First Report of Exploitation of Coffee Beans by Black Twig Borer (*Xylosandrus Compactus*) and Tropical Nut Borer (*Hypothenemus obscurus*) (Coleoptera; Curculionidae: Scolytinae) in Hawaii

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Abstract. The black twig borer, *Xylosandrus compactus,* is an ambrosia beetle that was reported in Hawaii in 1960 and attacks branches of more than 200 plant species, including coffee. This beetle was found for the first time boring coffee berries in the district of Hilo on the island of Hawaii. Beetles reached the endosperm and caused damage without making galleries or ovipositing. The tropical nut borer, *Hypothenemus obscurus,* is a pest of macadamia nuts that has been in Hawaii since 1988 and was recently found for the first time in Hawaii attacking coffee berries. Its entry hole was observed close to the blossom area or the side of the berry. Sometimes damage was caused near the endosperm but no galleries or eggs were found. Descriptions of the biology, behavior and management of these beetles are provided in this paper.

Key words: *Coffea arabica*, coffee berry, *Xylosandrus compactus*, *Hypothenemus obscurus*

The landscape of the Kona district of the island of Hawaii is characterized by a wide diversity of plant species, including both endemic and naturalized plants (Elevitch et al. 2009). Coffee (*Coffea arabica* L.), macadamia nut (*Macadamia integrifolia* Maiden & Betche), and avocado (*Persea americana* Mill.) are the main agricultural crops in Kona (Beardsley 1990, Jones et al. 1992, Bittenbender and Easton Smith 1999). Vegetation surrounding coffee plantations in Kona often includes plants that are hosts for several Scolytinae species such as the black twig borer *Xylosandrus compactus* Eichhoff and the tropical nut borer *Hypothenemus obscurus* Fabricius (Coleoptera: Curculionidae) (Hara 1977, Hara and Beardsley 1979, Jones 2002). The black twig borer was reported in 1961 attacking pink tecoma, *Tabebuia pentaphylla* (L.) Hemsl. on Oahu (Beardsley 1964), and it is now present on all major islands of the state (Hara and Beardsley 1979, Bittenbender and Easton Smith 1999). The black twig borer is classified as an ambrosia beetle because the parent beetles provide a food source of fungus for their offspring (Hara 1977, Burbano 2010). The black twig borer is a familiar pest of coffee in the Kona area, where it bores into stems and causes branches to die back. The tropical nut borer was reported in Hawaii in 1988, attacking macadamia nuts, and its impact is most serious in the drier production areas (Beardsley 1990, Jones et al. 1992). Neither of these species has previously been reported to attack the berries of coffee. This paper describes

the biology, damage and management of *X. compactus* and *H. obscurus* in coffee berries in Hawaii.

General characteristics of the black twig borer and tropical nut borer. The family Curculionidae, subfamily Scolytinae, comprises ambrosia beetles that have a symbiotic association with fungi and live in wood or other plant tissue, as well as bark beetles and other sub-cortical feeding beetles (Rudinsky 1962). All species of the tribe Xyleborini are ambrosia beetles and the black twig borer, *Xylosandrus compactus*, is among the most economically important species of this tribe (Wood 1982) (Fig. 1A). This beetle lives in symbiotic association with ambrosia fungus cultivated on the walls of galleries in stems constructed by the female (Hara 1977, Beaver 1989, Daehler and Dudley 2002). Members of the tribe Cryphalini, unlike the ambrosia beetles, are primarily phloeophagous, feeders of phloem tissues of the inner bark, or myelophagous, feeders on pith within small stems (Wood 1982). Among the members of the tribe Cryphalini is the tropical nut borer, *H. obscurus* (Fig. 1B) a pest of macadamia nuts (Beardsley 1990, Jones 2002).

Origin and distribution. *Xylosandrus compactus* attacks more than 200 host plant species, including macadamia nut (*Macadamia integrifolia* F. Muell), litchi (*Litchi chinensis* Sonn), avocado (*Persea americana* Mill), anthurium (*Anthurium* spp. Schott), mango *(Mangifera indica* L), coffee (*Coffea arabica* L.), *Eucalyptus* spp., and koa (*Acacia koa* A. Gray) (Hara 1977). The black twig borer is native to Asia and is widespread in Japan, Vietnam, Indonesia, Malaya, Sri Lanka, Madagascar, South India, Seychelles, Mauritius, West Africa, Fiji, Cuba, and Brazil (Venkataramaiah and Sekhar 1964, Vasquez et al. 1996, Oliveira et al. 2008). In the United States, the black twig borer was first reported in Fort Lauderdale, Florida in 1941 (Ngoan et al. 1976) and has spread throughout the southeast US, along the coastal plain from Texas to North Carolina. In Hawaii, this beetle was first reported in 1961 attacking pink tecoma, *Tabebuia pentaphylla* (L.) Hemsl. (Beardsley 1964) on Oahu, and it is now present on all major islands of the state (Hara and Beardsley 1979, Bittenbender and Easton Smith 1999).

Hypothenemus obscurus has been reported in Florida, Puerto Rico, Mexico, Guatemala, Nicaragua, Costa Rica, Colombia, Panama, Dominican Republic, Trinidad, Guyana, Venezuela, Surinam, Brazil, South Africa, Southeast Asia, and Jamaica (Wood 1982). This beetle was first reported in Hawaii attacking macadamia nuts in the Kona district of Hawaii island (Beardsley 1990) and it is now present on all major islands of the state (Jones et al. 1992).

Biology. The black twig borer reproduces by a form of haplodiploidy (arrhenotokus parthenogenesis), whereby males develop from unfertilized eggs (Hara 1977). Adult females produce haploid males from unfertilized eggs, while fertilized eggs produce diploid female progeny. It is possible however, that a functional haplodiploid breeding system occurs in this species, as is the case in closely related species (Brun et al. 1995), where the male progeny have the full chromosomal component, albeit with one chromosome set condensed and non-functional.

Pupation and mating of brood adults occurs within the infested plant material before emergence of the brood. Damage to plants is caused only by adult females; the male is flightless, remains in the brood galleries and is rarely observed outside the plant. Female beetles excavate the tunnels into the host plant and inoculate the plant with an ambrosia fungus, which is the source of nutrients for larvae and adults

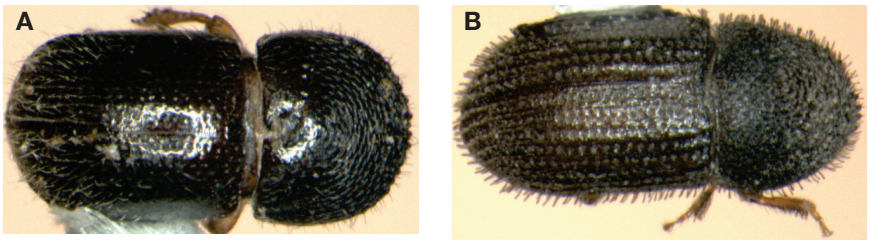

Figure 1. Dorsal view of adults of *Xylosandrus compactus* (A, left) and *Hypothenemus obscurus* (B, right).

(Ngoan et al. 1976, Hara and Beardsley 1979, Beaver 1989). Females initiate cutting the xylem after reaching the pith (cambium) and excavate it along the twig on either side of the initial entrance tunnel to make a brood chamber where the eggs are laid.

The tropical nut borer exhibits a female-biased sex ratio, incestuous inbreeding (sib-mating) as usually attributed to haplodiploidy, whereby unfertilized eggs result in males (Constantino et al. 2011). The life stages consist of the egg stage, two larval instars, the pupa, and the adult, and it takes 28 days at 26°C to develop from egg to adult (Constantino et al. 2011). Females bore a hole in the pericarp of macadamia nuts and construct galleries in the endosperm where eggs are deposited in the husk or in the kernel, and larvae can be found in either location (Jones et al. 1992, Constantino et al. 2011). Females lay between 10 and 30 eggs. Adults and larvae feed within the kernel. After mating, females bore several holes in the endocarp and emerge to colonize other fruits (Jones et al. 1992, Constantino et al. 2011). Males are smaller than the females, and are flightless.

Damage to host plant material. Beetles of the subfamily Scolytinae are among the most damaging insects in the world. Their cryptic life cycles inside the host plant make these insects difficult to control (Rudinsky 1962). Most ambrosia beetles attack unhealthy, stressed, or dying trees by boring into the wood (Kajimura and Hijii 1994). However, *X. compactus* is one of the few ambrosia beetles that attack healthy plants as well as plants that are under stressed conditions such as drought, pruning, or recent transplanting (Hara and Beardsley 1979, Jones and Johnson 1996, Hayato 2007, Burbano 2010).

Xylosandrus compactus females bore a hole into the branch and construct galleries (Fig. 2A) where they then lay eggs (Fig. 2B) (Hara 1977). There are two potential mechanisms through which the black twig borer can cause damage to, or the death of, the host plant: mechanical damage and the introduction of the ambrosia fungus, which may be phytopathogenic (Hara and Beardsley 1979, Daehler and Dudley 2002). Mechanical damage might also be caused by feeding subsequent to excavation of the gallery and the inoculation of the ambrosia fungus introduced by the female (Hara and Beardsley 1979).

Initially, leaves of infested branches turn light green (Fig. 3A), and wilted leaves and bark beyond the affected area turn brown or black within a few days of beetle attack (Fig. 3B) (Ngoan et al. 1976, Daehler and Dudley 2002). The dieback of twigs is the result of the mechanical damage to water-conducting vessels caused by beetle boring (Daehler and Dudley 2002). Subsequent necrosis in the bark and the desiccated zone in the xylem is likely the result of the invasion of associated fungi into the twig tissue, which then invades the

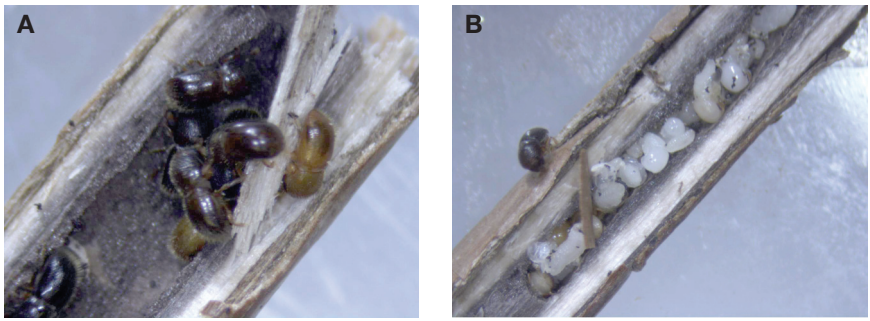

Figure 2. Gallery of *Xylosandrus compactus* in coffee branches. *Xylosandrus compactus* female adults (left) and immature stages (right).

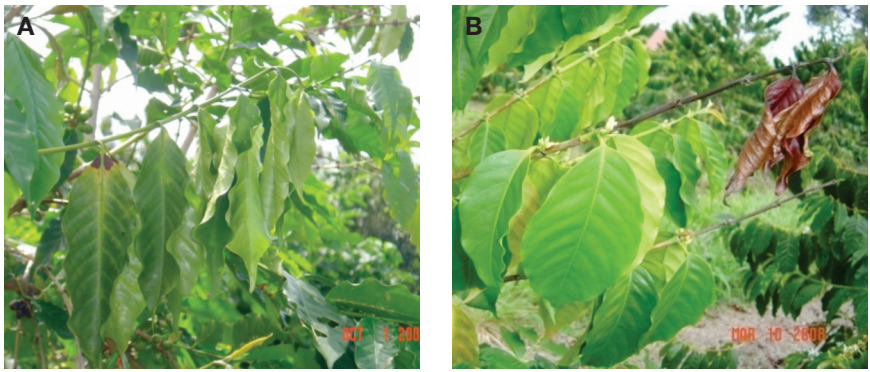

Figure 3. Damage symptoms of *X. compactus* in coffee branches. First leaves turn light green (A, left), then the wilted leaves and bark beyond the affected area turn brown or black (B, right).

xylem of the tree, obstructing the flow of water and nutrients (Hayato 2007).

Xylosandrus compactus has previously been reported attacking branches or saplings (Ngoan et al. 1976, Hara and Beardsley 1979, Oliveira et al. 2008, Burbano 2010). However, in July 2007, females were observed attacking coffee berries in Hawaii in samples from the district of Hilo, Hawaii (19.605556 N 155.045556 W) (Fig. 4A). Females were observed burrowing a hole into the fruit around the blossom area and on the side of the berry. Damage to the fruit was through the exocarp and mesocarp, and occasionally the tunnel reached the endocarp (Fig. 4B). The damage was characterized by a single hole, and galleries or immature stages were not observed. This type of damage was observed in a coffee farm with a high level of black twig borer infestation, trees under stress conditions, and a high density of coffee berries. *X. compactus* typically lives inside branches and feeds on ambrosia fungus, and this is the first report of this beetle attacking coffee berries. Berries with black twig borer attack become susceptible to microorganisms, such as bacteria or fungi, which cause necrosis of the area around the entrance hole.

Hypothenemus obscurus damage occurs both in macadamia nuts that are on the tree and those that have dropped to the ground. During the first 7 to 10 days on the ground, females bore the husk and tunnel directly through the shell and into

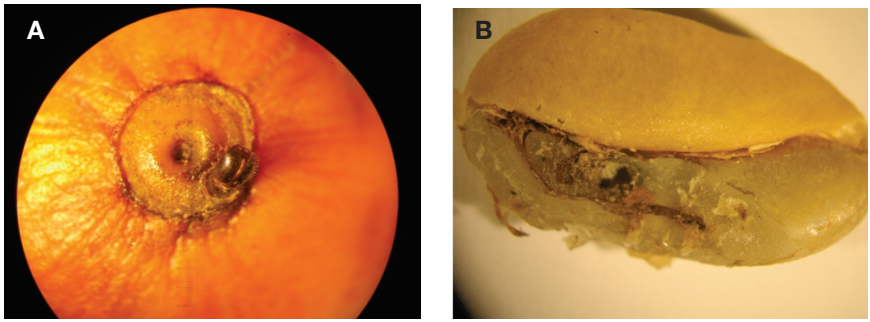

Figure 4. *Xylosandrus compactus* boring coffee berries around the blossom area. *X. compactus* boring a coffee berry (A, left), hole made by *X. compactus* on the endosperm (B, right); galleries or immature stages were not found.

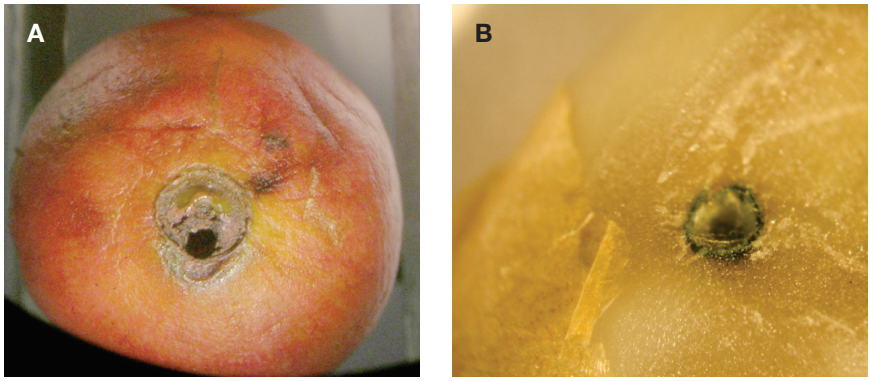

Figure 5. Damage of *Hypothenemus obscurus* to coffee berries. Holes were observed around the blossom area or on the side of the berry (A, left) and sometimes holes were observed reaching the endosperm (B, right).

the kernel (Jones et al. 1992). A single entrance hole is observed on green husks on the trees, and multiple holes are observed in mature husks on the ground and on the trees (Beardsley 1990**,** Jones et al. 1992). *Hypothenemus obscurus* is similar in size and appearance to *H. seriatus* (Eichhoff), which has been in Hawaii for several years (Beardsley 1990). *Hypothenemus seriatus* infests branches and occasionally attacks seeds (Beardsley 1990).

Hypothenemus obscurus was found tunneling inside coffee branches and boring into coffee berries around the blossom area (Fig. 5A) or on the side of the berry, penetrating to the endosperm (Fig. 5B). No *H. obscurus* immature stages or galleries were found inside the beans. *Hypothenemus obscurus* was observed attacking coffee berries when coffee plantations were located close to macadamia plantations. In Colombia, *H. obscurus* is a pest of macadamia nuts and has been recorded attacking coffee berries without affecting the beans (endosperm) (Constantino et al. 2011). Under laboratory conditions, *H. obscurus* fed on coffee and 3% of the beans presented superficial damage (Constantino et al. 2011). Thirty-two percent of the fruits had *H. obscurus* immature stages present, feeding on pulp and mucilage between the beans, and

these were able to develop to adult stage (Constantino et al. 2011). Galleries were not observed inside beans, and only one egg was laid inside a bean. The present study further confirms the polyphagous nature of *H. obscurus*, including coffee as a food source.

Management. The management of *X. compactus* in Hawaii has focused on the use of cultural practices such as sanitation (removing and destroying the infested material) (Burbano 2010). Jones and Johnson (1996) reported that destruction of pruned branches using chippers or shredders results in approximately 90% mortality of the beetles in the stem. Promoting tree health and vigor has also been recommended to help in resisting infestation or recovering from attack (Jones and Johnson 1996). Several parasitoids were released by the Hawaii Department of Agriculture in 1961 for biological control of *X. compactus*; however, there were no follow-up studies of their establishment in Hawaii. Burbano et al. (2012) studied the efficacy of lures and repellents as another management technique. Japanese beetle traps baited with ethanol are an important tool for monitoring black twig borer populations, predicting outbreaks, and possibly as a physical control through mass trapping.

The management of *H. obscurus* has focused mainly on cultural practices (Jones et al. 1992). Tropical nut borer damage in macadamia nuts can be reduced by harvesting every two to three weeks and processing nuts immediately. Although this control method was developed for a different crop, it may be applicable to *H. obscurus* in coffee following the discovery of its feeding habit in coffee berries, should damage levels become economically significant.

Presence of natural enemies for coffee borers in Hawaii. The predatory beetle *Cryptamorpha desjardinsi* (Coleoptera: Silvanidae), has been observed inside macadamia nuts feeding on the tropical nut borer (Jones et al. 1992). This facultatively predacious beetle was also found on coffee trees, inside coffee branches, and inside coffee berries feeding on larvae of the black twig borer and on larvae of the Mediterranean fruit fly *Ceratitis capitata* (Diptera: Tephritidae) (Burbano 2010). This predator can be considered a potentially useful natural enemy for black twig borer, the tropical nut borer and other coffee pests with cryptic behavior.

The Hawaii Department of Agriculture introduced and released three Braconidae species for *X. compactus* control in 1961. They were *Dendrosoter enervatus* Marsh, *Dendrosoter protuberans* Nees, and *Ecphylus* sp. None became established (Bernarr Kumashiro, HDoA, personal communication). The Eulophidae subfamily Tetrastichinae contains two species, *Phymastichus xyleborini* and *P. coffea,* which attack adult stages of scolytines (Graham 1987, Chang 1993, LaSalle 1990). *Phymastichus xyleborini* was reported in Hawaii attacking adults of *Xyleborus perforans* Wollaston (Coleoptera: Curculionidae), a pest of macadamia nuts (LaSalle 1995). *Phymastichus coffea* is present in Africa and attacks the coffee berry borer (*Hypothenemus hampei*) there (LaSalle 1990). Although no host information exists for *P. coffea* from other areas, it is possible that this species might be present in Hawaii. Therefore, they might be good candidates for future studies in biological control programs for the black twig borer, the tropical nut borer, and the coffee berry borer. To the extent that these biological control agents may be useful in suppressing damage by these three beetles, it will be important to avoid disrupting their populations through indiscriminant use of insecticides.

Acknowledgments

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