HISTORICAL REVIEW OF SHOT-HOLE BORER INVESTIGATIONS

G. D. Austin

Shot-hole borer, (*Xyleborus fornicatus*), has been recognised as one of the most serious pests of tea for the past sixty years and for several years was the subject of almost continuous study. No insect pest in this country has been investigated by such a galaxy of experts—first by Green (1898-1913), Rutherford (1913-1915), Speyer (1914-1919) and Jepson (1920-1926) of the Department of Agriculture; then from 1936 by Stuart Light, Redman-King, Gadd, Baptist and, since August 1955, Judenko of the Tea Research Institute of Ceylon.

Partly owing to its wide range of distribution, in that it appears in tea from an elevation of 4,000 feet downwards, there is probably no other insect pest of tea in Ceylon with which planters are more familiar, by name if not experience, or which has been more prominently before the planting public, than this little beetle.

The first mention of *Xyleborus fornicatus* was in 1868 when the female beetle was described by Eichoff from a specimen collected in Ceylon. Unfortunately there is no record either of the locality or of the host plant from which Eichoff's type specimen was secured, but since it was at this time that the tea industry was established in the island it is possible that Eichoff's specimens were obtained from the tea plant.

It is not known whether the insect is indigenous to Ceylon or whether it has been introduced. Outside Ceylon this species is known to occur only in Java, Malaya, Formosa and India. If introduced, therefore, it probably originated from one of these countries and may have been established in some growing plant which had been imported.

It is interesting to record that Speyer was of the opinion that there were two races of this species—a large and a small one. Both races attack *Albizzia falcata* with equal frequency but the larger race is more often found in *Ricinus cummunis* (the castor oil plant) and *Erythrina lithosperma* (the common dadap) while the smaller one predominates in tea.

In 1890, Mr. E. E. Green, at that time a tea planter and subsequently Ceylon's first Government Entomologist, published a book entitled "Insect Pests of the Tea Plant". Although most of the familiar pests of tea are dealt with in this work, it is interesting to find that no mention is made of shot-hole borer, from which it may be concluded that the insect at that time was not considered a pest of tea. In 1892, however, it was reported on tea for the first time when it appeared on Craighead Estate, Nawalapitiya.

In 1903 the beetle had invaded Uva and the Government Entomologist reported that this Province, which from its position was usually the last to be affected by new pests, had not escaped, the borer having established itself in the Haputale and Badulla districts.

The same year Green published a most readable description of the beetle, giving an account of its life history and habits in the "Circulars of the Royal Botanic Garden, Peradeniya". Even after half a century this publication is still the best account of the pest.

In 1907 it was declared a pest under Ordinance 7 to check its internal distribution.

By 1909 Green was considering biological control, and subsequently imported a predacious beetle (*Clerus formicarious*) from Scotland. But when the consignment arrived it was found that the larvae of *C. formicarious* were too large to live in the galleries of *Xyleborus fornicatus*!

By 1910 the pest had appeared in Sabaragamuwa when it was observed to have spread in the Balangoda and Ratnapura districts. Invasion is reported to have occurred through infested planting material brought over from the Ambegamuwa and Lower Hewaheta districts.

By 1912 the ordinance passed previously had been proved ineffective and the beetle was declared a pest within the meaning of Ordinauce No. 6 of 1907, which made it compulsory for an affected estate to report its presence to the Department of Agriculture.

In 1913 Green resigned his post of Entomologist and was succeeded by Andrew Rutherford. During the brief spell of two years—until his untimely death in 1915—Rutherford concentrated his investigations on a study of the insect underground. The results of his experiments proved that the beetle could live, breed and multiply in prunings, buried to any depth consistent with estate practice. Rutherford was of the opinion that the burial of prunings, as a means of control, was useless, and that certain disadvantages would accrue from the concentration of so much decaying organic matter in close proximity to the roots of the tea plants. He therefore recommended burning of the prunings as the only effective method of control.

1914 saw the appointment of E. R. Speyer as Special Entomologist to investigate the shot-hole borer problem. Speyer was in the island until 1919 and carried out his investigations at Peradeniya and at Poonagalla Estate in Uva. He made a careful study of the problem and published his findings in 23 papers, which appeared in the Tropical Agriculturist, and as leaflets and bulletins of the Department of Agriculture. His first big work the "Treatment of Prunings on Infested Estates" dealt with his experiments to ascertain the effect of the disposal of prunings on the habits and propagation of the beetle. His chief findings, in his own words, were that "when prunings are buried to depths varying from 4 to 18 inches below the ground, with or without the manurial mixtures commonly used on estates, development in the woody stems proceeds normally below the ground for a period of at least 30 days. From these depths adult female beetles may continue to reach the soil surface during a period of at least 56 days in dry weather and for a lesser period in heavy rains".

Speyer's results corroborated those of Rutherford that the wholesale burial of prunings was not an efficacious measure of control. He, therefore, suggested that the soundest method of disposing of prunings was to "slash off the leaves and small twigs from the branches after they have been cut from the bushes. These are buried in holes or forked into the soil, and the remaining thicker wood is burnt immediately, and the ashes returned to the soil. Leaving the prunings on the ground and burying the prunings, both allow adult beetles to escape".

Speyer's next investigation was a control pruning scheme and the application of a special paint to be applied to the collars and lower branches. The chief aim of the paint was "to prevent insects escaping from the bushes between the time of pruning and the output of new shoots and also to protect the 'eyes' of the branches from attack by borer".

Speyer was also of opinion that the true host of *Xyleborus fornicatus* was the castor oil plant, *Ricinus communis*, and that the only remedy was the complete extermination of this plant throughout the whole tea growing area. He also proposed to break up the vast tea areas by shelter belts of immune trees and undergrowth, in order to check migration and facilitate control.

With the departure of Speyer in 1919, F. P. Jepson was appointed Special Entomologist for shot-hole borer investigations and he worked on the pest until 1926. Jepson too carried out part of his investigations in Uva, on Sarnia Group near Badulla. His first assignment was to try out some of Speyer's recommendations relating to the control pruning scheme and "Speyer's Mixture" and the treatment of buried prunings on shot-hole borer infested estates. Jepson's experiments indicated that Speyer's control pruning scheme resulted in too severe a mutilation of the bush to warrant its adoption; the paint mixture was too costly to be used generally and tended to cause injury to the bushes and promote die-back.

Jepson was not content to pursue only the lines of research hitherto followed, because this work had been almost exclusively confined to the investigation of measures designed to reduce the numbers of the pest. He, therefore, decided to investigate the possibilities of agricultural methods with special reference to manuring.

He was also not satisfied with Speyer's recommendation relating to the destruction of prunings. He, therefore, decided "that the action of all manures, in common use, should be tested (with buried prunings) as in the event of a fertiliser being found to have a beneficial agency in causing the death of the inmates below ground, it would, at the same time, augment the fertilising value of the prunings". The results were most disappointing and Jepson had to fall back on Speyer's recommendation to lop the smaller prunings, bury them, and burn the larger branches.

Jepson next launched a series of manurial experiments. The first, which was of a preliminary nature, was a trial with a selection of individual manures to ascertain the effects of nitrogen, potash and phosphoric acid upon shot-hole borer. Gadd, then Assistant Mycologist in the Department of Agriculture, analysed Jepson's data and their conclusion was that potash was beneficial except when combined with nitrogen as nitrate of potash.

These results encouraged Jepson to determine the effects of a complete fertiliser applied at varying rates per acre, and of several artificial manures. The results may be summarised as follows:—

The manuring of tea does not definitely impart any degree of immunity to the bushes against shot-hole borer attack, though the complete manure mixture plots showed more empty galleries than the controls. Manuring, however, definitely promotes healing over of the entrance to the galleries.

Jepson also looked into the possibilities of biological control. He considered that the prospect of controlling shot-hole borer by means of natural enemies "was not promising", but that its possibility should not be dismissed until a thorough search had been made for enemies of the pest in countries other than Ceylon, where the species was known, or might later be found to occur.

As to chemical control Jepson was of opinion that while insecticidal measures were an invaluable method of controlling many pests they could not profitably be adopted against shot-hole borer.

His final recommendations at the Agricultural Conference at Peradeniya in March 1926 were that "shot-hole borer cannot be exterminated or economically reduced, nor can the bushes be protected against attack. They can, however, be so

stimulated by systematic and suitable manuring that the damage caused by the borer is inconsiderable and in some cases almost negligible."

1926 saw the establishment of the Tea Research Institute of Ceylon. The investigation of shot-hole borer and other pests of tea was passed on by the Department of Agriculture to the Tea Research Institute. Jepson's recommendations continued to be advocated by the Institute until a further enquiry into the shot-hole borer problem was opened at the newly established sub-station at Passara towards the end of 1935.

From 1936 onwards the problem was investigated by Austin and Fonseka at Passara, and the results of their experiments were published in a series of papers by Redman-King and Gadd in both the *Tea Quarterly* and the Annals of Applied Biology. An early achievement was the determination of the life history of the beetle under field conditions—hitherto never attempted by earlier workers.

The life history was recorded as follows:— from the commencement of boring a gallery to egg-laying, 8 days; egg period, 7 days; larval stage, 15 days; pupal stage, 7 days. The life cycle, therefore, from egg to egg was found to be about 40 days. It was also observed that beetles were most active during the warmer parts of the day, emerging from galleries between 10 a.m. and 2 p.m. Green and Speyer had studied the behaviour of the beetles and recorded that they flew a certain distance and Speyer was emphatic that they were not attracted to lights at night. Mating was never observed.

Ten years later Gadd and Loos described the Ambrosia fungus present in galleries, as *Monacrosporium ambrosium*. Speyer had earlier referred to *Monacrosporium* as a finding by Petch and he himself had also observed the spores of the fungus within galleries about 7 days after the female beetle had commenced to bore a gallery in the stem. The same year (1946) Gadd succeeded in rearing the beetle from egg to adult in artificial cultures of *Monacrosporium ambrosium* at St. Coombs.

Damage to the tea bush is assessed as follows:— Primary damage is caused during the construction of galleries in the stems. This of itself would be of little importance were it not for other consequences which result more or less accidentally from the presence of the galleries. The consequences, really secondary damage, are:— (1) die-back, (2) wood-rot, (3) branch breakage. The last named is the most important as it leads to the greatest loss of crop.

Very interesting information was next collected from the Passara N.P.K. experiment. This experiment was designed and laid down by Eden, with the object of determining the effect of manurial treatments on the yield of tea in a shot-hole borer infested area of the Passara district, at an elevation of 3,500 feet above sea level. The treatments were as follows:—

(1) No manure.

(2) Nitrogen alone at the rate of 40 lbs. per acre per annum.

(3) Potash alone at 40 lbs. per acre.

(4) Phosphate alone at 30 lbs. per acre.

(5) Nitrogen and potash together.

(6) Nitrogen and phosphate.

(7) Potash and phosphate.

(8) A complete mixture of nitrogen, phosphate and potash.

Where more than one element was used the quantity of each was the same as that applied alone.

Jepson's experiments had indicated that nitrogen, potash and phosphates all tended individually to promote the healing of galleries. It was assumed that such healing would be beneficial in preventing branch-breakage, and Gadd, therefore, analysed Jepson's data and also the data collected at Passara to answer the question: "Does the use of manures reduce the number of broken branches?" To quote Gadd: "Manuring does not reduce damage caused by shot-hole borer. The number of broken branches collected from the experiemntal plots was greatest in the plots giving the heaviest crops. Nitrogen caused the greatest increase in yield; it also caused the greatest increase in insect damage". Furthermore, it was subsequently proved that in any case healing of galleries in no way prevented branch breakage.

Another experiment proved that there was a definite relationship between shot-hole borer and wood-rot; both die-back and wood-rot were more extensive in shot-hole borer infested branches than in non-infested branches.

Earlier experiments at Passara also indicated that:—

(1) Attack by shot hole borer does not become of economic importance during the first year from pruning.

(2) The main period of attack is usually in the latter half of the second year when the number of galleries increases.

(3) The attack dies out in the third year.

(4) Sufficient occupied galleries are left after pruning to ensure an attack during the next pruning cycle.

(5) Such measures as the burning of prunings can do little or nothing towards preventing a later attack.

(6) The heavy mortality amongst adult beetles, coupled with the mortality that occurs in the galleries, raises doubt that the presence of a parasite would materially improve matters.

During 1952, an intensive six months' study of the pest in new clearings was undertaken by the Assistant Entomologist on an estate in the Ratnapura district. The following are a few of the main observations recorded:—

(1) *Xyleborus fornicatus* and *X. compectus* were the only two species of borer met with, *X. fornicatus* being the commoner species.

(2) Nursery plants, supplies and young tea in clearings are liable to attack when plants are 12 to 18 months old.

(3) Early attacks are slight.

(4) Severe infestation occurs when plants reach their fourth year from planting, and are ready for plucking.

(5) Destruction or removal of prunings does not contribute to a decrease in the intensity of future attacks. This observation corroborates evidence first obtained at Passara.

(6) No parasitic or predacious insect was found in the thousands of galleries dissected.

(7) The whitish exudation, frequently found within galleries, and occasionally emanating from entrance holes, and associated with dead beetles and larvae, was found to be a species of saprophytic bacteria.

(8) Of several insecticides tested, Dieldrin gave the most promising results.

In 1953 a few field experiments were laid down in Sabaragamuwa, the more important of which were to determine (1) loss of crop, (2) age of young tea most susceptible to borer and (3), the feasibility of chemical control in clearings.

A feature of these experiments was the appearance and persistence of tea tortrix in the sprayed areas, especially in those treated with Dieldrin. This underlines very forcibly the risks of applying new persistent insecticides, the effects of which are unpredictable on the natural enemies of insects other than the pest to be controlled.

Dr. Baptist, during the short period he was in the Institute, made a study of the problem. In a paper in the *Tea Quarterly* entitled "Tea Leaf-eating Tortrix Caterpillar as a Limiting Factor in Insecticidal Application on Tea" he indicated that insecticidal applications should only be made in the period immediately following pruning.

1955 saw an intensive study of the pest being launched in a search for clonal material resistant to borer; a resolution from the Sabaragamuwa Planters' Association that there should be a symposium on shot-hole borer; and the arrival of Dr. Judenko to investigate the problem.