by the different tree species when choosing an appropiate shade tree for the cultivation of coffee (Kagezi et al., 2013). Based on our interviews no exact shading degree exist where problems increase, because for the researchers and officers the aspects of the constitution of the crown and the density of leaves seems to matter. This suggest specific spacing of shade tree species based on the unique shading degree the tree species provide. This in particular for the shade trees that have been reported to be an alternative host to BCTB (Kagezi et al., 2013).

The trade-off between increasing risks of BCTB infestation under shade and the benefits of shade for coffee production has been investigated. For example, better quality coffee beans of arabica coffee was achieved when grown under shade of the forage legume tree *Erythrina peoppigiana* (Muschler, 2001). The same statement was used for robusta coffee by one researcher and one officer. The use of shade trees is very desirable especially in the establishing phase of the coffee, and to accomplish the right amount of shade pruning have to be practiced (Anuar, 1986). The researchers and officers all recommended general pruning of shade trees, but not to cut them down. However seventen out of 20 farmers had cut down shade trees. The reasons for cutting down the trees were unstated by 11 farmers, however, four farmers explained it to be because they wanted to reduce the amount of shade. By pruning the shade trees the heavy shade can be reduced and limit the infestation of BCTB (Anuar, 1986). This technique could help prevent further trees from being cut down, which four of the surveyed farmers did in their attempt to confine the attacks by BCTB. Also the coffee plants seemed to need pruning (about 40% of the farmers reported to remove the sprouts of the coffee plants) as many of the coffee plots investigated included tall and large coffee plants with overlapping crowns, which resulted in more shade. If the coffee plants were to be trimmed and pruned regularly, it would decrease the shading degree so that it might not be necessary to remove the whole coffee plant as one officer and one researcher suggested for coffee plants with more than 70% damage of BCTB. Kagezi et al. (2013) found higher BCTB infestation in the lower parts of the coffee plant, why they recommended the pruning of mature and unproductive twigs to take part in the lower section of the coffee plant.

Having selected an appropriate shade tree that is not a host and has good shading properties the BCTB infestations can be limited by having the shade trees pruned regularly. As intercropping is important to the farmers and the shade plays a crucial role for the development of BCTB, a spacing system between coffee plant and crop or shade tree should be convenient to the farmers. The opinions regarding the appropriate spacing between coffee plant and shade tree ranged between 1.5m (the majority of the farmers) and the recommended spacing of 3m (the majority of the officers), and the only researcher giving an opinion about this recommended it to be 1.8m. The spacing between shade trees ranged from 6-46m for the farmers, and 3-12m for the officers. The spacing recommendations by the officers varied a lot depending on tree specie and the only researcher giving an opinion, believed that a triangular pattern of shade trees would provide optimum shade for the coffee plants. The spacing applied ought to be based on the identity of the shade tree or crop (Kagezi et al., 2014b), so that it would grow as well as the banana plants was said to do with coffee, providing the shade needed without competing for nutrients and water.

BCTB is quite a new phenomena in the two districts surveyed, and the severity was disputable among the researchers and officers, while the majority of farmers experience more severe damage caused by the beetle than before. The farmers surveyed estimated their coffee yield losses to range between 20-75% due to the pest, whereas the estimation was lower by the officers (5-50%). The researcher's view of it was that in organically grown coffee the yield loss caused by BCTB to be about 50%, but only 9% in conventional. However, there are several factors that make it difficult to exactly estimate the yield losses due to BCTB. First of all can the symptoms easily be mistaken for BCTB, when it might have been for example coffee wilt disease since both have similar symptoms of dried leaves and dead branches. Coffee wilt disease is however characterized by the dieback of the whole or partially diseased plant with rotting tissue beneath the bark of the coffee plant (Flood, 2010). Four farmers mentioned the "drying of the whole coffee plant" as a symptom of BCTB and might have been mistaken it for coffee wilt disease. This because BCTB only dries the coffee plant partially. Other factors include the lack of water and therefore nutrient shortage for the coffee plants as most part of the nutrition is water-soluble. However, only one farmer raised the issue with the difficulties with estimating the yield loss merely because of the BCTB.

The available management methods are primarily based on sanitation methods (cutting off affected coffee branches and burning them). Systemic insecticides were highly recommended to be combined with the sanitations methods by all researchers and production- and agricultural officers interviewed. One researcher estimated the yield loss of 50% in organic coffee production systems could be lowered to 9% if switched over to produce coffee conventionally with insecticides. However 65% of the farmers (35%

were using chemical insecticides) either lacked knowledge or financial resources in order to continously combat the BCTB with insecticides (Egonyu et al., 2009). Therefore it is of major interest to find other solutions to handle the situation with the BCTB. Furthermore, the risk for developing pesticide resistance has to be addressed before it becomes too prevalent. The use of pesticides has to include substances with different modes of action and must be used only when absolutely necessary in order to reduce the risk of resistance development (Svenskt växtskydd, Jordbruksverket, 2016). Also for this reason there is an urgent need to develop an integrated pest management strategy on how to control the BCTB effectively (Egonyu et al., 2009).

There are many factors that have to be included in order to find a good design for coffee production systems that suppresses BCTB. As BCTB acts as a generalist (having a wide host range with more than 225 host plants worldwide and 48 in Uganda) it makes it more difficult to design an agroforestry system that would involve a combination of plants that mutually would reduce the pest and disease risk by: (1) reducing the population build-up and dispersal of it, (2) host their natural enemies or (3) create unfavorable environmental conditions for the pest, since this is easier achieved with specialist herbivores and diseases (Schroth et al., 2000). Some potential hosts or repelling plants and natural enemies were mentioned by the interviewees that could be interesting to be further investigated. For example the formicid ant *Plagiolepis sp.* has been confirmed by Egonyu et al., (2015) to be an indigenous predator of BCTB. This relationship was mentioned a several times during the interviews by four farmers, one officer and two researchers. To design an agroforestry coffee producing system that would reduce the pest and disease risk would have to take advantage of both the traditional and scientific knowledge based upon the relationship between plants and their environment, and not merely trust the benefits of increased diversity and its impacts (Schroth et al., 2000). Therefore there is a need for further investigation involving the site conditions, component selection, belowground and aboveground characteristics of the trees and crops, and also the management methods (Nyaga et al., 2015).

On a global scale it is important to maintain trees in order to sequester carbon and mitigate climate challenges. Moreover the use of shade trees in coffee production systems is an economically feasible way for farmers to protect their crops from extremes in micro-climates and to maintain soil moisture (Lin, 2007). From the farmers perspective it is important to have a diverse agriculture, using the agroforestry methods to secure the families' livelihood by intercropping.

4.1 Limitations of the study and possible improvements

We selected farms which had high levels of infestation of BCTB. A study done by (Kagezi et al., 2013) showed that about 72% of the farmers within 26 districts surveyed knew BCTB. With our objective the coffee plots with no infestation were ignored why this set of data isn't necessarily representative for the coffee farmers in the two districts. To achieve that we would have needed to pick farms at random.

4.1.1 Field method

It takes some time for every untrained eye to learn what to look for. In the beginning the uncertainity about the entrance holes and how to estimate the shade degree were significant, but we had a few trials before we set off to do our field study including the interviews. As a result of the errors each person was responsible of, the mean error that we made shouldn't have caused too much of a problem since we investigated the same amount of coffee plants. Since we only surveyed the coffee plots during 6 weeks the variation due to the seasons can not be taken into account (Ngoan et al., 1976), why our study only gives an indication of the infestation degree of the dry season this year. Because of the chosen segment to be investigated on each coffee plant (the middle third part), the remaining parts were excluded from the survey. However, as the researcher from NaCORI pointed out the BCTB is flying around 1-1.5 m above ground (Kagezi et al., 2013) which seemed to represent the middle third part of the coffee plant very well. The coffee plants differed a lot in terms of length, age and number of stems and this hindered us from taking every/every second coffee plant in the row, as we skipped the too outstretched coffee plants. It might also have been of importance to have excluded the small plants lower than 1m, since this data wasn't analyzed differently from the rest. This because of the reason to select coffee plants with a more similar physical dimensions in terms of age and height. Also the transects had to been adjusted because of the not always rectangular pattern of the coffee plots. Our aim was therefore not fulfilled to 100% due to the circumstances at the field as we had to take the different appareance of each coffee plot into consideration and thereafter choose the investigation lines of coffee plants.

4.1.2 Interview method

If we would redo our interview study we would have made our questionnaire more specialized. For example we could have asked whether the different management methods had helped or not. The only effect we noted was the resignation from a few farmers who had stopped their attempts to control the BCTB. We would also have included a question considering BCTB infestation on the areas surrounding their coffee plot. As the female

BCTB can fly at least 200m in distance it limits the chances of isolating the coffee plants from alternative host plants, as the majority of the coffee plots' shapes are irregular, sometimes small and outstretched, so that the BCTB status of the neighbors closeby might have had an impact. Another relevant question that we should have paid more attention to is the explanations to why the eleven farmers had cut down their shade trees. The questionnaires for the officers and researchers could also have been more similar, for example with the inclusion of the question on changes in infestation levels of BCTB in appendix 3, to make a comparison of their answers.

Since BCTB only has a descriptive name in Luganda (major language in Uganda) this could refer to several other pests or diseases. For instance, four farmers reported drying of the whole coffee plant, a symptom that might be more related to the coffee wilt disease than to BCTB. Also during the interviews we sometimes mistakenly asked leading questions when explaining an unclear question. What more happened is that since we needed a guide to find the farms, the actual extension worker joined us and sometimes helped with the interpretation. Their presence might have influenced the answers from the farmers. The farmers might have wanted to be as helpful as possible and delivered answers of what they thought was true, even if they were unsure. We fear that this happened to at least one of the interviewed farmer, why we are a bit doubtful about some of the reported data but we still chose to include it in the dataset.

The six officers compromised three agricultural officers, two in Kalungu and the third in Bukomansimbi. The fourth officer was a production officer in Bukomansimbi district and he was a veterinarian. In general only the agricultural officers daily interact with the farmers and are thus well-informed about coffee production. The production officer was more involved in veterinary matters, why he might not be directly involved in the issues of BCTB, but he answered our questions and had similar sources of information as the agricultural officers. The other officers included one Development director from UCDA, one Production and marketing assistant and one Entreprenuership Services Manager from NUCAFE based in the capital, Kampala. Because of their different background and their different sources of information it brings us different aspects to the BCTB.

4.2 Future work and challenges

The researchers face a lot of work since BCTB is quite a new phenomenon. The pressure on them is big from the government and in their own opinion their resources are very limited. They receive some finances from EU, but they are also limited from buying chemicals which they would like to tryout because of the restrictions set by World bank. The extension arm is perceived to be too weak and hinder the transfer of information to the farmers. At the same time the farmers face a hard economic situation with scarce resources available, and this also may contribute to the difficultness of changing the farmers' attitude. However, both officers and researchers had a general positive attitude towards the farmers, because of the farmer's work of removing the affected branches and burning them. The officers mentioned, though, that the collaboration between farmers is missing, and the sanitation methods highly depend on the neighbors' management. In general, more research is needed in this area and results should be made available in local languages. The survey conducted contains two questions that could be of importance to the future work for developing the control methods of BCTB. One of them regarded the active time (dry/rainy) of BCTB to know when to start looking for symptoms and limit the pest to spread by removing the branches as soon as possible. The other question regarded the possibility of a vulnerable period in the lifecycle of BCTB. On both questions our interviewees gave different answers which indicate the lack of knowledge or the potential that the questions hold many different answers.

For a follow up of this study, my recommendation is to continue the work on other farms in the same districts to gather more data for statistical analysis. Especially to include more data in the higher categories of more than one shade tree per coffee plant and the higher degrees of shading. The gathering of more data would play an important role to further investigate relationship between shade degree and the BCTB, and other shade trees species could be involved in order to set up a design that could be recommended for the farmers' usage. The shade trees need to be investigated to make clear which ones that hosts BCTB and to what extent these could be recommended to be intercropped with coffee. An alternative to our study would be to compare farms that grow coffee under shade with farms that grow sun-exposed coffee.

5. Conclusions

The situation today regarding the BCTB in Bukomansimbi and Kalungu is severe, as the farmers surveyed lose between 20-75% of their coffee yield. Our survey indicates the uncertainty and the different opinions addressing the issue of BCTB, as the officers in the same districts (as these farmers have their coffee plots) estimated lower yield loss percentage of 5-50%. Furthermore the change in infestation has been observed differently with the farmers experiencing an increasing infestation degree, whilst two of the officers meant that BCTB on the contrary is decreasing. *A. chinensis* is not believed to be a potential host of BCTB by the majority of the interviewed, since only one researcher and one officer mentioned this relationship (to different degrees). However, in the study conducted and the training material produced by Kagezi et al., (2014a, 2014b), *A. chinensis* is clarified to be a host to BCTB. However, a study based on the shading properties of different shade trees concluded no significant relationship with the BCTB and *A. chinensis* (Kagezi et al., 2013). The study instead showed that the shade degree matters to the infestation degree of BCTB. Our field work agrees with this latter study - in our survey no relationship between BCTB infestation and density of *A. chinensis* was found. This could however, have been a matter to the limited dataset for the higher categories of more than one *A. chinensis* within 5m radius to the coffee plant, why further investigation on whether *A. chinensis* should be recommended as a shade tree or not in coffee production systems is therefore needed.

Therefore a design of an agroforestry system including non host shade trees of BCTB that allow coffee berries to ripen but at the same time, not increases the infestation degree of BCTB would be of great convenience to many coffee farmers in Uganda.

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References

Anuar, A.M., 1986. Observation on damage by Xylosandrus compactus in Coffee as affected by shade and variety. Mardi Re Bull 14, 108–110.

Batra, L.R., 1967. Ambrosia Fungi: A Taxonomic Revision, and Nutritional Studies of Some Species. Mycologia 59, 976–1017. doi:10.2307/3757271

Batra, L.R., 1963. Ecology of Ambrosia Fungi and Their Dissemination by Beetles. Trans. Kans. Acad. Sci. 1903- 66, 213–236. doi:10.2307/3626562

Beer, J., Muschler, R., Kass, D., Somarriba, E., 1998. Shade management in coffee and cacao plantations, in: Nair, P.K.R., Latt, C.R. (Eds.), Directions in Tropical Agroforestry Research, Forestry Sciences. Springer Netherlands, pp. 139–164.

CABI, 2016. Xylosandrus compactus (shot-hole borer) [WWW Document]. URL http://www.cabi.org/isc/datasheet/57234 (accessed 5.14.16).

Chamberlin, W.J., c1939. The bark and timber beetles of North America, north of Mexico;the taxonomy, biology and control of 575 species belonging to 72 genera of the super family Scolytoidea,. Corvallis, Or. :

CIA, 2013. The World Factbook [WWW Document]. World Factb. URL https://www.cia.gov/library/publications/the-world-factbook/geos/ug.html (accessed 2.16.16).

Dahlqvist, J., 2016. What is the view of the Black Coffee Twig Borer (Xylosandrus compactus (Eichhoff)) among farmers, advisers and experts, and is the infestation on robusta coffee trees (Coffea canephora) higher or lower when grown close to a Ficus natalensis? (Bachelor thesis). 2016:6 Swedish University of Agricultural Sciences, Uppsala.

Egonyu, J.P., Baguma, J., Ogari, I., Ahumuza, G., Kyamanywa, S., Kucel, P., Kagezi, G.H., Erbaugh, M., Phiri, N., Ritchie, B.J., Wagoire, W.W., 2015. The formicid ant, Plagiolepis sp., as a predator of the coffee twig borer, Xylosandrus compactus. Biol. Control 91, 42–46. doi:10.1016/j.biocontrol.2015.07.011

Egonyu, J.P., Kucel, P., Kangire, A., Sewaya, F., Nkugwa, C., 2009. Impact of the black twig borer on Robusta coffee in Mukono and Kayunga districts, central Uganda. - CAB Direct. J. Anim. Plant Sci. 3, 163–169.

Flood, J., 2010. Coffee Wilt Disease. CABI.

GISD, 2015. Xylosandrus compactus [WWW Document]. URL http://www.iucngisd.org/gisd/species.php?sc=175 (accessed 6.3.16).

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

Greco, E.B., Wright, M.G., 2012. First report of exploitation of coffee beans by black twig borer (Xylosandrus compactus) and tropical nut borer (Hypothenemus obscurus)(Coleoptera: Curculionidae: Scolytinae) in Hawaii, in: Proc. Hawaii. Entomol. Soc. pp. 71–78.

Hayato, M., 2007. Note on the dieback of Cornus florida caused by Xylosandrus compactus [WWW Document]. URL http://agris.fao.org/agris-search/search.do?recordID=JP2007005345 (accessed 2.22.16).

Hulcr, J., Dunn, R.R., 2011. The sudden emergence of pathogenicity in insect–fungus symbioses threatens naive forest ecosystems. Proc. R. Soc. B 278, 2866–2873. doi:10.1098/rspb.2011.1130

Hultman, C., 2016. Black Coffee Twig Borer, Xylosandrus compactus (Eichhoff) on robusta coffee in Uganda – Impact of shade level on abundance of BCTB and knowledge levels about BCTB (Bachelor thesis). 2016:5 Swedish University of Agricultural Sciences, Uppsala.

Jonsson, M., Raphael, I.A., Ekbom, B., Kyamanywa, S., Karungi, J., 2015. Contrasting effects of shade level and altitude on two important coffee pests. J. Pest Sci. 88, 281–287. doi:10.1007/s10340-014-0615-1

Kagezi, G.H., Kucel, P., Egonyu, J.P., Ahumuza, G., Nakibuule, I., Kobusinge, J., Wagoire, W.W., 2014a. Implications of Black Coffee Twig Borer on cocoa in Uganda. Uganda J. Agric. Sci. 15, 179–189.

Kagezi, G.H., Kucel, P., Egonyu, J.P., Kyamanywa, S., Karungi, J., Pinard, F., Jaramillo, J., van Asten, P., Wagoire, W., Chesang, F., Ngabirano, H., 2014b. Management of the Black Coffee Twig Borer (BCTB), Xylosandruscompactusin Uganda.

Kagezi, G.H., Kucel, P., Kobusingye, J., Nakibuule, L., Wekhaso, R., Ahumuza, G., Musoli, P., Kangire, A., 2013. Influence of shade systems on spatial distribution and infestation of the Black Coffee Twig Borer on coffee in Uganda. Uganda J. Agric. Sci. 14, 1–12. doi:10.4314/ujas.v14i1.

Kagezi, P Kucel, Egonyu, P., L. Nakibuule, J. Kobusinge, G.Ahumuza, R. Matovu, S. Nakendo, H. Luzinda, C.P. Musoli, A.Kangire, B.F. Chesang, 2013. Impact of the black coffee twig borer and farmer's coping mechanisms in Uganda. Afr. Crop Sci. Soc. 285–292.

Karlsson, L., 2015. Landguiden [WWW Document]. Landguiden. URL http://www.landguiden.se/Lander/Afrika/Uganda/Jordbruk-Fiske (accessed 2.16.16).

Komakech, V., 2016. Head of Technical Support Unit/Env't & Climate Change Officer Vi Agroforestry- Uganda.

Lin, B.B., 2007. Agroforestry management as an adaptive strategy against potential microclimate extremes in coffee agriculture. Agric. For. Meteorol. 144, 85–94. doi:10.1016/j.agrformet.2006.12.009

Lin, B.B., Perfecto, I., Vandermeer, J., 2008. Synergies between Agricultural Intensification and Climate Change Could Create Surprising Vulnerabilities for Crops. BioScience 58, 847–854. doi:10.1641/B580911

Muschler, R.G., 2001. Shade improves coffee quality in a sub-optimal coffee-zone of Costa Rica. Agrofor. Syst. 51, 131–139. doi:10.1023/A:1010603320653

Ngoan, N.D., Wilkinson, R.C., Short, D.E., Moses, C.S., Mangold, J.R., 1976. Biology of an Introduced Ambrosia Beetle, Xylosandrus compactus, in Florida, in: Annals of the Entomological Society of America. University of Florida, pp. 872–876.

NSC, 2014. Uganda Training Materials for Coffee Production, 1st ed. National Steering Committee of the National Coffee platform.

Nyaga, J., Barrios, E., Muthuri, C.W., Öborn, I., Matiru, V., Sinclair, F.L., 2015. Evaluating factors influencing heterogeneity in agroforestry adoption and

practices within smallholder farms in Rift Valley, Kenya. Agric. Ecosyst. Environ. 212, 106–118. doi:10.1016/j.agee.2015.06.013
Orwa et al., 2009. Albizia (Albizia chinensis) | Feedipedia [WWW Document]. URL http://www.feedipedia.org/node/336 (accessed 3.17.16).
Pumariño, L., Sileshi, G.W., Gripenberg, S., Kaartinen, R., Barrios, E., Muchane, M.N., Midega, C., Jonsson, M., 2015. Effects of agroforestry on pest, disease and weed control: A meta-analysis. Basic Appl. Ecol. 16, 573–582. doi:10.1016/j.baae.2015.08.006
Ranger, C.M., Reding, M.E., Persad, A.B., Herms, D.A., 2010. Ability of stress-related volatiles to attract and induce attacks by Xylosandrus germanus and other ambrosia beetles. Agric. For. Entomol. 12, 177–185. doi:10.1111/j.1461-9563.2009.00469.x
Schroth, G., Krauss, U., Gasparotto, L., Aguilar, J.A.D., Vohland, K., 2000. Pests and diseases in agroforestry systems of the humid tropics. Agrofor. Syst. 50, 199–241. doi:10.1023/A:1006468103914
Svenskt växtskydd, Jordbruksverket, 2016. Resistens; herbicidresistens, fungicidresistens, insekticidresistens [WWW Document]. Issuu. URL https://issuu.com/jordbruksverket/docs/ovr292v4 (accessed 4.2.16).
UCDA, 2012. Uganda Coffee Development Authority [WWW Document]. UCDA. URL http://ugandacoffee.go.ug/index.php?page&i=15 (accessed 2.12.16).
UCDA, 2008. Robusta coffee production handbook. Kampala, Uganda.
Vandermeer, J., Perfecto, I., Philpott, S., 2010. Ecological Complexity and Pest Control in Organic Coffee Production: Uncovering an Autonomous Ecosystem Service. BioScience 60, 527–537. doi:10.1525/bio.2010.60.7.8
Vi skogen, 2016. Vad vi gör | Vi-skogen [WWW Document]. URL http://www.viskogen.se/vad-vi-gor/ (accessed 4.25.16).
Wekesa, A., Jönsson, M., 2014. Agroforestry, in: Sustainable Agriculture Land Management - A Training Material.
White, R., 2015. - ILDIS LegumeWeb [WWW Document]. URL http://ildis.org/cgi-bin/Araneus.pl?version~10.01 (accessed 3.17.16).