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Xylosandrus Compactus (EICHH) (Coleoptera: curculionidae), the shot hole borer or black twig borer- a review

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ABSTRACT

Shot hole borer, *Xylosandrus compactus* (Eichh) is one of the most serious pests of robusta coffee. Small black beetle bore into green succulent stem and make galleries which leads drying of the twig. Ambrosia fungus grows inside the gallery helps the development of the beetle. Whole stages develop inside the gallery and this concealed nature makes it difficult to control. The present review discusses the distribution, taxonomy, biology and the control of shot hole borer.

Introduction

*Xylosandrus compactus (*Eichh) commonly known as shot hole borer or black twig borer or ambrosia beetle, comes under the family Curculionidae of the order Coleoptera. The black twig borer is a serious pest of coffee, *Coffea canephora* Pierra (esp.var.robusta Ineae) (Brader, 1964). This beetle is highly problematic since it attacks healthy plants (Dixon *et al*, 2005).Twig borer belongs to the tribe Xyleborini in which all the members feed on ambrosia fungus and are called ambrosia beetles. *Fusarium solani* is the fungus, associated with the ambrosia beetle *Xylosandrus compactus* (ISSG, 2005).

Distribution

The black twig borer is native to Asia. It has spread to the coffee growing areas of the world. It is widely distributed in the coffee growing areas of East Africa, West Africa, Madagascar, Mauritius, Seychelles, India, Malaysia, Java, Sumatra, and Fiji. In Hawaii the first occurrence was reported in 1961 and spread to all islands of Hawaii (Hara *et al* 1976). Pantropical distribution of the beetles includes Brazil, Cuba, Indonesia, Japan and Sri Lanka (Ceylon) (Bright, 1968, Murayama & Kalshoven 1962, Wood 1982).

Pathways to new locations

These beetles are breed under the bark therefore making it easy to transport them through International trade (ISSG 2005). Black twig borers/shot hole borers are commonly intercepted in food products such as seeds and nuts. Black twig borers are among the most commonly intercepted families of insects on solid wood packing materials. Scolytids were the most commonly intercepted group of insects found in association with solid wood packing material in Chile and Newzeland (Haack, 2003).

Taxonomy

Until 1962 the species was identified as *Xylosandrus morstatti* Hagedorn when Murayama and Kalshoven recognised the precedence of Eichoff's 1875 description of *Xyleborus compactus*. In 1963, Brown resurrected the genus *Xylosandrus* Reitter (1913) from its long time synonymy with *Xyleborus.* Xylosandrus is distinguished by having the anterior coxae widely separated rather than contiguous or narrowly separated. Bright (1986) and Wood (1982) recognised *Xylosandrus* as a distinct genus with about 25 species worldwide.

Description

Shot hole borer is a very small, shiny, black cylindrical beetle. Adult female length is 1.4 to 1.9 mm, width 0.7 to 0.8 mm body stout, cylindrical, elongate, brown to black, distinct punctures on pronotum posterior, transversely oriented hair tuft at base of pronotum and long strial setae.

Male of shot hole borers are rarely found and flightless. Body rounded, dark, reddish brown and all characters are poorly developed. Eggs are extremely small, oval, white and translucent. Grubs are white and legless. Young grubs are pointed at the rear while older grubs have a brownish heads and rounded tail. Pupa about the size of adult with distinct legs, wings and head (Barker, 1994).

Hosts of Shot-hole borer

There are 224 plant species belong to 62 families, are susceptible for black twig borer infestation (Ngoan *et al* 1976) include coffee, cocao, avocado, brush box,(*Tristania conferta)*, turpentine tree (*Syncarpia glomulifers*), paper-bark(*Melaleuca leucadendron*), red- iron bark eucalyptus (*Eucalyptus sideroxylon),* black butt eucalyptus (*E. pilularis*), robust eucalyptus(*E.robusta*) Koa haole(*Leuceana glauca*), guava, vervain(*Stachytarpheta jamaicensis)*, Christmas berry(Schinus terebinthifolia) floral red ginger, litvhi, macadamia, mango, mahagony, kukui, star jasmine, pikake, periwinkle, Surinam cherry, *Hibiscus*, Cattleya, *Dendrobium*, *Epidendrum*, *Vanda* and *Anthurium(* Davis,1963;Davis 1969;Dixon and woodruff, 1982; Hara and Beardsley, 1979; Mangold *et al*, 1977;Marsden, 1979; Nelson and Davis, 1972). It also attacks *Clerodendron*, dadap, neem, *Annata sp.* and *Crotalaria* (Anonymous 2000). It also attacks apple, pear, cherry (Mike *et al*, 1993).

Biology

The life cycle of shot hole borer is completed in about a month. Males spend entire lives inside the brood gallery.

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Females lay eggs inside the gallery. Hatched females mate inside the brood chamber and leave the gallery in search for new plants. Females without mating are able to reproduce and the offspring are all males (Le Pelley, 1968).

Eggs are smooth, white, oval less than 1mm long and are laid inside the galleries. They hatch in about 3-5 days (Hara and Beardsley, 1979). Females lay eggs 7-8 days after the entry (Brader, 1964). Grubs are white and legless. Usually two larval instars are found which nourishes on the ambrosia fungus and pupates after 7 days (Hara and Beardsley, 1979). Some studies showed that, there were three instars as per the head measurements of the larvae. Pupae are initially white, later changes to light brown before emerging. It takes atleast 6 days (Hara and Beardsley, 1979). Adult females turn shiny black in 3- 4 days after emergence. Males turn from light brown to reddish brown in 3 – 4 days (Hara and Beardsley, 1979).

Damage

Beetles in the sub family Scolytinae are among the most damaging insects in the world (ISSG, 2005). *Xylosandrus compactus* (Eichhoff) is one of the few ambrosia beetles that infest healthy plants. Shot-hole borer tunnels into woody twigs leaving a pin-sized entry holes. Detection of the borer is difficult due to the cryptic lifestyle (Coyle, 2005). In coffee it attacks the tertiary branches. It causes serious problem for young coffee plants since it attacks the main stem. The mining of the borer can interfere with the movement of fluids through cambium between wood and bark (Mike *et al, 1993)*. A severe infestation can kill host plants, including large trees (Nelson and Davis, 1972; Hara and Sewake, 1990). Insects prefers internodal region for tunnelling (Anonymous, 2000). One or more females may occupy a twig or branch if the twig diameter is less than 7 mm, but up to 20 females can be found in branches of 8-22 mm diameter. After entry they excavate galleries and lay eggs. Beetles inoculate the host with an associated fungus and feed on that fungus (Buss and Foltz, 2006). Damage is not caused by feeding since beetle feeds on ambrosia fungus. Beetles sometimes introduce pathogenic fungi or bacteria, which may cause wilting, die back or death. Excavation and introduction of pathogens cause damage. Wilting of twigs becomes evident within weeks after infestation.

Optimum conditions for the attack is a temperature of $26.5\,^{0}$ C – $29\,^{0}$ C and a relative humidity 72-78% in the absence of rain. Adult females emerge in the large numbers in the afternoon (Le Pelley, 1968). Flight capacity of the beetles has been reported upto vertical distance 7 mm, and 200 mm of longitudinal distance from plantations. The highest population occurs during the June- Sep.

Association with the fungus

Members of nearly all insect orders are associated with fungi (Hammond and Lawrence, 1989). In some cases specific fungi are cultivated under complex conditions. The insects control the type, growth, and form of the fungi cultured in their gardens. In the absence of insects the fungal garden is soon over run by bacteria and other microorganisms and the cultured fungus is replaced by other fungi. The insects appear to maintain and cultivate their fungal gardens, through oral, anal and epidermal excretions and through continuous harvest of the fungal crop. The insect's anatomy is modified for carrying and dispersing the fungus in order to ensure transmission from one insect generation to the next (Tanada and Harry, 1993).

The ambrosia beetles are found mainly in the two families of Scolytidae and Platipodidae and also in *Lamexylidae*. They differ from bark beetles in the feeding habit; they feed on fungi while the latter feed on wood and are serious pests. Beetles have developed feeding strategies for handling the various types of fungal substrates and specific morphological adaptations (mainly mouth parts) to carry out these strategies (Lawrence, 1989).Initially the ambrosia was considered to be a mixture of insect spittle and crusts of coagulated sap, but subsequently it was found to be fungal in nature. Ambrosia fungi are not able to exist without the beetles. They are transported and cultured for food by the beetles (Beaver, 1989). The fungi invade phloem and wood, spread widely, forming ambrosial layers covering the walls of the beetle gallery. These layers are browsed upon by the larval and adult stages of the beetle (Tanada and Harry, 1993).

The ambrosia fungi are highly specialized forms and are not easily isolated and cultured. Most of them are known only in the imperfect state (*Duteromycotina*) and where the perfect states are known, they belong mainly to *Ascomycotina* and a few to *Basidiomycotina* (Francke, 1967; Beaver 1989; Lawrence 1989).The common genera of imperfect fungi are *Fusarium, Cephalosporium, and Ambrosiella* and those of *Ascomycetes* are *Endomysopsis, Ascoidea, Ceratocystis.* The ambrosia fungi are pleomorphic and may form hyphae and an extended mycelium or produce ambrosia, or become yeast like in form (Tanada and Harry, 1993).

The ambrosia fungi are not species specific to ambrosia beetles, and other beetles may feed on them. The ambrosia beetles and their larvae probably feed on a complex of fungi and bacteria (Haanstad and Morris 1985).

The fungi are carried in specialized integumental organs (Mycangia or Mycentangia) of the beetles (Baker and Morris, 1968). The location of the organs is mainly in the head and thorax and rarely on the elytra and legs (Beaver, 1989). The organs are generally found only in the female beetles. Some beetles however, lack these organs and carry the fungi in their digestive tracts or carry the spores in association with fatty or oily secretions on their body surface. (Tanada and Harry, 1993). All the stages of the beetle feeds on the white, glistening ambrosia which provides complete nutrition for the growth and reproduction of the beetle (Baker and Morris, 1968).

The beetles carry the ambrosia fungus in specialised tubes, pouches, cavities or pits (Mycangia) that occur in different body locations among the insect species. Depending upon the species the Mycangia may occur in the males only, the females only or in both sexes. (Batra, 1963).

The mycangia are associated with thin-walled cells that secrete oily or waxy substance that protect the thin-walled spores from desiccation. The mycangia are also associated with various amino acids that are utilised for the germination of the spores and the growth of the fungus. The gland cells are active during the flight of the beetles, and the fungus actually grows slowly as yeast-like cells that multiply by budding and fission. Additionally, spores and cells of fungi other than the ambrosia fungi are selectively eliminated, perhaps due to special chemicals secreted in the mycangia or by antibiotics produced by the ambrosia fungi (Moore and Landecker, 1996).

In Indian Muthappa and Venkatasubbaiah (1981) reported the presence of *Ambrosia macrospore* (fr. Grosmann) Batra in the tunnels of shot-hole borer on robusta coffee. Occurrence of another species of Ambrosia fungus *viz, Ambrosiella xylebori* in association with *X. compactus* on robusta coffee is also reported (Bhat and Sreedharan, 1988).

Ambrosia fungi

Ambrosia beetle line tunnels, chambers and galleries with a cushion like growth or ambrosia fungi. When originally observed, the glistening layer of ambrosia fungi was thought to be dried exuded sap(known then as "ambrosia", the food or drink of the gods).The ambrosia fungi are filamentous yeast-allies in the order Endomycetales (especially endomycopsis and Ascoidae) and Deuteromycota(especially *Monilla* and *Ambrosiella*). The fungi form hyphae that penetrate through the wood, while surface of the tunnels and galleries are covered with a palisade layer of conidiophores, conidia, and yeast -like sprout cells that bud from conidia. The yeast like cells constitutes the ambrosial stage on which the beetles feed. It usually is the sole source of food for the larvae and is also important in the diet of the adult. This symbiotic relationship between the beetle and fungus is obligate, as neither the ambrosia fungi nor the beetles are found without the other in nature (Beaver, 1989; Kok, 1979; Norris, 1979).

The wood within which the beetles and ambrosia fungi grow is not suitable as a sole source of food for the beetles. The wood consists mainly of cellulose and lignin, which are resistant to digestion by enzymes found in most beetles. Compared with other organic resources, the wood is a poor source of nitrogen and is also deficient in B vitamins and sterols, which are required by the beetles. As the mycelium of the fungi grows through the wood outside of the tunnels, its enzyme degrades the cellulose and lignin, and nutrients are translocated through the hyphae to promote growth of the fungal cells lining the tunnels and galleries. The growth habit of the ambrosia fungi provides great advantage to the beetles because nutrients become available to them with a minimum of effort expended to produce tunnels.

The ambrosia fungi provide the beetles with a food rich in proteins, B-vitamins, and sterols such as ergosterol. The sterols are essential for the normal sexual development of the beetles, as they are required for egg-hatching, complete larval development, pupation and oocyte development. There is evidence that atleast some of the ambrosia beetles may have an absolute requirement for the ergosterol produced by the fungi.

When the beetles bore new tunnels in the spring, they prepare a mixture of faeces and wood fragments, which they smear on the tunnel walls as a bed for the fungi growth. The beds are inoculated with ambrosia fungi through incidental contact with the mycangia. The adult insects must feed on the ambrosia fungus in order to reproduce sexually-they are dependent upon particular amino acids present in the ambrosia fungus. If the founding beetles are unable to culture the ambrosia fungi, they eventually die without laying eggs. Assuming that the ambrosia fungi are established and the adult beetles do reproduce, they must continue to tend the ambrosial fungus until the larvae reach adulthood. The beetles tend to maintain a pure culture of the ambrosia fungus and are able to do so when the tunnels are fresh(Moore and Landecker, 1996).

Often, secondary ambrosia fungi (Dipodascopsis) may appear in the tunnel and the beetles may feed on them. Unlike the primary ambrosia fungus, these secondary fungi are not transported in mycangia, and the beetle is not dependent on their presence. The ambrosial stage is dominant as long as the beetles are present, but the beetles vacate the tunnel, the mycelial form dominates (as it does in pure culture). Also, contaminating fungi of several types develop profusely in a vacated tunnel.

The beetles obviously benefit greatly from this symbiotic relationship, obtaining nitrogen compounds, vitamins, and sterols from the fungus required for their growth and reproduction. The fungus also gains from this symbiotic association in several ways. Because the fungus is protected from desiccation during transport in the mycangia, the number of cells available for inoculation of wood is increased by the mycangial secretions.

Injury of the wood by beetle facilitates rapid penetration by the mycelium, and urea and uric acids in the beetle's faeces serve as an important source of nitrogen. Attempts to establish the fungus in the host plant in the absence of the beetle have been unsuccessful (Moore and Landecker, 1996)

Management of *Xylosandrus*

Cultural control

Prune the affected twigs two – three inches below the hole and burn to destroy the beetle. It should be started as soon as the first attack, and continued in regular intervals. Unwanted suckers should be removed and destroyed during summer, since the pest breed in the suckers during dry period(Anonymous, 2000). Practices that promote tree vigour and health will aid recovery from beetle damage (Dixon and Woodruff,1982; Bambara, 2003). Maintaining adequate shade is also important for the management of borer. In Malaysia, Anaur(1986) found that SHB attack on robusta and Liberian coffee in shaded and open conditions are highly different; the frequency and severity of damage was higher in shade grown robusta.

Biological control

Shot hole borers are preyed upon by woodpeckers, checkered beetles, parasitic hymeopterans and parasitic bacteria and fungi (Mike *et al*, 1993).

Parasites: The ectoparasitic mites *Pyemotes harsfsi* , feed on the immature stages of the borer, and during hot months on fresh emerged adults(Balakrishnan *et al*., 1994 b). Another species *P. ventricosus* parasitizing the borer was reported from Ivory Cost (Lavabre, 1962). A Bethilid (undescribed) is reported asparasitizing the pest (Le Pelley, 1968). A Eulophid, *Tetrastichus sp. Nr. Xylebororum* attack borer which was first time reported from India during 1992(Dhanam *et al,* 1992). Solitary pupae of *Eurytoma* sp. (Hymenoptera: Eurytomidae) were also found to be attacking this insect(Balakrishnan *et al*, 1994 b).

Predators: The grub of a clerid beetle *Callimerus* sp. prey on the pest. *Eupelmus* sp. is reported as predator which feeds on egg, larvae and pupae of the beetle(Balakrishnan *et al*, 1989). Life stages of *X. compatcus* are preyed by Formicidae (Balakrishnan *et al.*, 1994 b).

Competitors: *Asynapta,* coming under the family Cecidomyiidae is reported as the competitor of the borer (Balakrishnan *et al*, 1994 b).

Entomopathogenic fungus: *Beauveria bassiana* attacks ***X****. compactus.* Natural infection of this fungus was very low, but an experiment with sprays of conidial suspensions of the fungus at 10^7 / ml water caused 21 % of the colonies to be infested after two weeks (Balakrishnan *et al*., 1994). *Paecilomyces fumoroseus* and *Verticillium lecanii* are other two fungi found in India attacking *X. compactus* (Balakrishnan *et al,* 1994 b).

Chemical control

Due to the mode of attack it is not economically feasible to control the pest in Coffee. Complete and continuous protection of the plant is difficult (Anonymous,2000). Meiffern and Belin (1961) claimed considerable success when insecticides are sprayed mixed with fungicides. Chlorpyrifos provided 83% mortality for all the stages of this pest in flowering dogwood in Florida (Mangold *et al.,* 1977). Chlorpyrifos shows 100% mortality of adult females (Hata *et al*, 1989). A systemic fungicide, Propiconazole which prevents the fungal spores from germinating was found effective to control the borer.

Yan *et al* (2001) used quinalphos or chlorpyrifos plus cymethrin mixed with yellow soil and painted on the main stem of chest nut tree and reported good control.

Green Japanese beetle traps baited with ethanol were the most effective traps for *X. compatcus* was significantly more effective than multiple funnel traps baited with ethanol(Elsie *et al.,* 2006).

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