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Forest Landscapes Influence Black Coffee Twig Borer, *Xylosandrus compactus* Eichoff Infestation in Adjacent Robusta Coffee Gardens: Management Implications

Godfrey H. Kagezi[a*], Patrick Kucel[b], Judith Kobusinge[c], Lilian Nakibule[d], Geofrey Arinaitwe[e]

[a,b,c,d,e]National Coffee Research Institute (NaCORI), National Agricultural Research Organisation (NARO), P.O. Box 185 Mukono, Uganda

[a]Email: gkagezi@gmail.com

[b]Email: patkucel@gmail.com

[c]Email: judithkobusinge24@yahoo.com

[d]Email: liliannakibuule@yahoo.com

[e]Email: aggarinaitwe@gmail.com

Abstract

The black coffee twig borer, *Xylosandrus compactus* Eichhoff (Coleoptera: Curculionidae) is one of the major constraints facing the Robusta coffee industry in Uganda since its advent in 1993. Once in a new location, it spreads rapidly within and between coffee gardens. This is mainly driven by favorable climatic conditions, presence of alternate hosts, limited management by farmers and the fact that natural enemies present in the new eco-systems are yet to adapt to it. Its management is difficult due to its cryptic nature of spending almost its entire lifespan is spent inside the host galleries. *X. compactus* has >200 host plant species worldwide, whereas, >50 plant species have been proven to be hosts in Uganda including: - commercial and ornamental crops as well as shade and forest trees/shrubs. In addition, these trees provide shady conditions that promote infestation of this pest. A study was therefore conducted in central Uganda to elucidate the effects of forest landscapes on the distribution of *X. compactus* damage in the adjoining Robusta coffee gardens. New alternate host plants of *X. compactus* within the forests were also documented. This could inform further development of its management strategy Uganda.

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* Corresponding author.

Results showed that the percentage of coffee suckers and primary branches infested by *X. compactus* increased significantly ($p=0.0171$ and $p=0.0001$ respectively) with increasing distance away from the forest edge towards the center of the forest. The percentage infestation however decreased significantly ($p<.0001$ and $p=0.2367$) for suckers and primary branches respectively with increasing distance from forest edge towards the center of the adjoining coffee plantation. These observations are explicable by the fact that the forest acts as a source of *X. compactus* infestation for the adjoining coffee plantation, commonly referred to as "pull-effect", the nearer the coffee trees to the forest the greater the initial infestation. Nine alternative host plant species, namely: - charcoal tree *Trema orientalis* Linn. Blume (Ulmaceae), African celtis, *Celtis mildbraedii* Engl. (Ulmaceae), bastard-wild-rubber, *Funtumia africana* Benth. Stapf (Apocynaceae), velvet-leaved combretum, *Combretum molle* R. Br. Ex. G. Don. Engl & Diels (Combretaceae) and five unidentified tree species were recorded in the forest. These tree/shrub species have been added to the existing inventory of *X. compuctus* alternate host plants in Uganda. This study clearly demonstrates the influence of natural forest landscapes on incidence and damage of *X. compactus* infestations in adjoining Robusta coffee gardens. The results suggest that farmers with coffee gardens neighboring forested landscapes should take into account managing the source of *X. compactus* infestation from natural forests as well as that on coffee and alternate hosts in their gardens. NARO-BCTB traps should therefore be deployed along the forest boundaries in order to intercept the *X. compactus* from the forests before they enter the coffee gardens. However, there is need to fully elucidate the interactions between the 'pull-effect' and landscape and aggregation factors that influence incidence and damage of *X. compactus* attacks so as to inform its management.

Keywords: Alternate-host-plants; black-coffee-twig-borer; damage; edge-effect; pull-effect; Robusta-coffee; Xylosandrus-compactus.

1. Introduction

The Black Coffee Twig Borer, *Xylosandrus compactus* (Eichhoff) (Insecta: Coleoptera: Curculionidae: Scolytinae) is currently one of the most destructive insect pests of coffee in Uganda [1, 2, 3, 4, 5, 6]. It is a small brown to black exotic ambrosia beetle [7] that infests more than 200 plant species worldwide [8, 9, 10, 11]. In Uganda, *X. compactus* attacks mostly Robusta coffee but has also been observed on more than 50 plant species, including: - commercial crops as well as ornamentals, shade and forest trees/shrubs [2, 6]. In coffee, the female beetle bores a characteristic pin-sized entry hole and excavates tunnels inside the berry-bearing coffee primary branches causing them to wilt and die within a few weeks [7, 8, 12]. The infested primary branches will not bear berries, resulting into loss of harvest and thus income for the smallholder farmers [1, 5] who produce about 98% of Uganda's coffee [13]. Recent studies by [4] showed that 9.6% of the primary branches of coffee in Uganda were infested by *X. compactus*. This could be translated into 9.6% loss of the current 4.53 million 60 kg bags of coffee being exported valued at US$ 42.9 million of the US$ 439 million raised from coffee exports [14]. Once in a new location, *X. compactus* spreads rapidly within and between coffee gardens [1, 2, 5]. Flight of adult females is the main means of movement and dispersal to new plants and new areas over short distances - dispersing at least 200 m, though, dispersal over several kilometers is probably possible, especially if wind-aided [15]. However, the main sources of *X. compactus* remain uncertain [16]. Habitats, especially wooded and forested areas, surrounding farmers coffee gardens could be important potential sources of *X. compactus*. In fact, recent studies of ambrosia beetles confirmed that source populations in ornamental nursery production in USA were originating from overwintering sites in forests adjacent to production fields [16, 17]. However, this hypothesis has not been tested experimentally for coffee, nor has the movement of *X. compactus* within the farmers' coffee gardens characterized in Uganda and elsewhere. Secondly, although, population density, colonization behavior and attack severity of several ambrosia beetles may be influenced by forest edges [18, 19, 20], these effects are poorly understood for most of these beetles including *X. compactus* [19, 21, 22]. We therefore conducted a study in coffee gardens neighboring forest to further improve the existing *X. compactus* management package by minimizing infestations of coffee gardens from adjoining forested landscapes. Specifically, the study sought to: - i) determine the distribution of X. *compactus* damage on wild coffee in a natural forest adjacent to a coffee plantation, ii) establish the pattern of *X. compactus* damage in the coffee garden adjoining the natural forest, iii) search for new alternative plant hosts of *X. compactus* in forested landscapes adjoining coffee gardens, iv) use the information generated to further strengthen the efficacy of existing *X. compactus* management package.

2. Materials and Methods

2.1 Study site

The study was conducted in Mabira forest and on farmers' coffee gardens adjacent to the natural forest in Mubango Village, Nsakya Parish, Najjembe Sub-county, Buikwe District (Figure 1). The district lies between 0° 18' 4.32" N and 33° 3' 6.624" E in central Uganda, 1000-1300 m above sea level [23]. The climate is tropical with two rainfall peaks from April to May and October to November ranging between 1,250-1,400 mm per annum. Annual mean temperature range, minimum: 16–17 ° C, maximum: 28–29 ° C [24]. The vegetation is medium altitude moist semi-deciduous forest. The soil types in the reserve and the surrounding areas can be summarized as ferrallitic sandy clay loams with dark clays in the valleys [25]. Crop farming is the main sources of livelihood to the community with Robusta coffee being the most important cash crop grown in the area [26].

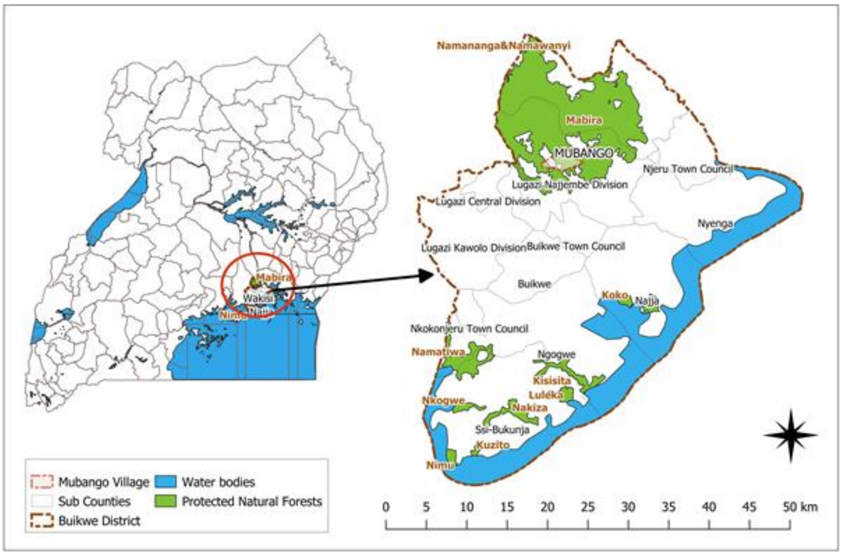

Figure 1: Location of the study area

2.2 Data collection

Three different points having wildly growing coffee in the forest and their adjacent coffee gardens were purposively selected for the study. A transect measuring 10 m in width was demarcated at the forest edge into the interior. All the coffee plants in the transect were sampled to the last plant in the forest. Similarly, an equal transect was demarcated from the forest edge into the adjacent coffee garden and all the coffee plants sampled. The distance of each sampled coffee plants from the forest edge was measured using a measuring tape (in meters). All the coffee stems on each of the sampled coffee plant were assessed for *Xylosandrus compactus* infestation by establishing the total number of suckers and primary branches and those with characteristic pin-sized entry holes [1, 4, 5]. In addition, other plant species in the forest were also examined for the characteristic entry holes in order to establish alternative host plant species of *X, compactus*. Samples of these tree species were taken to the National Coffee Research Institute (NaCORI) laboratory and identified where possible.

2.3 Statistical analysis

X. compactus infestation was calculated as percentage of the infested suckers and the primary branches to the total number of each parameter. We used simple regression analysis using Statistical Analysis System (SAS) software [27] to test for the relationship between the percentage of coffee suckers and primary branches infested by *X. compactus* to the distance from the forest edge.

3. Results and Discussion

Our study aimed at determining the effects of forest landscapes on the distribution of *X. compactus* damage in the adjoining Robusta coffee gardens so as to inform its management. Results for the distribution of *X. compactus* damage on wild Robusta coffee in the natural forest adjoining coffee gardens showed that the percentage of infested coffee suckers and primary branches increased significantly ($p<0.05$) with increasing distance from the boundary into the interior of the forest (Figure 2a and b). Our funding is in agreement with earlier studies on several insects including: - beetles [19, 20, 28, 29], leaf-miners [30], ants [31], butterflies [32], weevils, as reported by [20]. This could be in part due to the fact that as one moves into from the boundary or edge into the interior of forest, there are more conducive abiotic conditions that are provided by shade [33, 34]. Shade has been reported to have positive influence on the incidence and damage caused by *X. compactus* infestation on coffee [35, 36, 37, 38, 39, 40]. This is most likely because the high humidity provided by shade favors the growth of the ambrosia fungus, *Fusarium solani* (Mart.) Snyd. & Hans. (Hyphomycetes) that is associated with *X. compactus* and other beetles of the xyleborini tribe [12, 41]. This fungus provides food for the mother and her brood while in the coffee gallery [42]. On the other hand, forest boundaries or edges are characterized by reduced humidity, increased light, and greater temperature variability and wind disturbance [43, 44] that negatively affect reproduction and survival, and therefore, damage caused by several insect species [30, 32, 45] including *X. compaactus*.

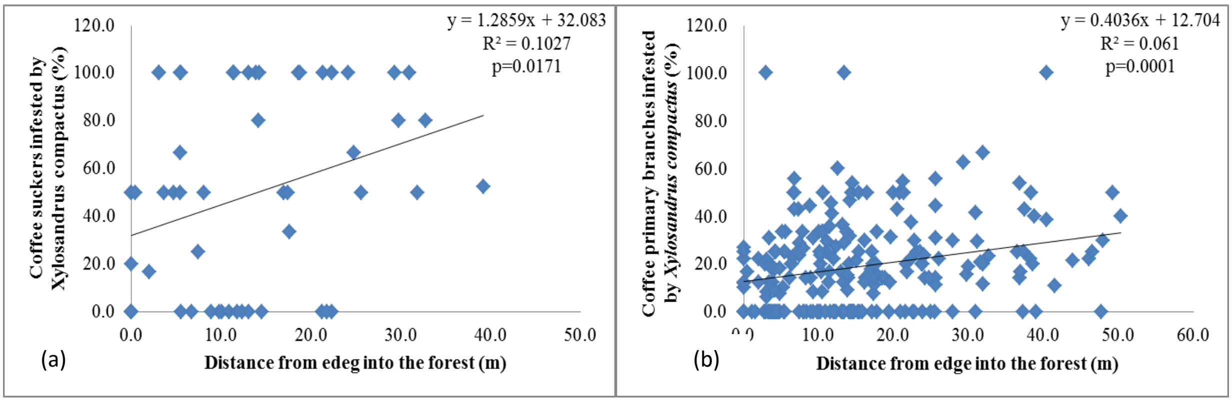

Figure 2: Relationship between the distance from the edge into the forest and the damage caused by *Xylosandrus compactus* on (a) coffee suckers, and, (b) primary branches

Contrary to the trend observed in the natural forest, the percentage of suckers and primary branches infested by *X. compactus* decreased with increasing distance from the forest boundary into the adjoining Robusta coffee garden. However, this decrease was significantly (p<.0001) for the suckers (Figure 3a) but not in case of the primary branches (p=0.2367; figure 3b). Our result supports prior studies by [16, 17, 46] that showed a decrease in captures of ambrosia beetles (majority being *X. compactus*) as the distance from forest edge to the nursery increased. Similarly, diversity and abundance of other beetle species were also reported to decrease from forest edge to sun-grown coffee garden [47] and pasture field [48]. This in part is due to the fact that trees are more diverse and abundant close to the forest margin, decreasing with increasing distance into the coffee garden [49, 50, 51]. This implies that even the shady conditions that favor development of *X. compactus* and its associated ambrosia fungus [12, 41] and therefore, *X. compactus* damage will decrease with increasing distance from forest margin into the coffee garden [35, 36, 37, 38, 39, 40].

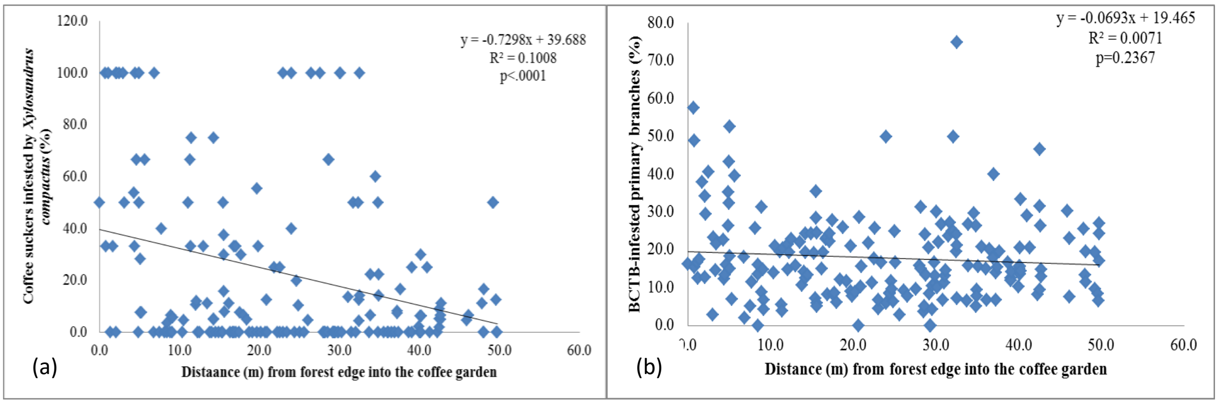

Figure 3: Relationship between the percentage of suckers (a) and primary branches (b) of coffee infested by *Xylosandrus compactus* and the distance from forest edge into the coffee garden

Furthermore, the search for alternative plant host in the forest yielded nine new tree/shrub species, namely: - Charcoal-tree (*Trema orientalis* Linn. Blume), African celtis (*Celtis mildbraedii* Engl.), Bastard-wild-rubber (*Funtumia africana* Benth.), Velvet-leaved combretum (*Combretum molle* R.Br ex G. Don) and five unidentified species. These plant species have been added to the existing list of alternative host plant species of *X. compactus* in Uganda. Of all these plant species, *X. compactus* has been report to infest only tree species in the genus Celtis [11, 53]. However, other related ambrosia beetles have also been reported to infest these plant species. For example, *X. morigerus* (Blandford) has been observed on *C. mildbraedii* and *T. orientalis* [54], *Xyleborus fornicatus* (Eichh.) and *Xylotrechus suscutellatus* (Chevrolat) on *T. orientalis* [55, 56]. Also, *Euwallacea whitfordiodendrus* (Schedl) has been reported on *C. molle*, *C. mildbraedii* and *T. orientalis* [57] while, *Ambrosiodmus guatemalensis* (Hopkins), *A. obliquus* (LeConte) and *Xyleborus sharpi* (Blandford) on *Trema* spp., and *Xyleborus perebeae* (Ferrari) on *Combretum* spp. [58]. This finding further illustrates that although the sources of *X. compactus* that colonize (attack) coffee are still uncertain [16], habitats such as wooded and forested areas that surround coffee gardens are potential sources of beetles that infest coffee [17, 46].

5. Limitations of the Study

The main limitation of this study was that we never quantified the damage caused by *X. compactus* on the alternative hosts as well as assessing the adult insect population emanating from the forested landscapes. This makes estimation of the contribution of forested landscapes to *X. compactus* infestation on Robusta coffee in gardens difficult.

6. Conclusion

Results emanating from our study clearly showed that the incidence and damage of *X. compactus* on wild Robusta coffee in the forest increased with increasing distance from forest. On the other hand, *X. compactus* incidence and damage were higher on Robusta coffee at forest boundary, decreasing significantly into the garden. In addition, nine new alternative plant hosts of *X. compactus* were also recorded in the forest landscapes and these have been added to the existing list of alternative hosts in Uganda. Our study therefore clearly demonstrated the influence of natural forest landscapes on incidence and damage of *X. compactus* infestations in adjoining Robusta coffee gardens.

7. Recommendations

Basing on our results therefore, farmers neighboring forested landscapes should always take into account managing the source of *X. compactus* infestation in natural forests in addition to the infestation on coffee and alternate hosts in their gardens. NARO-BCTB traps [59] should also be deployed along the forest boundaries in order to intercept adult flying *X. compactus* from these forested landscapes before they enter the coffee gardens [46]. However, there is need to fully understand local and landscape factors that influence the population dynamics and damage of *X. compactus* [60, 61] as well as this 'push-pull' strategy for managing it [62, 63].

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