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Influence of shade systems on spatial distribution and infestation of the Black Coffee Twig Borer on coffee in Uganda

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Abstract

Studies were conducted to determine spatial distribution and effects of shade systems on *Xylosandrus compactus* infestation on coffee. Number of twigs varied significantly (p<.0001) within canopy portions with the highest (17.7±6.1) in upper and least (9.1±4.6) in lower portions. Percentage of infested twigs and number of *X. compactus* entry holes varied significantly (P<.0001) within canopy and along twigs respectively. The highest percentage of infested twigs (10.7±15.9%) was in the middle whereas, the lowest (3.2±7.2%) in upper portion. The highest number of entry holes (0.9±0.7) was on basal and the lowest (0.3±0.6) on tip section of twigs. Tunneling by *X. compactus* was neither inclined towards base nor the tips of twigs. Percentage canopy cover varied significantly (P=0.0276) across shade tree species; with highest (60.0±26.5%) on jackfruit tree and the lowest (11.7±7.6%) on Chinese silk tree. Percentage of infested trees and twigs varied but not significantly (P≤0.05) across shade categories and tree species. Coffee under full shade had the highest percentage of infested trees (70.8±27.8%) and twigs (14.8±18.3%); whereas, coffee under full sun registered the lowest (45.8±17.3 and 5.7±9.1% respectively). However, ANCOVA showed that shade and percentage canopy cover of Albizia, jackfruit and mango tree species had a significant (at P≤0.05) positive influence on *X. compactus* infestation. The highest percentage of infested trees (77.8%) and twigs (15.7%) were observed on coffee under *Ficus natalensis*; whereas coffee under *Maesopsis eminii* had the lowest (44.4% and 1.5% respectively). These studies provided vital preliminary ecological information for designing and implementing appropriate management strategies for *X. compactus*.

Key words: Black-coffee-twig-borer, coffee-tree-canopy, damage, shade-tree-systems, *Xylosandrous-compactus*

Introduction

Black Coffee Twig Borer, *Xylosandrus compactus* Eichhoff (Coleoptera: Curculionidae) is a relatively new but rapidly spreading pest of coffee in Uganda (Egonyu *et al.*, 2009; Kagezi *et al.*, 2012; UCDA, 2012; International Institute of Tropical Agriculture, IITA, unpublished data). Female beetle makes a characteristic entry hole into primary branches (twigs) of coffee, causing them to wilt and eventually die within a few weeks (Ngoan *et al.*, 1976). It also cultivates an ambrosia fungus in coffee galleries for feeding its young larvae. Thus, the name "ambrosia beetle" (Ngoan *et al.*, 1976). Many ambrosia beetle species infest specific locations on their host plant species and this optimises their colonisation efficiency and allows for resource partitioning (Lee *et al.*, 2011). For example, *X. compactus* usually attacks primary branches on coffee (Egonyu *et al.,* 2009). It also has a preference for terminals in lower than upper portions of southern magnolia, *Magnolia grandiflora* (Chong *et al.*, 2009). Thus, these patterns offer information on beetle behavior and underlying attack strategy when beetles commence colonisation of live host plants (Lee *et al.*, 2011). Therefore, understanding within-plant distribution of *X. compactus* and its damage is vital in designing appropriate sampling techniques and effective Integrated Pest Management (IPM) strategies (Chong *et al.*, 2009; Lee *et al.*, 2011).

Traditionally, farmers in Uganda often deliberately plant and/or maintain naturally established trees in their coffee plantations. Also, modern research and extension often promote and encourage farmers to plant trees in their coffee plantations particularly for shade. However, shade use in coffee agro-systems has long been a hotly debated topic particularly among producers and researchers (Rice, 1996). Shade systems are known to promote *X. compactus* infestation on coffee in Uganda (Kucel *et al.*, 2011). This could be in part because shade systems provide favorable micro-environments for development and completion of *X. compactus* life cycle (Kucel *et al.*, 2011). In addition, a number of shade tree species commonly intercropped in coffee, have been reported to be alternate host plant species for *X. compactus* in Uganda (Kucel *et al.*, 2011; Kagezi *et al.*, 2012; IITA, unpublished data). Against this background, we conducted an ecological study to determine (i) within-coffee tree canopy and along infested twig distribution of *X. compactus* damage, (ii) effect of shade systems on percentage of coffee trees and primary branches infested by *X. compactus* in coffee agro-systems.

Materials and methods

Study sites

A study on spatial distribution of coffee twigs and *X. compactus* infestation within coffee tree canopy was conducted in established coffee plantations at Coffee Research Center (COREC), Kituza. On the other hand, effect of shade systems on *X. compactus* infestation was studied on farmers' coffee plantation in Kyampisi sub-county, Mukono district in 2012.

Spatial distribution of *X. compactus* infestation within coffee tree canopy

One hundred and seventy nine (179) coffee trees were randomly selected for inclusion in the study. Using imaginary horizontal planes, each coffee tree canopy was partitioned into upper, middle and lower portions. Total number of twigs and those infested by *X. compactus* (wilting and with characteristic entry holes) were determined in each portion and percentage of infested twigs was computed. The infested twigs were then carefully pruned off as close to the coffee stem as possible using secateurs, put in polythene bags and taken to the laboratory. Out of these, 154 were randomly chosen and each partitioned into basal (lower 3rd length proximal to the stem), middle and tip (upper 3rd portion distal to the stem) sections. Number of *X. compactus* entry holes in each section was then determined after which, they were dissected near the entry holes and the direction of *X. compactus* tunneling determined (whether to basal or tip end).

Effect of shade systems on *X. compactus* infestation and damage

A split plot experimental design with shade tree species as main plot and location of coffee trees from shade tree trunk (shade categories) as subplot was replicated 3 times on farmers' plantations. Three (3) shade trees of each species were randomly sampled in each coffee plantation. Eight (8) shade tree species, commonly intercropped in coffee agro-systems by farmers in Uganda (Kagezi *et al*., 2012; IITA, unpublished data), were sampled. These included: - *Albizia chinensis* (Osbeck) Mer (Chinese silk tree; Fabaceae), *Albizia coriaria* Welw. Ex Oliv. (Albizia; Fabaceae), *Artocarpus heterophyllus* Lam., (jackfruit; Moraceae), *Ficus natalensis* Hochst. (backcloth fig; Moraceae), *Maesopsis eminii* Engl., (umbrella tree; Rhamnaceae), *Mangifera indica* L. (mango; Anacardiaceae), *Markhamia lutea* (Benth.) K. Schum. (Nile tulip tree; Bignoniaceae) and *Persea americana Mill*. (Avocado; Lauraceae). For each shade tree species, percentage canopy cover was determined by visually estimating the amount of light penetrating through canopy at 1m from shade tree trunk (full shade). In addition, 3 coffee trees growing at full shade, edge of shade tree canopy (minimal shade) and 3 m from canopy edge (full sun) were sampled. Total number of twigs and those infested by *X. compactus* was determined and the percentage of infested coffee trees and twigs was computed.

Data analysis

Before analysis, data were transformed in order to reduce non-normality and heterogeneity of variances. Percentage of infested coffee trees and twigs, and, canopy cover of shade trees were subjected to arcsine transformation; whereas, number of entry holes to square root transformation. Data were subjected to analysis of variance (ANOVA) with general linear model (GLM) procedure of Statistical Analysis System (SAS) software (SAS Institute, 2008) to determine significant difference in the measured parameters across treatments. Means were separated by Tukey's test at 5% when significant difference was detected. We also used analysis of covariance (ANCOVA) model to determine whether shade tree species, shade category (fixed factors) and percentage canopy cover of shade trees (covariate) had an influence on percentage of twigs infested by *X. compactus*.

Results

Spatial distribution of primary branches and *X. compactus* infestation

Total number of coffee twigs and those infested by *X. compactus* were determined so as to ascertain their spatial distribution within a coffee tree canopy. Our results showed that both total and infested twigs varied significantly ($p<.0001$) within canopy portions. The highest number (17.7±6.1) was recorded in upper while the least was in lower portions (9.1±4.6; Fig. 1). The highest percentage of infested twigs (10.7±15.9)

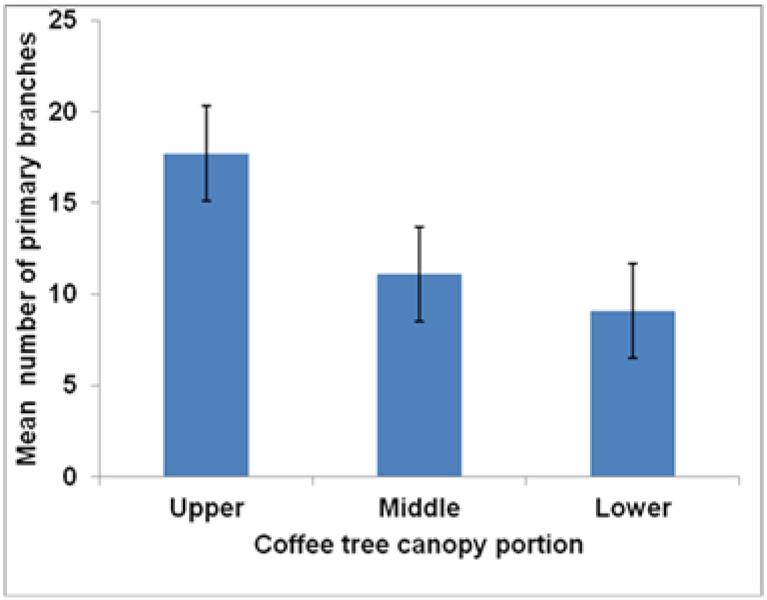

Figure 1. Mean number of primary branches recorded in upper, middle and lower portions of coffee tree canopy at Coffee Research Center (COREC), Mukono, central Uganda.

was recorded in middle and the least (3.2±7.2) in upper portion of coffee canopy (Table 1).

The number of *X. compactus* entry holes was also determined to establish their distribution along the infested twigs. The number of entry holes varied significantly (P<.0001) along the infested twig; with the highest (0.9±0.7) on basal, then middle (0.5±0.6) and the least (0.3±0.6) on tip portions (Table 2). Equal numbers of *X. compactus* tunnels were pointing towards basal and tip of dissected infested twig (50-50%).

Effect of shade systems on *X. compactus* infestation

Percentage canopy cover and total number of twigs plus those infested by *X. compactus* were determined to ascertain the effect of shade systems on *X. compactus* infestation. Percentage canopy cover at full shade varied significantly (P=0.0276) across shade tree species. The highest canopy cover (60.0±26.5%) was recorded on jackfruit tree and the lowest (11.7±7.6%) on Chinese silk tree (Table 3).

Both percentage of *X. compactus* infested coffee trees and twigs varied but not significantly (P≤0.05) across shade categories. The highest percentage of infested trees(70.8±27.8) and twigs (14.8±18.3%) were observed on coffee trees growing at full shade. Coffee trees growing at full sun registered the least percentage of infested trees (45.8±17.3) and twigs (5.7±9.1%; Table 4). However, analysis of covariate (ANCOVA) showed that shade and percentage canopy cover of some shade tree species including Albizia, jackfruit and mango had a significant (at P≤0.05) positive influence on percentage of twigs infested with *X. compactus* (Table 5). Further, the percentage of *X. compactus* infested

Table 1. Mean percentage (±SD) of coffee primary branches bored by Black Coffee Twig Borer, *X. compactus* (damage) in upper, middle and lower portions of coffee tree canopy at Coffee Research Center (COREC), Mukono, central Uganda

Coffee tree canopy portion	Means
Upper	3.2±7.2 (1.1±1.0) b
Middle	10.7±15.9 (2.0±1.7) a
Lower	9.9±18.5 (1.8±1.8) a
F value	15.23**
CV	95.12

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

Table 2. Mean number (±SD) of *X. compactus* characteristic entry holes observed on basal, middle and tip sections of infested coffee primary branches at Coffee Research Center (COREC), Mukono, central Uganda

Infested primary branch section	Means
Tip	0.3±0.6 (0.3±0.5) b
Middle	0.5±0.6 (0.4±0.5) b
Basal	0.9±0.7 (0.8±0.5) a
F value	49.68**
CV	99.64

Same letters within a column indicate means (after square root transformation) are not significantly different by Tukey's test (*P≤0.05). Values in parenthesis are transformed means

Table 3. Mean percentage canopy cover (±SD) provided by various shade tree species estimated at 1m from shade tree trunk (full shade) on farmers' coffee plantations in Kyampisi sub-county, Mukono district, central Uganda

Shade tree species	Canopy cover (%)
Artocarpus heterophyllus (jackfruit)	60.0±26.5 (6.0±1.5) a
Mangifera indica (mango)	50.0±17.3 (5.5±0.9) ab
Persea Americana (avocado)	46.7±11.5 (5.4±0.6) ab
Albizia coriaria (Albizia)	36.7±15.3 (4.7±1.0) ab
Ficus natalensis (backcloth fig)	33.3±23.1 (4.4±1.5) ab
Markhamia lutea (Nile tulip tree)	26.7±5.8 (4.1±0.5) ab
Maesopsis eminii (umbrella tree)	20.3±19.5 (3.7±1.2) ab
Albizia cinensis (Chinese silk tree)	11.7±7.6 (2.6±0.9) b
F value	3.14*
CV	22.4

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

Table 4. Mean percentage (±SD) of *X. compactus* infestation on coffee trees growing at three locations relative to shade tree trunk on farmers' coffee plantations in Kyampisi sub-county, Mukono district, central Uganda

Location of coffee trees	Percentage of infested coffee trees	Percentage of infested primary branches
1 m from shade tree trunk (full shade)	70.8±27.8 (6.5±1.4) a	14.8±18.3 (2.5±1.8) a
Canopy edge (minimal shade)	62.5±27.8 (6.1±1.4) a	11.0±13.6 (2.2±1.6) a
3 m from canopy edge (full sun)	45.8±17.3 (5.3±1.0) a	5.7±9.1 (1.5±1.3) a
F value	2.01ns	2.512ns
CV	21.18	23.74

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

coffee trees and twigs varied across shade tree species but not significantly (P≤0.05). The highest percentage of infested coffee trees (77.8±19.2%) and twigs (15.7±13.6%) were recorded on coffee trees growing under backcloth fig tree shade. On the other hand, lowest percentage of infested coffee trees (44.4±50.9%) and infested twigs (5.2±15.0%) were on coffee growing under umbrella tree shade (Table 6).

Discussion

Understanding spatial distribution of *X. compactus* infestation within coffee tree canopy is vital in designing appropriate sampling techniques and effective IPM strategies for the pest. Our results showed that spatial distribution of twigs on coffee trees varied significantly (p<.0001) within coffee tree canopy; with the highest number in upper and the least in lower portions. These results are in agreement with a study by Chong *et al.* (2009) which reported less number of primary branches (terminals) in lower than upper portions of southern magnolia, *Magnolia grandiflora*. This could probably, partially be caused by the senescence of twigs located at lower portions of coffee tree canopy (Chong *et al.*, 2009). Secondly, farmers usually maintain their coffee by pruning off mature twigs (Musoli *et al.*, 2001) which are located in lower portions of coffee canopy.

Spatial distribution of coffee twigs infested by *X. compactus* also varied significantly (p<.0001) within coffee tree canopy. *Xylosandrus compactus* preferentially attacked twigs located in middle and lower than those in upper portion of coffee tree canopy. These results concur with Chong *et al.* (2009) who reported that *X. compactus* showed a marked preference for terminals in lower than upper portions of southern magnolia. This characteristic preference for colonisation of twigs located in lower portions has also been observed with other ambrosia beetles. For example, Oliver and Mannion (2001) recorded the highest number of entry holes of *X. crassiusculus* and *X. germanus* on lower portions of chestnut in nurseries. Similarly, Reding *et al.* (2010) reported higher captures of *X. crassiusculus* and *X. germanus* adult beetles in ethanol-baited

Table 5. ANCOVA results for the effect of location of coffee trees relative to the shade tree trunk, percentage canopy cover and shade tree species (covariate) on the percentage of primary branches infested by *X. compactus*

Source of variation	Standard error	T	Pr> ltl
Intercept	7.084	0.338	0.737
*Albiziacinensis**Full shade	16.496	1.271	0.211
*Albiziacinensis**Minimal shade	10.047	0.956	0.345
*Albiziacinensis**No shade	10.019	0.538	0.594
*Albiziacoriaria** Full shade	20.325	3.042	**0.004**
*Albiziacoriaria** Minimal shade	11.190	2.209	**0.033**
*Albiziacoriaria** No shade	10.019	0.744	0.461
*Artocarpusheterophyllus** Full shade	19.573	4.258	**0.000**
*Artocarpusheterophyllus** Minimal shade	11.715	1.782	0.082
*Artocarpusheterophyllus**No shade	10.019	0.954	0.346
*Ficusnatalensis** Full shade	15.990	1.289	0.205
*Ficusnatalensis** Minimal shade	10.112	1.200	0.237
*Ficusnatalensis** No shade	10.019	-0.017	0.987
*Maesopsiseminii** Full shade	13.098	0.425	0.673
*Maesopsiseminii** Minimal shade	10.431	0.590	0.558
*Maesopsiseminii** No shade	10.019	0.427	0.672
*Mangiferaindica** Full shade	24.773	-2.112	**0.041**
*Mangiferaindica** Minimal shade	14.027	-1.736	**0.090**
*Mangiferaindica** No shade	10.047	-0.087	0.931
Markhamialutea * Full shade	28.534	1.102	0.277
Markhamialutea * Minimal shade	16.698	1.672	0.102
Markhamialutea *No shade	10.157	0.108	0.915
*Perseaamericana** Full shade	30.916	1.616	0.114
*Perseaamericana** Minimal shade	12.403	2.002	0.052
*Perseaamericana** No shade	10.202	0.429	0.672
*Albiziacinensis** canopy cover	1.123	-0.749	0.458
*Albiziacoriaria** canopy cover	0.482	-2.517	**0.016**
*Artocarpusheterophyllus**canopy cover	0.280	-3.510	**0.001**
*Ficusnatalensis**canopy cover	0.374	0.525	0.603
*Maesopsiseminii**canopy cover	0.415	-0.661	0.512
*Mangiferaindica**canopy cover	0.453	2.890	**0.006**
*Markhamialutea**canopy cover	1.002	-1.037	0.306
*Perseaamericana**canopy cover	0.627	-1.639	0.109

The study was conducted on farmers' coffee plantations in Kyampisi sub-county, Mukono district, central Uganda.Significant *P*-values are highlighted in **bold**

traps hung in lower and middle than in higher height traps. Igeta *et al*. (2004) also captured more adult *Platypus quercivorus* beetles in sticky screen traps placed at lower than upper sections in and around forest gaps. This could probably be partially due to the fact that branches in lower portion of canopy are usually more mature than those in upper portion; possessing less plant defenses which can easily be overcome by *X. compactus* (Coley and Barone, 1996). Secondly, due

Table 6. Mean percentage (±SD) of *X. compactus* incidence (percentage of infested coffee trees) and damage (percentage ofinfested primary branches) on coffee trees growing under various shade tree species on farmers' coffee plantations inKyampisi sub-county, Mukono district, central Uganda

Shade tree species	Percentage of infested coffee trees	Percentage of infested primary branches
Ficusnatalensis	77.8±19.2 (6.9±0.8)a	15.7±14.5 (2.8±1.6)a
Albiziacoriaria	77.8±19.2 (6.9±0.8)a	14.7±13.6 (2.7±1.5)a
Artocarpusheterophyllus	66.7±0.0 (6.4±0.0)a	13.4±23.9 (2.2±2.1) a
Markhamialutea	66.7±33.3 (6.3±1.7)a	8.1±11.6 (1.9±1.4)a
Albiziacinensis	55.6±38.5 (5.7±1.9)a	10.9±12.1 (2.2±1.6)a
Mangiferaindica	45.4±38.5 (4.5±3.4)a	8.6±14.5 (1.8±1.7)a
Perseaamericana	44.4±50.9 (4.3±3.7)a	7.4±15.0 (1.6±1.6)a
Maesopsiseminii	44.4±50.9 (4.3±3.7)a	5.2±8.0 (1.5±1.2)a
F value	0.674ns	0.807ns

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

to their physiological state (stressed), mature plant parts usually emit various volatile organic compounds (VOC's) such as acetaldehyde, acetone, ethane, ethanol, ethylene and methanol (Kimmerer and Kozlowski, 1982) which attract adult *X. compactus* and other beetles (Chong *et al.*, 2009; Ranger *et al.*, 2010). Thirdly, presence of sap exudation in healthy or young host plants or plant parts has also been reported to have a repellent factor for *X. compactus* (Hara, 1977). Several ambrosia beetles have been reported to generally fly near the ground and thus more likely to attack branches located low on host plants (*e.g.* Igeta *et al.*, 2004; Chong *et al.*, 2009). This could be applicable to *X. compactus*. Another possible reason which has been advanced for other closely related ambrosia beetles (e.g. *Platypus koryoensis*), is lack of adequate moisture which is needed for growth of associated ambrosia fungus in small-diameter twigs in upper layer of host plant canopy (Igeta *et al.*, 2004; Esaki *et al.*, 2009). Most probably when twigs are attacked by *X. compactus*, those located in lower layers of canopy can maintain higher levels of moisture than those in upper layers because of their larger diameter (Igeta *et al.*, 2004). However, more studies on this hypothesis need to be conducted to come up with more conclusive evidence.

Our data showed that *X. compactus* characteristic entry holes varied significantly (p<.0001) along infested coffee twigs; with the highest number on basal and the lowest on tip portions. These data concur with studies by Chong *et al.* (2009). This could be due to the fact that basal parts are more mature and thus more stressed than tip sections of coffee twigs. As earlier mentioned, mature (stressed) plant parts possess less plant defenses (Coley and Barone, 1996) or repellants against *X. compactus* attack (Hara, 1977). They may also emit various volatile organic compounds (Kimmerer and Kozlowski, 1982) which may attract adult *X. compactus*.

In addition, tunneling by *X. compactus* once inside coffee galleries was either inclined towards base or tip of infested coffee twigs; implying that equal numbers of tunnels were pointing to basal and distal end. This implies that *X. compactus* has no preference in direction of tunneling once inside coffee galleries. Our results are in agreement with Hara (1977) who reported that female beetles initiate cutting into vascular tissue, reach the pith of stem and excavate it along the twig on either side of initial entrance tunnel to make a brood chamber where eggs are laid (Ngoan *et al*., 1976).

Our results showed that the highest percentage canopy cover was observed on jackfruit tree whereas Chinese silk tree registered the lowest. These results support other studies which have reported that jackfruit tree has a dense and conical or pyramidal canopy (Tarroza, 1988); whereas, Chinese silk tree has a light, spreading and flat canopy (http://www.worldagroforestry.org/treedb2/AFTPDFS/Albiziachinensis.pdf). This difference in percentage canopy cover has implications in managing *X. compactus*. Shade cover has been reported to increase infestation of some insect pests of coffee (*e.g*. Kucel *et al*., 2011) mainly by influencing micro-environmental conditions prevalent within coffee farms (Lin, 2007). This directly influences the dynamics and life cycle of arthropod populations and their natural enemies (Moguel and Toledo, 1999) and/or indirectly by influencing coffee defense mechanisms against the insect pests and stimulation of trophic chains (Mouen Bedimo *et al*., 2007).

Percentage of *X. compactus* infested coffee trees and twigs varied within shade categories and shade tree species but not significantly (P>0.05). These results are at variant with those of Kucel *et al*. (2011). This discrepancy in results might have been due to variations in data collection methodology employed in the 2 studies. Data for the present study were collected only once as compared to Kucel *et al*. (2011) study which presents an average of data collected over a period of time, thus, taking care of seasonal influences. In fact, *X. compactus* infestation has been reported to fluctuate throughout the year, depending on seasons among other ecological conditions (Ngoan *et al*., 1976; Burbano and Wright, 2008). However, ANCOVA results showed that shade and percentage canopy cover of some shade tree species including Albizia, jackfruit and mango had a direct significant (at p<0.05) positive relationship with percentage of twigs infested with *X. compactus*. This implies that influence of shade systems on *X. compactus* infestation might probably be dependent on canopy cover of the shade tree species in question. Shade systems promote *X. compactus* infestation because they provide micro-environments that may favor development and completion of its life cycle (Lin, 2007; Kucel *et al*., 2011). These humid micro-climates may also facilitate development of associated ambrosia fungus (Wintgens, 2009). Further, Albertin and Nair (2004) reported that coffee growing under shade is usually more stressed than sun grown coffee due to high competition for resources such as soil nutrients, water and light between coffee and shade trees. Thus, shade grown coffee is likely to be more prone to *X. compactus* attack because most ambrosia beetles prefer dead or stressed plant hosts (Ranger *et al*., 2010). Secondly, as earlier mentioned, stressed plant hosts emit several volatile organic compounds (Kimmerer and Kozlowski, 1982) which attract adult *X. compactus* (Chong *et al.*, 2009; Ranger *et al.*, 2010). All in all, role of shade systems in promoting *X. compactus* infestation remains a mystery; they probably invoke some other unknown biochemical mechanisms that may promote its infestation (Orozco-Cardenas *et al.*, 1993).

Our results showed that *X. compactus* infestation was higher on coffee growing under backcloth tree than Chinese silk tree, contrary to Kucel *et al.* (2011) study. This discrepancy calls for further comprehensive studies on mechanism through which shade systems of various tree species influence *X. compactus* infestation and population dynamics before any authoritative conclusion is drawn. In our study, it is most probable that the dense canopy provided by backcloth tree species (Tarroza, 1988) was responsible for promoting higher *X. compactus* infestation due to various reasons earlier mentioned (Kimmerer and Kozlowski, 1982: Orozco-Cardenas *et al.*, 1993; Albertin and Nair, 2004; Lin, 2007; *Wintgens, 2009;* Ranger *et al.*, 2010; Kucel *et al.*, 2011). On the other hand, in Kucel *et al.* (2011) study, Chinese silk tree probably acted more as a refuge and therefore a potential and source or reservoir for *X. compactus* infestation to coffee plants. In addition, farmers, extension and research reported that Chinese silk tree is one of the major alternate hosts for *X. compactus* in Uganda (Kucel *et al.*, 2011; IITA, unpublished data; Kagezi *et al.*, 2012).

Conclusion

Our study showed that *X. compactus* infestation was more concentrated in lower portions of coffee tree canopy and basal parts of infested twigs. Thus, spraying with insecticides and/or bio-pesticides, and, trapping with lures should target these sections. This reduces the amount of chemicals used and thus, costs and risks to human beings and environment in general. In addition, farmers should routinely prune off mature and unproductive twigs which are located in lower sections of coffee tree canopy to reduce sources of *X. compactus* infestation. However, the physiological and morphological cues that induce higher numbers of attacks on the lower sections of coffee tree canopy and mature plant parts twigs warrant further investigations. These studies will form a basis in developing lures for attracting adult beetles. Our study also demonstrated the importance of making right decisions when choosing shade tree species to be intercropped in coffee agro-systems and shade management regimes (by pruning). However, a more comprehensive ecological study should be conducted in the five major coffee growing agro-ecosystems of Uganda. This should be both in wet and dry seasons, over a period of time and on more shade tree species particularly those which have been reported to be alternate host plant species for *X. compactus*.

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