TEA ENTOMOLOGY IN PERSPECTIVE

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There are about one hundred and sixty five species of insects and six species of mites recorded as feeding or breeding on tea in Ceylon ; of this number only about 25 insects and four mites are regarded as pests. The Tea Tortrix (*Homona coffearia* Nietner) and the Nettle Grubs (*Lepidoptera :* Limacodidae) are the main leaf feeders. The Shot-hole Borer of Tea (*Xylcborus fornicatus* Eichh.), a stem-boring beetle, is our most important insect pest, and is responsible for much economic damage. The White Grub (*Holotrichia disparilis* Arrow), a subterranean feeder of the collar and the roots of tea can be a serious pest of newly planted bushes at high elevations. The four species of mites, the Yellow Mite (*Hemitarsonemus latus* Banks), The Red Spider Mite (*Oligonychus coffeae* Nietner), the Purple Mite (*Calacarus carinatus* Green) and the Scarlet Mite (*Brevipalpus californicus* Banks), feed on the sap of tea leaves and are important pests in certain districts. This article pinpoints these and other entomological problems of tea, traces the development of their control measures during our first hundred years of tea cultivation, and discusses their complexes and also reviews the present position.

The Pests

The first major entomological problem that faced Ceylon's tea industry was that of the Tea Tortrix. Although first recorded from the coffee plant in 1861 by Nietner, it was not considered an important coffee pest. The first extensive outbreak of Tortrix on tea was in 1889 when it began to plague the estates in the Dimbula and Dickoya districts. Subsequent attacks during the years 1911 to 1914 in many tea growing areas caused considerable alarm. Between 1917 and 1919 the Tortrix problem was the subject of a special investigation by entomologists of the Department of Agriculture. With the establishment of the Tea Research Institute of Ceylon in 1926, the problem became the Institute's responsibility. The impressive work of the TRI entomologists during this period culminated in the introduction of the parasite *Macrocentrus homonae* Nixon from Java in 1935 and 1936. The parasite was first released at St Coombs and later on two estates in Maskeliya. They multiplied fast and eliminated the pest status of Tortrix within a few years. Control of Tortrix by *Macrocentrus* is often cited as one of the most successful instances of biological control ever achieved anywhere in the world. Tortrix control in 1936 must certainly rank as an important milestone in the development of pest control on tea for otherwise, this caterpillar would have been a serious problem on tea, even today.

The earliest report of a nettle grub as a pest in Ceylon was made by Nietner in 1817 when he referred to *Parasa lepida* as a pest of coffee. This species which is commonly called the Blue Striped Nettle Grub was at that time known as *Limadodes graciosa*. It assumed pest status on tea in 1890. It was only in 1899 however, that nettle grubs became prominent when the first outbreak of *Thosea recta* occurred in the Morawak Korale District. This species later came to be commonly known as the Morawak Korale Nettle Grub. Nettle grub attacks became serious in the 1920's and 1930's, by which time seven species were known to be involved, the commonest being the Fringed Nettle Grub (*Macroplectra nararia* Moore), the Blue Striped Nettle Grub (*Parasa lepida* Cramer), the Morawak-Korale Nettle Grub and the Saddle Backed Nettle Grub (*Thosea cervina Moore*). Associated with nettle grubs, and belonging to the same family are the small Green Gelatine Grub (*Narosa conspersa*) Walker), not uncommon but very seldom a serious pest, and the large Gelatine

Grub (*Belippa laleana* Moore), which is of minor importance and is found only in small numbers. At present nettle grub outbreaks are seasonal and localized, but cause devasting damage if uncontrolled, and in general, estates in the Uva Province and less frequently in certain low and mid-country districts are affected. Among the other important leaf eating caterpillars are the Twig Caterpillar (*Ectropis bhurmitra* Warr), and the Looper Caterpillar (*Buzura strigaria* Moore) which came into prominence recently. The first outbreak of the Twig Caterpillar occurred in 1900 in the Kandy district, but the recent occurrences appear to be a biological side-effect associated with dieldrin spraying for shot-hole borer control. In addition to these, there are about ten other caterpillar species which are less important as pests, and are referred to below.

In contrast to the extensive damage caused by caterpillar pests, damage done by the four species of mites is relatively less ; Indeed in most cases their attack is insidious, with a slowly increasing percentage of yield losses due to their depredations. The damage appears as a defoliation, stunting or a general debilitation of the bushes.

The White Grub, *Holotrichia disparilis* is of considerable economic importance when new clearings are opened in districts above 3000 feet. The damage is more predominant above 4000 feet and is serious in the first year in new clearings and nurseries where the larvae feed on roots and lower parts of stems, ultimately causing ring-barking at soil level. There are six other species of white grubs associated with tea, but there is no evidence that they do any damage except perhaps *Anomala superflua* Arrow which does occasional damage to tea roots in the low country.

The most complex and serious pest problem in tea today is that of the Shot-hole Borer. This scolytid beetle has been a serious pest of Ceylon tea for over sixty years and is responsible for considerable losses of crop in more than a third the Ceylon's tea acreage. It is present in abundance between the elevations of 1000 and 4000 feet covering an area of about 200,000 acres involving almost the whole tea area in the Mid Country, Uva and Low Country. The young mature females damage tea stems by making galleries to bring up their broods. This causes branch breakage, wood rot and destruction of buds before they emerge, all of which ultimately lead to dieback of branches and dilapidation of bushes. This, the most elusive of all tea pest problems, has been tackled by no less than fifteen senior entomologists since 1898, but an acceptable answer to its elimination is yet to be found.

Plant feeding bugs on tea are represented by the Lygus Bug (*Lygus viridanu* Motsch.), the Tea Mosquito Bug (*Helopeltis theivora* Waterh.), the Tea Aphid (*Toxoptera anrantii* Boyer), and the scales, Brown Bug (*Saissetia coffea* Wlk.), and the Green Bug (*Coccus viridis* Green). The Lygus Bug feeds on the buds and young leaves inducing necrosis around the feeding punctures and is responsible for the so-called ' corroded flush '. It is found only at high elevations between 4000 and 6500 feet. The Tea Mosquito Bug is a rare low-country pest largely confined to the Morawak-Korale District causing damage similar to that caused by *Lygus*, but the necrotic areas of leaves are larger. The Tea Aphis is an occasional pest found in nurseries and newly pruned fields. As their attack is confined to the youngest leaves and buds, aphids are unusual on tea in plucking. The Green Bug and the Brown Bug are occasional high-country pests generally found on the green shoots and undersides of leaves along the mid-ribs and veins. Outbreaks occur mainly during the dry seasons of the year.

The Termites are a group that are considered as minor pests. There are several species of termites associated with tea, but the Live-wood Termite of the high-country (*Neotermes militaris* Desneux) is the species that is most damaging to tea plants at elevations between 3500 and 4500 ft, particularly in the Maskeliya District. The

PLATE 1 — *The caterpillars of the Tea Tortrix feeding on tea leaves*

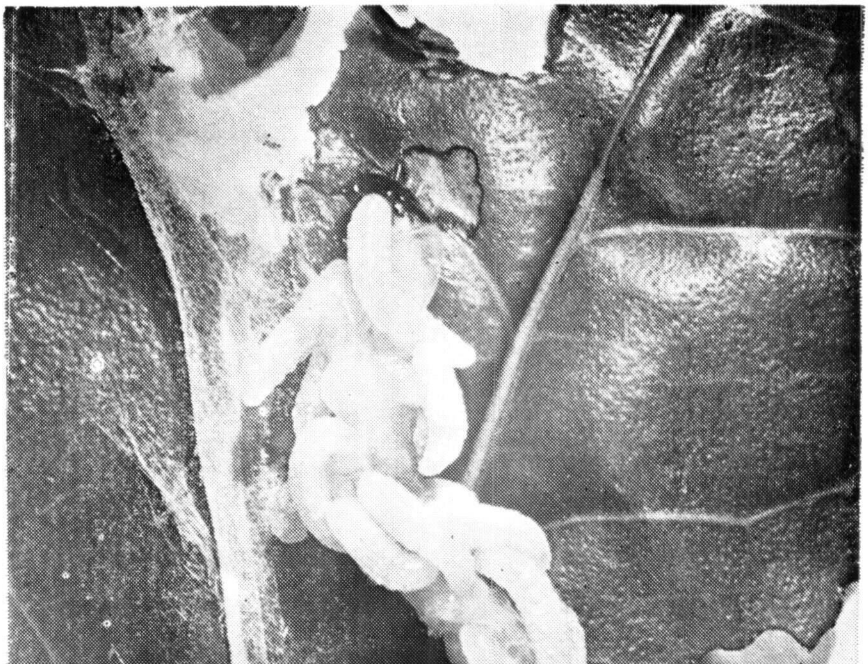

PLATE 2 — *The larvae of the parasite of Tortrix* (Macrocentrus homonae) *emerging from a parasitized caterpillar*

low-country counterpart of this species is *Glyptotermes dilatatus* which is widely distributed below 3000 feet. *Coptotermes formosanus* Shiraki is another destructive live-wood termite which is said to be a recent introduction into Ceylon. Then there are the mound-building and soil-nesting termites belonging to the genera *Hospitalitermes, Odontotermes, Nasutitermes, Micorcerotermes* and *Hypotermes*, which are all strictly scavengers feeding on dead wood, but cause secondary damage during the process.

Pest Origins

Before the introduction of tea into Ceylon some of the more important insect and mite pests were found on coffee where they did little or no damage. When coffee was replaced with tea, these pests transferred their activities to the tea plant, acquiring the status of serious pests. The Tea Tortrix, the Blue Striped Nettle Grub, and the Red Spider Mite are three such examples. As tea is an introduced plant, brought in the form of seed, it is unlikely that the pests were introduced at the same time. The species that were not coffee pests were feeders of other host plants, *eg* the Shot-hole Borer originally lived on the Castor Oil Plant (*Ricinus communis*). Some were forest insects like the up-country Tea Termite (*Neotermes militaris*), the Red Slug (*Eterusia aedea cingala*) and the Twig and Looper Caterpillars. *Neotermes militaris* was evidently a legacy from forest trees which were felled to open land for tea. In addition to the castor oil plant, the Shot-hole Borer is known to breed on 26 host plants the majority of which are forest trees.

Certain species may have been introduced with the shade and green manure trees, a likely example being the Lobster Caterpillar (*Stauropus alternus*) which is known to damage *Acacia, Albizia, Cassia* and *Grevillea.* This caterpillar is also associated with certain cultivated plants such as cocoa, roses, tamarind, mango and cotton.

How has it come about that these pests transferred their activities from coffee and other hosts to tea soon after it was introduced ? It would seem that when environmental conditions were changed by replacing coffee, forests or grassland with tea, the species present had either to adapt themselves to tea or perish. Many insects and mites would have changed their characteristics evolving strains or races more suitable to thrive on tea, along the principle of ' evolution ' based on the theory of ' natural selection ' as formulated by Charles Darwin over a hundred years ago. It is not difficult to visualize this because the operation of natural selection is not exclusively a long term process, but goes on constantly month by month and year by year along different lines, in varying localities. Pests we consider today to be serious, such as the Shot-hole Borer, the Tea Tortrix and mites are so adapted to tea that these species now appear to be specialized feeders of tea. This specialization can be explained in terms of the well-known theory known as Hopkin's ' host selection principle '. According to this, the preference of an insect for a host may become modified within a generation by a specific association ; thus a species having versatile dietary habits tends to select, for its egg deposition, the plant species on which it was reared. In this way the progeny tends to be narrowly restricted to the host plant species of the parent generations.

Pest Damage

In more than two-thirds of our tea acreage at least one, and usually more insect or mite species have reached economic pest status. Crop losses caused by them can be determined provided the pests are sufficiently serious to cause significant damage and also if very good methods of control are available. Recent experience with dieldrin spraying showed that crop losses caused by the Shot-hole Borer may range from 10 to 25 percent or more depending on the severity of the attack. It has also been found that control of the beetle can improve the plant's response to increased fertilizer applications. Further, spraying of dieldrin enabled pruning cycles of certain low-country fields to be extended from 18 months to two years or more. Improvements in yields to be obtained by controlling the beetle seem, therefore, to be additive over the years rather than be restricted to a single cycle.

The Yellow Mite usually occurs in the up-country estates during the dry seasons from August to October and January to March with the attacks lasting about a month. It has been found that a crop increase of nearly 80 per cent can be obtained during this period by controlling a heavy attack with acaricides. A combined attack by the Red Spider Mite and Scarlet Mite has been shown to reduce crop by more than 10 per cent. At present, experiments are being conducted to determine more critically, the yield losses caused by the four types of mites.

It is estimated that a fairly heavy infestation of the Nettle Grub can cause complete defoliation of bushes within a few weeks resulting in losses of crop ranging from 30 to 50 percent. Population explosions of nettle grubs are, however, generally localized, often covering not more than 30 to 100 acres. In the same way, geometrid caterpillar outbreaks are liable to cause complete devastation to tea fields. The extent of crop losses caused by the other pests are not known with certainty, either because their appearance is rare or their distribution is limited to small pockets at any one time.

Natural Control

Our knowledge of insect ecology indicates that pests are created by man's activity. There is evidence that under natural conditions the numbers of living organisms show relatively small fluctuations. This state of equilibrium is commonly called the balance of nature. Cultivation of the soil, and growing extensive stands of plants of the same kind disturbs this balance and provides favourable conditions for the animals which feed on these hosts. The intensive monoculture of tea over large areas during the last hundred years must have, therefore, contributed immensely to the development of pests from minor to major levels. In other words host specificity, reproductive capacity and limits of occurrence of the present day tea pests would have greatly increased during the first century of tea cultivation in Ceylon. This is obviously the reason why some species continue to be increasingly troublesome pests.

Some of the reasons for the fluctuations of pest populations and the diversity of their abundance in space and time are known. Population size of any one species in a given region represents a balance between births and deaths. The maintenance of this balance is called population regulation. As many insects and mites are capable of laying hundreds of eggs, then of all the offspring of one female, only two insects, one male and one female need survive upto the stage where they are capable of reproduction. The rest of the progeny is eliminated during the course of their development by a multiplicity of factors such as adverse weather, parasites, predators, diseases caused by fungi, bacteria or viruses. When for some reason, these restraining factors fail to operate, the population builds up excessively ; then the individuals of that one species begin to compete with one another for food and for living space setting the final limit to the increase in numbers. The natural balance of the species is, thereby, restored. From our point of view, it is the outcome of this many-sided battle between the pests, their enemies and other factors that is important. On this basis it is possible to explain how some pest like the Shot-hole Borer continues to exist in large numbers throughout the year during all seasons, and from one year to the next, and also explain why other insects like the Twig Caterpillar or the Red Slug remain so scarce at certain times as to be unnoticed, but erupt into astronomical numbers and then vanish even more abruptly.

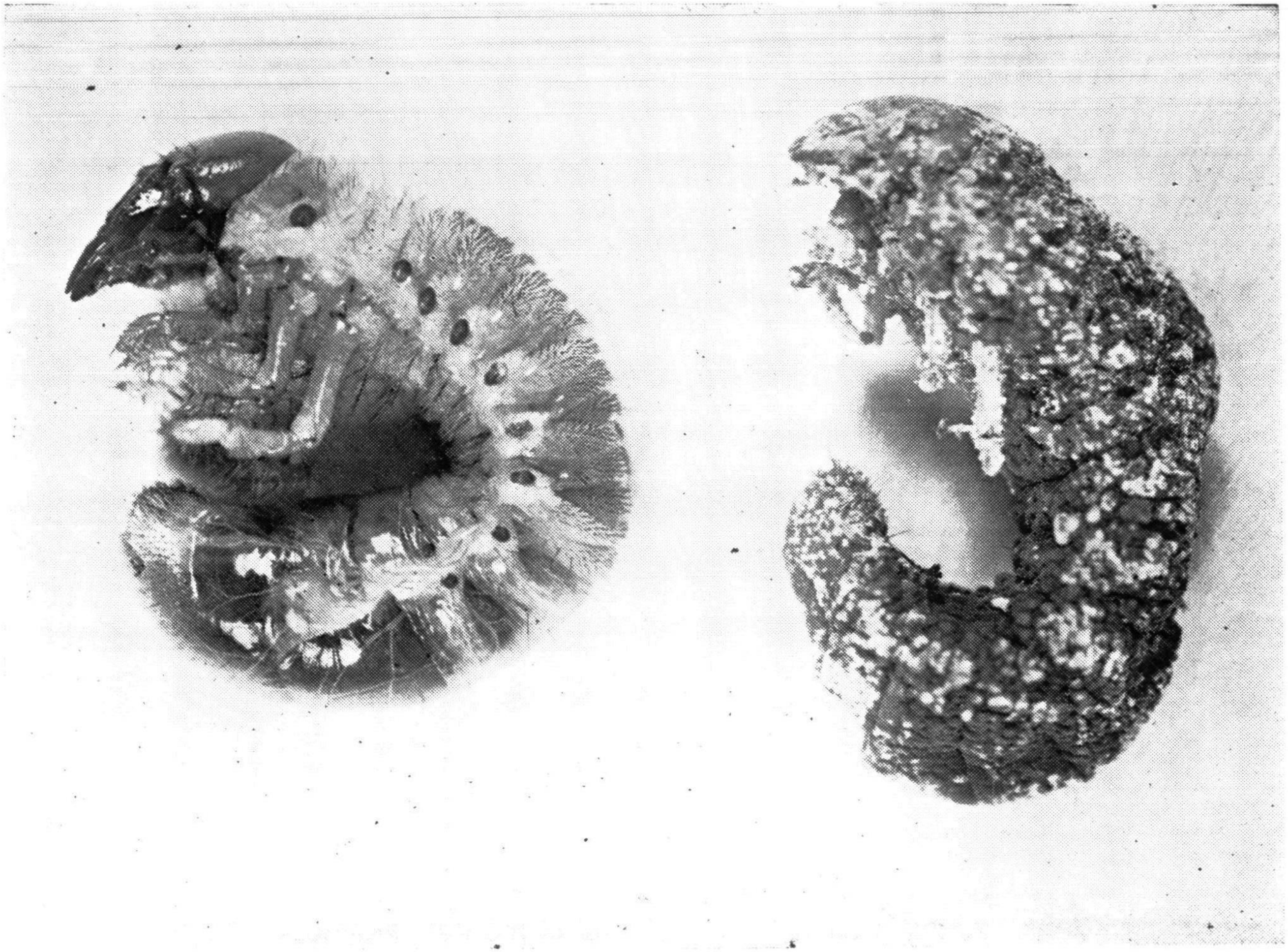

PLATE 3 — *The White Grub* (Holotrichia)
left — A heathy grub
right — A grub parasitized by a fungus

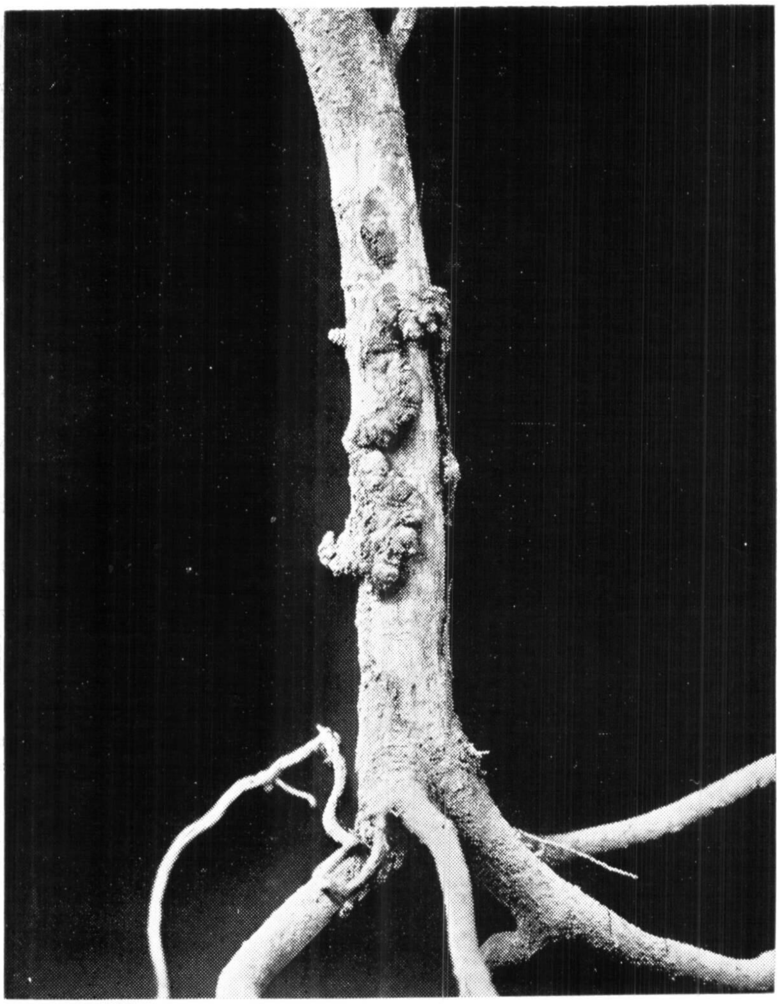

PLATE 4 — *A young tea plant showing damage caused by the White Grub,* Holotrichia

The Shot-hole Borer appears to be a remarkably successful insect because it lacks enemies in the form of predators or parasites, and furthermore, pathogens affecting it under natural conditions are not yet known. A probable reason for this lack of natural enemies is that the whole life-cycle is completed within the galleries. Indeed, the most notable biological characteristic of the Family Scolytidae, to which the beetle belongs, is the secluded life of all its stages. The adults are in the open only long enough to disperse and find new host plants in their proper condition for attack. The galleries made in tea stems by the female is a simple communal chamber where it rears its young and cultivates the Ambrosia Fungus for the larvae to feed upon. The Shot-hole Borer with its semi-social habit is, therefore, not limited by parasites, predators or disease. As a pest it is widely distributed at elevations between 1000 and 4000 feet. Its degree of success is probably dependent on humidity and temperature because these two factors, together with the availability of food, determine the distribution of insect life in general. Insects of this nature which lack effective natural enemies are usually kept in check by other factors, particularly the climate and the availability of food or breeding space. The latter has been found to be decisive in outbreaks of bark beetles. As long as suitable breeding material is available the Shot-hole Borer will, therefore, continue to increase its numbers. The presence of large areas under the single crop of tea has favoured the beetle in this way, and moreover, when tea stems become saturated with galleries towards the end of the third year from pruning, the lack of space, begins to control the borer. Bushes are pruned again making new, more suitable wood available. Perhaps if tea was not grown over such large continuous areas and was not periodically pruned, the borer might have been a less troublesome insect; but since these cultural practices are part and parcel of tea cultivation the Shot-hole Borer has to be accepted as a pest factor in tea production.

Although the above is an extreme example of a species without obvious parasites, predators or pathogens to hinder its existence, almost all other tea pests appear to be generally kept in check by the parasite, disease and climatic factor complex. This is particularly true of the lepidopterous (butterflies and moths) and hemipterous (bugs) pests. The Tortrix Caterpillar, before the introduction of tea was a minor coffee pest with a range of local parasites. When it succeeded in breeding on tea, for some reason, it began to increase in numbers until the introduction of the parasite *Macrocentrus homonae* from Java which was able to restore the balance.

Necessity to introduce parasites to control the other pests, with the exception of the Shot-hole Borer, did not arise, because these are kept sufficiently well in check by indigenous parasites, predators and pathogens. For instance, the nine species of nettle grubs known to us are destroyed by eight insect parasites, three known predators, as well as by a wilt disease caused by a granulosis virus. The parasites and predators seem to maintain nettle grubs in low numbers with the wilt disease operating at high densities. Outbreaks of nettle grubs occur during temporary lapses of these factors during the dry seasons when the climate favours rapid increase of numbers. In the 1930's some attempts were made to introduce parasites from abroad to control nettle grubs, but this did not meet with any success, and later it became clear that the local parasites and other factors provide a suffcient degree of control. In the same way the Twig and Looper Caterpillars are parasitized by two hymenopterous parasites, a *Charops* sp. and an *Apanteles* sp. A polyhedrosis virus disease and a fungus disease are also known to affect these two caterpillars. A tachinid fly *Carcelia gnava* Mg. and the Braconid Wasp *Apanteles taprobanae* are two known parasites of the Lobster Caterpillar which appear to keep them in check. Another important example of natural control is found with the Red Slug Caterpillar which is known to be very effectively controlled by the parasitic fly *Exorista heterusiae*, the characteristic hum of which can usually be heard in a red slug area. The importance of natural balance in restraining insect numbers was amply demonstrated during the recent outbreaks of the Tea Tortrix and Geometrid Caterpillars. The origin of these outbreaks in dieldrin-sprayed areas showed that dieldrin killed many useful parasites creating a series of side-effect problems. Other less important occurrences of various pests resulting from wide spread dieldrin applications were those of the Red Slug, faggot worms (*Clania cramerii* Westwood, *Kotochalia doubledayi* Westwood), bag worms (*Manotha albipes* Moore, *Acanthopsyche subteralbata* Hampson), cut worms (*Agrotis segatum* Schiffy, *Agrotis suffusa* Hubner) and the Army Worm (*Spodoptera litura* Fab.) Hundreds of parasites are known from these and other pests of tea, the mention of these will not be made in the interests of brevity. The act that forms such as the Tea Aphid, scales, Tea Leaf Roller, Army Worm, Lobster Caterpillar, Red Slug, Red Borer the thrips and many others are present in small numbers, but at the same time do not give us much trouble, shows that natural control factors are at work all the time.

Cultural Control

From the foregoing account it would seem that control of tea pests is primarily due to natural causes. Chemical, cultural, biological or other methods are necessarily supplementary, to achieve a high standard of protection. The normal cultural practices in tea cultivation involve such operations as propagation, pruning, plucking and fertilizer application. Before the post-war era of modern insecticide use, attempts to control tea pests were predominantly by manupulating cultural practices. These methods were not found to be successful ; for instance, alteration of the duration of pruning cycles, changes in the method of pruning and applications of different fertilizer combinations have failed to control the Shot-hole Borer. Although it is known that severe caterpillar or mite outbreaks can be eliminated by pruning, other factors concerning the pests are not generally considered in determining the timing of pruning. On the other hand, the Yellow Mite can be controlled by two close rounds of hard plucking, but at present, acaricides give better protection. Moreover, when quality is the prime factor in tea production, such as is the case in Ceylon today, coarse plucking as a measure for yellow mite control will not be popular.

The use of pest-resistant varieties of tea as a cultural measure against insects and mites has not been practised hitherto. Restrictions on the opening up of new land for tea cultivation, and the fact that tea is a long-lived plant with an economic life span of 80 to 100 years, do not encourage development of pest-resistant or tolerant varieties of tea. Furthermore, other factors that are even more important, such as yield, the quality of the made tea, rooting ability, growth factors and drought resistance are given primary consideration in developing clones and clonal seedlings of tea.

A number of tea clones, less susceptible to shot-hole borer attack are known, but the interesting point is that there are clones which are heavily attacked by the beetle but at the same time give higher yields than some of the resistant varieties. In the case of mites, current research indicates that the degree of susceptibility of tea clones to mites can be determined biochemically because certain pigments found on mites also occur in clones susceptible to heavy mite attacks.

The slow rate of replanting high-yielding clones in Ceylon as well as the length of time required to bring new varieties into bearing necessarily make research developments on these lines long-term ones. Also, pest-resistance is not a fixed condition because environmental factors of rainfall, temperature, soil fertility and soil reaction may each influence the resistance shown to a pest. Added to this is the possibility of the continuous development of new races of insects and mites able to breed on the resistant varieties of their host plant.

Planting shade trees is a common cultural measure practised on many estates. Often it has been found that shade trees function as alternate hosts for a number of tea pests. *Grevillea robusta* and *Albizia falcata* are host plants for the Red Spider

PLATE 5 — *A colony of aphids* (Toxoptera aurantii) *feeding on a young tea leaf*

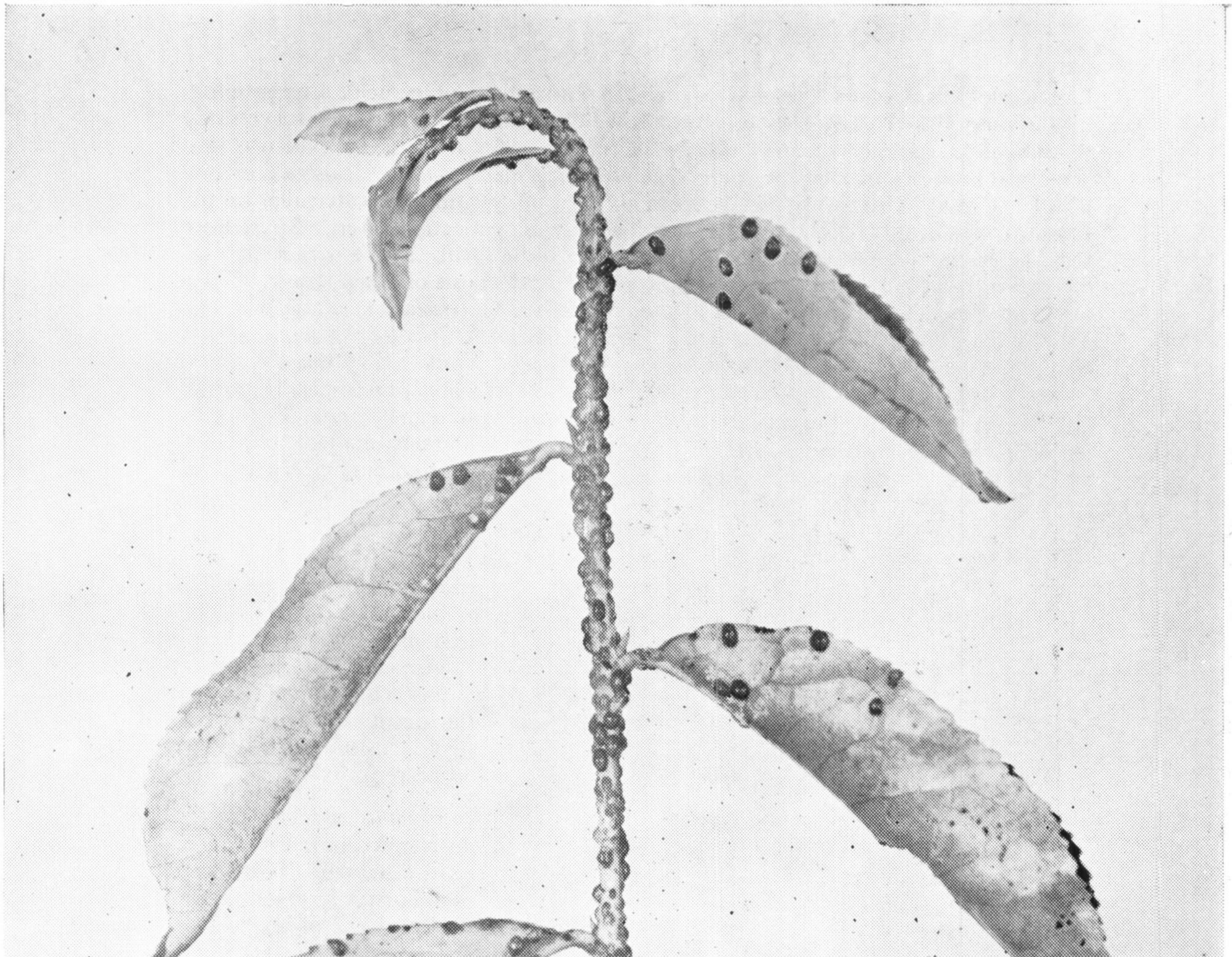

PLATE 6 — *Brown bugs* (Saissetia coffeae) *feeding on a tea shoot*

and Scarlet Mites, and are thought to increase reinfestation of tea fields after pruning. In the case of the Shot-hole Borer, it is known that the beetle can breed successfully in *Albizia falcata* and *Erythrina lithosperma* (dadap), but there is no evidence that these two species are a source of infestation to tea. *Albizia falcata* is also a common host for Tortrix, which may survive spraying measures against the caterpillar on the tea nearby, so that *Albizia* may become a source of reinfection later. Apart from tea, the only other recorded food plant of the Nettle Grub *Thosea recta* is *Albizia. Cassia auriculata* and *Albizia* are two known alternate hosts of *Thosea cana.* Twig and looper caterpillar outbreaks have often originated on *Grevillea robusta.* The first extensive twig caterpillar attack in 1900 occurred on a large *Grevillea* clearing. Other shade trees which are known to harbour these two caterpillars are *Acacia decurrens Acacia pruinosa,* and *Gliricidia maculata.* Thinning out shade is practised as a partial control measure because shade trees are indispensible for egg laying. Helopeltis and lygus attacks also have been shown to be associated with moist shaded conditions. Reduction of shade and clearing up of the ground cover often control these pests without the need for chemical measures.

Biological Control

Introduction and/or augmentation of parasites, predators and pathogens for the purpose of controlling pests is generally referred to as biological control. The outstanding feature of successful biological control is that it is largly permanent, because the introduced organisms perpetuate themselves. Among its other advantages over chemical methods are that it avoids chemical residues, taint, phytotoxicity, possible side-effects and the danger of developing pesticide-resistant varieties of the pests. If, on the other hand, a biological method of control is insufficient to avoid economic loss, chemical or other methods of control would be required.

The biological control of the Tea Tortrix with *Macrocentrus* reduced tortrix populations below the level of economic injury and this has resulted in large savings to the industry because the need for chemical applications is obviated. For many years biological control of a number of tea pests other than Tortrix received much attention without success. All attempts at biological control of the Shot-hole Borer in the past by the introduction of parasites and predators have failed. Attempts have also been made to control nettle grubs biologically. When larval density is high during humid weather, nettle grubs are normally affected by a granulosis virus disease. Artificial spread of this disease by spraying suspensions of the virus was found to be effective on a small scale, but the action of the virus was too slow to prevent serious damage, whereas control with low doses of DDT was found to give rapid control. Similarly in recent experiments, the bacterium *Bacillus thuringiensis* failed to control the Tea Tortrix in contrast to the degree of control achieved with certain insecticides, even though this pathogen has been found to be useful in controlling many caterpillar pests elsewhere. The success of an introduced parasite, or predator as a pest-control agent depends largely on the ability of the organism to establish and generate effective numbers and in the case of a pathogen, to reduce the pest population before the latter can expand in numbers or cause significant damage. Biological control is, therefore, not the answer to every insect or mite pest problem.

Chemical Control

In controlling pests of tea we have had more success with chemical methods than with any others. Although natural control helps maintain the majority of our pests in low numbers, when outbreaks occur chemicals are indispensible if serious damage is to be avoided. Also many occasions arise when immediate action in the form of direct chemical control is the only means of preventing loss. Our achievements in chemical control include the control of nettle grubs, Tea Tortrix, other caterpillar pests, termites, mites, various species of bugs and several others, in fact practically all important tea pests other than the Shot-hole Borer.

Insecticides that were available before the advent of DDT were almost exclusively inorganic chemicals with the exception of a few plant derivatives such as nicotine, pyrethrins and rotenone, together with petroleum, creosote and thiocyanates. Inorganic materials included compounds of arsenic, fluorine and sulphur and these compounds, as well as petroleum oil and thiocyanates, are in varying degrees inherently dangerous to plants with a very small margin of safety between pest control and plant tolerance. Probably because of this, and the fact that residues of arsenic and fluorine could not be tolerated in made tea, these compounds were not used for tea pest control. The advent of DDT and other organic insecticides after the war has clearly changed and advanced tea pest control techniques with chemicals. Nicotine was used during the 1930's for tea aphid control, but was replaced later by malathion. White oil emulsions and lime-sulphur were used previously for controlling scales; these have now been replaced with the much more effective Sevin, a carbamate compound.

Before many of the present day insecticides were known, various forms of soap were used for controlling mites and caterpillar pests. It was subsequently shown that soap is effective only against the Red Spider Mite for about two weeks, whereas acaricides give better and much more lasting control of all four species of mites. Thirty five years ago soap, and later the detergent ' teepol ' was widely used against nettle grubs, but this has now been replaced with DDT which gives a more rapid and effective control. It must be mentioned here that there are some who still believe that soap is an effective pest eradicant, but experiments with mites, nettle grubs, Tortrix, Twig and Looper Caterpillars have repeatedly shown that this is not so ; insecticides are far superior. On the other hand the use of elemental sulphur has been adopted for mite control on tea for over 60 years and is still being used. Sulphur controls all four species of mites, but its serious disadvantage is that it imparts a taint to the made tea so that the plucked leaf has to be discarded for several weeks, and at least two well-timed sprayings are usually required. Availability of efficient non-tainting acaricides have now restricted to the use of sulphur sprays and dusts to new clearings and newly pruned fields where no plucking is done. A search for new chemicals for mite control recently, has yielded a number of highly effective, non tainting, and persistent acaricides with no residue problems and undesirable side effects. Of these, dicofol (Kelthane) has been found to be effective against all four species of tea mites. It has a long residual action, superior to that of sulphur. Tetradifon (Tedion V-18) is highly effective, against the Red Spider and Yellow Mites. It has a long initial action against adults, is relatively non-toxic to eggs, but particularly effective against nymphs. This compound with its property of diffusing through leaves has a long residual action.

DDT has been found to be a highly toxic contact and stomach poison against caterpillar pests of tea in general. It is being used against, the Tortrix, Twig and Looper Caterpillars, cut worms, army worms, nettle grubs, red slugs, faggot worms, bag worms and many others. In recent experiments on twig caterpillar control it became evident that DDT is superior to other well-known insecticides, particularly the organochlorine insecticide endrin and the organophosphorous compounds, parathion, methyl parathion, fenitrothion, trichlorfon (Dipterex), and the carbamates metacil and sevin. The Lygus Bug, Helopeltis Bug, and the thrips are three other notable tea pests that can be controlled with DDT. The white grub *Holotrichia* in contrast was found to be remarkably resistant to powerful organochlorines such as aldrin, dieldrin, telodrin, chlordane, DDT and BHC. A small degree of control can be achieved with soil applications of high doses of BHC. For termite control, applications of dieldrin, aldrin, or chlordane will give satisfactory control of live wood, mound building and subterranean termites. The use of dieldrin and aldrin against our major pest, the Shot-hole Borer from 1961–1966 though effective had to be given up following a series of undesirable side effects. An acceptable

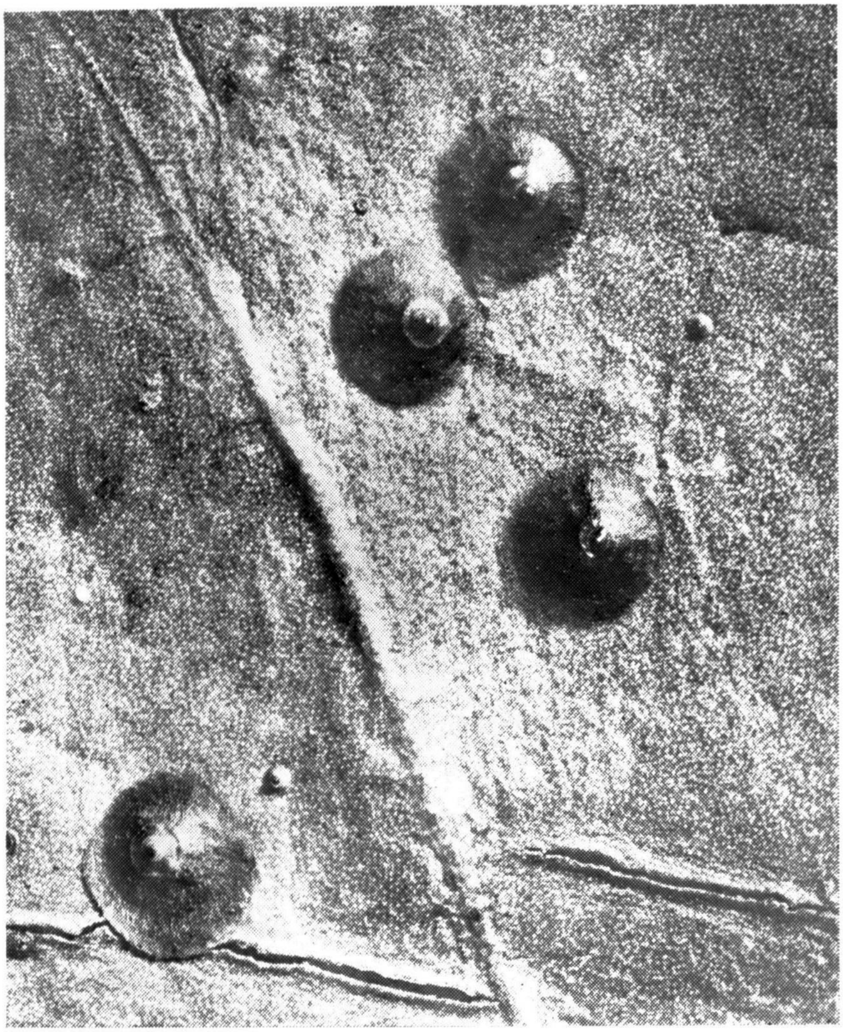

PLATE 7 — *Diaspine scales* (Hemiberlesia rapax) *on a tea leaf*

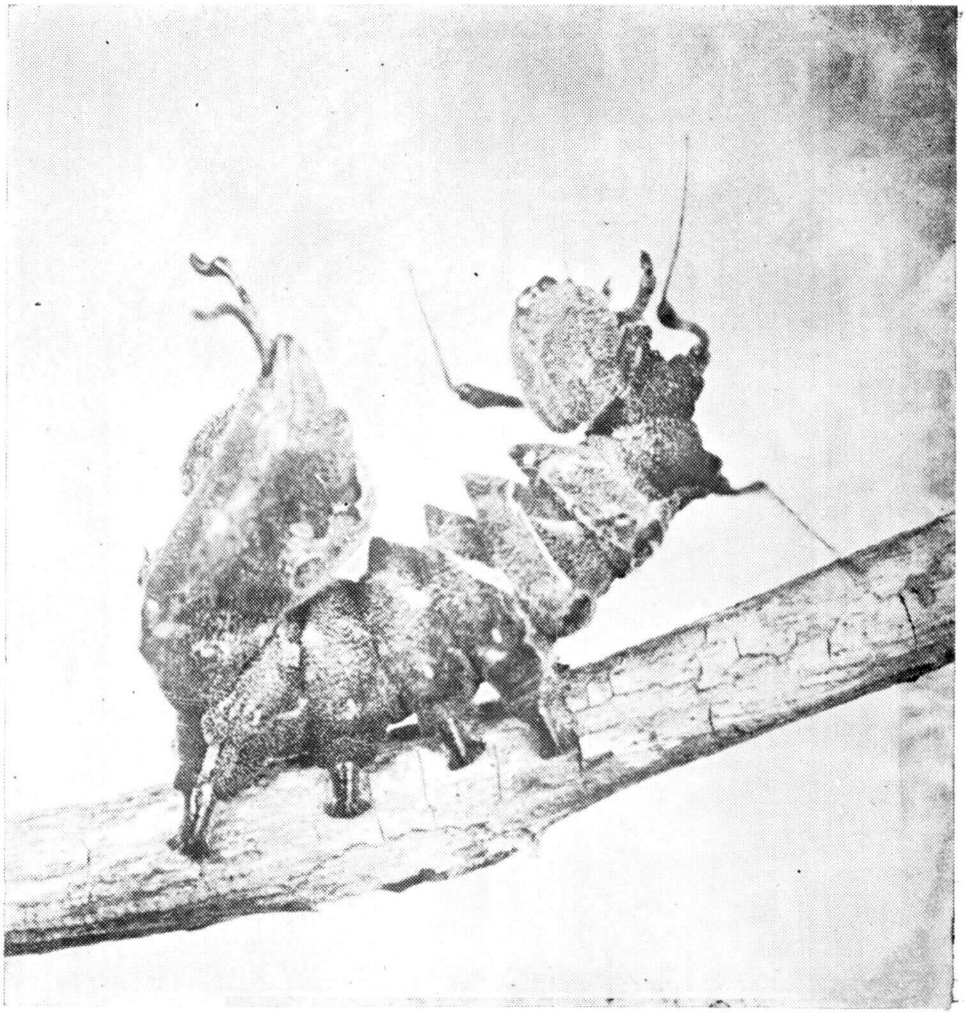

PLATE 8 — *The Lobster Caterpillar* (Stauropus alternus) *resting on a tea stem*

method of shot-hole borer control is therefore urgently needed and the present programme of the Entomology Division of the Institute is devoted to investigating all possible avenues to find an early solution.

Broadly speaking, the policy of using chemicals for tea pest control has been successful. There have been instances where we did experience undesirable secondary effects. Use of DDT for caterpillar control in certain areas can bring about red spider and scarlet mite outbreaks specially when the weather conditions are conducive. This has been particularly found to be so in the north-east monsoon zone where there is a long period of dry weather. The effect of DDT in the buildup of mite populations is known to be the result of the destruction of beneficial insects and acarines, but this point has yet to be investigated in respect of tea mites. Fortunately the mite problems that are created by DDT applications can be solved by incorporating a good acaricide into the spray solution as a prophylactic. Other insecticides known to induce red spider mite outbreaks are methoxychlor, TDE, carbaryl (Sevin) and metacil. As with DDT, copper spraying for blister blight control is also known to bring about red spider and scarlet mite problems. It is of interest to note that nickel chloride, a possible alternative to copper fungicides, which is used as a solution in water does not increase mite numbers.

The other example, but with a larger dimension is the widespread outbreaks of caterpillar pests that occurred from 1962 to 1966 when dieldrin was used for shot-hole borer control. The side effects of dieldrin began with tortrix outbreaks, but with the increase of the acreage under dieldrin treatment, two other more destructive pests, namely the Twig Caterpillar and the Looper Caterpillar appeared. By the middle of 1966 it became clear that it would be dangerous to continue dieldrin spraying for shot-hole borer control, and steps were taken to withdraw the recommendations made in 1961. Dieldrin which was applied soon after pruning and before budbreak did not create residue problems, but it eliminated many hymenopterous parasites, particularly *Macrocentrus homonae* the parasite of Tortrix and *Apenteles* sp. and *Charops* sp. parasites of the Twig and Looper Caterpillars. It is likely that there had been a certain amount of destruction of other beneficial insects because unusual outbreaks of several previously less important pests occurred in localized areas where there has been dieldrin spraying. Among these could be included occurrences of bag worms, faggot worms, red slug, army worms, and cut worms. Indeed, side-effect problems with insecticides have been experienced in other parts of the world as well, a typical example being that in the Californian citrus groves where the Lady Bird Beetle *Vedalia cardinalis*, was introduced in 1886 to control the Cottony Cushion Scale *Icerya purchasi* with great success, it was found that the lady bird has proved more susceptible to modern insecticides than the scale insect itself. Such a case was also seen in England when soil applications of insecticides have been highly successful in dealing with the Cabbage Root Fly, but at the expense of largely eliminating the carabid beetles and other predators that are keeping it in check. This resulted in small doses of insecticides actually increasing the numbers of the Cabbage Root Fly rather than diminishing it because the predators suffered more than the pest.

Side-effect problems do not detract from the importance of pesticides in the control of insect and mite pests of tea, because at the present time, there is no known substitute for their use. The problems we have had, merely illustrate some of the complexities of the biological relationships we have to encounter. Another important factor worthy of consideration is the cost of widespread pesticide use. Spectacular short-term yield increases following insecticide applications may not necessarily be the most economic answer over a long period. It is now being appreciated that pest control is a long-term matter in which annual expenditure is additive ; the yield increases obtained from pest control must more than balance the cost of control, as well as losses caused by immediate side-effects or those that may come later on.

The development of machines and devices for applying pesticides during the last twenty years has been as rapid as the development of various types of insecticides. The use of ultra modern wheeled power sprayers has not been possible in Ceylon because of the steepness of the terrain or because of the methods of planting employed. For a long time hand-operated or pressurized knapsack sprayers have been found to be of immense value and are still being used on many estates. When applying chemicals against the leaf-eating insects and mites the aim should be to obtain adequate coverage of the foliage using 50 to 100 gallons of spray per acre, the lower volume (from 40—60 gallons) being sufficient for the feeders of the top layer such as the Yellow Mite or Tortrix ; the higher volumes (more than 60 gallons) are used against pests that attack the ' maintenance foliage ' as well as the top layer. In recent years the motorized mistblowers with small two-stroke engines have become increasingly popular. Mist-blowing or low-volume spraying is cheaper on labour costs, is faster, and is suitable in areas where there is a scarcity of water because effective control with 5 to 20 gallons of spray volume per acre could be obtained. Shortage of labour, higher costs of production, scarcity of water and the types of chemicals to be sprayed must be regarded as the major reasons for changing from high-volume to low-volume spraying. It would seem that more research is needed on spraying techniques and timing of chemical applications in order to ensure the highest degree of control of tea pests with the minimum expenditure and least side-effects. Improvements is spraying techniques and the timing of spraying in turn would be ineffective in the event of faulty spraying and inadequate supervision.

A problem associated with spraying is that of chemical residues. Taints imparted to made tea is another problem encountered in using chemicals. There are many pesticides, the toxic residues of which are not tolerated in food stuffs by the consumer. The residues must not exceed the minimum predetermined safety levels. Of all our tea acreage, very little indeed is sprayed with pesticides for insect and mite control, and the number of chemicals used are few, the commonest being DDT for caterpillar pests and dicofol, tetradifon and sulphur for mites. Use of dieldrin for shot-hole borer control is now restricted to newly planted tea which is not plucked. Other insecticides used, but sparingly, are malathion, sevin and aldrin. The estimated acreage sprayed with DDT in 1966 is about 50,000 whereas not more than 15,000 acres would have been sprayed with acaricides. The use of other pesticides are mostly restricted to nurseries and new clearings and would in contrast be negligible. Thus, 55,000 acres out of the total cultivated 600,000 is not a formidable acreage in comparison to those under other crops.

Residue and taint problems have been tackled by manupulating the spraying and cultural practices. It is the usual practice to apply sprays immediately after a plucking round. The rapid growth of young shoots before the next round of plucking, and often, heavy rainfall, bring down the level of residues left on the plucked leaf from subsequent rounds. Further, safe intervals are recommended between spraying and the next round of plucking. In the case of DDT, Kelthane and Tedion, a safe interval of seven days is required, whereas for other chemicals it may range from two to six weeks. For instance sulphur which taints tea leaf is given an interval of four weeks between spraying and plucking. Alternately, the leaf is plucked and discarded for three rounds. As only a small fraction of a field or an estate is sprayed at any one time, the possible taint and residue levels are further reduced by bulking the leaf from sprayed areas with five to ten times the quantity of leaf from unsprayed areas. This bulking is done before or after the process of manufacture. During manufacture itself, a further loss of residues occurs. In the case of DDT one-third to half the residues are lost during manufacture, and with less stable materials hardly any residues are left in the final product. It has also been ensured that DDT does not get into the tea infusion because it is not water soluble. The end result of all this is that any residue there may be on the manufactured tea which reaches the consumer is negligible and far below the accepted limits of safety.

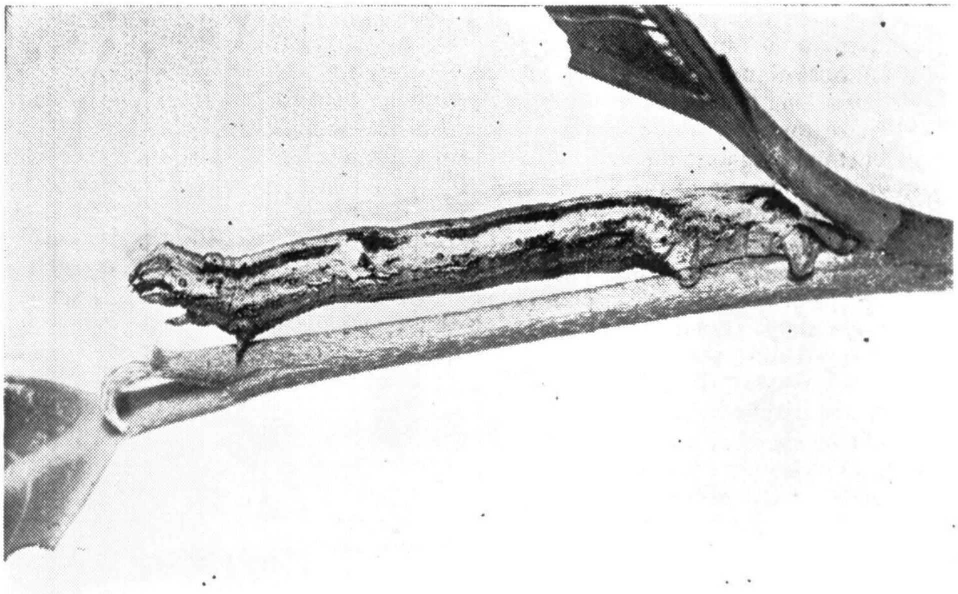

PLATE 9 — *The Twig Caterpillar* (Ectropis bhurmitra)

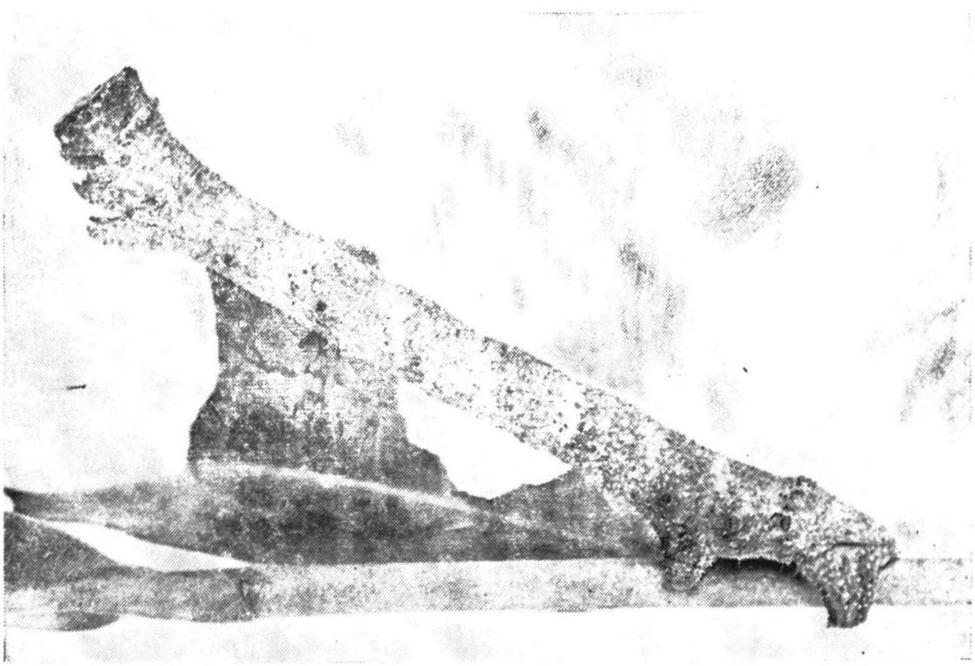

PLATE 10 — *The Looper Caterpillar* (Buzura strigaria) *resting on a tea leaf*

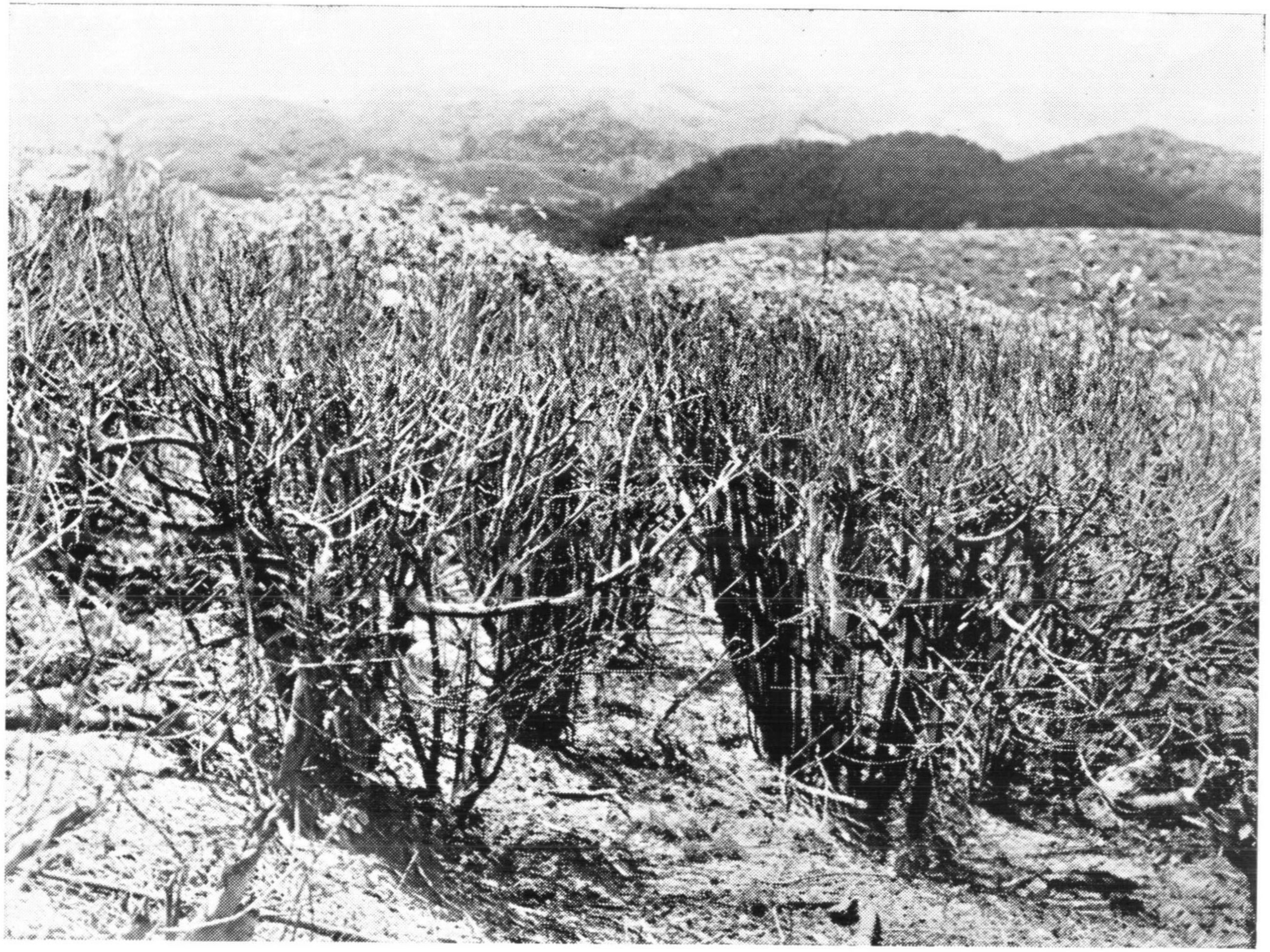

PLATE 11 — *Damage to tea caused by a severe outbreak of the Twig and Looper Caterpillars on an estate in Uva*

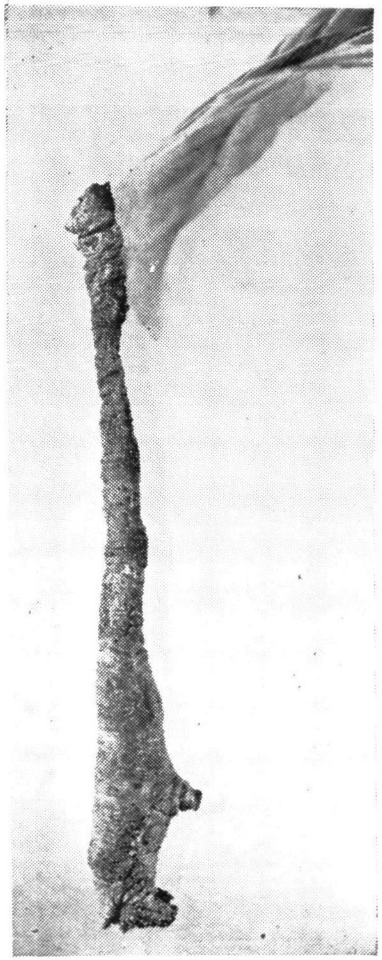

PLATE 12 — *A looper caterpillar killed by a granulosis virus disease*

PLATE 13 — *A looper caterpillar attacked by the insect-parasite* Apanteles

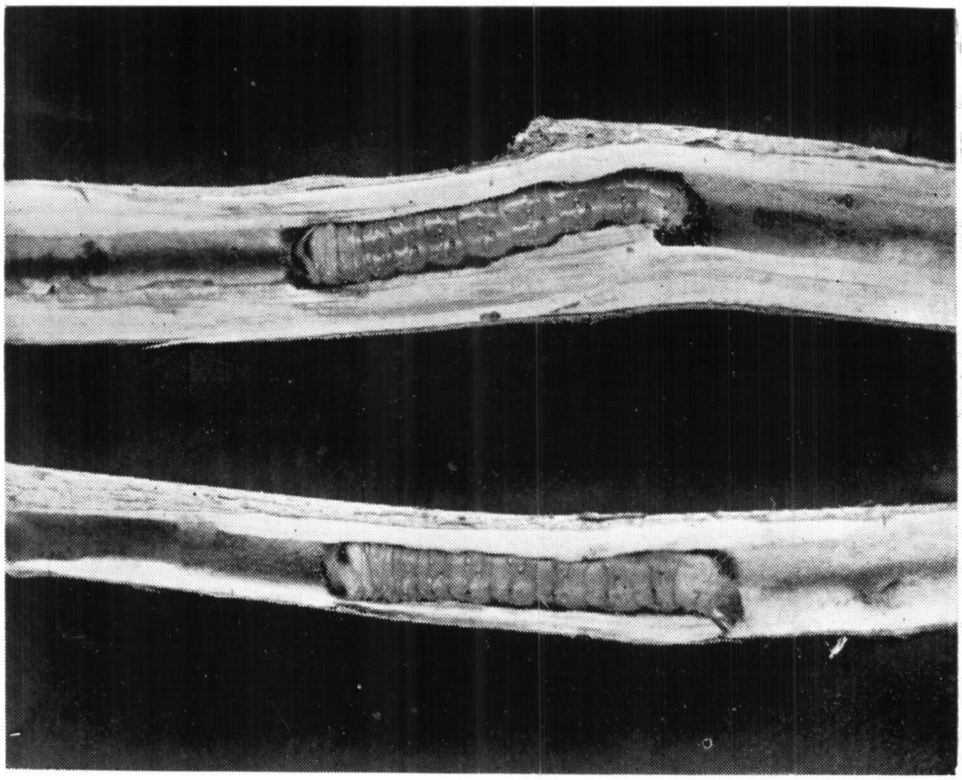

PLATE 14 — *Tea shoots attacked by The Red Borer* (Zeuzera coffeae)

PLATE 15 — *The Faggot Worm* (Clania cramerii)

Conclusions

It appears that in the past, pest control in tea has been achieved with natural control and biological control with the aid of cultural measures wherever possible. Chemicals have been used when there has been no other alternative. Recent experience with dieldrin indicated that the tea industry must be cautious in its approach to, and acceptance of new chemicals because there is a complex, many-sided natural balance among the fauna associated with tea – a situation that must be preserved if we are to keep the potentially dangerous insects and mites in low numbers. It must, therefore, be appreciated that chemicals should never be widely and indiscriminately used until they have been fully tested and all side effects are either known or anticipated. The final solution to the problem of pest control may well lie in careful combinations of cultural, biological and chemical methods, none of which in themselves provides the complete answers to all our problems. This concept should particularly be applied to shot-hole borer control, because the chemical control of this pest has caused enumerable reperrcussions in the past. Indeed, it is being accepted all over the world that rational pest control means a judicious combination of biological and chemical methods. This is a position in-between the 'idealist biological control' which does not always work, and the 'indiscriminate use of chemicals'.

Detailed ecological studies of economic pests are essential for a positive approach to our pest problems. Past outbreaks depend on the ability of a species to disperse over the host crop and to increase in numbers rapidly enough to cause damage. These two problems of dispersal and population regulation are now being studied in detail with regard to our major pests, particularly the Shot-hole Borer and the caterpillar pests. A question that is often asked is why don't we attempt some of the new techniques we hear about against the Shot-hole Borer. These new exotic methods of pest control, as for instance the gamma sterilization technique, chemosterilization, introducing lethal genes into pest population using specificaly bred insects the use of sex attractants or high frequency radio waves, are all mostly experimental. Also, for various reasons these methods are not applicable to many insect and mite pest problems. Until such time as an acceptable method is developed for shot-hole borer control it appears that chemicals against his pest must be used with great caution. It must be recalled that the Shot-hole Borer is a serious past in a continuous area between the elevations of 1000 and 4000 feet. Routine applications of and insecticide against the beetle is, therefore, likely to recreate the chain of caterpillar pest problems that occurred earlier, unless the insecticide is specific to the Shot-hole Borer or to the insect group it belongs to. If this article seems to have become a discussion on the implications of shot-hole borer control, it is purely because the Shot-hole Borer is our most formidable pest and the other pest problems have been found to be closely connected with chemical control attempts against this beetle in the recent past.