Tea Quarterly, 39 / 1968

THE DISTRIBUTION AND HOST-RANGE OF THE SHOT-HOLE BORER (*XYLEBORUS FORNICATUS* EICHH.) OF TEA

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The Shot-hole Borer of tea, *Xyleborus fornicatus* Eichh. is essentially an insect of the oriental tropics, its distribution extending from Ceylon to India, Burma, Indo-China, Formosa, Malaya, Indonesia, Phillipines and New Guinea. More recently it has also been found in a few pacific islands. The beetle is polyphagous, breeding in a wide variety of host plants. Altogether 99 host species have been recorded, belonging to 36 families. Among the host families, the Leguminosae, Verbinaceae, Moraceae and Euphorbiaceae seem to have a general attraction for the beetle. In Ceylon, the beetle has been found to attack 49 host species, whereas in India, Malaya and Indonesia, it has been recorded from 12, 16 and 39 host plants respectively. Tea, castor and kesambi are the principal economically-important host plants. The pest could be of importance in silviculture and fruit growing.

The need for a review on the distribution and host range of Shot-hole Borer has recently become increasingly apparent when a sustained effort is being made to devise a satisfactory method of controlling this pest. Most of the basic information on the subject is contained in numerous scattered reports. This fact, and the growing need for the collation of such data for the use of research workers have made it imperative that the information on all aspects of the subject be published in a review such as this. The main objective of this article is, therefore, to provide background information for those who are investigating such problems as the host-pest relationships and the possibility of the biological control of Shot-hole Borer. Although this has been the main aim of the writer, an effort has also been made to include every pertinent contribution in the bibliography. It is hoped that this critical review will in addition, provide useful information to those who are generally interested in this pest and in doing so would answer many questions that may have lingered on in their minds, in the past.

Geographical distribution

The existence of life zones that differ in their fauna is a well-established fact in Zoogeography. These differences are mostly attributed to the climate of the zones and also, to some extent, on the geological history of the regions. As an animal species reaches the edge of its area of distribution, it reproduces more slowly and becomes rarer until finally, zones are reached where it is an irregular casual (Filipjev 1929). At the extreme edge of a range of species, immigration and extinction tend to balance, and beyond this range, the species is not found. In the same way, in the centre of the range, the climate and other features of the habitat are optimal and the species is, therefore, found in abundance. Deviation from the environmental conditions (*eg* temperature) of the central or optimal area will usually reduce the reproductive rate which is generally a very sensitive index of such conditions (Richards 1961). These are some of the factors that underline the principles of the geographical distribution and the abundance of insects in particular areas.

The original distribution of Shot-hole Borer was restricted to the oriental region, particularly to the Indo-malayan region, extending from Ceylon to India, Burma, Malaya, Indo-China, Sumatra, Java, Borneo, the Phillippine Islands, Formosa and New Guinea. It has also been recently found in Hawaii, Fiji and the New Hebrides, where according to Schedl (1959) the occurence may have been brought about by the human agency.

TABLE 1—*The host-range of Shot-hole Borer*

Family/host plant	Economic importance	Region	References
ANACARDIACEAE			
Odina wodier (*Lannla grandio*)	Gum	India	Beeson (1930)
**Spondias dulcis*		Java	Kalshoven (1958)
ANNONACEAE			
Fissistigma elegans		Malaya	Browne (1961)
ARALIACEAE			
Arthrophyllum diversifolium		Malaya	Browne (1961)
		Sunda Islands	Browne (1961)
BIGNONIACEAE			
Pajanelia longifolia		Malaya	Browne (1961)
BIXACEAE			
Alberia gardneri (Ceylon gooseberry)	Tropical fruit	Ceylon	Rutherford (1914)
Bixa orellana (Anatto)	Annatto dye	Ceylon	Speyer (1918)
		Malaya	Rutherford (1914a)
			Browne (1961)
BOMBACARCEAE			
Bombax malabraricum	Provides "Red cotton"	Ceylon	Speyer (1918)
Ceiba pentandra	Provides "silk cotton"	Java	Kalshoven (1958)
Durio zibethinus (Civet fruit)	Tropical fruit	Java	Kalshoven (1958)
BURSERACEAE			
**Protium serratum*		Java	Kalshoven (1958)
**Canarium commune* (Java almond)		Java	Kalshoven (1958)
Unidentified spp.		Malaya	Browne (1961)
CASUARINACEAE			
Casuarina equisetifolia (Whip tree)		Ceylon	Gadd (1942)
COMBRETACEAE			
Terminalia catappa (Country almond)	Tropical fruit	Ceylon	Speyer (1918)
DIPTEROCARPEAE			
**Shorea robusta*		India	Beeson (1916)
Shorea sp.		Malaya	Browne (1961)
EUPHORBIACEAE			
**Hevea brasiliensis* (Para rubber)	Natural rubber	Ceylon	Speyer (1918)
		Java	Dammerman (1929)
		Malaya	Kalshoven (1958)
Phyllanthus emblica (Embal)	Tropical fruit	Java	Kalshoven (1958)
**Ricinus communis* (Castor)	Castor oil	India	Speyer (1918)
		Ceylon	Beeson (1930)
		Java	Kalshoven (1958)
		Sumatra	
Schima noronhae		Java	Kalshoven (1958)
FAGACEAE			
Castamopsis spp. (2)		Malaya	Browne (1961)
		Sunda Islands	Browne (1961)
Kopsia flavida		Java	Kalshoven (1958)
FLACOURTIACEAE			
Alberia gardneri (=*Dovyalis hebecarpa*	Tropical fruit (Ketambilla)	Ceylon	Rutherford (1914 a)
LAURACEAE			
Persia gratissima (Avocado)	Tropical fruit	Ceylon	Speyer (1918)
LECYTHIDACEAE			
Planchonia sp.		Ceylon	Speyer (1923)

LEGUMINOSAE			
Albizia chinensis (=*A.stipulata*)	Shade for tea, Fuel	Ceylon	Rutherford (1914a)
**Albizia falcata* (=*A.moluccana*)	Shade for tea	Ceylon	Speyer (1918) Beeson (1930) Judenko (1961)
Albizia odoratissima	Shade for tea	India	Beeson (1930)
Albizia procera		Java	Kalshoven (1958)
Albizia sumatrana	Shade for tea	Ceylon	Judenko (1961)
Bauhinia sp.		Ceylon	Rutherford (1914a)
Bauhinia malabarica		Java	Kalshoven (1958)
Cassia alata	Ornamental	Ceylon	Speyer (1918)
Cassia fistula		Java	Kalshoven (1958)
Crotalaria anagyroides	Green manuring	Ceylon	Huston (1932)
Crotalaria sp.	Green manuring	India	Rau (1937)
**Crotalaria striata*	Green manuring	Ceylon	Rutherford (1914a) Speyer (1918)
**Crotalaria usaramoensis*	Green manuring	Ceylon	Gadd (1942)
Dalbergia latifolia		Java	Kalshoven (1958)
Derris eliptica	Fish poison, Insecticide	Java	Kalshoven (1958)
Derris robusta		Ceylon	Light (1928)
Desmodium cephalotes		Ceylon	Speyer (1918)
Erythrina indica	Ornamental	India	Beeson (1930)
Erythrina lithosperma	Shade for tea	Ceylon	Speyer (1918) Gadd (1942) Judenko (1961)
Gliricidia sepium	Shade for tea	Ceylon	Gadd (1942)
**Inca vera*		Java	Kalshoven (1958)
Intsia palembanica		Malaya	Browne (1961)
**Mimosa bracaatinga*		Ceylon	King (1940a)
Parkia speciosa		Java	Kalshoven (1958)
Peltaphorum ferrugenium		Java	Kalshoven (1958)
**Pithecolobium lobatum*		Java	Kalshoven (1958)
Poinciana regia	Ornamental, shade	Ceylon	Rutherford (1914a)
**Tephrosia candida*	Green manuring	Ceylon	Speyer (1918) King (1941)
Tephrosia maxima	Ornamental	Ceylon	Speyer (1923)
Tephrosia sp.		Sumatra	Kalshoven (1958)
**Tephrosia vogelii*		Ceylon	Speyer (1918)
Tephrosia mozuma		Java	Schedl (1931)
LOGANIACEAE			
Fagraea gigantea		Malaya	Browne (1961)
MAGNOLIACEAE			
Michelia vulutina (Manglit)	Timber	Java	Kalshoven (1958)
MALVACEAE			
Gossampinus hexaphylla		Java	Kalshoven (1958)
MELASTOMACEAE			
Melastoma sp.		Ceylon	Rutherford (1914a)
Melastoma malabathricum		Ceylon	Speyer (1918)
MELIACEAE			
Lansium domesticum (Langsat)	Tropical fruit	Java	Kalshoven (1958)
Cedrela toona (Indian mahogany)	Timber	Ceylon	King (1940b)
Swietenia mahagoni		Java Sumatra	Kalshoven (1958)
MORACEAE			
*Artocarpus integra (Jack)	Timber Tropical fruit	Java	Kalshoven (1958)
Ficus hispida		Ceylon	Speyer (1923)
Ficus nervosa		Ceylon	Beeson (1930)
Ficus septica		Java	Kalshoven (1958)
**Ficus toxicaria*		Java	Kalshoven (1958)

MORINGACEAE			
**Moringa obifera* (Horse-raddish)	Vegetable	Java	Kalshoven (1958)
MYRISTICACEAE			
Myristica fragrans (Nutmeg)	Spice	Ceylon	Speyer (1918)
		Malaya	Dammerman (1929)
MYRTACEAE			
Psydium guayava	Tropical fruit	Ceylon	Green (1903)
PALMACEAE			
Caryota urens (Kitul palm)	Toddy, sago, palm sugar, timber	Ceylon	Speyer (1918)
PROTEACEAE			
Grevillea robusta	Timber, fuel and shade for tea cultivation	Ceylon	Speyer (1918)
ROSACEAE			
Photinia japonica (Loquat)	Tropical fruit	Ceylon	Rutherford (1914a)
			Speyer (1918)
Planchonia sp.		Java	Kalshoven (1958)
RUBIACEAE			
Anthocephalus indicus		India	Beeson (1930)
			Kalshoven (1958)
Cinchona calisaya	Quinine	India	Speyer (1918)
		Ceylon	Beeson (1925)
Ixora parviflora		India	Beeson (1930)
		Ceylon	Beeson (1925)
RUTACEAE			
Citrus aurantium	Fruit	Ceylon	Huston (1932)
SAPINDACEAE			
Allophylus cobbe		Ceylon	Speyer (1918)
Schleichera sp.		Malaya	Dammerman (1929)
**Schleichera olesa*	Timber, oil	Java	Van Hall (1920)
		Sumatra	Van Hall (1925)
			Kalshoven (1958)
STERCULIACEAE			
*Theobroma cacao	Cocoa beverage	Java	Speyer (1918)
		Ceylon	Dammerman (1929)
		Malaya	Kalshoven (1958)
		Sunda Islands	Browne (1961)
			Browne (1961)
Scaphium affine		Malaya	Brown (1961)
THEACEAE			
**Camellia sinensis*	Tea beverage	India	Beeson (1930)
		Ceylon	Speyer (1918)
		Indonesia	Kalshoven (1958)
		Formosa	Sonan & Tadasa (1939)
URTICACEAE			
Trema orientalis		Java	Kalshoven (1958)
VERBENACEAE			
Clerodendron infortunatum		Ceylon	Gadd (1942)
Clerodendron siphonanthus		Ceylon	Speyer (1923)
Clerodendron sp.		Ceylon	Speyer (1918)
Camelina arborea		India	Beeson (1930)
		Malaya	Browne (1961)
		Sunda Islands	Browne (1961)
Lantana aculeata		Ceylon	Speyer (1923)
Lantana sp.		Ceylon	Green (1903)
Petraea volubilis		Ceylon	Speyer (1918)
Tectona grandis	Timber	Java	Kalshoven (1958)
		Burma	Beeson (1925)
Vitex pubescens		Java	Beeson (1935)
		Sumatra	

*Able to breed in

Distribution in Ceylon

In Ceylon the distribution of Shot-hole Borer as a pest is limited to regions ranging from about 500 ft to 4,000 ft in altitude, where it does serious damage to tea; but it has been recorded up to 4,500 ft and below 500 ft. Within the range 500 to 4,000 ft, there is an ascending and a descending gradation in its abundance, with peak populations within the range 1,500 to 3,000 ft. Above 4,000 ft and below 500 ft it is not a serious pest of tea. Outside the zone of economic damage, therefore, the beetle may be present in low numbers and in isolated habitats.

The history of the beetle's distribution in Ceylon shows that it was first noticed at Craighead Estate, Nawalapitiya in 1892. The next record comes from Atabagie Estate in the Pussellawa District in 1899, and according to Speyer (1918), by 1903 the insect was already distributed in a number of widely-separated districts. By 1909, estates in Maturata and Wattegama were added to the affected list. Since 1912, the range extended to Balangoda, Dickoya, Dolosbage, Galle, Haputale, Kalutara, Kandy, Kegalle, Madulsima, Matale, Ratnapura and Uva. These regions cover the whole of the mid-country, low-country and Uva tea-growing districts, and represents about two thirds of the tea-growing areas in Ceylon.

Host range

The first description of *Xyleborus fornicatus* was made by Eichoff (1868), from a specimen collected in Ceylon, from an unknown host plant. Although there was tea in Ceylon at that time its range of distribution was confined to a few specimens in the Royal Botanical Gardens, Peradeniya and a few newly-planted acres on Loolecondera Estate (Lower Hewaheta District). It is improbable, though not impossible, that Eichoff's specimens were attacking the tea plant. It is, however, more likely that Shot-hole Borer was originally restricted to tropical forests with a large number of host species (Table 1). The beetle has now adapted itself to tea bushes (Schedl 1959) and thrives in living tea plants, causing considerable damage, particularly in Ceylon, Taiwan and South India. According to Speyer (1918) and Beeson (1930) the castor oil plant (*Ricinus communis*) is another principal host plant. In Ceylon records from castor are rare at present because of the legislation enacted in 1916 prohibiting the growing of castor in the tea-growing districts.

In India, the area of distribution of Shot-hole Borer is very restricted and is confined mostly to the Central Travencore District in Southern India where it is increasingly becoming a serious pest of tea (Ananthakrishnan 1961). Its occurence in tea in Java and Sumatra is occasional, but it has become a pest of kesambi plants (*Schleichera oleosa*) which provide an oil seed of some importance (Kalshoven 1958). In Malaysia it is a potential menace to pure plantations of forest or agricultural trees, but it has not yet been shown to be destructive (Browne 1961). Table 1 summarizes the available knowledge on the host range of Shot-hole Borer. It is apparent from Table 1 that in addition to tea, the beetle is associated with a number of other economically important plants such as teak, avocado, *Citrus,* castor, cocoa, derris, rubber, cinchona, nutmeg and *Caryota* (Kitul palm).

It is interesting to note that the borer is also associated with a number of trees grown for shade and for green manure on tea estates. Judenko (1961) has pointed out that the beetle can successfully breed only in *Albizia falcata* and *Erythrina lithosperma.* Among the green manure trees, there are records of its ability to breed in *Crotalaria* spp. and *Tephrosia candida.*

The family to which the Shot-hole Borer belongs (Scolytidae), can be divided into four ecological groups according to the nature of their breeding material (Rudinsky 1962). On this classification, *X. fornicatus* comes within the group which

invades living, normal and healthy trees, and are designated as primary borers. It has also in a few instances shown tendencies to become a secondary borer as it can attack living trees of subnormal physiological condition, temporarily or permanently weakened by drought, age, fungi, competition, defoliation, injury *etc.* Such instances have been recorded by Eggers (1922); Beeson (1925) and Kalshoven (1958).

Schedl (1958) has proposed a number of terms to denote the degree of host selection in arboricole (wood-boring) insects. According to this, *X. fornicatus* comes under polyphagy of the first degree in which the insect is associated with many plants of different families, but of the same botanical class. It should be noted that the terms ending in the suffix -phagy are not strictly applicable to ambrosia beetles, because they denote 'feeding'; but in this instance, the beetle does not feed directly on the host.

TABLE 2—*Host families of Shot-hole Borer*

Family	Number of host species recorded			
	Ceylon	India	Malaya	Indonesia
Anacardiaceae	—	1	—	1
Annoniaceae	—	—	1	—
Araliaceae	—	—	1	1
Bignoniaceae	—	—	1	—
Bixaceae	2	—	1	—
Bombacaraceae	1	—	—	2
Burseraceae	—	—	1	2
Casurinaceae	1	—	—	—
Combretaceae	1	—	—	—
Dipterocarpaceae	—	1	1	—
Euphorbiaceae	2	1	1	4
Fagaceae	—	—	2	2
Flacourtiaceae	1	—	—	—
Lauraceae	1	—	—	—
Lecythidaceae	1	—	—	—
Leguminosae	17	3	1	11
Loganiaceae	—	—	1	—
Magnoliaceae	—	—	—	1
Malvaceae	—	—	—	1
Melastomaceae	2	—	—	—
Meliaceae	1	—	—	2
Moraceae	2	—	—	3
Moringaceae	—	—	—	1
Myristicaceae	1	—	1	—
Myrtaceae	1	—	—	—
Palmaceae	1	—	—	—
Protaceae	1	—	—	—
Rosaceae	1	—	—	1
Rubiaceae	2	3	—	—
Rutaceae	1	—	—	—
Sapindaceae	1	—	1	1
Staphyleaceae				
Sterculiaceae	1	—	2	2
Theaceae	1	1	—	1
Urticaceae	—	—	—	1
Verbinaceae	6	2	1	2

The feeding habit of Shot-hole Borer may be termed xylomycetophagy (Schedl 1958) in which the beetles commonly known as ambrosia beetles, live in tunnels in wood but feed on moulds (ambrosia fungi) that grow on the walls of the burrows. The ambrosia fungus of shot-hole borer of tea is known as *Monacrosporium ambrosium* (Gadd & Loos 1947). The spores, stored in a buccal pouch of the female, are disseminated during the construction of the gallery (Fernando 1960). Although Table 1 indicates that the beetle is able to breed in a large number

of host plants, particularly of the family Leguminosae, there is also a certain amount of selectivity as is indicated by its preference to, and wide occurrence in tea, castor and kesambi. The host families of Shot-hole Borer are listed in Table 2. It will be noticed that nearly every major woody plant family of the oriental tropics is included, with the noteworthy exception of members of the Sapotaceae. Among the families included, the Leguminosae, Verbenaceae, Moraceae and Euphorbiaceae seem to have a strong attraction for this species. It is also noteworthy that the beetle has been recorded from 99 host plants altogether. It is clearly known that the borer is able to breed in 21 of these species (see Table 1).

Host resistance

Resistance to shot-hole borer attack has been shown by healthy *Grevillea obusta* (Green 1903), *Poinciana regia, Alberia gardneri* (Rutherford 1914), *Swietenia mahogoni* and *S.macrophylla, Albizia procera* and *Adenthera microsperma* (Kalshoven 1958). These plants resist the attack by exuding gum in which the beetles get entrapped. Similarly, a number of plants such as *Dalbergia latifolia, Tectona grandis, Vitex pubescens, Peltophorum ferrugineum, Cassia fistula, Trema orientalis* and *Cebia pentranda* react by the exudation of sap (Kalshoven 1958), and the borer succeeds only in piercing the bark or penetrating the wood for only a few millimetres. More recently, several instances of shot-hole borer attack on *Hakea saligna* have been reported to the author. *H.saligna* was recently introduced into Ceylon from East Africa as a shelter plant for tea fields. *H.saligna* produces a gum and, therefore, the Shot-hole Borer is not able to construct complete galleries in its stems.

Among tea clones, the highest tolerance and/or resistance to Shot-hole Borer have been shown by TRI 2023, QT 1/5, NL 4/2 and OT 5/8, but of these only TRI 2023 possesses the other suitable characteristics required to justify large scale propagation. Comprehensive lists of tolerant and susceptible clones tested in the mid country, are given in two recent publications (Calnaido & Kanapathipillai 1967; Thirugnanasuntharam & Calnaido 1968).

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(*Accepted for Publication—14th July 1968*)