MONOGRAPHS ON TEA PRODUCTION IN CEYLON

No. 6

INSECT AND MITE PESTS OF TEA IN CEYLON AND THEIR CONTROL

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FOREWORD

By

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I am sure the first thing that the possessor of this book will do is to scan it casually and then his eyes will catch the superb colour plates. From then on he will not be able to put the monograph down until he is certain that he has at some time or other in his career encountered all the pests described. Encountered but not conquered for we still have not got the answer to the control of our worst pest—Shot-hole Borer; however, radically new techniques are being tried against this pest and in the end it is bound to be mastered.

Mr J. E. Cranham's monograph is the most up-to-date source of information about tea-pests in the world. His work is presented with painstaking accuracy and great detail but nevertheless it is still very readable and all tea planters in Ceylon and elsewhere will profit by it. To have so much factual and practical information in so handy a volume will be a boon to everyone interested in Tea pests.

Dr W. Danthanarayana, has re-written parts of the section on Shot-hole Borer and on the Tea Tortrix in the light of the findings of the Institute in the past year.

AUTHOR'S PREFACE AND ACKNOWLEDGEMENTS

This book has been written to provide a popular account of the commoner insect and mite pests of tea in Ceylon, including a brief account of the pests of shade trees and green manure plants. It is essentially a collection of advisory pamphlets for tea planters, on the biology, recognition and control of these pests. No such work can be exhaustive and give all the necessary advice with regard to specific outbreaks of pests; this book is intended to assist the advisory work of the Institute, not to replace it.

Whilst this is the main purpose of the book, I hope it may also prove of interest to scientific workers. Some of the subject matter is perhaps not of particular interest to planters but has been included to make the book a fairly complete review of our present knowledge of the subject. I have been deliberately selective, however, in the choice of references.

Above all I have tried to illustrate the pests, and the damage they cause, as well as possible. Such merit as the book has in this respect is very largely due to the technical skill of Mr D. J. Hettiarachi, Photographer of the Institute, and it is a pleasure to acknowledge his efforts, the results of which speak for themselves. Certain pests demand illustration in colour and we were fortunate in that Shell International Petroleum Company Ltd offered to assist us in producing colour plates, and as a result the eight-page insertion of colour plates was printed in England by Messrs Keliher, Hudson & Kearns Ltd. I would like to express our gratitude to Shell International Petroleum Company Ltd and Shell Company of Ceylon Ltd for their generous assistance in this respect.

I am most grateful for particular help from Mr D. J. W. Ranaweera and Mr E. F. W. Fernando and for the use of their drawings in Figures 9, 20, 32, 36 and 37, also to all who have read through the text and offered helpful suggestions, and to Dr W. Danthanarayana for seeing the work through to publication after I had left Ceylon. Finally I must thank successive Directors of the Institute, Dr D. L. Gunn, C.B.E., Dr A. W. R. Joachim, O.B.E., and Dr E. M. Chenery, for their encouragement and support.

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CHAPTER 1

INTRODUCTION

1.1. HISTORICAL

A scientific interest in the insect and mite pests of tea developed with the expansion of tea cultivation on estates in Ceylon, India and Indonesia in the late 19th century. Notable treatises by pioneers in the field are those of Green (1890) in Ceylon and of Watt and Mann (1903) in India. Ernest Green was at that time a planter and keen amateur entomologist and was later appointed the first Government Entomologist in Ceylon (1898-1913). His 'Insect pests of the tea plant' is a modest work but full of interest to the tea planter; Green was evidently an astute observer of insect life and made detailed observations on nearly all the pests of tea which are important today. His writings are mostly in the Circulars of the Royal Botanic Gardens, Peradeniya. Green was a world authority on the Coccidae (scale insects and mealy bugs) and published a four-volume work, 'Coccidae of Ceylon' (1896-1922) which is still a standard work on the subject.

The Indian Tea Association appointed their first Scientific Officer, H. H. Mann, in 1900, who, in collaboration with Sir George Watt, the Reporter on Economic Products to the Government of India, published 'The pests and blights of the tea plant' in 1903 (an earlier edition by Watt only was published in 1898). This is a remarkably detailed work, well illustrated and of over 400 pages; it covered both India and Ceylon and clearly owed much to Green's work on the Ceylon pests.

Work on tea pests in Ceylon was continued by the entomological staff of the Department of Agriculture, by Rutherford (1913-1915) and E. Speyer (1914-1919) and later by F. P. Jepson, N. K. Jardine and J. C. Hutson, all of whom joined the staff in 1919. Hutson, in particular, as senior entomologist, contributed many papers on tea pests. The Tea Research Institute of Ceylon was founded in 1926 and the staff concerned with entomology have been S. Stuart Light (1926-1928), C. B. Redman King (1929-1940), C. H. Gadd (1941-1948), C. A. Loos (Pathologist, 1949-1955), B. A. Baptist (1955-1956), G. D. Austin (Asst. Entomologist, 1930-1956, and Entomologist, 1956-1958), and E. Judenko (Special Entomologist on Shot-hole Borer, 1955-1961).

In India and Indonesia, which have many tea pests in common with Ceylon, similar research has been carried on at the Tocklai Experimental Station (Indian Tea Association), the Scientific Department of the United Planters' Association of Southern India, and the

Tea Research Station at Buitenzorg, Java. However, there has been no general detailed account of tea pests in Ceylon subsequent to those of Green and of Watt and Mann; but more general works which make considerable mention of tea pests are those of Dammerman (1929) and Kalshoven (1950) on Indonesian pests and of Beeson (1941) on the forest insects of the Indian region. 'Tea' by T. Eden (1958) contains a brief account of tea pests. Hainsworth's 'Tea pests and diseases and their control' (1952) is based on experience in N. India and does not cover many Ceylon pests. A further account of the tea pests of N. E. India (Das, 1965) has recently been published, and also a scientific review of work on tea pests (Cranham, 1966).

1.2. ECOLOGY OF TEA PESTS

The science of ecology is essentially the study of the distribution and abundance of animals and plants as affected by their environment. The term 'environment' in this ecological sense implies all the factors in the surroundings of an organism that affect it directly or indirectly, and these may be broadly grouped under four headings: (1) the quantity and quality of food, (2) climatic and other physical factors, (3) other organisms of the same species and other species, including natural enemies and diseases, and (4) a suitable 'place in which to live'. To expand on this definition of 'environment' as it applies to the insect and mite pests living on tea, let us consider each heading in turn. Each broad category of environmental factors is diverse and complex in character and frequently interacts with the others; we can only deal briefly with the subject here.

Food.—The tea plant, or rather some part of it, is the food supply and the abundance of pests is affected by the quantity of suitable food available. The genetically determined characters of the tea bush are often very important, especially to the sucking insects and mites; for instance, high-jat tea is more prone to attack by Scarlet Mite (*Brevipalpus* spp.) and low-jat tea more prone to Tea Red Spider Mite (*Oligonychus coffeae* Nietn.) There are usually marked differences in the susceptibility of various clones to various pests, and the development of resistant clones is a basic approach to the problems of pest control, but a necessarily long-term one on such a long-lived crop as tea.

The effect of the nutritional and physiological condition of the bush on the incidence of pests is also very great. On various crops there is work showing the effect of major and minor nutrients, of water balance, age of foliage, etc., on the development of pests. Some pests thrive on debilitated bushes or those below par (e.g. the scale insects) but with others attack is generally greatest on healthy vigorous bushes (e.g. Shot-hole Borer).

Climatic factors affect our tea pests directly and also indirectly through their effect on the growth of the tea bush. The chief climatic factors are temperature, moisture and rainfall, light and sunshine, and wind. For each species of animal there are definite optimum conditions for growth, survival and reproduction, and a geographical range outside which conditions are unsuitable. The distribution of several of our Ceylon tea pests is influenced by physical conditions, especially by temperature as controlled by elevation. Thus Shot-hole Borer (*Xyleborus fornicatus* Eichh.) occurs mainly between 500 ft. and 4000 ft; *Lygus viridanus* Motsch. is a high elevation pest, usually at 4000 ft. to 6000 ft.; *Helopeltis theivora* Waterh. is a low-country pest. Tea districts with different climatic conditions have characteristic pests, an effect that is mainly due to climate although not necessarily entirely due to it. Certain pests have a wider range and are present in all districts and at all elevations to some degree.

Seasonal changes in the weather affect the abundance of pests, and outbreaks of some species, e.g. Scarlet Mite, appear to be largely regulated by weather factors. In addition, there is evidence that many pests show long-term fluctuations in numbers over the years which are largely regulated by cyclical weather patterns; this is probably true, for example, of Tea Tortrix and Fringed Nettle Grub.

Other organisms.—The effect of some environmental factors is largely dependent upon the population density of the species. The purest type of 'density-dependent' factor is competition between the individuals of the same species for food, breeding space, mating, etc; competition becomes more intense as the population density rises. This can limit numbers only when population density is so high that it approaches the limit of the available resource of food or breeding space; the vast majority of species never reach such densities but it can happen with some of the few species we know as pests. For example, in a dense nettle-grub outbreak there is not enough food for more than a small proportion of the larvae to develop; in a heavy attack by Shot-hole Borer there is very little suitable wood left in which new galleries can be formed. Such natural limitation of numbers is, however, little use to the planter!

Most pest species have natural enemies which include many other 'entomophagous' insects—parasites and predators—and there are also predatory vertebrates, spiders and mites, parasitic nematodes, and diseases which may be bacterial, virus or fungal in nature. The effects of these are largely density-dependent e.g. parasitism is increased when the host insect is numerous and more easily found by the parasite, and diseases are more easily spread in dense populations.

The ecologist's concept of '*a place in which to live*' implies a 'niche', not taken up by some other organism, which provides the right physical conditions and shelter and fulfils the requirements for mating, reproduction and feeding. With tea pests, there are species that feed on the flush, on mature leaves, on the bark, on mature or new wood, or on the roots. Many of them have to find other suitable places at stages of the life cycle when they are not feeding on some part of the tea plant. A tea field, although more uniform than any wild habitat, provides diverse local situations of which some are more suitable than others in providing the requirements of each species and of their natural enemies. Hence these insects are distributed in an uneven and patchy way over a field or larger area, sometimes very markedly so.

This consideration brings us to the question of how insects find the niches in which they are best suited to live, which involves migration and dispersal. In many insects there is a phase of dispersal when the insect becomes adult, when it flies upwards to the light and may be carried quite long distances in the wind and by upward convection currents in the middle of the day; Calnaido (1965) has shown that this happens with Shot-hole Borer when the adult female beetles first emerge from the parent galleries. Even mites, although wingless, are commonly dispersed by wind, and may also be carried from field to field on the clothing of labourers, on birds or mammals or on winged insects. With many lepidopterous caterpillars there is also a phase of dispersal by the tiny newly-hatched larvae which, once hatched, climb upwards to the light, launch themselves on silken threads and may be carried quite far in the wind. The process of dispersal is as important for the survival of the species as reproduction itself.

Tea is a long-lived perennial crop grown intensively as a monoculture—except for shade trees—on large continuous areas. As such, it creates a relatively stable environment for insects and can be compared with that of a single-species forest; indeed the range of pest species bears some similarity to that of forest entomology. This environment is disturbed relatively little, or only locally, by the use of pesticides, for they are much less used on tea than on many other crops.

There are many plant-feeding insects and mites, together with many others parasitic and predatory upon them, and scavenging species, which are very widely distributed in tea in small numbers i.e. in numbers sufficiently low for the plant-feeding species not to be regarded as pests. Those which quite commonly reach damaging levels we regard as serious pests; others which only occasionally do so are minor or occasional pests. There are also other plant-feeding species widely distributed in tea, some of which might become pests if changes in the environment permitted them to increase sufficiently in numbers.

The importance of the 'balance of nature' is certainly appreciated by planters. This idea should not, however, conjure up a mental image of a pair of scales in perfect balance. The numbers of a species and its natural enemies are constantly fluctuating as they are affected by the complex of environmental factors. These fluctuations are not necessarily similar over a large area; on tea they are usually greatly influenced by the growth of the bushes within the pruning cycle and this makes for differences from field to field. The 'balance of nature' is not a static balance but a dynamic one; as far as mental images are useful, we may liken it more to the surface of a live volcanic crater with small and large eruptions popping up and subsiding all over the place, the large eruptions representing local outbreaks of a pest.

In the event of an outbreak of a pest, the planter is often inclined to ask 'Where did they come from'? In most cases, the answer is that they were already there on the field, or close by, and changes in the environment have resulted in a large increase in numbers. It is usually a very difficult matter to find out what changes have been most influential. It usually requires detailed 'population studies' over many years in order to gain an understanding of the environmental factors that regulate the numbers of one pest species. Very little thorough work of this nature has been done on tea pests. Studies on the life-history and seasonal occurrence of various pests have certainly helped in timing control measures. There is, however, a dearth of information on the physiological requirements of even the more important species, and more detailed ecological studies are likely to be one of the most fruitful lines of investigation in the future. The better we know our 'enemies' the better we may be able to design measures to control them, or to 'integrate' chemical control measures with the natural factors regulating their numbers.

In the past, much of the entomological work has necessarily been of a strictly applied nature in the field. Before the post-war era of powerful synthetic insecticides, much of the effort was directed towards finding means of adjusting cultural practices to minimise pests or to alleviate the damage they cause.

1.3. THE EFFECTS OF CULTURAL PRACTICES

Tea is unusual as a perennial tree crop, firstly in that it is periodically pruned to keep it in the vegetative phase of growth, and secondly in that the youngest leaves are the required harvest. Hence insects and mites that feed on the 'flush' cause the most direct damage. The numbers of many pests are influenced by pruning and the growth of the bushes within the pruning cycle. Pruning removes most or all of their food supply and must also greatly alter the 'micro-climate' for those left; this is followed by the growth of young sappy shoots, a change in the quality of their food. A number of pests are more common on tea recovering from pruning, mostly pests of the flush and younger leaves e.g. Purple Mite, Yellow Mite, Tortrix, *Lygus* bug and thrips. These occurrences are doubtless in large part due to the quality of the foliage, and to plucking not being done during the recovery period, but the balance of pests and their natural enemies may also be upset e.g. Tortrix often builds up faster than its parasite on tea recovering from pruning. In contrast, a few pests, notably Scarlet Mite and scale insects, are usually numerous only in the later years of long pruning cycles.

The type of pruning practised (whether it is hard or light, 'clean' or leaving foliage), the season of pruning, and the length of the pruning cycle, may all have an effect on the numbers of pests. Examples of such effects are available. More Scarlet Mite and Red Spider survive the kind of pruning that leaves more foliage on the frame; in N. E. India, complete defoliation by hand after the annual winter prune is used as a useful method of control of Red Spider (Das 1963). The season of pruning affects the incidence of Tea Tortrix and of Yellow Mite.

For our major pest in Ceylon, Shot-hole Borer, pruning is particularly important, for it is pruning itself and the subsequent regrowth that periodically recreates an abundance of young wood susceptible to attack by this pest. Early workers thought that the beetles in the prunings reinfested the pruned frames and experiments were carried out on the burning and burial of prunings; later this was found to be valueless. Later work has shown that the numbers in the pruned frames decline very greatly after pruning and the bush appears then to become much less suitable as a host. Nevertheless it seems likely that fewer beetles will be carried over into a new pruning cycle after hard pruning than after light pruning, and this may be important in relation to the build-up in numbers in the new cycle; but in any event the effect of hard pruning can sometimes be very damaging on bushes in the low and mid-country, especially those debilitated by borer attack.

In respect of the length of the pruning cycle, Gadd (1944a) suggested a three-year pruning cycle for the low country because he found that borer numbers drop to low levels in the third year and the tea then recovered from attack and responded better to fertilizer. However, this did not prove acceptable generally for low country conditions. Walter (1956), on the other hand, found that an 18-month cycle was beneficial, the effect of this being not to allow time for the borer to build up to peak numbers; estate experience with this, however, suggests that because the pruning was necessarily very light the build-up of borer numbers occurred somewhat more quickly.

In conclusion on this subject, it is abundantly clear from agronomic studies that correct pruning, suited to local conditions, is absolutely vital to the health of the bushes; probably no single cultural practice has more far-reaching effects. Hence it can sometimes be extremely dangerous to modify this practice, for purposes of pest control, in a way unsuited to local conditions.

Plucking is a routine measure that has an effect on pests of the flush. For control of Yellow Mite, two close rounds of hard plucking were recommended in the past as a control measure; but this usually gives only partial control because there are young growing points that are not removed. With Tea Tortrix, plucking is also a partial control measure, and quite a sound one, for it removes mostly young larvae which are not parasitised, whereas hand collection of caterpillars inevitably removes parasites as well. In the case of *Lygus* bug, some of the eggs are laid too low down on the green stem to be removed by hard plucking (Calnaido, 1959).

The use of fertilizers can have marked effects on the incidence of pests. There is a school of thought that believes that the balanced nutrition of a crop will minimise the incidence and damage caused by pests and diseases, but apart from the use of natural manure and compost it is not easy to determine what is meant by balanced manuring in this context. Generally in agriculture high nitrogen ratios in the manure create a pre-disposition to pests and diseases, and lack of available phosphate and potash may induce a decline in resistance. Andrews (1923), working on tea in N. E. India, claimed that manuring of tea so as to produce a high ratio of available potash to phosphate in the soil greatly reduced attacks by *Helopeltis theivora.* With Shot-hole Borer, there is trial evidence that the use of nitrogeneous fertilizer can increase the numbers of borers. In the author's opinion, it is likely that the greatly increased use of fertilizers on Ceylon tea over the last 10-15 years is the major reason for the increased incidence of this pest. Other pests may be reduced by manuring; for instance, in N. E. India, Das (1963) found that high dosages of nitrogen (ammonium sulphate) greatly reduced attack by Red Spider in the unshaded and lightly shaded plots of a fertilizer trial, although they had no effect under heavier shade. Relatively little work of this nature has been carried out on tea, and there is clearly need for closer investigation of the effects of nutrients supplied in fertilizer, and of interactions with the effect of shade density, on the incidence of pests.

With regard to shade trees, some species are additional hosts for certain pests. Thus, *Grevillea robusta* and *Albizia falcata* are host plants for Scarlet Mite and Red Spider Mite, and tend to increase reinfestation of the tea after pruning (Baptist & Ranaweera, 1955). Most shade tree species, especially *Albizia* spp., are also hosts for Tea Tortrix and may create a problem in reinfesting tea which has been sprayed to control this pest. *Albizia falcata* is also a host for Shot-hole Borer of tea (Judenko, 1961) although the importance of this is not yet clear. As noted above, apart from being hosts for tea pests, the degree of shade provided by shade trees influences pests. The mirid bugs *Helopeltis theivora* and *Lygus viridanus* are favoured by moist shaded conditions. Mites, with the possible exception of Yellow Mite, flourish better on unshaded or lightly shaded tea. In South India it is believed the drastic removal and pollarding of shade trees following the introduction of Blister Blight disease in 1946 has been one important factor in the very great increase of Purple Mite as a pest.

In conclusion, it is apparent that cultural practices greatly affect the incidence of pests on tea but the extent to which they can be modified for purposes of pest control is strictly limited. Past investigations on these lines have not on the whole been very rewarding, but there is a need for further investigation of some aspects. Good management may do much to alleviate the damage done by pests, even to increase the resistance of tea bushes to those pests which prefer plants below par; in the long run, however, it is those pests which prefer healthy vigorous bushes which cause most concern.

1.4. BIOLOGICAL CONTROL

The term 'biological control' is generally used to mean introductions made by man of one organism for the purpose of controlling another. The example of the introduction of the parasitic ichneumon *Macrocentrus homonae* Nixon from Java in 1935-36 for the control of Tea Tortrix in Ceylon tea (described in more detail in Chapter 3) ranks as one of the most successful instances of biological control achieved anywhere in the world. The value to the industry of this introduction has been enormous, and the method of control is pleasing in its natural simplicity and economy. It is not to be expected however, that this method can be widely applied to tea pests. Tea Tortrix occurs throughout most of S. E. Asia and as a minor pest of tea in India and Indonesia, but for unknown reasons it appeared previously to lack a really effective parasite in Ceylon; such a parasite was found to exist in material imported from Java. Such a situation is not likely to be common. None of our tea pests are recently-introduced species which may lack the natural enemies present in their original home. All in fact have been known from the early days of tea planting, several were previously pests of coffee, and many are certainly indigenous forest insects. There exists already on tea in Ceylon a natural balance of many pests and potential pests with their natural enemies, a condition which it is vitally important to preserve.

In respect of our major pest, Shot-hole Borer, no effective predators or parasites are known to exist in Ceylon or elsewhere, and for the other members of the genus *Xyleborus* there are relatively few recorded and these do not appear to be important factors in natural control. The prospects for biological control of this pest are remote.

For plant-feeding mites, especially the spider mite family, there are many predacious insects and mites recorded as natural enemies, and these do appear to be important factors in natural control; several indigenous natural enemies of tea mites have been recorded in India and Ceylon. Some studies have been carried out by the Indian Sub-station of the Commonwealth Institute of Biological Control in Bangalore. However, manipulation of the natural enemies of mites entails special difficulties and there have been no outstanding successes so far (Boudreaux, 1962); for tea mites the present prospects cannot be considered encouraging.

Another technique of biological control is the artificial dissemination of virus, bacterial and fungal diseases of insects. On tea, work has been carried out on the granulosis virus disease of Fringed Nettle Grub (*Macroplectra nararia* Mo.) which is an important natural factor in the control of outbreaks; this work showed that the disease could be successfully spread by spraying a suspension of the virus but that the action was too slow to prevent serious damage to the tea bushes by the pest. One bacterial disease that affects various lepidopterous caterpillars, but is harmless to man, is caused by *Bacillus thuringiensis* Berliner; this has been produced in commercial formulations. It was found to be ineffective against Tea Tortrix and Fringed Nettle Grub in Ceylon, and partially effective but too slow acting against 'Looper', *Biston suppressaria* Gn., in Assam. Further advances in this field of 'microbial insecticides' should, however, be well worth considering for control of tea pests.

1.5. CHEMICAL CONTROL

The first synthetic organic insecticides, DDT and B.H.C., date from the second world war, and since then chemical industry has provided a powerful battery of chemicals which have revolutionised the chemical control of pests. On tea, their use provides much better control of many pests than was available previously but raises special problems related to the nature and cultivation of the crop. The precautions and measures necessary to protect labourers, and also to prevent taint and the presence of insecticide residues in made tea, are given in Chapter 10. To complete this introduction, some aspects of recent developments in chemical control will be briefly discussed.

Spraying technique—Because tea is densely planted on steep and often rough ground in Ceylon, the use of wheeled power sprayers is obviously out of the question. Knapsack-type hand-operated sprayers have long been used. Following the introduction of Blister Blight disease in 1947, the use of these was improved considerably by employing groups of pressurized knapsack sprayers filled at a portable mechanised or hand-operated pump. With these volumes of around 15 gallons of water per acre are adequate for blister-blight control, but the control of insects and mites requires 50-100 gallons of water per acre of mature tea, and renders spraying very tedious on large acreages. In the last few years, the motorised knapsack mist-blower, with a small two-stroke engine, has revolutionised spraying practice and permits effective control with much smaller volumes of spray fluid, around 5-20 gallons per acre for insecticides. Mist-blowing is cheaper on labour costs and is faster, and therefore allows better use to be made of suitable weather conditions. For the control of foliage pests, it is an effective technique not only against pests of the flush but also against pests of the maintenance foliage such as nettle grubs and geometrid caterpillars, and even of Scarlet Mite on the undersides of the leaves.

Even with the improved spraying techniques available today, estates not uncommonly report poor results from knapsack spraying or mist-blowing, but experience leaves no doubt that in a large proportion of these cases the cause lies with faulty spraying and inadequate supervision.

Pesticides and side-effects—Planters are well aware that the use of pesticides may create undesirable 'side-effects' in inducing the increase of another pest or pests, generally by destroying the parasites or predators. Investigations on the use of pesticides on tea must always involve careful study of the possible side-effects.

Amongst recent developments, the specific acaricides such as 'Kelthane' and 'Tedion' are virtually ideal for control of mites on tea; they are highly effective at low dosage rates, non-tainting, of low toxic hazard, and they do not create a difficult residue problem. Being specifically toxic to mites, and with little or no insecticidal toxicity, they do not induce any unwanted side-effects. These materials represent a valuable addition to our means of control and can be used to advantage more widely than at present.

With the insecticides, experience so far points to two main types of unwanted side-effects; firstly that of inducing outbreaks of mites, as shown by DDT, and, secondly, that of inducing outbreaks of Tea Tortrix and other defoliating caterpillars by destroying their parasites, as shown by dieldrin.

DDT is effective against most insect foliage pests of tea and is a non-tainting insecticide of low toxicity, satisfactory for use on tea except for the side-effect of increasing the numbers of Red Spider Mite and Scarlet Mite. Research efforts have therefore been concentrated on finding an equally effective material free of this side-effect. Dipterex (trichlorfon) is largely free of it and has been recommended and widely used for control of Tea Tortrix; it is, however, much less persistent than DDT and has not proved generally so effective. So far no entirely satisfactory substitute for DDT has been found; experience has, however, shown that DDT causes mite outbreaks only in a minority of cases, where conditions are conducive to a build-up in numbers. Where this is so, low dosages of Kelthane or Tedion can be added or used separately to prevent an increase of mite numbers. In respect of the second type of side-effect it is notable that, when used for the control of Tea Tortrix, DDT does not interfere at all with the re-establishment of natural control by the parasite *Macrocentrus homonae*.

The control of Shot-hole Borer presents more difficult problems because the insecticides so far found to have useful activity against this pest interfere to some extent with the parasite of Tortrix and probably with those of other caterpillar pests. Applications of dieldrin after pruning do not create a residue problem in made tea, and the toxicity is such that it is practicable for use on tea estates. The side-effect of Tortrix outbreaks is the serious disadvantage, and estate experience over the last few years has shown that this effect can be intensified as the scale of spraying is increased. More recently it has been found that outbreaks of other pests, such as geometrid caterpillars, may be induced or aggravated by dieldrin. With the increase in the acreage sprayed with dieldrin, the incidence of Tea Tortrix and Geometrid Caterpillars increased to such an extent that dieldrin spraying on mature tea has had to be completely abandoned. In the writer's view, estate experience of large-scale spraying against Shot-hole Borer over the last few years has been, on balance, of great value to the industry. It has demonstrated beyond doubt the very great loss of crop caused by this pest and, further, that the pest has been a key factor limiting the improvement of yield on most low and mid-country estates.

Experience with post-pruning sprays of dieldrin now focusses attention on the need for alternative insecticides to control the beetle. It is to be hoped that further work will establish control measures with negligible side-effects.

CHAPTER 2

SHOT-HOLE BORER

(Xyleborus fornicatus Eichhoff)

2.1. STATUS AS A PEST AND DISTRIBUTION

Shot-hole Borer is by far the most serious pest of Ceylon tea, of greater economic importance than all the other insect and mite pests together. It is a serious pest on at least 200,000 acres or over one-third of the island's tea-growing area.

The species was described by Eichhoff in 1868 from a specimen collected in Ceylon, but there is no record of the locality or host plant. It is not mentioned as a pest of tea in the 1890 edition of Green's 'Insect pests of the tea plant' and was first reported as a pest of tea on Craighead Estate, Nawalapitiya in 1892. By the early 1900's it was established as a serious pest in most mid-country and low-country districts.

This insect has been recorded, on a wide range of host plants, in India, Burma, Indo-China, Indonesia, Borneo, New Guinea, Formosa, Fiji, New Hebrides, Sandwich Islands and Hawaii (Schedl, 1959; Browne, 1961). On tea it is a serious pest only in Ceylon and in S. India, and in the latter it is much less widespread than in Ceylon though its importance there is reported to be increasing (Ananda Rau, 1956; AnanthaKrishnan, 1963). Reference to Shot-hole Borer as a pest of tea in N. India (Das, 1963a, 1965) probably involves other *Xyleborus* spp.

In Ceylon, Shot-hole Borer occurs to some extent on virtually all the tea that lies between 500 ft and 4000 ft in elevation and is a serious pest on most of it. The optimum conditions for the insect probably occur around 2000 ft and become gradually less favourable above and below this elevation. Below 500 ft attack is generally not severe, although some severe attacks have been noted in tea almost down to sea-level. Similarly, serious attacks can occur locally near the upper limit of the pest's range, around 4000 ft; the upper limit of occurrence is about 4300 ft. With this distribution Shot-hole Borer is a pest in all tea planting districts except Nuwara-Eliya, i.e. even such 'up-country' districts as Dimbula, Dickoya, Maskeliya, and Udapussellawa experience attacks on tea around 4000 ft and below. Planting opinion often holds that the pest is extending its range upwards; this is not entirely certain but it could be happening.

2.2. BIOLOGY

The Shot-hole Borer of Ceylon tea is a small beetle of the Scolytidae, a family which contains several thousands of species of wood-borers, bark beetles, 'shot-hole' and 'pin-hole' borers, found in both temperate and tropical forests. Many species are serious pests of forestry and the timber trade, particularly attacking newly-felled trees.

The genus *Xyleborus* alone includes hundreds of species; about forty species have so far been named and described from Ceylon and it is probable that the number present is much greater. Certain Scolytidae, including *Xyleborus* species, are called 'ambrosia beetles' because the larvae feed largely, if not entirely, on specific fungi which they cultivate on the walls of the galleries and which are introduced by the parent female beetle. In the case of *X. fornicatus* Gadd and Loos (1947) determined that the ambrosia fungus involved was *Monacrosporium ambrosium*, and Gadd (1947b) succeeded in rearing larvae through to maturity on laboratory cultures of the fungus.

Gadd also made detailed studies of the life-cycle (Gadd, 1941; 1949) and the formation and healing of galleries (Gadd, 1947a). In *X. fornicatus*, as in the *Xyleborus* genus generally, the male beetles are much smaller than the female (Figure 3) and the wings are undeveloped, so that they are flightless. The males, which have a shorter adult life than the females, average about 10% of the adult population at any time, but the true sex ratio in the broods is probably nearer 4 : 1, females to males.

The young mature female beetle, after emergence from the parent gallery and a dispersal flight, makes a new gallery in the wood of a tea stem and introduces the ambrosia fungus on to the walls of the gallery. The galleries are made mostly in younger stems from three-sixteenths to half an inch in diameter, and many are excavated close to the outside of the woody cylinder of the stem, often separated from the cambium by only a thin layer of the youngest wood (Figure 4). The method by which different species carry the spores of the fungus to the new galleries varies. Fernando (1960) has shown that in *X. fornicatus* the spores are carried in special sacs in the head. The female lays eggs over a period of time (probably 10-20 days or more) and the larvae, which are white legless grubs (Figure 3), hatch and feed on the ambrosia fungus, pupating in the gallery after three development stages (instars) and successive moults. The young female beetles emerge from the pupal stage and remain in the parent gallery for several days (maturation phase) before they leave through the original entrance hole.

The fact that egg-laying and consequently the development of the young is staggered over a period makes it difficult to estimate the average brood size and period of development under different conditions. Occupied galleries usually contain a mixture of the different immature stages, commonly the parent female and eggs and larvae of different ages—or the parent female and larvae, pupae, and young adults. Gadd (1941) reported that from the entry of the female parent to the emergence of first female offspring took about 45 days at Passara (3500 ft.). Emergence of the brood is also spread over a period of time. There are no distinct generations and new galleries are started all the time.

The parent female beetle usually dies within the gallery, after the brood, or most of them, have developed and emerged. She raises only one brood and the gallery is not used again by another female. In healthy wood the opening of the gallery heals over by growth from the cambium, but internally the gallery in the wood remains.

Calnaido (1965) has recently shown that the young female beetles, after emergence from the parent gallery, enter a phase of aerial dispersal. They 'take-off' in upward flight by day, the peak of their flight activity being around noon, and, although their own powers of flight are not great, many are carried considerable distances by wind and convection currents.

Xyleborus fornicatus has been recorded in a wide variety of host plants, and has a natural reserve in the forests of Ceylon. Quite often, beetles bore in tree species in which they do not appear to

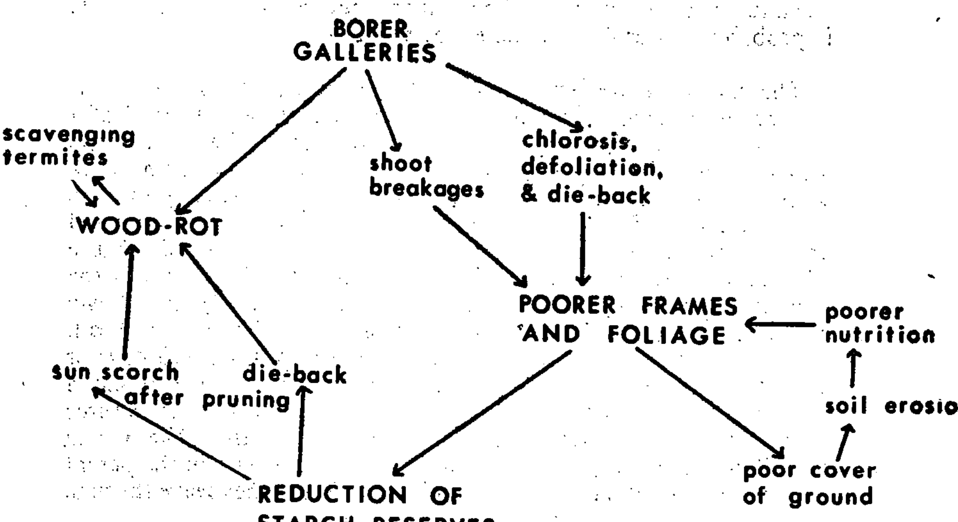


FIGURE 1.—A schematic representation of the secondary effects of shot-hole borer damage and some of the inter-actions which results in chronic debilitation of tea bushes.

be able to raise broods successfully. The shade trees commonly interplanted in Ceylon tea contain several other species of Scolytidae, including other *Xyleborus* species very similar to *fornicatus* to the untrained eye; but Judenko (1961b) found that only *Albizia falcata* and to a much lesser extent dadap (*Erythrina lithosperma*), showed evidence of *X. fornicatus* breeding in them. He further showed that beetles taken from *A. falcata* could breed successfully in tea. Whether this has any effect in practice on infestation in tea, which contains much greater numbers, is as yet undetermined.

2.3. DAMAGE TO THE CROP

The presence of recently formed galleries in thin stems of the tea bush has a marked effect on growth, which at the peak of a severe attack (usually in the late second year after pruning) can result in some defoliation and die-back of shoots and often accentuates chlorotic symptoms in the foliage. Galleries also weaken thin stems so that many are broken, at the points where galleries are formed, during plucking and other cultural operations. These factors lead to a direct loss of crop which in severe attacks is often 20%-30% in the second and third years of the pruning cycle.

In addition there are secondary and chronic effects (Gadd, 1947c). Attack impoverishes the bush frames and the maintenance foliage, which on the one hand gives the bushes less chance to maintain good reserves and, on the other, can result in a poor cover of tea, and vacancies, with the concomitant effects of soil exposure.

Bushes with poor reserves are liable not to recover well after pruning, with possibly die-back of the shoots and sun-scorch on the frame after pruning. The association of the secondary damage of wood-rot with borer-damaged frames is well known, and is particularly severe in the low country. Wood-rot fungi gain a hold in dead or moribund wood caused initially by galleries that do not heal, and from die-back on younger shoots, and secondarily in larger branches that suffer sun-scorch and die-back after pruning. Scavenging termites, strictly a secondary pest, clean up the dead wood but, in so doing tend to expose fresh surfaces of live wood, on which the callusing tissue is attacked before a callus can properly form. It is remarkable that the rotten frames that often exist after many cycles of severe borer attack can support any reasonable yield at all.

This 'vicious circle' has been described to show how borer damage is linked with cultural factors that cause chronic debilitation of tea. The good health of the tea bush is dependent upon a good frame, maintenance foliage and good reserves. Obviously, any factors which injure these will debilitate the bushes. Any type of wound will tend to enhance wood rot.

However, experience with chemical control over the last few years leaves no doubt that Shot-hole Borer, in mid-country and low-country districts, is very often a key factor which limits the response of the tea to increased fertilizer and other cultural improvements.

2.4. PATTERN OF ATTACKS

In mature tea, heavy attacks follow a typical pattern through the pruning cycle. Pruning removes much of the wood that contains live beetles and young, the proportion depending on the hardness of pruning and how much of the younger wood is removed. After pruning, the number of borers in the pruned bush frames declines very markedly and very few fresh galleries are made; evidently conditions become unfavourable. The reasons for this are not certain, but probably are connected with the sudden reduction of sap flow. Because conditions remain unfavourable for several months, beetles emerging from the prunings cannot successfully recolonise the pruned bushes. The prunings usually dry up fairly quickly so that many of the young stages fail to develop.

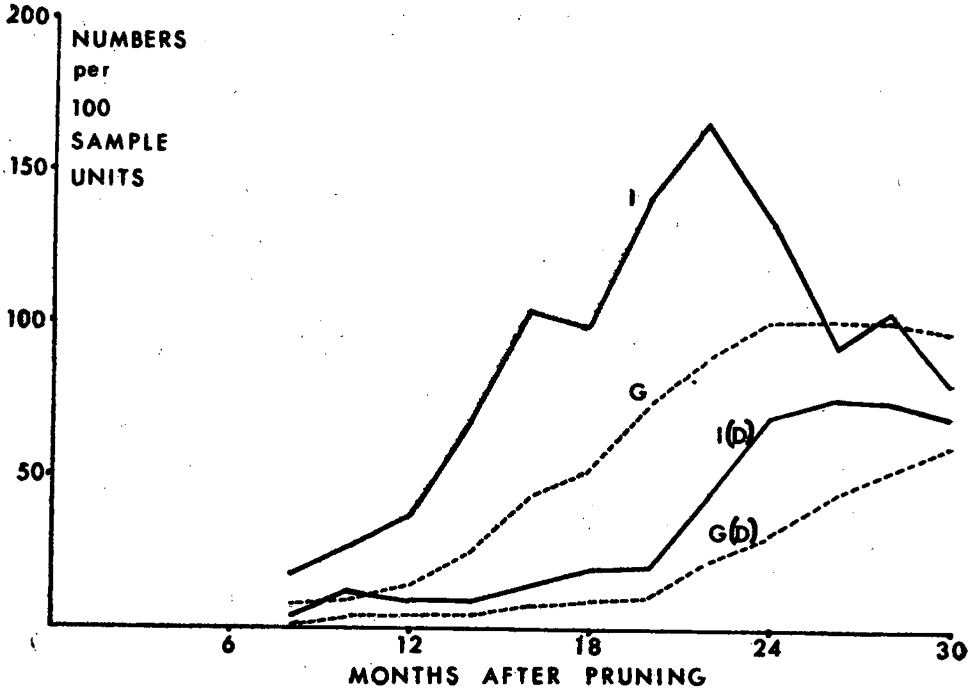


FIGURE 2.—The average results of borer control with dieldrin on eleven field trials, to the 30th month after pruning—the number of live borers (I) and of galleries (G) per 100 sample units on the unsprayed plots; and the number of live borers, I (D), and of galleries, G (D), on the dieldrin sprayed plots. The counts are the averages for each bi-monthly sampling period.

Conditions become favourable again with the growth of the new wood and, as soon as this is thick enough (3/16th to 1/4th inch) to render it physically possible for borers to make galleries, the attack of the new cycle starts to build up. From the first year the number of borers and galleries increases to a peak of attack which usually occurs in the latter half of the second year. Sometimes the new wood suffers quite heavy attack by the end of the first year, but more generally the attack is not very noticeable until the 15th month. When a heavy peak attack occurs in the late second or early third year it is followed by a massive decline in infestation to low numbers by about the 30th month. In longer cycles numbers then may show a further rise and decline between the late third and the fourth year, but much less than the second-year peak of attack.

Galleries do not heal up internally in the wood, but remain permanently, and incidentally provide a record of past attack. It has been found, however, that the gallery density (the numbers assessed by unit sampling) does usually decline after the peak attack, because of the growth of new wood and thickening of thin stems not previously attacked.

Recent studies (Cranham, 1966a) have shed some light on the factors which influence the growth and decline of attacks. Optimum conditions for gallery formation and brood rearing are found in young, vigorous wood, generally stems under half-an-inch thick. In mature tea, the practice of pruning and subsequent regrowth results in abundant young wood free of old galleries and susceptible to attack. Gadd (1949a) was of the opinion that the new wood becomes progressively less suitable as it ages through the pruning cycle, and that this brings about the decline in numbers after the peak attack in the second year. There is, however, strong evidence that the accumulated attack itself renders conditions progressively less suitable. Heavy attacks develop to an upper limit of gallery density where, in effect, nearly all the suitable wood for gallery formation and brood rearing has been used up; fewer and fewer new galleries can then be formed and the infestation declines. Seasonal weather changes also affect the borer; it is not yet known how they act, but probably they act indirectly through their effect on the sap-flow and growth of the bushes. It has also been found (Calnaido, 1966) that there are seasonal peaks of aerial dispersal. These aspects require further investigation but evidently conditions are not continuously favourable for increase throughout the year.

In many fields, in line with Gadd's hypothesis, the potential for increase in the third year after pruning does appear to be less; but in certain others it has been seen that if there is not a heavy peak attack in the second year, as for instance when dieldrin spraying prevents it, this can occur in the third year.

No parasites of *X. fornicatus* have been found in Ceylon or elsewhere, nor any predators other than the larvae of the drosophilid fly *Phortica xyleboriphaga* Senior-white. True predation by this dipterous larva is in doubt, however, and Gadd (1941) showed that it was chiefly associated with fermentation in unhealthy galleries. Similarly no diseases of *X. fornicatus* are known; although some may exist, it is unlikely that they are important.

2.5. FERTILIZATION AND BORER ATTACK

It is generally considered that the borer has increased markedly over the last 10 15 years. Whilst the reasons for this may be several, there is evidence that the greatly increased use of fertilizers, by promoting more wood and more vigorous growth, has created better conditions for Shot-hole Borer.

Over 20 years ago, Gadd (1944, 1944a) in a trial at Passara found what he termed an "unusual" correlation between the severity of stem breakages due to the borer and the yield of plots as influenced by fertilizer treatment. He concluded that fertilizer treatments that increased the yield also increased the borer attack and damage, thus resulting in a reduction of the benefit obtained from manuring. That this can occur has been further demonstrated in the Endane manurial trial.

If these findings are valid generally, they are clearly of great importance, for over the last 15 years the yields of many tea fields have been doubled or more than doubled in response to much heavier fertilizer dosages and other cultural changes. The response has been poorest in the mid-country and low-country districts suffering from Shot-hole Borer, sometimes resulting in uneconomic manuring, and static, or even declining, yields which render the economy of such estates precarious. On many of these estates, chemical control of the borer has in fact reversed this trend and the increases in yield have often greatly exceeded what we would expect from borer control alone, suggesting a much improved response to additional fertilizer.

These ideas may puzzle planters, for it is true that in the past the 'answer' to borer attack was to increase fertilizer dosage. It is important here to distinguish between the effects of the borer and the actual numbers of borers. Good cultural management and generous fertilization can do a great deal to alleviate the effects of borer attack, enabling the bushes to maintain a yield level or even produce more; but these measures do not reduce the numbers of the borer and may actually increase them, since young vigorous wood offers ideal breeding conditions.

The effects are deceptive in that many heavily attacked fields on well-managed estates give high yields. Experience of chemical

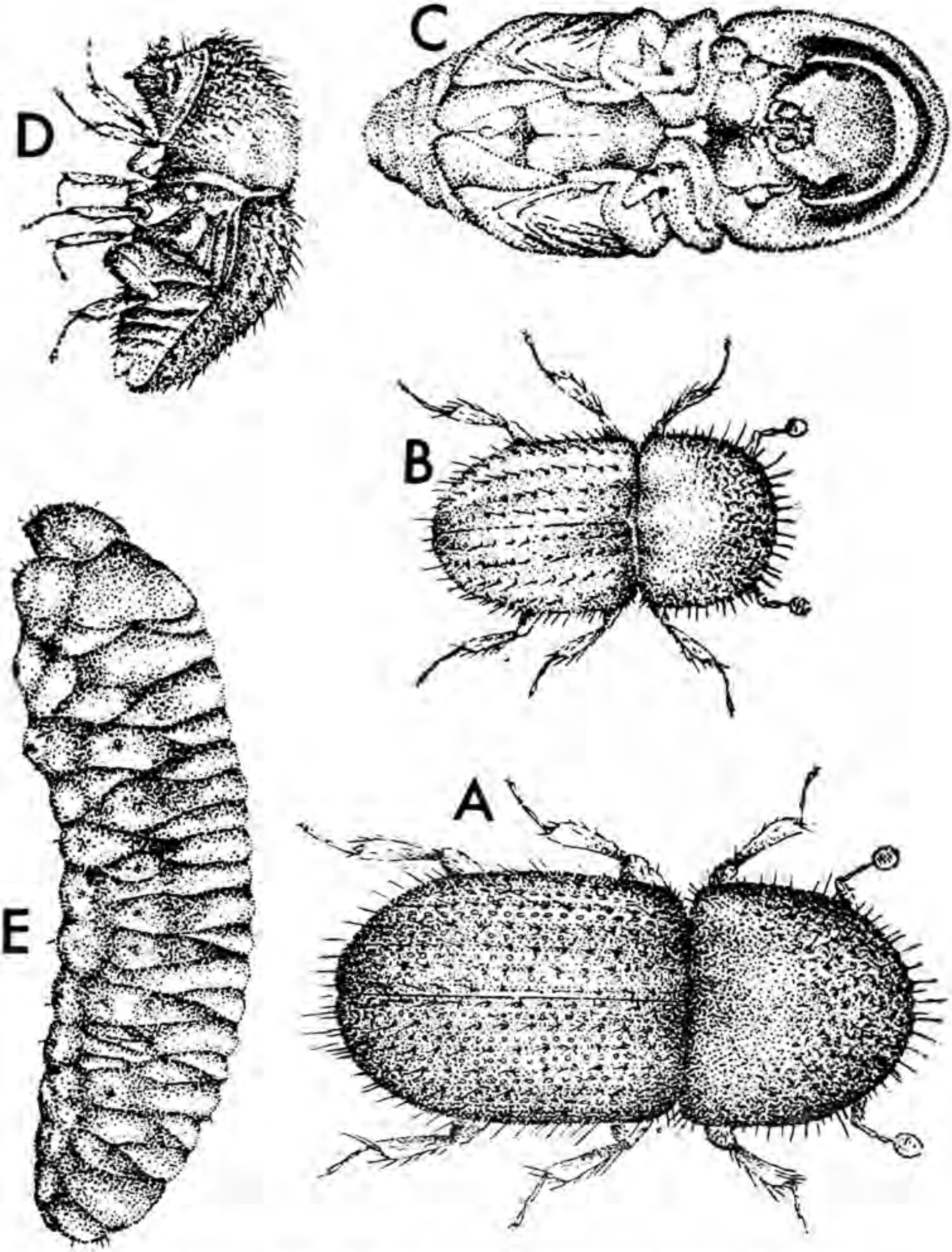


FIGURE 3.—Shot-hole borer of tea (*Xyleborus fornicatus* Eichh.): A—female beetle; B and D—male beetle; C—pupa; E—mature larva; all greatly enlarged on same scale. (Drawings by W. T. Fonseka, from Gadd (1949)).

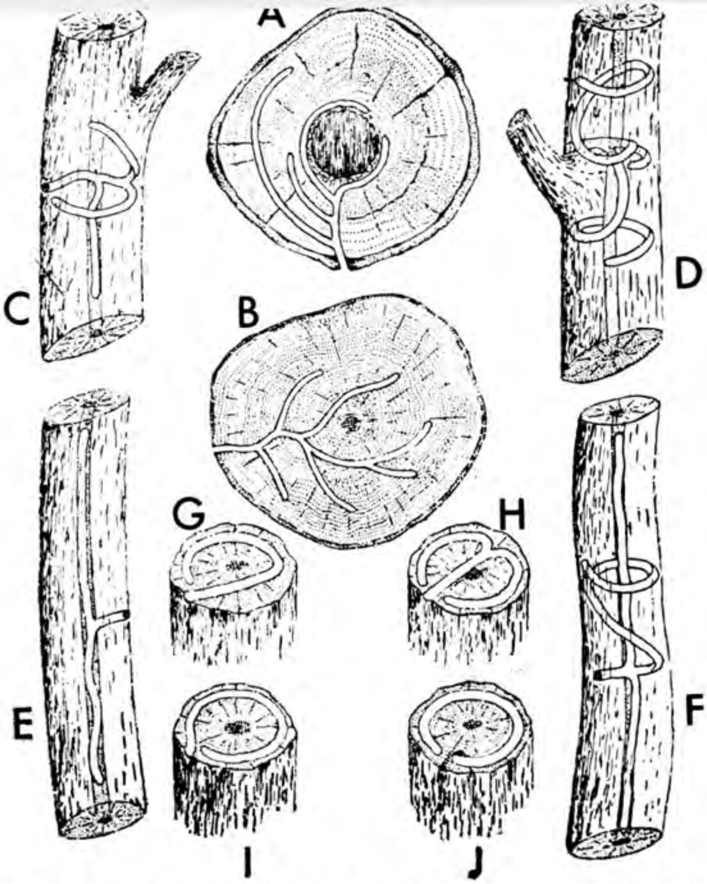


FIGURE 4—Galleries made by shot-hole borer:—A—in castor stem; B—in large tea stem; C. E. D. F—longitudinal and spiral galleries in smaller tea stems; G. H. I. J—galleries at fractured ends of tea stems.
(Drawings by W. T. Fonseka, from Gadd (1947))

FIGURE 5.—Shot-hole borer attack: split four-inch 'sample units' of tea stems, for assessing the degree of attack.

control has now shown that such fields will usually give much higher yields when the borer is controlled; indeed the response to borer control in such fields is generally much greater proportionately than in low-yielding fields.

There is a quite widespread belief also that heavy potash manuring, sometimes even more than is given in the T. 750 mixture, will reduce borer incidence. Again, potash may have an important role in alleviating the effects of borer attack but there is no evidence whatever in T. R. I. trials that it has any effect on the numbers of the borer.

2.6. DEVELOPMENTS IN CHEMICAL CONTROL

Until the advent of modern insecticides, there were no effective control measures. The effectiveness of dieldrin was first demonstrated by Austin (1955), but outbreaks of Tea Tortrix arising as a side-effect (Baptist, 1956) discouraged the use of this insecticide for several years. Judenko and his colleagues carried out many field experiments with dieldrin (Judenko, 1958, 1960; Judenko, Shanmugam & Hasselo, 1962) which provided further information of value, although they were mostly on small plots and of limited duration. Interest was then focussed on the value of spraying just after pruning when the bush frames are readily accessible for good spray coverage and the risk of undesirable residues in the made tea can be avoided (Cranham, 1962). A series of large plot trials was started on tea estates in 1960 to evaluate post-pruning sprays of dieldrin under normal estate practice (Cranham, Danthanarayana and Ranaweera, 1962; Cranham 1966) . DDT sprays were used for control of Tortrix outbreaks caused by the effect of dieldrin on the Tortrix parasite, *Macrocentrus homonae* Nixon. It was notable that serious Tortrix outbreaks occurred on only half the trials and where they did occur the outbreaks were very largely confined to the dieldrin-sprayed area. Until natural control was re-established, Tortrix could be controlled by one or two sprays of DDT. Control of the heavy second-year borer attack was very promising.

As a result of these trials and others, and also experience by a few estates (e.g. Newton, 1960), the decision was taken in late 1961 to give provisional recommendations on post-pruning sprays of dieldrin, with the use of DDT for control of Tortrix as an integral part of the method (Cranham, 1961). It was realised at that time that the effects of dieldrin, as regards both borer control and more particularly the Tortrix side-effect might well be influenced by the scale of spraying measures. However, this could not be assessed by trials but only by the actual results of extensive spraying on estates. Rough estimates of the acreage sprayed show that about 6000 acres were sprayed in 1961, 12,000 acres in 1962 and about 25,000 acres in 1963 and in 1964.

This estate experience together with precise yield trials, showed beyond doubt that the yield increases to be obtained from controlling the borer were in many cases far greater than had previously been expected. The method of spraying could be applied successfully under the wide variety of estate conditions, even in the wettest districts. Application by mist-blower proved effective and often rendered spraying much more practicable, especially in the low-country.

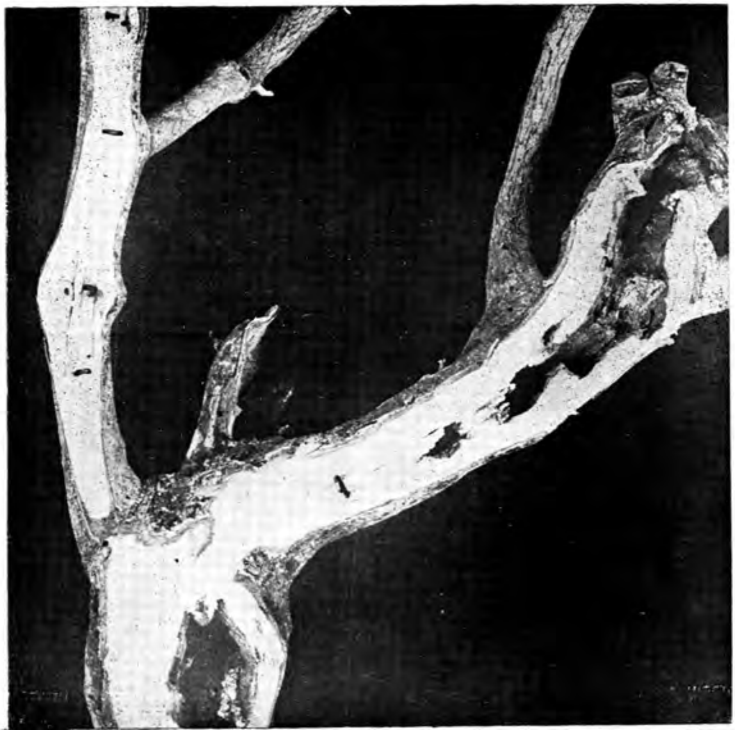
On the other hand, estate experience also showed that as the scale of spraying increased the magnitude of the Tortrix side- effect usually increased. Tortrix outbreaks tended to occur on nearly all sprayed fields and more frequently required two or three sprayings with DDT or Dipterex to achieve control; in addition, outbreaks often occurred on neighbouring fields not sprayed with dieldrin, sometimes extensively. The parasite *Macrocentrus* was sometimes at very low numbers for several months, and though it always built up again it took much longer to do so. This problem was worst in districts mostly above 3000 ft and not nearly so severe in districts at lower elevations which in fact were spraying a larger proportion of their acreage with dieldrin. In 1963-64, natural outbreaks also occurred extensively in up-country districts at 4000-6000 ft and these were quite unconnected with dieldrin spraying; there is no doubt that these were years in which the natural incidence of Tortrix was high. It was appreciably less in 1965.

Towards 1964 and 1965, after about three years of wide use of dieldrin, two more caterpillar pests began to be prominent in a large number of estates where dieldrin spraying have been done. These two pests, known as the Twig Caterpillar (*Ectropis bhurmitra* Wlk.) and the Looper Caterpillar (*Buzura strigaria* Mo.=*Biston Suppressaria* Gn.) belong to a group of moths known as Geometrids (Lepidoptera: Geometridae.) It is known from past experience and from their occurrence in India that these two caterpillars can be more dangerous than the Tea Tortrix, and when outbreaks occurred in estates during 1964 and 1965, many were greatly alarmed because in most instances the damage done was devastating. The increase in the incidence of the Twig and Looper Caterpillars and the persistance and recurrence of Tortrix attacks in areas where dieldrin had been sprayed made it necessary to reconsider the recommendations given previously for Shot-hole Borer control. It was evident that the damage caused by dieldrin to the parasites of caterpillar pests was sufficiently serious to recommend estates completely to abandon the use of dieldrin in mature tea and over large areas (see Danthanarayana 1966).

This experience focussed interest on possible alternatives to dieldrin. Of the many other insecticides tested (Cranham, 1964) useful control of the borer was afforded only by aldrin and Telodrin,

FIGURE 6—Secondary effects of shot-hole borer—Section of branch showing internal wood-rot which has gained entry through old borer galleries at a pruning cut, and is extending downwards in the heartwood around old galleries.

FIGURE 7.—An example of advanced internal wood rot, showing cavities cleared out and gradually enlarged by scavenging termites. (*see also* figure 35)



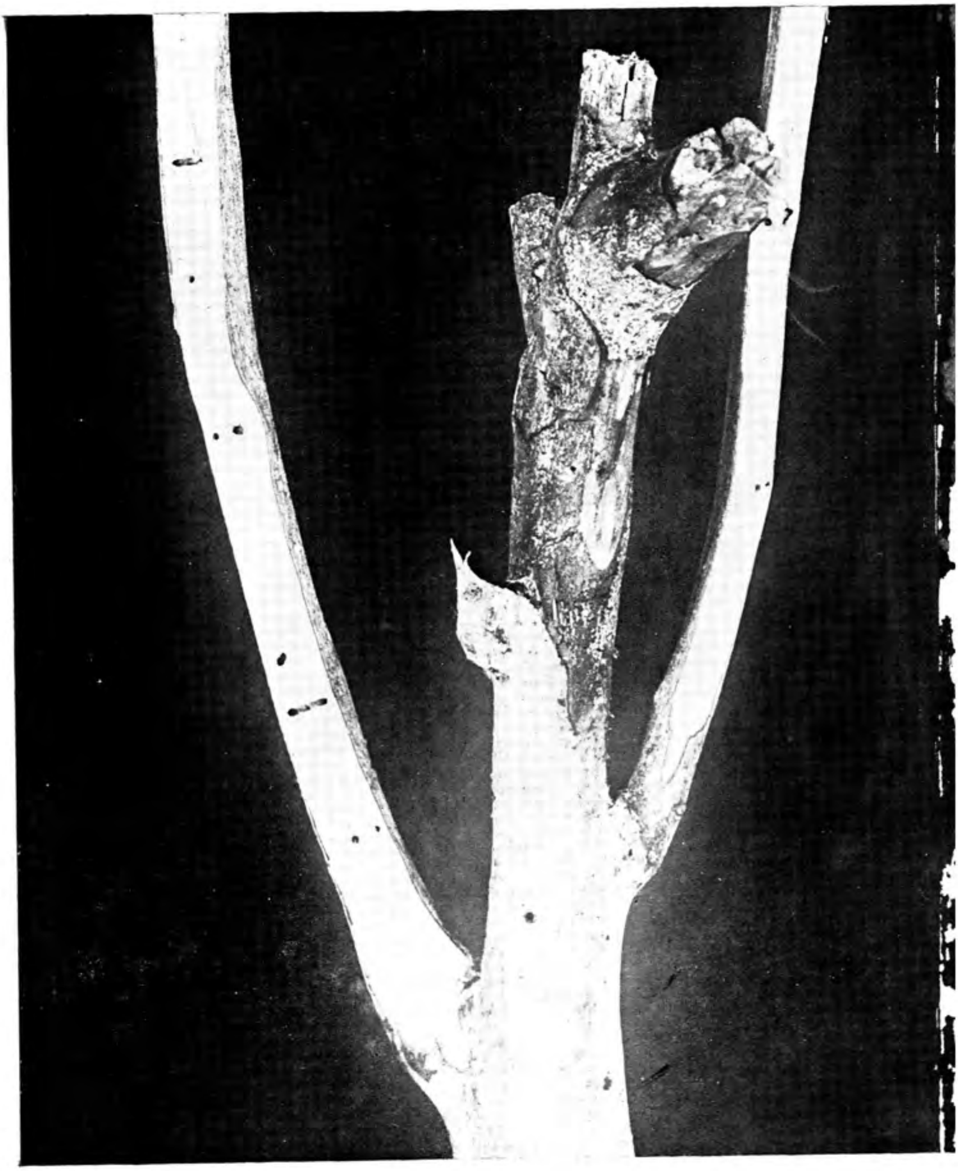


FIGURE 8—An example of die-back of a pruned branch in which buds have been killed by shot-hole borer. New stems have grown from buds lower down, but these stems are in turn heavily attacked.

organo-chlorine compounds of a similar type to dieldrin. Telodrin, whilst very effective at low dosages, was considered too toxic for use on tea estates. Aldrin is very closely related to dieldrin and the mammalian toxicity is of the same order; it is more volatile and much less persistent than dieldrin on plant surfaces; small residues that remain, however, are converted to dieldrin by oxidation. Being less persistent, aldrin does not give control of Shot-hole Borer as lasting as that obtained from dieldrin; nor, on the other hand, does it interfere so severely with the natural parasitic control of Tea Tortrix, although it is not free from this effect and can induce outbreaks when the natural incidence of Tortrix is high.

Field trials showed that as a post-pruning spray aldrin would not be a satisfactory alternative except possibly for short pruning cycles of 18-24 months in the low-country. Aldrin did, however, perform well in certain trials as a 'mid-cycle' spray applied to the basal parts of the bush frames about one year after pruning (between the 9th and 15th months). This was intended to reduce the effects of second-year build up of borer but the results were not always consistent. This type of spraying is only practicable on tea where the frames are accessible for spraying i.e. where there is an incomplete cover of tea and more particularly on high jat bushes.

When the use of dieldrin for Shot-hole Borer came under review, it became evident that aldrin spraying is not an answer to the problems created by dieldrin spraying because a part of the aldrin applied is converted to dieldrin. Geometrid caterpillar outbreaks were reported on fields where mid-cycle applications of aldrin were done. Spraying of aldrin as a control measure against the borer has since been abandoned (Danthanarayana 1966).

2.7. CONTROL AFFORDED BY SPRAYING

The average results of the trials on post-pruning sprays of dieldrin are shown in Figure 2. The reductions in the numbers of beetles and of galleries on the dieldrin-sprayed plots were rather similar. There was close to a two-third reduction by the 12th month and the greatest effect occurred at the 18th month, more than 80% reduction. The effect of spraying gradually declined over the next 18 months and was negligible by the end of the third year. Thus, dieldrin gave good control up to 24 months after application, at which stage the average count of galleries was reduced by more than two-thirds; but in several of the trials the attack was rising by the end of the second year and the crucial question then was whether spraying would give useful control over pruning cycles longer than two years. In fact, in most trials, the attack on the sprayed plots in the third year was much less severe than had occurred on the unsprayed plots earlier i.e. the delayed build-up on the sprayed plots resulted in a delayed and lower peak of attack.

However, the results in the third year were variable. In some trials there was little or no build-up, whereas in others the third-year build-up was almost as severe as the typical heavy second-year attack. Examples of the latter occurrence have also been apparent on estates. The reasons for this variability are not well understood but probably they are connected with the suitability of the wood for attack in the third year, which appears to vary greatly in different types and conditions of tea.

2.8. YIELD INCREASES FOLLOWING CONTROL

In the first cycle after spraying, trial evidence shows that there is usually a 15%-25% increase in crop over a two- or three- year cycle, with most of it occurring in the second and third years. This applies to the control of heavy attacks; obviously we cannot expect a large response from controlling a light attack.

The heaviest infestations generally occur in good high-jat fields and these fields tend to respond well after borer control. There is definite trial evidence that the response to increased fertilizer can be improved; we are also finding many examples on estates of dieldrin sprayed fields in which the increase in yield, compared to previous cycles, is rather more than we would expect purely from borer control e.g. over 50% in the second year. In these cases there may have been an improved response to increased fertilizer (and perhaps to other cultural improvements) additional to the effect of borer control *per se*. On tea showing static, or even declining yields, the effect of borer control has often been to create a trend of increasing yield.

Results on low-jat fields, however, have been more variable. These fields usually carry only low or moderate infestations and the increases in crop after control are smaller. There is so far no evidence of an improved response to fertilizer, probably because the potential yield is, in any event, much lower than in high-jat fields.

2.9. NEW CLEARINGS

Shot-hole Borer attack in new clearings is less predictable and does not follow such a regular pattern as in mature tea. Infestation can develop more rapidly and decline more rapidly (particularly after drought). The attack can start on young plants as soon as the wood is over a quarter of an inch thick. It can start even in the nursery if there are infested mature bushes nearby. Galleries have been noted even in green stems of a quarter of an inch or so in thickness—which on the more vigorous clones they can sometimes be.

How soon the attack starts on susceptible plants appears to depend somewhat on sources of infestation. If a new clearing is isolated from infested mature tea, the borer will usually take longer to develop. Quite often the attack starts in the first year after planting and is really heavy by the second or third years.

The wood of young bushes in many new clearings, seedling or clonal, appears to offer very favourable conditions for borer development; we suspect that the very liberal manuring practised nowadays contributes to this. Infestation can sometimes develop to considerably larger numbers than are ever found in mature tea; the number of immature stages per gallery (brood size) is often larger. The effect on the growth of the bush can be very great. This is demonstrated by the immensely better growth made after chemical control of the borer, which can show up markedly within three to six months after spraying. If the stems are allowed to grow up to 3 4 feet in height or more, the top weight is conducive to breakages and the incidence of breakages can be high from relatively light attacks. Bringing-into-bearing by bending can result in excessive breakages in attacked clearings, and even pruning can be hazardous.

2.10. SHOT-HOLE BORER CONTROL IN NEW CLEARINGS

The revised recommendations for Shot-hole Borer control (Danthanarayana, 1966) emphasize that, at present, chemical control measures should be taken only in New Clearings. The necessity to control the borer in newly planted tea is thought to be important as it is considered that the first four to six years from the time of planting is a very vital period during which the stems need some protection from borer attack. On estates where Shot-hole Borer is considered a serious pest, the following spraying programme applicable only to newly planted tea has been suggested:

1. A solution of 2 pints of dieldrin (20% E.C.) in 100 gallons of water to be sprayed at the end of the first year from planting, and repeated every year until the first prune,
2. A solution of 4 pints of dieldrin (20% E.C.) in 100 gallons of water to be sprayed immediately after the first prune,
3. No further dieldrin spraying

It is important to spray on dry frames to cover most of the stems, avoiding the leaves. Spraying should be done only with knapsack sprayers fitted with nozzles having a disc size of approximately 1 mm. *Mist-blowing is not recommended because of possible spray drifts.*

If plucking is done at all, when 2 pints of dieldrin are used, there should be a safety period of four weeks between spraying and the next round of plucking by discarding the plucked leaf or by resting the tea. The Tortrix side-effect following low doses of dieldrin should be less, but every round of dieldrin spraying must be followed by prompt DDT application (spray at the first signs of the presence of Tortrix Caterpillar) for control of Tortrix if necessary. Tortrix side-effect could be greatly minimized by timing the dieldrin spraying towards the end of the dry weather, with the monsoon ahead.

This spraying programme should enable estates to obtain Shot-hole Borer control in new clearings until good bush frames are well established. Control of the borer in newly planted tea should minimize the problems of sun scorch, wood-rot, subsequent termite damage and poor recovery from pruning.

Dieldrin formulations—Suitable 20% dieldrin E.C. formulations available in Ceylon are 'Dieldrex 20' (*ex* Shell Company of Ceylon Ltd.) and 'Baur's Dieldrin 20% E.C.' (*ex* A. Baur & Co. Ltd.).

> N.B.—"E.C." means 'emulsifiable concentrate', a liquid concentrate of the active insecticide in a solvent which forms an emulsion on mixing with water. 'Dieldrex' is a trade name for an E.C. formulation containing 20% of the active insecticide dieldrin (*i.e.* 2 lbs. per gallon).
>
> There is no practical advantage to justify the additional cost of using 'Dieldrex Extra' (*ex* Shell Co.), a 20% dieldrin E.C. containing added conmarone resin.

CHAPTER 3

TEA TORTRIX (*HOMONA COFFEARIA* NIETNER)

3.1 STATUS AS A PEST

Tea Tortrix is an indigeneous pest in Ceylon, first described by Nietner (1861) as a pest on coffee and later noted by Green (1890) as a serious pest on tea. This species is a minor pest of tea in South India, North-east India and in Indonesia also; but in these areas another leaf-rolling tortricid, Flush-worm, *Cydia leucostoma* Meyrick, is of greater importance and this species, curiously, is not present in Ceylon at all. In China, Japan and Formosa, *Homona menciana* Wlk., stated by Meyrick (1932) to be a geographical form of *H. coffearia*, is recorded as a pest of tea.

From 1910 to the late 1930's Tea Tortrix was as serious as any pest of the Ceylon tea industry, being prevalent in districts above 3000 ft in the South-west monsoon zone. This situation changed radically after the successful introduction by the Tea Research Institute in 1935-36 of the parasite *Macrocentrus homonae* Nixon from Java, one of the most successful instances of biological control ever achieved in the world. By 1940 the parasite had spread itself all over the island's tea-growing districts and Tortrix had become an occasional and local pest. In recent years, outbreaks of Tortrix have become more common for two reasons. Firstly, outbreaks of Tortrix following the use of dieldrin for control of Shot-hole Borer have been common in mid-country and low-country districts. Secondly, there has been an increased natural incidence of Tortrix in up country districts; this started from about 1956-7, that is, long before dieldrin spraying was started in the mid-country, and the evidence does not point to this having anything to do with dieldrin spraying.

3.2. RECOGNITION AND LIFE CYCLE

The life-cycle of Tortrix is that of a typical moth. Eggs are laid in masses of 100-150 by the female moths on the upper surfaces of mature leaves; these masses are thin, pale in colour and gelatinous in appearance, and generally under half-an-inch on the longest axis (Colour Plate 7). They are not at all easy to find unless they are numerous. The tiny larvae hatch after 6-11 days, and they scatter and move upwards to the growing points of the bushes and commence feeding. The larvae make leaf "nests" by means of silk threads, sometimes of one leaf rolled over so that the sides are spun together, sometimes of two or more leaves together (Colour Plate 9). Younger larvae are mostly found in the flush, and the older larvae on both flush and maintenance foliage. The larvae are dark green in colour with a shiny black or dark brown head and about one inch in length when full grown (Colour Plate 8). Unhealthy larvae are very pale-coloured or even yellow in colour. Several nests are usually constructed by one larva in the course of its development, and the mature larva pupates (turns into a pupa or chrysalis) inside the final nest. The adult moth emerges about ten days later. The adult female is a small brown tortrix moth, bell-shaped in outline when at rest and 12-13 mm in length; the male is more grey in colour and about 8 mm long (Colour Plate 10). The life-cycle of Tortrix takes about 7-8 weeks up-country and probably 5-6 weeks at elevations around 2000 ft. Tortrix has a wide range of host plants other than tea. Severe damage to *Albizia falcata* (=A. *moluccana*) and dadap is not uncommon, and Tortrix larvae may also be found on *Gliricidia*, *Grevillea*, *Crotalaria*, *Tephrosia*, *Acacia*, many forest trees and some annual weeds.

The only caterpillar pest of Ceylon tea which can be confused with Tortrix is Tea Leaf Roller (*Gracillaria theivora* Wlsm.) which can easily be distinguished by the habit of rolling the leaves from the apex downwards, not from the side and together as Tortrix does (*See* Chapter 5).

3.3. PARASITISM AND DISEASE

Various entomologists were concerned with the control of Tortrix for more than thirty years, including Green, Jardine, Hutson, Light and Redman-King. King spent several years studying possibilities for biological control. The indigenous parasites of Tea Tortrix which occurred at this time were well known and studied; they were numerous but none provided an effective control. It was not until 1935 that various parasites of Tea Tortrix present in Java were imported from that country. Amongst these was *Macrocentrus homonae* which was released at St Coombs in 1935 and again in 1936 (Gadd, 1941a). By February, 1937, it was clear that the parasite had established itself on about 50 acres of St Coombs and about 50% of the Tortrix larvae examined were parasitised. Subsequent examinations on neighbouring estates showed that the parasite was migrating quite fast. Only two further liberations were made—one at Maskeliya in October, 1937, and the other at Madulsima in August, 1938. By 1939 it was known that the parasite had established itself in Dimbula, Maskeliya, Pussellawa, Dolosbage, Punduloya, Kotmale and Morawak Korale. It is interesting to note the remarkable migration of the parasite to the last named district, as this district is widely separated from others by extensive areas of jungle and other crops. These facts speak highly of the powers of migration of *Macrocentrus*.

Since 1940, Tortrix has been a minor pest of tea, and it is generally kept at a very low population density by *Macroncentrus*. It is important to stress that Tortrix is not wiped out by *Macrocentrus*;

if this happened, *Macrocentrus* would itself be destroyed, for as far as we know, Tortrix is the only suitable host insect for this parasite in Ceylon. Tortrix and *Macrocentrus* have been present on every field that we have examined for this purpose, although usually in extremely low numbers.

Macrocentrus homonae is a small wasp-like parasite (Colour Plate 10). The adult female, by means of her long ovipositor, lays a single egg in each Tortrix larva that she parasitises. Gadd (1946a) observed that this single egg gives rise by division (poly-embryony) to several grubs, sometimes as many as 30-40 within the body of one Tortrix larva. The grubs feed on the body fluids of the host, finally emerging from the skin of the Tortrix larva when the latter is mature and turning back to consume the whole host body except for the head capsule and part of the cuticle. Each larva then spins a silken cocoon inside which it pupates; all the cocoons from a single host are matted together to form a mass of brown cigar-shaped cocoons (Colour Plate 11) within the original leaf "nest" of the Tortrix and from these cocoons the adults later emerge. The cocoon masses are the only stage of *Macrocentrus* which will commonly be seen by the planter.

M. homonae is a very efficient parasite of Tortrix which disperses rapidly and has good host-searching capacities. It has a high rate of reproduction, being poly-embryonic, and the generations coincide well with the generations of the Tortrix host. Also tea, as a long lived perennial crop, relatively undisturbed by the use of pesticides, is an environment suited to the maintenance of parasitic control.

As noted above, about twenty species of parasites of Tortrix were recorded before the introduction of *M. homonae*; the commonest species were *Phytodietus capuae* Morley (Ichneumonidae), *Bethylus distigma* Motsch. (Bethylidae) and *Elasmus homonae* Ferr. (Elasmidae) on the larvae of Tortrix, and *Brachymeria euploeae* Westw. (Chalcididae) on the pupae. These are now rarely found and appear to have been 'squeezed out' by *M. homonae*. Five *Trichogramma* species occur as minute parasites of the eggs of Tortrix; the commonest is *T. erosicornis* Westw.

Parasitic insects often themselves have parasites; *Ceraphron fijiensis* Ferr. (Ceraphronidae) is the commonest of such 'hyper-parasites' on *M. homonae* and emerges from the pupae in the cocoons of the latter. This species is known to have been present in Ceylon, hyper-parasitic on other Tortrix parasites, before the introduction of *M. homonae* (Cranham, 1961.)

Larval disease

Diseases of the Tortrix larvae also appear to be an important mortality factor, and the incidence of disease is generally greatest when Tortrix numbers are high and in continuous wet weather, as during the S. W. monsoon period. King referred to this as a 'wilt' disease, but recent checks show that it is not a virus disease and may be caused by a bacterium. There may also be a fungus disease, or diseases, which affect the larvae and pupae, and these diseases of Tortrix require much detailed investigation.

3.4. NATURAL OUTBREAKS AND THEIR CONTROL

Local outbreaks occurring in up-country districts are not generally associated with dieldrin spraying and are termed 'natural' in this sense. They were occurring in Dimbula, Upper Dickoya, Maskeliya, Nuwara Eliya and Udapussellawa districts long before dieldrin spraying in the mid-country was started, and the pattern of outbreaks is what we would expect to happen in biological control, i.e. no parasite can be expected to keep a pest under complete control everywhere and all the time.

There is evidence that the numbers of Tortrix fluctuate through the years, several years of high incidence being followed by years of low incidence and so on; and that these fluctuations are influenced by long-term weather patterns. 1963 and 1964 were years of high incidence; the incidence in 1965 was much less.

Peak numbers of Tortrix usually occur in the dry weather season of the S. W. monsoon zone, from December to April, and typically on fields in the first year after pruning. Sometimes older fields are attacked. All jats of tea may be attacked, but attacks often persist for longer on low-jat tea than on high-jat tea.

Tea in plucking that is attacked by Tortrix should not generally be taken out of plucking; if it is badly defoliated by attack it can be sprayed and then rested. Plucking is a partial control measure, since it removes a lot of the youngest Tortrix larvae that are not yet parasitised. Hand collection of the larvae, on the other hand, is not recommended, since it results in collection of the parasite as well. Spraying is preferable.

The use of DDT is recommended if the damage being done clearly warrants it. It has been determined quite definitely that the use of the available DDT formulations will not interfere with the re-establishment of natural control by the parasite afterwards and the effect of spraying is to leave the balance more in favour of the parasite than before. Hence, whether or not to spray is largely a question of economics.

The percentage parasitism is *not* a certain guide as to whether an attack will continue or not. Natural control factors other than the parasite *Macrocentrus* are also important, including larval diseases (favoured by wet weather) and possibly insectivorous birds.

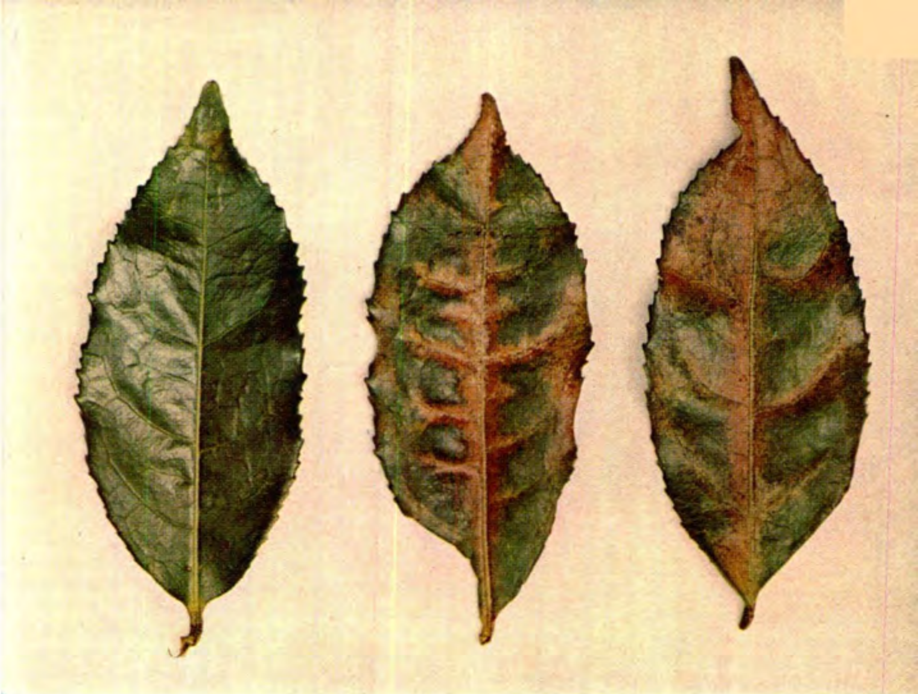
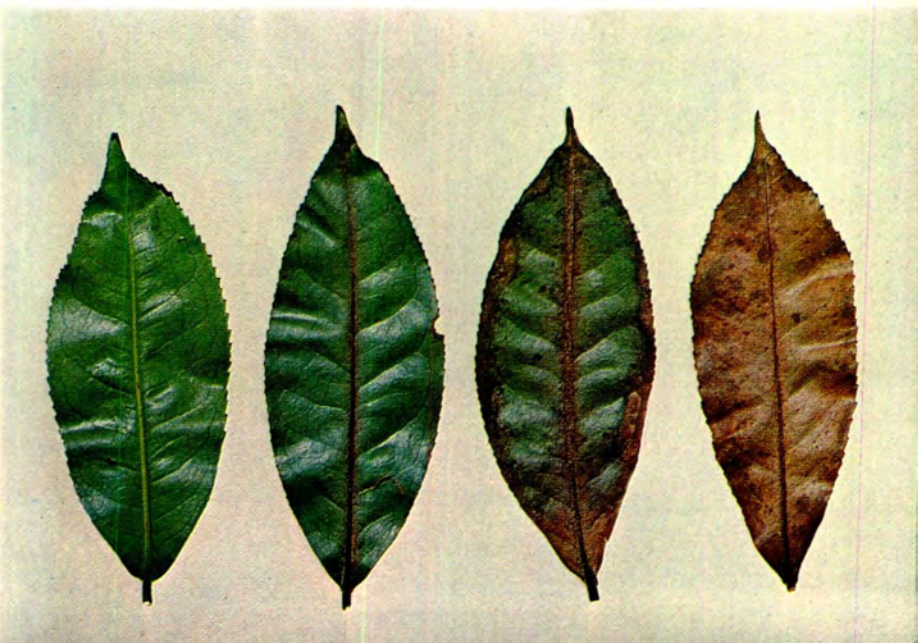


Plate 1. Leaves (upper surfaces) showing attack by Tea Red Spider Mite, *Oligonychus coffeae* (Nietn.); unattacked leaf on left.

Plate 2. Leaves (under surfaces) showing attack by Scarlet Mite, *Brevipalpus californicus* (Banks); unattacked leaf on left.



In dry weather Tortrix attacks may continue despite a high incidence of the parasite. The likelihood is that attacks beginning in the early part of the dry season (December-February) will go on for some time, and that attack starting late in the dry weather will soon be cut short by the effect of the pre-monsoon rains.

The decision to spray or not to spray must therefore rest on the planter's assessment of the damage being done or likely to be done, balanced against the cost of spraying. It is not at all certain whether a moderate attack by Tortrix causes loss of crop; the bushes sometimes appear to make up crop afterwards. A heavy attack certainly causes loss of crop and it is best to spray without delay. Tortrix can be particularly injurious on new clearings and here it is best not to risk damage. Tortrix can sometimes defoliate shade trees and, unless pollarding is culturally desirable, trees up to 20 feet in height can be sprayed by mist-blower.

3.5. OUTBREAKS FOLLOWING THE USE OF DIELDRIN IN NEW CLEARINGS

Tortrix outbreaks occur after most dieldrin sprayings and their control must be regarded as an integral part of the use of dieldrin for shot-hole borer control in new clearings.

The effect is caused because the parasite *Macrocentrus homonae* is reduced to very low numbers by dieldrin spraying and it usually takes four to six months before the parasite is re-established on the sprayed area. Tortrix outbreaks usually develop two to three months after dieldrin spraying and can arise from spraying in any month of the year, although they are worst if they come in the drier months.

Until natural control is re-established on a sprayed field it is essential to control Tortrix chemically and to repeat spraying if necessary. Generally it is not necessary to spray for Tortrix more than twice at an interval of 6-8 weeks if spraying is well done and properly timed. Certain failures in control have been due to one or more of the following points: spraying too late, using less than the recommended dosages, spraying on wet foliage, poor spray coverage, or spraying in patches instead of the whole field.

Tortrix is a pest that disperses very rapidly, so that unless outbreaks are controlled as soon as they start the pest may spread and get out of hand. For this reason spraying only the bad patches in a field is not to be recommended.

Sampling the parasite.—The planter can search for fresh (i.e. not empty) cocoons of the parasite and if these are found quite easily and if Tortrix pupae are few, this indicates that the attack is likely to diminish.

Samples of the Tortrix caterpillars, for us to estimate parasitism by dissection, should be taken by collecting a large bag (say about 18″×12″) full of Tortrix nests taken generally from all over the field including the middle and the edges. The leaf is best sent like this in a cloth bag firmly closed and packed in a carboard box.

We are sometimes asked whether we cannot make releases of the parasite or prescribe measures to foster it. The surprising fact is that the parasite is always present and sooner or later resumes control; even when the incidence is low the numbers present per acre are far larger than we could hope to release artificially. We know of no way of helping it to become re-established more rapidly.

3.6. CHEMICAL CONTROL MEASURES

The insecticides recommended are liquid (E. C.) formulations of DDT. DDT gives an excellent control of Tortrix but may sometimes cause outbreaks of Red Spider Mite or Scarlet Mite, more particularly in districts liable to mite outbreaks. Dipterex is an alternative insecticide which does not have this effect; but it is less persistent than DDT and results have been somewhat more variable. It was recommended in 1962 for Tortrix control in estates where DDT is known to stimulate mite outbreaks. Recent experiments have indicated that Dipterex is inferior to DDT and is not now recommended for Tortrix control.

DDT.—Suitable liquid (E. C.) formulations are:—

Trade name	*Supplier*	*Percentage DDT*
'Arkotine D18'	Shell Co. of Ceylon, Ltd.	18%
'Deenol 25%	A. Baur & Co. Ltd.	25%
'Didimac 25'	Chemical Industries (Colombo) Ltd.	25%
'Sillortox'	Fisons (Ceylon) Ltd, and Harrisons and Crosfield, Ltd.	25%

The dosage recommended is 4 to 6 pints per acre, in 50-60 gallons of water when applied by knapsack sprayers, or in 10 gallons of water when applied by mist-blowers. Use the higher dose of 6 pints for bad attacks and dense bush stands.

In districts where Red Spider Mite is not prevalent, the risk of a mite outbreak is small when spraying is done in the wetter months or with the monsoon one or two months ahead; the maximum risk occurs when the spraying is done at the beginning of the dry weather period, i.e. December to February in the S. W. zone and April to June in the N. E. zone, To prevent a mite build-up occurring, half a pint of 'Kelthane MF' or 1 pint 'Tedion V 18' per acre can be added to the spray solution of 4-6 pints of DDT E. C. in 50 60 gallons of water or to that of 4-6 pints in 10 gallons of water (*See* Chapter 4). The latter mixture can be sprayed very effectively by mist-blowers thus saving on labour costs, or by knapsacks. It can be used on tea in plucking.

Sulphur wettable powders (e.g. 'Thiovit' *ex* Baur & Co., 'Spersul' *ex* Chemical Industries (Colombo) Ltd., or Shell dispersible sulphur, can be added at the rate of 4 lb to the DDT solution for knapsack spraying. It is not recommended that sulphur be used through mist-blowers because it taints made tea badly and there is a danger of drift on to tea in plucking. To avoid taint after sulphur is used there should be a 'minimum safe period' of four weeks between spraying and plucking for manufacture, either by resting or by discarding three plucking rounds.

CHAPTER 4

MITE PESTS

Tea Red Spider Mite, *Oligonychus coffeae* (Nietner)
Scarlet Mite, *Brevipalpus californicus* (Banks)
Yellow Mite, *Hemitarsonemus latus* (Banks)
Purple Mite, *Calacarus carinatus* (Green)

4.1. INTRODUCTION

Mites are not insects; together with ticks they form the order Acari of the Class Arachnida (including spiders); this group is no more closely related to insects than, say, birds are to mammals. Because of their small size, mites are seldom conspicuous, although there is a vast number of species and they are found in almost every habitat available to animal life—in the soil, in both fresh and salt waters, in stored food and other stored products, and parasitic both on other animals and on plants. Of the phytophagous (plant-feeding) mites, there are four families most commonly concerned as pests, each of which is represented by species on tea. Considering all tea-growing areas in the world, the mites are the most widespread and, as a group, probably the most serious pests of tea, especially Red Spider Mite in N. India and Purple Mite in S. India. In Ceylon they are only local and occasional pests, of much less economic importance than Shot-hole Borer, but they are an important factor which has always to be considered when using insecticides, many of which are not only valueless for mite control but sometimes actually lead to increased numbers. All four of the mite pests on Ceylon tea have been known from the earliest days of tea-growing and were noted by Green (1890) in Ceylon and also by Watt and Mann (1903) in India, and by Bernard (1909) in Indonesia. In Ceylon there is little evidence that any of them have become appreciably more common or damaging as pests.

4.2. DISTRIBUTION AND BIOLOGY

Tea Red Spider Mite.—This species belongs to the Tetranychidae or spider-mite family, so called because they spin a fine web of silken threads over the leaf surfaces on which they breed and feed. Hundreds of species of this family have been recorded on plants, several of major economic importance as pests, e.g. the Fruit Tree Red Spider Mite (*Panonychus ulmi* Koch), the Glasshouse Red Spider Mite (*Tetranychus telarius* L.) and the Citrus Red Mite (*Panonychus citri* McG.). *Oligonychus coffeae* occurs on tea in most, if not all, tea areas of S. E. Asia; it is considered the most serious pest of tea in N. E. India, a status previously shared with

Helopeltis theivora Waterh. It has also been recorded from the Transvaal, S. Africa, from Florida, U. S. A., and Queensland, Australia (Pritchard & Baker, 1955). It has a fairly wide range of host plants but on Ceylon tea estates it is common mainly on tea, *Grevillea robusta* and *Albizia falcata.*

Tea bushes attacked by Red Spider can hardly be overlooked. The ruddy bronzing of the upper leaf surfaces shows from a distance and examination shows the red mites running actively on the tops of the leaves and the tiny white cast skins of the mite, which are just visible to the naked eye. All stages can be seen under a 10 x hand lens, usually aggregated in patches over the mid-rib and veins or near the edges of the upper leaf surface. The adult female lays spherical bright red eggs, 0.11 mm in diameter which hatch after several days. There are three development stages—the six-legged larva, the protonymph and the deutonymph, in each of which a quiescent stage precedes the moult from which the next stage emerges. The adult female is elliptical in shape, broadly rounded at the posterior end, and 0.32-0.44 mm in length; she is bright crimson in colour anteriorly whilst posteriorly there are large purplish markings. The male is smaller and slimmer, 0.27-0.31 mm in length, and the abdomen tapers more to a point posteriorly. In Assam Das (1959) found that females laid an average of 90 eggs, at a rate of 4-6 per day, and the life cycle took about 9-12 days in the summer months and up to 28 days in the cooler winter months.

Generations are completely overlapping and all stages of the life cycle are found on the leaves throughout the year. In this species there is no diapause or dormancy phase for the purpose of surviving adverse weather conditions, as there is with several other Tetranychid mite pests; for instance, in Japan, the common species on tea is *Tetranychus kanzawai* Kishida in which the adult females enter a physiological dormancy (diapause) in the winter (Osakabe, 1962).

Scarlet Mites.—Three *Brevipalpus* species occur on tea and associated shade trees in Ceylon. *Brevipalpus californicus* Banks (=*B. australis* Tucker (Pritchard & Baker, 1958)) is the most common and important on tea; this occurs also on *Albizia falcata* but has not been found on *Grevillea robusta. B. phoenicis* Geijskes is found mostly on *Grevillea* but also on tea and *Albizia. B. obovatus* Donnadieu has been found rarely on tea but not on *Grevillea* and *Albizia* and appears to be uncommon. *B. californicus* appears to be the common species on tea in Ceylon and in S. India, and *B. phoenicis* is that reported in N. India (Das, 1963). However, these species are very similar morphologically and there is clearly need for further determination of the species occurring in the different tea areas.

These *Brevipalpus* species belong to the family *Tenuipalpidae* or False Spider Mites, which do not spin a web like the allied *Tetranychidae*. The family is not of such great economic importance but several species are pests of *Citrus* and other fruits, and ornamental plants, especially in Mediterranean and sub-tropical climates. *Brevipalpus californicus* has a very wide geographical distribution and 43 host plants are listed by Pritchard & Baker (1958) including *Citrus*, tea and many ornamental plants.

Scarlet mite feeds mainly on the under surfaces of the maintenance foliage, especially near the mid-rib and on the petiole, causing death of the petiole and rather severe defoliation even at fairly low mite densities per leaf. The adult female mite is about 0.28 mm in length, smaller and flatter than Tea Red Spider. The life cycle is very similar, but male mites are very rare and the development of unfertilised eggs, to produce females, appears to be the general rule. Baptist & Ranaweera (1955) found that the life cycle took about 5 weeks in the laboratory at St Coombs; after becoming adult the female commences egg-laying after 3-4 days and lays at the rate of about one egg per day over a period of seven weeks. The scarlet eggs are ellipsoid in shape, about 0.1 mm on the longest axis and are laid singly, mostly on the under-surfaces of leaves; they take about two weeks to hatch. As with Red Spider there are three development stages, the six-legged larva, protonymph and deutonymph and each of these stages lasts about 7-8 days. Development is thus rather slow compared to the other mitepests, and fecundity is lower.

Yellow Mite. Hemitarsonemus latus belongs to the family Tarsonemidae, which is very different to the other two mentioned above. It has been recorded as injurious on a wide range of plants including rubber (*Hevea*), *Cinchona*, cotton, *Citrus*, tomato, vines and potatoes, and to some hot-house ornamentals in temperate countries where it is known as the 'Broad Mite'. On tea it is of importance chiefly in Ceylon. Although it is common on jute and other plants in North India, it has very rarely occurred there on tea (Das, 1965). In South India it was unknown on tea until about 1955, since when it has gradually occurred more frequently suggesting that it has adapted itself locally to tea as a host plant.

Yellow mite breeds only on the youngest leaves of tea, the first two or three leaves and the bud on each shoot. The mites are very small and can only just be seen with the naked eye as a fine dust on the undersides of the youngest leaves; examination with a 10× lens reveals the presence of hundreds of minute, translucent, pale or amber-coloured mites. The flush becomes stunted, deformed and brittle, and paler and yellow in colour. From the second or third leaf downwards, as the shoot grows, the feeding area remains as a light corky-brown necrotic strip over the mid-rib, or as two lines parallel to the mid-rib, on the under-side of the leaf. These lines are often pressed out on the upper surface of the leaf. Planters sometimes notice this damage on the younger maintenance foliage when the attack is over; the condition of the flush and the presence of mites there will show whether the attack is still going on.

In Yellow Mite, as in other tarsonemids, there is a simplified life cycle which was investigated by Gadd (1946) in Ceylon. The egg is relatively large, about 0.1 mm long, and bears rows of tubercles; despite this large size the adult female mite, about 0.25 mm long, can lay four or more per day. The six-legged larva hatches from the egg in 2-3 days and soon passes into the quiescent nymphal stage—there is no active nymphal stage. The entire life cycle averages only about 5 days at St Coombs. In the males the posterior end of the body is adapted, with suckers, for carrying the quiescent nymphal stage of the female. On becoming adult the males dash around very actively until they locate a quiescent female nymph which they then wrest from the leaf surface. With a hand lens, males are seen to be dashing about carrying their burdens aloft and, although their movements appear to be rather indiscriminate, they always carry the female nymphs up the shoots to the youngest leaves. Copulation takes place as soon as the female emerges as an adult, and the fourth pair of legs in the male is adapted for grasping her. Gadd showed that unfertilised females produced only male offspring but mated females produced offspring of both sexes.

Purple Mite.—Calacarus carinatus belongs to the family Eriophyidae which includes a great many pest species, variously called blister mites, rust mites, bud mites and gall mites according to their habits. They are minute worm-like mites with only two pairs of legs. Various species are serious pests on fig, *citrus*, peach, pear and black currants in many countries.

Purple Mite occurs on tea in Ceylon, India, Indonesia, Indo-China and in Batum, U. S. S. R. Whilst it has been noted on a few other host plants elsewhere, it appears to have no other host plant than tea in the tea-growing areas of Ceylon. In recent years it has become the major mite pest and probably the major pest of tea in South India.

The mites are extremely small and cannot be seen at all with the naked eye. Older leaves are preferred but in heavy infestations, particularly in dry weather, mites are found on the younger leaves even up to the second and third leaf from the bud. They occur on both surfaces of the leaf, although the attack is initially more on the under-surface. Eventually, attacked leaves show a dull matt appearance with a purplish bronze discolouration but the mites can be present in vast numbers long before these symptoms show up clearly. Examination of the mature leaves with a hand lens will show thousands of minute white cast skins of the mite and amongst these the mites themselves, which are more difficult to pick out because their colour does not contrast with that of the leaf. The adult female mite is deep purple in colour with five white ridges or 'keels' of waxy material running longitudinally on the dorsal side of the abdomen; hence the name *carinatus* which means 'keeled'. The body is elongated, spindle-shaped, slightly broader anteriorly, and measures 0.15 to 0.2 mm in length. The two pairs of legs are directed forwards and the movements are rather slow. The abdomen of the adult male is much shorter than that of the female. The eggs are laid singly on the leaf surface, and are circular as viewed from above but flat and almost transparent, about 0.07 mm in diameter; they can be seen only by careful examination under the microscope. There are three development stages—the larva, protonymph and deutonymph—all of which resemble the adult in shape but which show a progressive increase in size and in the development of the white 'keels'. King (1937) found that the life-cycle took 10-12 days at St Coombs; in Assam (Das & Sengupta, 1962) it was found to take 6-13.5 days depending on the season and the prevailing temperatures.

4.3. RECOGNITION OF MITE ATTACK

The diagnostic symptoms of attack by the four mite pests can be summarised as follows:—

1. Attacking the flush: which becomes stunted, pale and brittle. The feeding area shows generally as a light corky brown stripe over the mid-rib, or as two such stripes parallel to the mid-rib, on the under-surface of leaves.......(Colour Plate 4) Yellow Mite
2. Primarily attacking the maintenance foliage:
   - leaves dull and matt, bronzed with a purplish tinge, defoliation not usually marked.........(Colour Plate 3) Purple Mite
   - prominent ruddy bronzing, starting in patches, on the upper surfaces of leaves, leading to defoliation. ....(Colour Plate 1) Red Spider Mite
   - dark-brown necrosis of the mid-rib and petiole on the under-surfaces of leaves and marginal dark necrotic patches, leading to chronic defoliation.........(Colour Plate 2) Scarlet Mite

4.4. OCCURRENCE OF MITES AND DAMAGE CAUSED

The occurrence of Scarlet Mite as a pest is common in up-country districts, and considerable acreages in Dimbula, Dickoya, Maskeliya, and Haputale are seriously affected from time to time. Outbreaks are not uncommon down to 2000 ft. elevation, but in the low country they are unusual. Since the rate of increase is rather slow, this

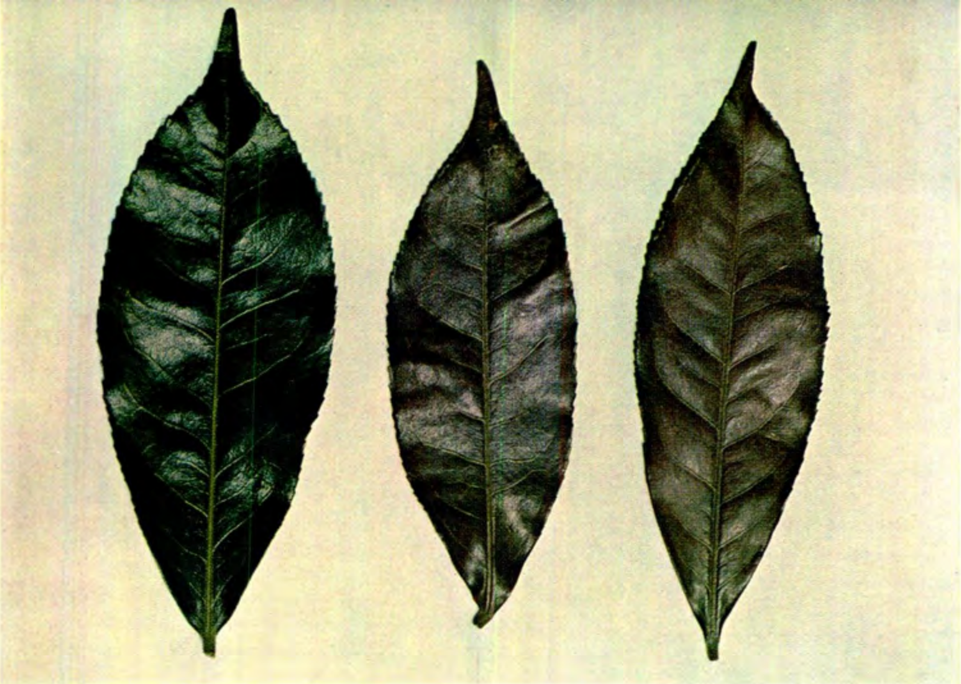


Plate 3. Leaves (upper surfaces) showing attack by Purple Mite, *Calacarus carinatus* (Green); unattacked leaf on left.

Plate 4. Shoots showing attack by Yellow Mite, *Hemitarsonemus latus* (Banks). Right: under surfaces; centre: upper surfaces; left: unattacked shoot.

mite is seldom a pest on mature tea until the second year after pruning; and most abundant in the third or later years. The numbers reach an annual peak in the dry weather, from December to May in the S. W. monsoon zone and in June to September in Uva, and they decline greatly in the wet season. A light monsoon followed by a long dry-weather period is conducive to a build-up. High-jat bushes are more attacked than low-jats. The attack is usually very patchy and more pronounced along roadsides, drains, on waterlogged areas, and where there is a poor cover of tea.

Scarlet Mites do not normally injure the flush directly although in heavy attacks in dry weather the mites tend to move on to the younger leaves. The damage caused by feeding on the mature leaves causes marked defoliation, but often without affecting the weight of crop taken in the same pruning cycle. With severe attacks, however, bushes suffer serious debilitation and the new wood is spindly and unhealthy looking. The damage done is chronic and insidious and difficult to assess quantitatively; there is little doubt that, since the mites are not conspicuous, they are sometimes overlooked as a cause of poor fields. Severe defoliation may not be noticed until the wet season when the mites which caused it have dropped to very low numbers. It is probable, however, that Scarlet Mites are chiefly secondary pests, attacking bushes already below par for other reasons and greatly aggravating their condition, but the matter requires more critical study.

Yellow Mite is commonest on tea recovering from pruning and on young tea in the post-monsoon periods from August to October and January to March. In prolonged dry weather the numbers decline, usually surviving longest under shade. Yellow Mite attacks the flush and causes the most direct and immediate loss of crop; in a severe attack the loss may be almost total over a short period of a few weeks. In one trial on an estate in Haputale, plots sprayed with Kelthane gave nearly 80% more crop than unsprayed plots which suffered Yellow Mite attack, over a period of one month (Cranham, 1962). Attacks often decline as quickly as they build up, but it takes much longer for the bush to recover from the set-back to growth; this is particularly important when attack occurs on tea recovering from pruning and argues the need for prompt spraying. Attack also affects the quality of made teas; the affected flush is brittle and makes flaky teas.

Red Spider is most common in the mid-country around Kandy and in the Uva and Sabaragamuwa districts; it can increase in dry or showery weather and will often withstand a good deal of rainfall. Low jats and the Manipuri jats are the most susceptible. Red Spider breeds mainly on the young maintenance foliage but in severe attacks the young shoots are also attacked, resulting in severe loss of crop and defoliation.

Purple Mite is more common in the up-country districts affected by Scarlet Mite, on high-jat tea and on the Manipuri jats. It occurs most often in the first year after pruning, and although it often appears to do relatively little harm in itself, it hardens the foliage and is believed to make it more susceptible to attack by Scarlet Mite and Red Spider. On the general evidence it is the least injurious of the four mite pests on Ceylon tea. However, since in South India it has developed as a widespread and major pest in recent years, this experience suggests the need for further study and closer observation of it in Ceylon; except when the symptoms of damage are very pronounced, it can easily escape the attention of the planter.

Yellow Mite and Red Spider are fairly common mite pests in nurseries and on young new clearings; in the latter the slower-developing Scarlet Mite is occasionally found doing damage.

Mite attacks not uncommonly involve more than one species; sometimes all four species are numerous and may occur along with attack by the scale insects, Green Bug (*Coccus viridis*) and Brown Bug (*Saissetia coffearia*). Such fields are then, needless to say, in very poor condition. The factors which lead to such a condition are not understood and require much further study. Mite attack is by no means confined to poor fields, however, although the weaker bushes present will suffer more.

4.5. NATURAL CONTROL FACTORS

All four of the mite pests are very widely distributed in small numbers. The reproductive potential, even of the slow-breeding Scarlet Mite, is great. They normally fail to achieve this potential because of various limiting factors, such as adverse weather, natural enemies and diseases, and the condition of the host plants. There has been no intensive study of these limiting factors and present knowledge is very sketchy.

In Ceylon, adverse weather conditions for mites occur during the heavy monsoons, but as far as is known, none of the four species has a special resting or protected stage with the function of surviving this period; smaller numbers of the normal stages can be found on the foliage, at least locally, reproducing more slowly.

Natural enemies of mites include various predatory mites and predatory insects which feed on the active stages and the eggs. Various predatory mites, notably *Typhlodromus* spp. and a *Phytoseius* sp, have been observed in Ceylon (Cranham, 1961); these are larger fast-running mites capable of catching and over powering adults of Red Spider. In N. India, Das (1959, 1960) has studied various coccinellid (lady-bird) beetles of which both larvae and adults feed on the eggs and active stages of Red Spider; he has also recorded a lacewing (*Chrysopa*) larva and staphylinid beetles as predators.

Coccinellid beetles have also been noted in Ceylon. This subject has also received attention by the Indian Station of the Commonwealth Institute of Biological Control, but at present the possibilities for biological control of the mite pests on tea are remote.

The condition of the tea bush that renders it susceptible to attack is also very important, and this may in turn be influenced by the effect of weather on the growth of the bush. This involves both genetic factors (e.g. high-jat tea is more susceptible to attack by Scarlet Mite and low-jat to attack by Red Spider) and factors affecting the physiological condition of the plant, such as nutrition, water balance and soil pH.

The dispersal of mites occurs largely by wind, and also by pluckers carrying the mites on their clothing. They may also be carried on birds and other animals, possibly including flying insects. Pruning results in an artificial break in the population but unless it is completely clean (all foliage and green twigs removed) mites survive in small numbers on the few leaves left and on various weeds. In the case of Scarlet Mite, leaves falling from the shade trees *Grevillea robusta* and *Albizia falcata* are usually infested and appear to speed up reinfestation of the tea.

4.6. THE EFFECTS OF PESTICIDES AND CULTURAL PRACTICES

It is widely believed by planters that the extensive use of copper fungicides for the control of Blister Blight (*Exobasidium vexans* Massee) has increased the incidence of mites. Research trials over a number of years have shown that copper fungicides can in fact increase the numbers of Scarlet Mite and Red Spider, and work in South India suggests a similar effect on Purple Mite, although the evidence there is somewhat conflicting. No effect has been determined on Yellow Mite. The demonstrated effect was small, however, being an increase of two or three times in numbers on the copper-sprayed plots; this is not a large effect when we know that mites often increase by a factor of a hundred times or more in the dry season, and is small also compared to the effect of DDT and some other insecticides. It was also notable that the effect occurred with wettable powder formulations of copper oxide or copper oxychloride but not with 'colloidal' copper (a wet dispersion). The results suggest that it may not be the copper salts which are directly responsible but perhaps the inert diluents or the physical nature of the spray deposit; such an effect has been recorded on *Citrus* in the U. S. A. (Fleschner, 1958).

Recently, work in South India has aroused interest in nickel chloride as an alternative fungicide for blister-blight control; this is used as a solution in water. Evidence in South India, although again somewhat conflicting, suggests that nickel chloride does not increase Purple Mite as copper sprays do. Trial work in Ceylon showed that nickel chloride did not increase Scarlet Mite and Red Spider when copper wettable powder increased numbers two or three times (Cranham, 1966b).

However, the use of copper fungicides is only one factor conducive to increasing mites, and probably not the most important. It is known that the reduction of shade tree cover can markedly increase the incidence of Red Spider and Purple Mite. Other cultural trends, notably higher rates of manuring and lighter pruning, have received very little consideration. There is clearly need for closer investigation of the effect of the nutrients supplied in fertilizer and of interactions with the effect of shade density.

DDT has been the most widely used insecticide on tea and it has been shown that it can markedly increase the numbers of Red Spider and Scarlet Mite when weather conditions are conducive to the increase in population. It has not been shown to increase Yellow Mite and work on this species on cotton in Uganda also showed that DDT did not increase numbers. So far there appears to be no definite evidence of an effect on Purple Mite. In practice however, DDT has been used on only a small fraction of the tea acreage each year, and mite outbreaks have been induced only occasionally.

There are marked differences in the effect of various insecticides (Cranham, 1963, 1964, 1965). It has been found that certain compounds related to DDT such as methoxychlor and TDE caused big increases but another close relative, Perthane, did not. Dieldrin and aldrin were shown not to increase Scarlet Mite or Red Spider Mite numbers. The various ways in which these effects are brought about has not yet been investigated on tea; interference with the insect and mite predators of the mite pests is probably the most important way, but direct effects on the dispersion and fecundity of the mites may also occur.

4.7. RECENT DEVELOPMENTS IN CHEMICAL CONTROL

Sulphur in various forms is the oldest acaricide and is effective against all four species on tea; in Ceylon it has been used chiefly in the form of sulphur wettable powders. Unfortunately it taints the tea made from sprayed leaf and necessitates discarding at least three plucking rounds after spraying.

In recent years many new synthetic acaricides have been developed with desirable properties e.g. toxicity to mite eggs (ovicides) as well as to active stages, specific toxicity to mites, high persistence on foliage, and low mammalian toxicity. Mite species, even those closely related, vary a great deal in their susceptibility to different chemicals. Work on tea has been directed towards determining effective non-tainting materials.

Chlorobenzilate (Akar) was the first non-tainting acaricide found to be effective against Scarlet Mite and Red Spider (Baptist and Ranaweera, 1955) but it was later found to be ineffective against Yellow Mite. Later, Tedion (tetradifon) was found to be highly effective for control of Red Spider in India (Das, 1963, Mukerjea, 1962) and in Ceylon (Cranham, 1963), with a good ovicidal action and often effective in one low dosage application. It is also effective for Yellow Mite and for Purple Mite but is quite ineffective for Scarlet Mite.

Kelthane (dicofol) has emerged as a non-tainting acaricide effective against all the mite pests on tea. It has a residual effect far superior to sulphur or Chloroenzilate for Scarlet Mite control.

Efforts were also directed towards making the method of spraying less tedious and more practically useful. Employing conventional knapsack sprayers, considerable volumes of spray fluid are necessary to obtain adequate coverage, and water is quite often in short supply in the dry season. The recommended use of 80-100 gallons of spray fluid per acre for Scarlet Mite control, spraying to cover the under-sides as well as the upper sides of the leaves, is particularly tedious.

Trials were carried out with applications by knapsack mist-blowers employing the same dose of acaricide per acre in 10-20 gallons of water (Cranham, 1963). The spray was directed down into the bushes by the normal method for insecticidal mist-blowing i.e. there was no attempt to spray from below the foliage. By this method Kelthane gives good control, not only of more exposed Red Spider and Yellow Mite, but also of Scarlet Mite.

Recent work has therefore established Kelthane and Tedion as highly effective non-tainting acaricides, which can be successfully applied through knapsack sprayers or mist-blowers. They have a low mammalian toxicity. They are toxic to the eggs as well as the active stages of mites so that they are often effective from a single spray application. They are specifically toxic to mites and do not cause undesirable side-effects with other pests. The cost per acre is somewhat more than that of sulphur wettable powder, but since the latter involves a loss of crop on tea in plucking it is generally a highly economic proposition to use Kelthane or Tedion.

4.8. DETAILS OF CONTROL MEASURES

Non-tainting acaricides.—Kelthane is supplied in Ceylon as 'Kelthane M.F.', an emulsifiable concentrate containing 36% of the toxicant, by Messrs Colombo Chemical and Fertilizer Co. Ltd., Colombo and Shell Co. of Ceylon Ltd. The standard dosage per acre for all four mites is 15 fluid ounces (¾ pint) applied in a suitable volume of water per acre for coverage, in one or two spraying rounds.

Tedion (tetradifon) is supplied as 'Tedion V 18', an emulsifiable concentrate containing 8% of the toxicant, by Messrs Lewis Brown & Co. Ltd., Colombo. The standard dosage per acre for control of Red Spider or Yellow Mite is 1½ pints per acre in one or two spraying rounds.

Chlorbenzilate is supplied as 'Akar 338', an emulsifiable concentrate containing 25% Chlorbenzilate, by Messrs Fisons (Ceylon) Ltd., Harrisons & Crosfield, Ltd., and A. Baur & Co. Ltd., Colombo. The recommended dosage for Scarlet Mite, Red Spider and Purple Mite is 1½ pints per acre in two spraying rounds. It is not recommended for Yellow Mite control.

These three materials are amongst the safest pesticides and no special precautions are necessary. The usual common-sense care should be used. They will not cause any taint or off-flavour of made tea if spraying is carried out after a plucking round, and if there is a seven-day interval between spraying and plucking for manufacture. Nevertheless, in order to minimise residues after spraying Kelthane or Akar, it is necessary to bulk the tea from sprayed areas with at least five times as much tea from unsprayed areas; if such bulking is not possible, allow 14 days between spraying and plucking. This precaution is not necessary with Tedion.

Sulphur wettable powders.—These are marketed in Ceylon under the trade names 'Thiovit' (A. Baur & Co. Ltd.), 'Spersul' (Chemical Industries (Colombo) Ltd.) and 'Shell dispersible sulphur' (Shell Co. Ltd.). The recommended dosage for all mites is 4 lb per acre in 50-100 gallons of water per acre applied by knapsack sprayers. Sulphur has no toxic hazard to man but it taints teas very badly, and it is essential, therefore, to discard flush for three weekly rounds after the last spray, or to rest the tea for a period of four weeks.

Spraying volumes.—With conventional knapsack sprayers and the usual nozzles for insecticidal spraying it is necessary to use at least 50 gallons of spray fluid per acre for Yellow Mite control, in order to wet the flush more thoroughly than for blister-blight control. Adequate coverage of the maintenance foliage for Red Spider control requires 50-70 gallons per acre, and spraying for Scarlet Mite to cover upper and lower surfaces of the leaves requires 80-100 gallons per acre.

Mist-blower applications of Kelthane and Tedion have proved very effective and are much less tedious than knapsack spraying.

The standard dosages should be used in 15-20 gallons water per acre for control of Scarlet Mite or Red Spider or in 10 gallons for control of Yellow Mite. These volumes require a fairly large output from the mist-blower and are best tackled with the machines of about 2-3 h.p.

Mist-blowing sulphur is a dangerous practice because of possible drift on to tea in plucking.

Spraying rounds.—Recent work has shown that to control an attack there is no need for several repeated spraying rounds at low dosage; it is better to use the same total dose in not more than two rounds.

Employing Chlorobenzilate and Sulphur, two spraying rounds are desirable, separated by 5-7 days for Yellow Mite, 10-14 days for Red Spider, and three to four weeks for Scarlet Mite.

Kelthane and Tedion are more persistent in effect, and one spraying round will often give good control. Where two rounds are considered advantageous they should be at the same intervals given above.

Young tea and tea out of plucking.—For tea that is not in plucking, for nurseries and new clearings, where taint is of no concern, sulphur is the obvious choice on cost. Alternatively, Kelthane can be used.

On young plants sprayed to run-off, use 1 lb sulphur or 5 fluid ounces of Kelthane M. F. per 25 gallons of water for two spraying rounds.

Mature tea.—The chief advantage of using non-tainting acaricides is to avoid discarding crop; thus it is more valuable to use them to prevent outbreaks, rather than to cure them when the tea has already suffered bad damage. If the latter has occurred, it may pay to rest the tea and use the much cheaper sulphur.

With Scarlet Mite, in fields prone to severe attack in the second, third and later years of the cycle, prophylactic (protective) spraying with Kelthane early in the dry weather can be done routinely. The time for this is generally about January on the S. W. side, and about May on the Uva side. This is probably the biggest use for a non-tainting acaricide on Ceylon tea and one which is likely to show benefits extensively. The older method of spraying with 100 gallons of spray fluid per acre is extremely tedious but the mist-blower method makes it possible to spray large areas quite easily; labour costs are low and add little to the cost of Kelthane, which is approximately Rs. 10/- per acre.

'Akar 338' can be used as an alternative to Kelthane, but the latter has generally given better results, particularly for prophylactic spraying. 'Akar' is not recommended for mist-blowing.

Considerable work was done in past years on the use of sulphur for controlling Scarlet Mite after pruning. Trials make it clear that the numbers of mites carried over to the new cycle are important. Clean pruning leaves less mites than when some foliage is left, but sulphur spraying is more effective than clean pruning. Sulphur spraying will delay the build-up of mites in the new cycle considerably, but not by more than one year at the most. Since it is cheap, we think that sulphur spraying after pruning is worth while in fields particularly prone to Scarlet Mite. There must be a one-month interval between spraying and tipping.

With Red Spider and Yellow Mite, we can achieve prophylaxis only by spotting incipient outbreaks and spraying without delay. Kelthane and 'Akar' are equally suitable for Red Spider control, but 'Akar' is not effective for Yellow Mite. Sulphur is again useful where the tea is rested.

Some fields, recovering from pruning, are prone to Yellow Mite attack before tipping; sulphur spraying, provided there is a one-month period until tipping, can again be useful. Plucking is a partial control measure for Yellow Mite, but hard plucking or stripping is not recommended.

Table 1. summarizes the present recommendations for the use of acaricides on mature tea.

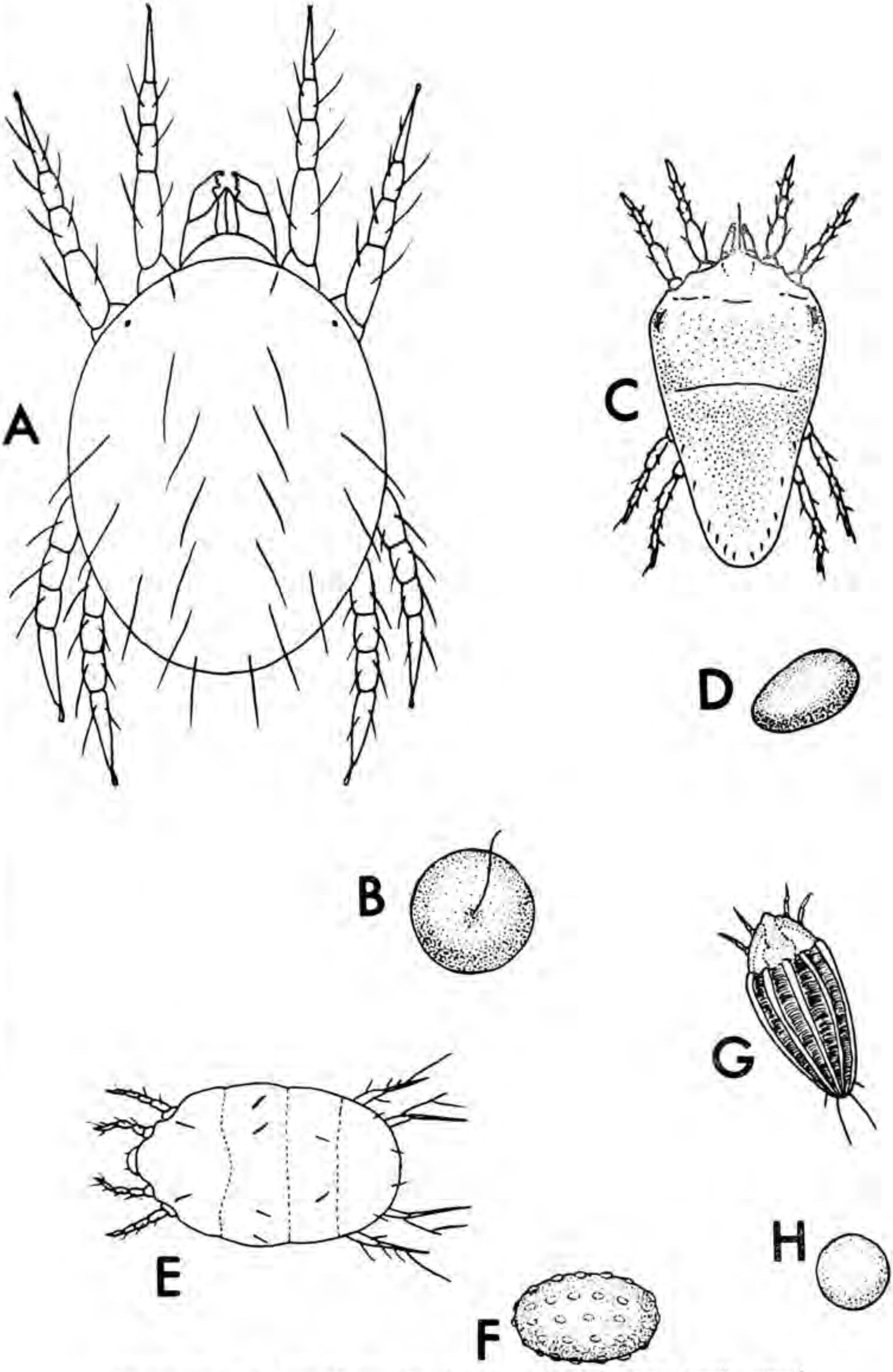


FIGURE 9—Mite pests of tea—line drawings of the four pest species greatly enlarged on the same scale. A & B—Tea Red Spider Mite, adult female and egg; C & D—Scarlet mite, adult female and egg; E & F—Yellow mite, adult female and egg; G & H—Purple mite, adult female and egg; (Drawings by E. F. W. Fernando).

FIGURE 10.—Tea foliage damaged by Fringed Nettle Grub (*Macroplectra nararia*: left—damage by young larvae, right—damage by older larvae.

FIGURE 11—Tea foliage damaged by bagworms (*Manatha albipes*)

TABLE I SUMMARY OF RECOMMENDATIONS FOR CONTROL OF MITE PESTS

Mite pest	*Pesticide formulation*	*Dosage and spray volume per acre*	*Comments on use*
Scarlet Mite (*Brevipalpus* spp.) and Purple Mite (*Calacarus carinatus*)	Kelthane M. F.	15 fl. oz. in 80-100 gal (K) or in 15-20 gal (M)	1. Kelthane gives good control of all mites, often from one spraying round only, and is also effective through a mist-blower even against scarlet mites on the under sides of the leaves, In fields prone to scarlet mite, spray as a prophylactic early in the dry season.
	Wettable sulphur	4 lb in 80-100 gal (K)	2. For curative spraying if tea is rested, on new clearings and for prophylactic post-pruning spraying on mature tea.
	Akar 338	1½ pints in 80-100 gal (K)	3. Kelthane is superior to Akar for prophylactic spraying.
Tea Red Spider Mite (*Oligonychus coffeae*)	Tedion V 18	1½ pints in 50-70 gal (K) or in 15-20 gal (M)	4. Tedion gives good control of Red Spider and Yellow Mite but *not* of Scarlet Mite. See note 1.
	Kelthane M. F.	15 fl. oz. in 50-70 gal (K) or in 15-20 gal (M)	
	Akar 338	1½ pints in 50-70 gal (K)	5. Akar gives good control of Red Spider and fair control of Scarlet Mite, but does not control Yellow Mite.
	Malathion 50% E. C.	1½ pints in 50-70 gal (K)	6. Two rounds at an interval of 10-14 days may be required; control achieved by Malathion is not lasting, and it is recommended only if other materials are not available.
	Wettable sulphur	4 lb in 50-70 gal (K)	7. For curative spraying when tea is rested and on young tea not in plucking. For these sulphur is the cheapest control. Prophylactic spraying after pruning as for Scarlet Mite (note 8) is not useful.
Yellow Mite (*Hemitarsonemus latus*)	Kelthane M. F.	15 fl. oz. in 50 gal (K) or in 10 gal (M)	See note 1.
	Tedion V 18	1½ pints in 50 gal (K) or in 10 gal (M)	See note 4.
	Wettable sulphur	4 lb in 50 gal (K)	8. For curative spraying when tea is rested, and in the recovery period after pruning and on young tea not in plucking.

CHAPTER 5

DEFOLIATING CATERPILLARS
(Other than Tea Tortrix)

Moths and butterflies comprise the order Lepidoptera, which contains a larger number of species which are pests of tea than any other insect order; all these tea pests are defoliating caterpillars with the exception of Red Borer (*Zeuzera coffeae* Nietn.), but they exhibit a great variety of form and habit. The stages in the life cycle are the egg, the larva (generally with five growth stages and successive moults), the pupa or chrysalis (often within a cocoon or an earthen cell), and the adult.

5.1. NETTLE GRUBS AND GELATINE GRUBS

Nettle grubs are well known in Ceylon, particularly to Uva planters, as pests of tea that have been troublesome for over sixty years. They are larvae of moths of the family Limacodiidae, in which the specides of economic importance are mainly tropical in distribution, being pests on tea, coconuts, plantains, coffee, oil-palms and other plants. Both the structure of the larvae and the form of the cocoons are unusual amongst Lepidoptera. Not all limacodid larvae are called nettle grubs; the name is due to the presence of stinging (urticating) spines on the body. Some species have no stinging spines and are called gelatine grubs. All have thick, fleshy bodies, a small retractile head and minute thoracie legs; the segmentation is indistinct, and there are no abdominal feet, although in some species there are secondary sucker discs on the first eight abdominal segments. The pupal cocoons are nearly spherical in shape, off-white to brown in colour, so that superficially they resemble large seeds; they possess a lid or operculum through which the adult moth emerges.

The species occurring on tea in Ceylon, and the history of their occurrence as pests, were reviewed in detail by Austin (1931-32) and by Hutson (1932). By far the commonest species causing severe damage is the Fringed Nettle Grub *Macroplectra nararia* (Moore), which exhibits sudden, remarkably localized, 'population explosions' which can be devasting if uncontrolled.

The Blue-striped Nettle Grub, *Parasa lepida* (Cramer) is not uncommon, but generally in much smaller numbers, and sometimes occurs with *M. nararia* in an outbreak. The Morawak-Korale Nettle Grub, *Thosea recta* Hampson, is so called because outbreaks first occurred particularly in Morawak-Korale; it is the next most common pest species after *M. nararia.* The large Saddle-backed Nettle Grub, *Thosea cervina* Moore, occurs in numbers occasionally in the low country districts; this species is also common in N. E. India, where it is known as the Tea-seed Nettle Grub, because the pupal cocoon resembles a small tea seed.

The small Green Gelatine Grub, *Narosa conspersa* Walker is not uncommon but very seldom a serious pest, whilst the large Gelatine Grub, *Belippa laleana* Moore, is of very minor importance and occurs only in small numbers. These species have no stinging hairs.

Fringed nettle grub—Outbreaks of *M. nararia* are commonest in the Uva Province, particularly in the Passara, Badulla and Bandarawela districts, although severe outbreaks occur occasionally in districts outside Uva, notably in Dolosbage and Matale. In Uva they occur mostly above 4,000 feet, and even above 6,000 feet. The incidence of outbreaks varies greatly from year to year, being affected directly or indirectly by weather conditions; the acreage involved may be several hundred acres and occasionally a few thousand acres each year. Whilst this is a small percentage of Ceylon tea, it is a serious problem on those estates which have several fields affected. A severe outbreak, if uncontrolled, can result in the complete defoliation of whole fields with total loss of crop for many weeks. The pest is most common in the dry weather months of the N. E. monsoon zone, and outbreaks usually occur from July to September, although severe attacks have been known to continue through wet weather later in the year. In the S. W. monsoon zone, attacks are more likely to occur from March to May.

Life-history—The eggs are not easy to find since they are laid singly by the female moth on the upper surfaces of mature leaves. They are oval and flattened, 1.25 mm x 1 mm in size, at first pale-yellow or greenish when seen on the leaf, and they become opaque or pale-brown before hatching. They have a shiny appearance, which is the most distinctive feature for finding them. Many eggs may be laid on a single leaf. The egg stage lasts about one week.

Although the eggs are laid on the upper surfaces of leaves, the newly-hatched larvae, which are 1 mm long, always migrate to, and begin feeding on, the undersurfaces of leaves, where at first they eat away small areas leaving only the upper epidermis of the leaf intact. When about two weeks old (3rd instar) the grubs are able to eat right through the leaves, resulting in a quite different appearance of damaged leaves (Figure 10). In serious attacks every part of all the foliage may be consumed leaving the frames of the bushes completely bare.

The older larvae, just under half-an-inch in length when mature, are illustrated in Colour Plate 14. The ground colour is pale yellowish-green to apple-green and the median dorsal stripe is darker and bordered on both sides with very pale yellow. The lateral fringe of hairs consists of nine pairs of tubercles bearing tufts of pale translucent urticating spines. There are also two pairs of anterior tubercles bearing much shorter hairs. The larval stage lasts 5-6 weeks.

The mature larvae pupate mostly on the ground beneath the bushes, among dead leaves or in crevices amongst stones, and sometimes on the lower branches. They spin a cocoon which is globular, one-sixth of an inch in diameter, consisting of a hard papery shell covered with a thin webbing of dark brown or purplish-brown silk. Inside this cocoon the grub pupates and the adult moth emerges about three weeks later by pushing off the circular lid (operculum) of the cocoon.

The adults are inconspicuous, very pale brown moths. Austin (1931-32) found that female and male moths lived for 3 to 12 days in captivity, averaging six days. Moths rest up during the day and become active at dusk; egg-laying commences soon after emergence and is carried out mainly between 6.30 p.m. and midnight. Females lay about 500 eggs, most of them within three to four days of emergence. Austin observed that the moths were not active on windy nights, and a mass migration of the moths has never been observed. The life-cycle from egg to adult took about ten weeks and this agrees with the frequency of generations observed by Gadd, Fonseka & Ranaweera (1946), so that there are probably five generations in a year.

The Fringed Nettle Grub in Ceylon is known to complete its life-cycle only on tea, coffee, and dadap (*Erythrina lithosperma*). Grubs have been found feeding on many other trees and shrubs in small numbers, but there is no evidence of them maturing on these plants.

Natural enemies—the following insect parasites have been reared from *M. nararia*:

Larval parasites—Ichneumonidae—*Goryphus variibalteatus* Cram., *Hemiteles macroplectrae* Fernando.

Braconidae—*Fornicia ceylonica* Wilk. and a *Rogas* sp.

Eulophidae—*Neoplectrus maculatus* Ferr., *Platyplectrus natadae* Ferr., *Autoplectrus taprobanae* Gadd, *Euplectrus* sp., *Tetrastichus taprobanensis* Ranaweera. Pupal parasite—*Tricholyga sorbillans* Wied. (Tachinidae).

Gadd (1946b) and Gadd *et al* (1946) made a detailed study of the Euplectrini (Eulophidae), common, tiny, wasp-like parasites of young nettle grubs, comprising four of the species listed above. *Neoplectrus maculatus* is unusual in that the adult females are predators, feeding on the body fluids of nettle grubs, whilst the larvae are internal parasites (Gadd and Fonseka, 1945). *Fornicia ceylonica* and *Rogas* sp. were noted by Austin (1931-32) and have been found frequently since that time. The adults and nymphs of the Pentatomid bug *Cantheconoidea robusta* Wolff. have been noted on several occasions as predacious on nettle grubs. The Crow (*Corvus splendens*) is the only bird recorded as feeding upon nettle grubs.

Wilt disease—The virus disease known as wilt or granulosis disease is an important factor in the natural control of nettle grub populations. The disease is transmitted from one larva to another by contact or by ingestion with the foliage eaten. A grub suffering from wilt disease soon becomes sluggish and loses appetite. The normal green colouration of the body changes to a dull yellow (a bright yellow is characteristic of parasitized grubs); finally the grub becomes motionless and the body turns to a brown colour at the time of death. At this stage, the larva is entirely flaccid and emits an offensive smell; the internal tissues have disintegrated.

Most diseases of insects are specific to one species or affect only a few. Thus, wilt disease of *M. nararia* affects *Parasa lepida* only slightly and does not appear to affect *Thosea* species of nettle grubs at all. The spread of wilt disease is increased by high host-density and generally by humid air conditions and wet weather. It does not normally become epidemic in an outbreak of nettle grubs until the grubs are nearly all mature and the major part of the damage to the tea bushes has been done. It is commonly epidemic at the onset of the N. E. monsoon in Uva, but not always, and outbreaks of the pest have been known to continue through very wet weather.

Little is known about the interactions of wilt and insect parasites as controlling factors of nettle grubs. Gadd *et al* (1946) have shown that, as might be expected, parasites cannot develop in a host suffering from wilt, and it seems possible that wilt is sometimes responsible for upsetting the balance between the nettle grub and its insect parasites. When outbreaks occur, they are sometimes brought under control by wilt within the span of a single generation, but never by insect parasites. Nevertheless, the latter may be of considerable importance in the normal balance of populations.

With a few lepidoterous pest species on other crops, virus diseases have been successfully disseminated artificially to effect control. In the case of *M. nararia*, work was carried out by Austin (1958) and later Cranham and Fernando (1960); in the latter work, a suspension of the virus was prepared simply by macerating diseased larvae in blood albumen solution and was sprayed on the bushes. It was found that a partial control was effected, but too slowly (2-3 weeks) to prevent much of the damage caused by the nettle grub attack. In contrast, DDT gave a much more complete and rapid kill. Control with the virus was not considered satisfactory.

Other nettle grubs and gelatine grubs—The Blue-striped Nettle Grub, *Parasa lepida* Cramer, has a wide range of host plants and is an occasional pest also on coffee, coconuts, cacao and plantains; it occurs from near sea level to over 5000 feet. The full-grown larva (Colour Plate 13) is about 1¼ inches long, greenish-yellow in colour with three pale blue longitudinal stripes edged with dark blue or black, one prominent stripe in the mid-dorsal line and the others lateral to it. There are three pairs of prominent ruddy-brown tufts, two pairs anteriorly and one pair at the posterior end. Four rows of tubercles bear green stinging spines tipped with black. The cocoons are generally formed on the stems. Larval development is much slower than in *M. nararia*, taking many weeks, and the pupal period is 1½-2 months.

Recorded parasites of *P.* lepida in Ceylon are *Apanteles parasae* Rohw. and *Rogas* sp. (both Braconidae), *Eurytoma monemae* Rushka (Eurytomidae), *Tachina munda* Wd. *Chaetexorista javana* B. & B., and *Podomyia setosa* Dol. (Cachinidae).

The Saddle-backed Nettle Grub, *Thosea cervina* Moore, occurs in numbers occasionally in Uva, Passara and low-country districts. It has also been recorded damaging pepper (*Piper nigrum*). The full-grown larva (Colour Plate 15) is 1 to 1¾ inches in length, green but with prominent white to brownish markings in the mid-dorsal line.

These vary considerably in form and colour but generally consist of three wider patches joined by narrow necks; the centre patch is the widest and gives the impression of a 'saddle'. The larvae fall to the ground and generally pupate about one inch deep in the soil or in leaf litter. The cocoon is roughly globular, about 5/8th of an inch across, smooth and dark brown and, as noted above, closely resembles a tea seed. Recorded parasites of *T. cervina* are:—Braconidae—*Fornicia ceylonica* Wlkn., *Apanteles* sp.; *Rogas* sp; Eulophidae—*Autoplectrus taprobanae* Gadd, *Metaplectrus solitarius* Gadd, *Metaplectrus thoseae* Ferr. and *Trichospilus pupivora* Ferr.; Tachinidae—*Phorocera magna* Bar., *Tachina munda* Wd. and *Chaetexorista javana* B. & B.

The Morawak-Korale Nettle Grub, *Thosea recta* Hampson, occurs chiefly on tea in low-country districts and in Uva. It has been noted also on *Albizia* spp. The full-grown larva (Colour Plate 16) is about half an inch in length with narrow, silvery-white, dorsal-band markings and much shorter stinging spines than in *T. cervina.* The cocoon is formed closely attached to leaves or twigs and is about 0.3 to 0.4 inches across, oval in shape and dark brown with lighter patches. Recorded parasites of *T. recta* in Ceylon are as follows:— Braconidae—*Fornicia ceylonica* Wlkn., *Rogas* sp., *Apanteles* sp. and *Spinaria* sp.; Tachinidae — *Podomyia setosa* Dol.

The full grown larva of the Green Gelatine Grub, *Narosa conspersa* Wlk. (Colour Plate 17) is 0.3 to 0.4 inches in length and yellow to green in colour. The body is naked, with a marked dorsal ridge, and shows segmentation. The cocoon is about 0.2 inches across and is formed closely attached to leaves; it is white with a brown operculum or lid at one end. Recorded parasites of *N. conspersa* in Ceylon are *Rogas* sp. (Braconidae); *Metaplectrus solitarius* Gadd (Eulophidae) and *Frontina* sp. (Tachinidae).

The Large Gelatine Grub, *Belippa laleana* Mo., (Colour Plate 18) is about half an inch in length, pale white with a bluish tinge, squat, rounded and slug-like in appearance. A *Rogas* sp. has been recorded as a parasite on this grub.

Chemical Control—Austin (1931-32) recommended spraying with soap solution at a strength of 1 lb soap in 30-40 gallons of water, using a full soaking spray to 'run-off', which in practice on mature tea may require 200 gallons or more of spray per acre. Later (1957), he recommended spraying with a 1% solution of the detergent 'Teepol' (*ex* Shell Co.), similarly with a very high volume per acre, but the results of this treatment have been shown to be poor compared to the effect of DDT spraying.

Nettle grubs are very susceptible to DDT and excellent control can be obtained with 3-4 pints of a DDT 25% E. C. in 50-70 gallons of water per acre applied by knapsack sprayers. Further, DDT is equally effective at the same dosage applied in 10 gallons of water by motorized mist-blowers; this is a valuable advantage, particularly where water is in short supply as in Uva in the dry season. More recent results show that 'Dipterex' is also effective (at least against Fringed Nettle Grub, and probably against other species) at 2 lb of 'Dipterex SP 80' in 50-70 gallons water per acre by knapsacks or in 20 gallons water per acre by mist-blower.

Hand collection—Hand-collection and destruction of both the grubs and cocoons was formerly recommended by Austin (1932). Whilst collection of the grubs is feasible in a light attack, it is totally impossible in a heavy attack by Fringed Nettle Grub when almost every leaf may carry grubs.

Collection of the cocoons on the ground is a more practicable measure with this species and with *Thosea cervina*. If an attack is seen and sprayed in the early stages, very few grubs should survive to pupate. However, if the attack has reached the stage where many cocoons are formed, collection and burning of these will help to prevent a further generation.

5.2. GEOMETRID CATERPILLARS

Two species of the family Geometridae have recently come into prominence as pests of Ceylon tea; these are the 'Twig Caterpillar', *Ectropis bhurmitra* Walker (=*Boarmia bhurmitra* Wlk.) and the larger 'Looper', *Buzura strigaria* Moore (=*Biston suppressaria* Guenee). Outbreaks of one of these species, or both together, have occurred on several estates in 1965 on fields sprayed with dieldrin for control of Shot-hole Borer, and an alarming feature of these attacks is their tendency to recur on the same field or adjacent fields.

The family Geometridae is a very large one with many pest species throughout the world. The larvae are elongate and slender and generally have only 2 pairs of abdominal feet (on the sixth and tenth segments) instead of the four or more pairs present in most other lepidopterous families; progression takes place by drawing up the abdomen in a loop and then extending the whole front of the body in a leech-like fashion. The name geometrid means 'earth-measurer' and various species are called 'inch-worms', 'measuring-worms' and 'loopers'. Another notable feature of these caterpillars is that the vast majority, when at rest, bear a remarkably close resemblance to twigs, and so are difficult to spot.

Ectropis bhurmitra was called Twig caterpillar by Green who observed a serious outbreak on a Kandyan estate in 1900, where the pest caused severe damage to tea, *Grevillea*, cardamoms and gum trees. A few outbreaks were recorded later in the 1930's and 1940's. This species is also an occasional pest of tea in S. India and Indonesia and occurs on a wide range of host plants.

Buzura strigaria has long being known as a serious local pest of tea in North India where it is called Looper; Das (1963) has recorded that, in some years, it was responsible for a loss of crop of 30-50% in localised areas of many estates in the North Bank and Sibsagar districts. In Ceylon, however, although known for a long time, outbreaks on tea have occurred only in the last 2 or 3 years.

Twig caterpillar (*E. bhurmitra*).—The eggs, which are bluish-green covered with buff-coloured hairs, are laid in clusters in crevices in the bark of shade trees and have been observed on *Grevillea*, *Gliricidia* and *Albizia*, but not so far on tea. The tiny newly-hatched caterpillars are dispersed by wind. On tea, the young larvae feed first on the epidermis of tender young leaves and as they grow larger, they eat out holes or feed from the margin of a leaf, chiefly on the maintenance foliage. Eventually, the larvae devour whole leaves, leaving only part of the mid-rib.

Plate 5. Tea bush (on right) badly affected by Scarlet Mite.

Plate 6. Tea bush (on left) badly affected by Yellow Mite.

The full-grown larva (Figure 13) is about 1½-2 inches long when extended. The colour is rather variable, generally dark ruddy-brown with pale lateral stripes and the posterior segments paler dorsally, the belly generally dark in colour, the spiracles (breathing apertures) buff-coloured and ringed in black. The cuticle is smooth compared to *B. strigaria*. The general tone of the colouration resembles that of the 'red' wood of tea. The larva often rests on a tea stem attached by the abdominal feet, and with the front of the body, head and thorax extended, still and rigid, with the legs bunched together, so that it closely resembles a thin dead twig. The small black pellets of frass (excreta) may be noticed on the ground below the bushes; jarring the bushes with a stick will often make some of the larvae fall down on silk threads.

When mature, the larvae pupate in the surface soil; the pupa or chrysalid is reddish-brown, smooth and glossy, 0.5 to 0.75 inches long. The adult moths are of slender build with the relatively large wings pale-greyish in colour, minutely spotted with dark wavy lines, 1½-1¾ inches in span. They are active at night but are not strong fliers. During the day they congregate on tree trunks and rocks and lie with the wings expanded; at this stage they can easily be collected.

Looper (*B. strigaria*) The life cycle is very similar to that of *E. bhurmitra*. The eggs are likewise bluish-green and laid in crevices in the bark of shade trees. The larva is 2½ to 3 inches long when full-grown and much thicker than that of *E. bhurmitra*. The colouration is variable but tends to be greenish-brown in the younger larvae changing to mottled grey or dull brown in the older larvae; the face of the head is paler in colour. The general colour tone resembles that of old tea bark. With a hand lens it can be seen that the 8 pairs of abdominal spiracles are red, edged with black; and that the cuticle of the body and head bears many small white tubercles and black tubercles and short black spiny hairs.

The pupa, formed in the surface soil, is brownish-black, smooth glossy and ¾ to 1 inch long. The moth is similar in build to that of *E. bhurmitra*, the wings grey but prettily mottled with yellow and black bands, 2 to 2¾ in. in span.

Occurrence of outbreaks.—Several outbreaks of Twig Caterpillar have been recorded in 1965 in the Kandy, Kelani Valley, Galaha, Nawalapitiya and Ratnapura districts. Quite often these have involved smaller numbers of Looper also; but only two outbreaks have consisted predominantly of Looper. All these outbreaks have occurred on dieldrin-sprayed fields and hence would appear to arise because of interference with the normal parasitic control of the geometrid caterpillars as happens with *Macrocentrus homonae* and Tea Tortrix. This aspect requires much further study.

Control measures.—Recent trials have shown that Twig Caterpillar can be very effectively controlled with DDT (18-25% E. C.) at 6 pints in 50 80 gallons water per acre applied by knapsack sprayers or at 6 pints in 15 20 gallons per acre by mist-blowers. It may be necessary to repeat spraying after a week if live caterpillars are still found. This treatment is also effective against the younger caterpillars of Looper, but it does not give a good kill of the more mature Looper caterpillars, those half to full-grown. Dipterex, Sevin, Malathion, Metacil and certain other insecticides have not proved effective against either species.

In most outbreaks so far, Twig Caterpillar has occurred alone, or with smaller numbers of Looper, and in these cases control should first be tackled by DDT spraying, in two thorough-rounds if necessary, though one round may afford good control. It is highly desirable to spray while the caterpillars are still small, if they can be spotted at that stage, for both species are then more susceptible. Mist-blower applications of DDT have proved just as effective as knapsack spraying, and this technique greatly facilitates prompt measures. Because of the different susceptibility of the two species, and the possibility of other species occurring, outbreaks should be reported to the Tea Research Institute for specific advice.

Hand collection of the caterpillars may also be useful, particularly with the Looper; it may sometimes be desirable to spray and then collect the survivors by hand after a week.

Since attacks tend to recur on the same areas or close by after several weeks or a few months, some interest has been focussed on insecticidal treatment of the soil with the object of killing pupae or the emerging moths. Effective methods have yet to be developed, however, and it must be stressed that soil treatment with insecticides such as aldrin, dieldrin, or chlordane may interfere with natural parasitic control of caterpillar pests, e.g. instances have been noted where soil treatment with aldrin induced an outbreak of Tea Tortrix.

Hand-collection and destruction of the adult moths, which tend to congregrate during the day on rocks and the trunks of shade trees, has been practised by a few estates and should prove a useful accessory measure. Adult moths might be more rapidly controlled by spraying them where they congregrate, and spraying the surfaces of the tree trunks may destroy many eggs. For this purpose, DDT can be used at the concentration of 2 pints E. C. in 25 gallons water.

5.3. BAGWORMS AND FAGGOT-WORMS (FAMILY PSYCHIDAE)

In this family, the larvae inhabit portable cases which they construct of silk covered with fragments of leaves or bark (bag-worms) or of small cut twigs (faggot-worms). When feeding, the head and

Plate 7. Egg-mass of Tea Tortrix, *Homona coffearia* (Nietn.).

Plate 8. Larvae of Tea Tortrix.

Plate 9. Typical leaf 'nests' of Tea Tortrix larvae.

thorax project from the case, but at the slightest alarm the larva withdraws in to the case which is often closed by an 'operculum' or lid. The case is suspended by silk from a leaf or twig. When the larva is mature, it reverses itself within the case and pupates. The female moths generally emerge from the pupal skin but remain within the larval case; they are degenerate and without wings, and in extreme forms even the antennae, mouthparts and legs are wanting—the adult female is simply a worm-like egg-sac. In contrast the male pupa pushes itself half out of the bottom end of the larval case and the moth emerges; the male moths are highly-specialised swift fliers, and the wings are thinly clothed with hairs and imperfect scales and almost devoid of markings. Copulation generally takes place by the male alighting on a case containing a female and inserting his protrusible abdomen into the case. The female lays eggs within the case, then emerges herself to die. Later the young larvae hatch and emerge from the case, each quickly forming a tiny case which is enlarged progressively as the larva grows. The young bagworm generally carried the case upright, but soon the case is too heavy and is carried in a pendent position.

Various species have been recorded on tea and shade trees from the earliest days of tea planting and have aroused interest from the oddity of their form and behaviour (Figure 15). *Clania cramerii* Westwood is the large Faggot-worm of Ceylon tea (Figure 12). The case is a rough bundle of thin twigs of fairly even thickness, and is 1½ to 2½ inches or more long for the full-grown larvae. The twigs are cut off the bush by the larva and attached to the silk case. This species is common in India and Indonesia and has been noted on a very wide variety of host plants, including species of *Acacia*, *Albizia*, *Casuarina*, *Shorea* and *Tamarindus*; the form of the case varies considerably with the plant material available and sometimes thorns and leaves are used. The youngest larvae use a protective covering of tiny fragments of bark, moss and leaves. Development takes several months and Beeson (1941) states that there is usually only one generation a year. Green (1890) has recorded that there is an ancient Sinhalese legend, according to which each insect contains the soul of a man who stole wood, and who is condemned for ever to carry around a burden of faggots.

Kotochalia doubledayi Westwood is the Small Faggot-worm of Ceylon tea, with a case ¾ in. or at a most ¼ inches long, in a similar bundle to that of *C. cramerii* but with the twig much smaller and thinner. Smaller larval cases of the latter may be confused with it but are formed of less regular lengths of twig.

Clania variegata Snell is a large, polyphagous species like *C. cramerii*, of which the case is very variable and irregular, composed often of twigs of very different thicknesses, and sometimes of leaves. It is uncommon on tea.

The commonest bagworms on tea are *Manatha albipes* Moore and *Acanthopsyche subteralbata* Hampson. The former occurs on tea, *Acacia* and *Albizia* and other plants; the case is ½ to ¾ inches long and generally covered with small fragments of bark; this species commonly damages both the leaves and bark of tea. *Acanthopsyche subteralbata* is common on *Albizia* and the larval cases are often seen hanging down on silk threads from this shade tree. The case is slender and under half an inch in length, usually covered with tiny bark fragments. The pupal case is pendent on a short silk thread. Another bagworm occasionally found on tea which can cause appreciable damage is *Chalioides vitrea* Hampson; the larval case is long and narrow, about one inch in the male but up to 1¼ inches in the female, off-white to very pale brown in colour and smooth.

Psychids mostly feed by eating holes right through the leaves; the typical example shown in Figure 11 is of severe damage by *Manatha albipes*. They also cause damage to the bark and the faggot-worms can seriously damage young plants by cutting twigs. Occasionally they are sufficiently numerous to merit spraying.

Natural enemies—The following have been recorded as parasites of psychids in Ceylon:-

Of *Clania cramerii*—*Mesostenus* sp. (Ichneumonidae) and *Simpiesis* sp. (Eulophidae)

Of *Manatha albipes*—*Elasmus ceylonicus* Ferr. and *E. hutsoni* Ferr. (Elasmidae) and *Bactromyia franssoni* Bar. (Tachinidae)

Of *Chalioides vitrea*—*Anastatoidea brachartonae* Gahan (Eupelmidae) *Brachymeria euploeae* Wtstn. (Chalcididae), *Tricholyga psychidarum* Bar. (Tachinidae)

Control measures—Psychids are not very easy to control, and the species may differ considerably in their susceptibility to various insecticides. Limited experience with the species on Ceylon tea indicates that the feeding larvae can be controlled by DDT at a dosage of 6 pints in 70-80 gallons of water applied by knapsack sprayers or in 10-15 gallons of water per acre applied by mist-blowers. Two thorough rounds may be required. Protected as they are by their cases, control of psychid larvae with DDT is mainly dependent on the stomach poison effect of the insecticide. It is important not to regard the old cases hanging on the bushes as not doing any harm; these will often contain female moths or be full of eggs which will give rise to a further generation; hence about 4-5 days after spraying it is desirable to collect and burn the remaining cases. Measures may also have to be taken against infestation in shade trees which will reinfest the tea beneath; the trees may have to be pollarded but those up to about 20 feet in height can be sprayed with DDT by mist-blower.

FIGURE 12.—Large faggot worm (*Clania cramerii*) two inches long.

FIGURE 13.—Twig caterpillar (*Ectropis bhurmitra*) (Natural size, two inches long).

FIGURE 14.—Lobster Caterpillar (*Stauropus alternus*) in defensive posture (Natural size 1½-2 inches long).

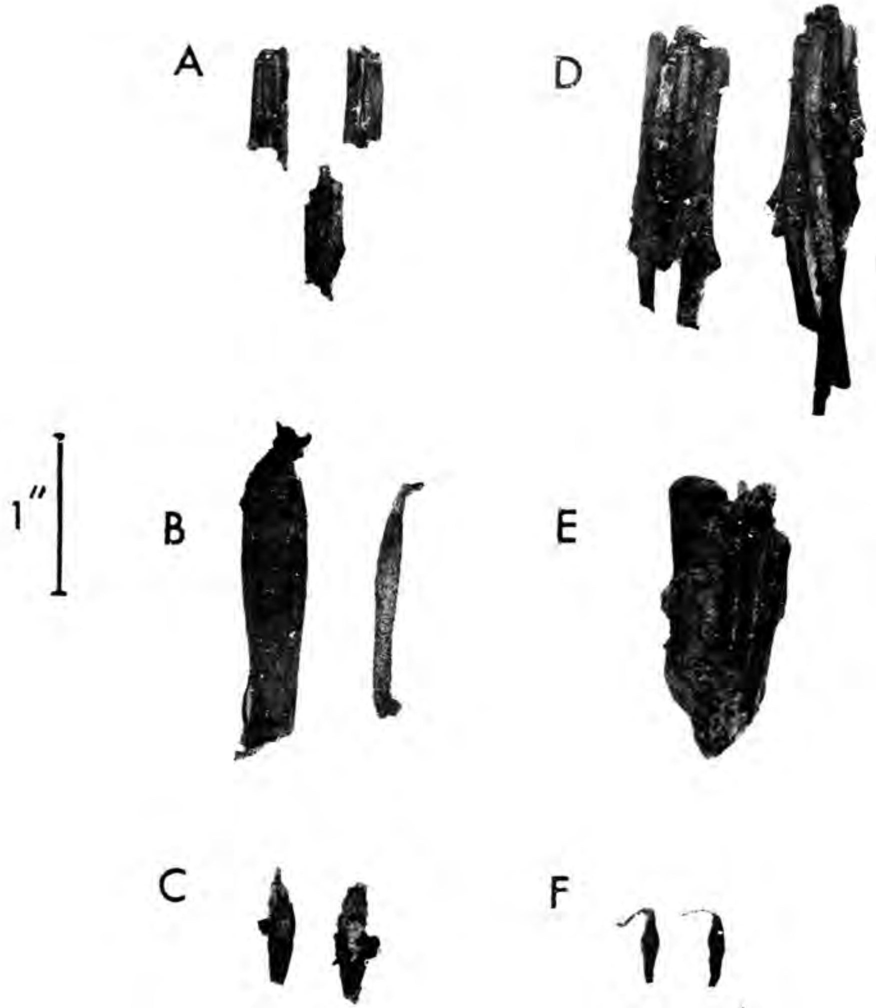


FIGURE 15—Bagworms and faggot-worms (Psychidae): cases of (A) *Kotochalia doubledayi*, (B) *Chalioides vitrea* female and male, (C) *Manatha albipes*, (D) *Clania cramerii*, (E) *Clania variegata*, (F) *Acanthopsyche subteralbata*.

5.4. RED SLUG (*Eterusia aedea cingala* Moore)

The larva of this moth is superficially like a nettle grub in slug-like appearance and bright colouration, but it belongs to a different family (Zygaenidae) and lacks stinging hairs. It has been noted as a local pest of tea from the earliest days (Green, 1890) and very occasionally causes severe defoliation over several acres. Other sub-species of *Eterusia aedea* are recorded as local pests of tea in N. India (*E. a. magnifica* Butler) and S. India (*E. a. virescens* Butler), and in Indonesia. The larva feeds on many host plants and the moths are very commonly seen at all elevations; outbreaks on tea, however, usually occur in Uva and low-country districts.

The larva (Colour Plate 20) is about 1 to 1¼ inches in length full-grown, and relatively broad, brownish-red to bright brick-red, usually with a paler area dorsally. It carries six longitudinal rows of fleshy tubercles, on the summit of each of which are two or three short hairs and one or two pores, and when the caterpillar is touched, the pores secrete globules of a clear viscous liquid, presumably as a defence mechanism against predators. The secretion has no irritant properties on human skin.

When the caterpillar pupates it spins a closely-woven cocoon of pinkish straw colour in the fold of the leaf. The pupa is creamy white. The adult moths are boldy marked, predominantly in white, black and metallic blue, with a yellow abdomen, and have long feathered antennae; the wing span is from about 1⅛ inches in the male to 1½ inches in the female. They fly by day and might be mistaken for butterflies on account of their bright colouration; for some reason they are surprisingly common on bungalow windows. The life-cycle from egg to adult appears to take above 10 weeks. Recorded parasites of Red Slug in Ceylon are as follows:—Braconidae — *Apanteles heterusiae* Wilkn., *Apanteles* sp.; Ichneumonidae—*Hemiteles* sp.; Tachinidae — *Zenillia heterusiae* Coq.

Chemical control—Red slug can be controlled by DDT spraying at the strengths recommended for control of nettle grubs. Other insecticides have not so far been tested, but Dipterex is probably also effective.

5.5. LOBSTER CATERPILLAR (*Stauropus alternus* Walker)

This curious grotesquely-formed caterpillar (family *Notodontidae*) was noted by both Green in Ceylon (1890) and Watt and Mann in India (1903) as a minor pest of tea and has frequently been reported over the years. It is mainly of consequence in nurseries and on young tea and very seldom occurs in sufficient numbers to cause serious damage to mature tea. The larva is polyphagous and may occur on tea, cacao, *Acacia, Albizia, Grevillea, Cassia,* etc.

The full-grown larva is 1½-2 inches long, the head is large, and along the back are a double series of prominent humps, while the last segments are broadly expanded into lateral flanges. The terminal segment is swollen and bears a pair of slender curved appendages or 'claspers'. The second and third pairs of thoracic legs are exceptionally long, which is very unusual in moth larvae; hence the name *Stauropus*, which means 'stake-footed'. The colouration is very variable, usually very dark brown or greyish-black tinged with green, or mottled light and dark brown. The larvae are very restless and when disturbed assume a typical threatening attitude that has earned the name of Lobster caterpillar; resting only on the four pairs of abdominal feet, the head and thorax are raised and curved back, and the 'tail' is raised with the claspers erect. The four long thoracic legs are stretched out, quivering (Figure 14). This behaviour is presumably a defence mechanism against predators such as birds and lizards. When still, the grotesque shape may be mistaken for a crumpled dead leaf.

Pupation occurs in loosely-woven yellowish-brown cocoons formed between two or three leaves spun together. The moths are pale greyish-brown, 1½ to 2½ inches in wing span. Beeson (1941) states that the life-cycle takes 6 8 weeks in S. India.

Recorded parasites of Lobster caterpillar in Ceylon are as follows:- Braconidae—*Apanteles taprobanae* Cam.; Tachinidae—*Carcelia gnava* Mg., *Zenillia resoides* Bar., *Zenillia sumatrensis* Tns., *Carcelia sumatrensis* Bar. and *Tricholyga sorbillans* Wd.

Control—In nurseries and on young tea, hand-collection will often provide satisfactory control. Spraying can be carried out if necessary, using DDT E. C. at 1 pint in 25 gallons water as a full soaking spray on young tea.

5.6. CUT-WORMS (NOCTUIDAE)

Certain noctuid larvae are known as cut-worms and rank as serious pests on various crops throughout the world. They are common pests in vegetable gardens on Ceylon tea estates and occasionally are destructive in tea nurseries and on very young tea in new clearings. Gadd (1947) recorded *Agrotis* (*Euxoa*) *segetum* Schiff as the common cutworm on St Coombs. Green (1890) noted *Agrotis suffusa* Hubner as a common species. Several species may occur and further work is required.

The eggs of cut-worms are laid on leaves and twigs of plants. The full-grown larvae are smooth, generally dark-brown with paler stripes, about 1½ inches in length, with three pairs of short thoracic legs and four pairs of abdominal feet. They hide in surface soil and debris during the day and come out to feed at night. In feeding, they often girdle the base of the stem of young tea plants or rooted

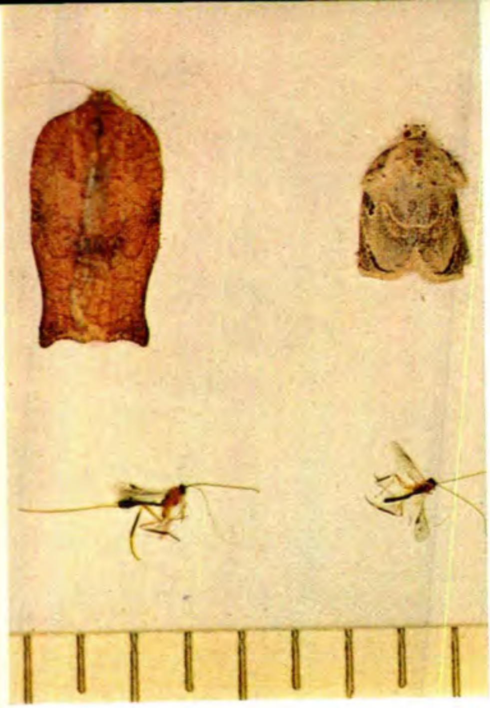


Plate 10. Adults of Tea Tortrix (above) and *Macrocentrus homonae* (below). Left: females; right: males. Scale in one-tenths of an inch.

Plate 11. Cocoons of *Macrocentrus homonae* Nixon.

Plate 12. Tea foliage badly attacked by Tea Tortrix.

cuttings in the nursery, so that the whole plant may die; hence the name 'cut-worm'. They also feed on leaves low down on the plant. Pupation occurs in an earthen cell in the soil. The moths are nocturnal fliers, and attracted by lights; by day they rest under leaves and rubbish with the wings folded. The fore-wings are dull brown, mottled and barred with darker markings, the hind wings predominantly white, yellow or orange in different species.

Control—Cut-worms can be controlled by spraying the surface of the soil with DDT. In new clearings an effective dose is 6-8 pints DDT E. C. in 80 gallons of water sprayed on the soil surface by knapsack sprayer, or the same dose in 10 gallons water applied by mist-blower. On nursery beds a similar dosage is provided by 1 fluid oz DDT E. C. in 2 or 3 gallons water sprayed over 30 square yards of bed; this should be watered into the soil of the bed, after spraying.

It is also possible to dig the soil over with a short pointed stake or a scraper and collect the grubs by hand but this causes undesirable disturbance to the tea roots in nursery beds.

5.7. ARMY-WORM. [*Spodoptera litura* (Fabricius)]

Spodoptera litura (previously *Prodenia litura* F.) is another noctuid moth; the larva is very similar in form to the cutworms and occasionally damages tea. This species is a serious pest on cotton, tobacco and other crops in various countries. It can appear in very large numbers and as the food becomes exhausted the larvae move gregariously in search of a fresh food supply, hence the name 'Army-worm'. On tea estates, it occurs in numbers very occasionally, feeding upon the ground cover of weeds and the lower maintenance foliage of mature tea. The feeding pattern is one of irregular holes eaten out of the mature leaves. The larvae are dull olive-green in colour with paler lateral stripes, 1½ inches long when full-grown. They do not hide in the soil during the day, as do cutworms. They pupate in the surface soil. The moth has greyish-brown forewings streaked in with silvery lines and the hind wings are white; wing span up to 1½ inches. Beeson (1941) states that there are five generations a year in S. India.

This species is rarely found in nurseries and on young tea in new clearings, and since damage is mostly confined to the lower maintenance foliage of larger bushes it is serious only when the larvae are very numerous. This occurs very occasionally, in low-country and mid-country districts.

Recorded parasites of *S. litura* in Ceylon are *Apanteles ruficrus* Hal. (Braconidae), *Actia monticola* Mall. and *Podomyia setosa* Dol. (both Tachinidae).

Control—Army-worms can be controlled by spraying with DDT E. C. at 4-6 pints in 60-80 gallons water per acre by knapsacks or in 10 gallons water per acre by mist-blower. The spray should be diverted to cover the lower maintenance foliage, and the ground cover of weeds if the larvae are feeding on them.

5.8. TEA LEAF ROLLER (*Gracilaria theivora* Walsingham)

The larva of *Gracillaria theivora* is, like Tortrix, a common leaf roller on tea but quite different in habit and it belongs to the family Gracillariidae. It is very common in low numbers, especially on tea recovering from pruning, and few such fields have to be searched for long to find it. Occurrence in sufficient numbers to be a pest is rather rare. It occurs also in India and Indonesia as a pest of tea and has been recorded from the earliest days of tea planting (Green, 1890; Watt & Mann, 1903; Kalshoven, 1951).

The eggs are deposited on the undersides of leaves. The tiny newly-hatched caterpillar burrows into the tissue of the leaf and passes its early life as a leaf-miner protected below the lower epidermis of the leaf. It follows a somewhat tortuous course towards the margin of the leaf. It then leaves the mine and becomes a leaf roller, first rolling over about ½ to 1 inch of the lateral margin of the leaf (Figure 16). Within this enclosure it feeds on the epidermis of the leaf. Shortly afterwards it leaves this marginal leaf roll and starts to roll over, downwards, the tip of the same leaf or another, fastening down the lateral edges of the nest with silk threads.

The full-grown larva is about half an inch or so in length, and slender, off-white or very pale green in colour and with the head also pale in colour. It feeds only on the surface of the leaf within the roll, and the wet frass is retained within the leaf roll, unlike that of Tortrix. Several leaf rolls are made during development. When mature the larva leaves the leaf roll and spins a small silken cocoon, one-quarter of an inch in length, which is formed in a depression of the leaf surface or close to the mid-rib. The moth is a small delicate insect, ¼ inch in length, with narrow wings deeply fringed at the margins, dark in colour but irridescent.

Recorded parasites of *Gracillaria theivora* in Ceylon are *Asympiesiella india* Gir. (Eulophidae) and *Bethylus distigma* Mots. (Bethylidae) on the larvae, and *Angitia* sp. (Ichneumonidae) on the pupae.

Control—Tea Leaf Roller can be controlled by DDT spraying employing the dosage and volumes used for Tea Tortrix.

5.9. TEA LEAF SKELETONIZER (*Piesmopoda rufimarginella* Hampson)

The larva of this pyralid moth is a very occasional pest of tea, described by Hutson (1924), and later reported by King (1935) as

FIGURE 16.—Tea Leaf Roller (*Gracillaria theivora*):—leaf showing mine (a) made by first-stage larva, ending at the marginal leaf-roll (b), and the leaf-roll (c) made by the older larva.

FIGURE 17.—Bark-eating Borer (*Indarbela quadrinotata*):—branch of *Albizia falcata* showing frass galleries made by larva and surface of bark eaten away in patches.

FIGURE 18.—'Corroded flush'—damage by *Lygus viridanus*.

FIGURE 19.—Young leaves showing necrotic spots around the feeding punctures of *Helopeltis theivora*

locally troublesome on a few estates in Ramboda and the Passara district.

The caterpillars are about half-an-inch long when full-grown, mottled with brown and black and with a tinge of olive green; younger larvae are yellow, brown and black. They eat away the leaf tissues, leaving only the leaf cuticle and the mid-rib and veins, so that the leaves may be completely 'skeletonised'. They are gregarious and the leaves are loosely webbed together to form a 'nest'; the presence of the pest is noticed from these small masses of skeletonised leaves in the top maintenance foliage. Attacks often attract many spiders. Development of the larva takes 5-7 weeks; they pupate on the leaves and the moths emerge after 11-12 days. The adults are small slender dark moths about a quarter of an inch long which rest on the bushes; when disturbed they make only short flights. There is no experience on the control of this pest with modern insecticides, but it would presumably be controlled by DDT spraying.

CHAPTER 6

SUCKING INSECT PESTS

The pests considered in this chapter are sucking insect pests of the foliage, belonging to the orders Hemiptera and Thysanoptera.

6.1. LYGUS BUG (*Lygus viridanus* Motschulsky)

This pest, the cause of 'corroded flush' on tea, is a small sucking bug of the family Miridae (Heteroptera). The majority of mirid bugs suck plant juices, but some are predacious on other insects and on mites.

Lygus is a localised pest of tea which occurs only in the high country between about 4000 feet and 6,500 feet, particularly where the tea borders jungle areas (Calnaido, 1959). It feeds on a wide range of host plants including many common weeds such as *Eupatorium odoratum* and *Solanum* spp., and on cover crops in tea such as *Drymaria cordata* and *Oxalis corymbosa.* It is a very common pest in bungalow gardens, damaging *Salvia, Geranium, Coleus,* etc. In point of fact, tea is not a favourite host plant of this insect. Attacks can occur throughout the year but are most common in April, May and June.

The adult bugs are small, delicate, winged insects, about one-fifth of an inch long, and greenish-yellow in colour (Figure 20). They feed and are most active around dusk and dawn and possibly by night. During the day they are not easily spotted and are 'shy', avoiding being seen. If present on tea, tapping the bushes will make them fly up very briefly and settle again a short distance away.

The eggs are found on tea but probably also on weeds and cover crops amongst the tea. They are laid singly, embedded in green stems, leaf stalks or mid-ribs, with only the egg-cap protruding. In development, there are five nymphal instars with successive moults. The form of the early nymph resembles the adult but without wings; rudiments of the wings appear in the third instar and develop in the succeeding stages. The egg stage lasts 13-20 days and the nymphal stage about 3 weeks. Adults may live for several weeks.

All active stages feed on the bud and the youngest leaves by inserting the proboscis or sucking mouthparts, which resemble a hypodermic needle. Saliva is injected into the feeding puncture and the bug sucks up the contents of the leaf cells. The saliva contains a toxin which causes the cells around the feeding puncture

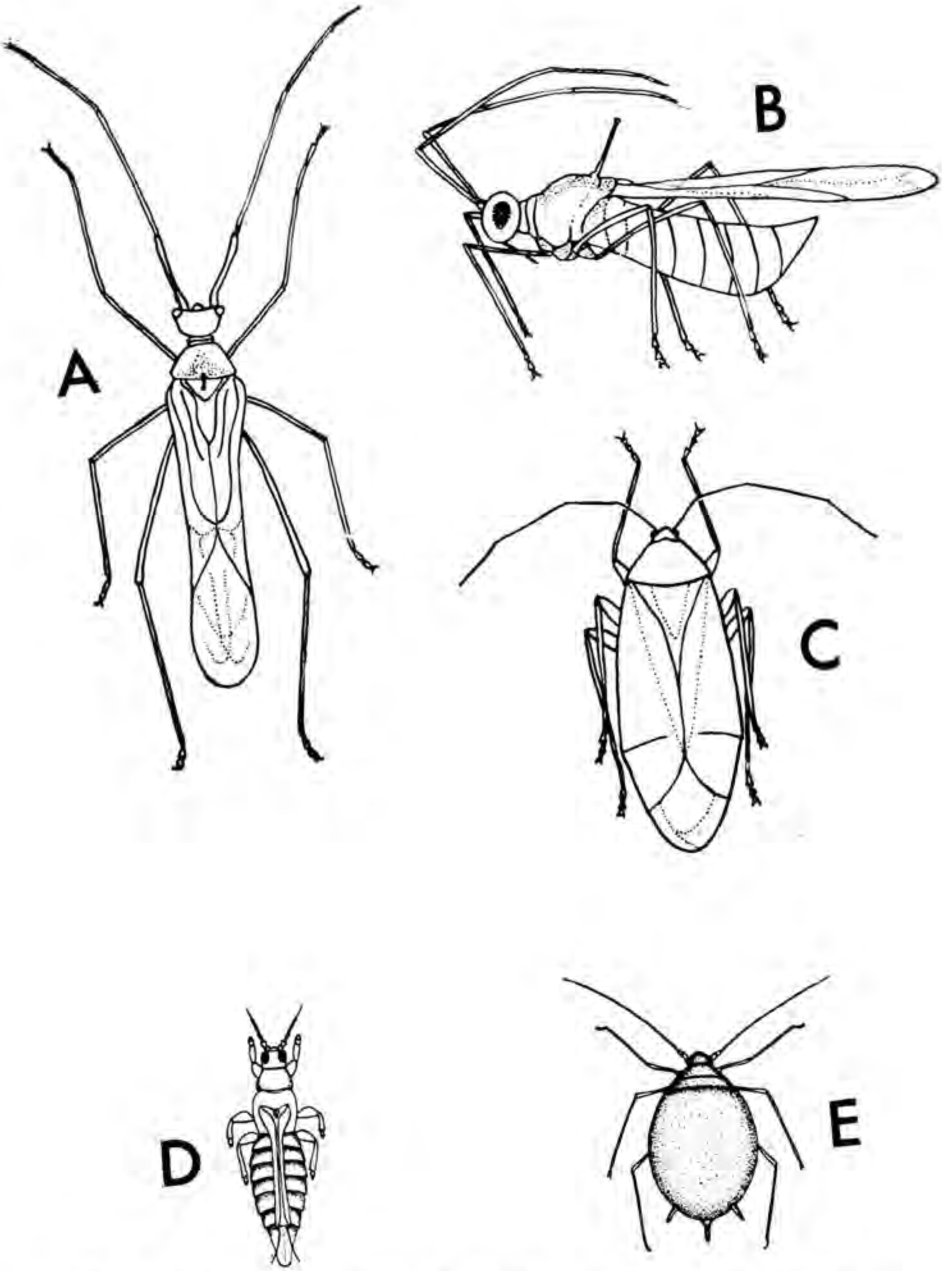
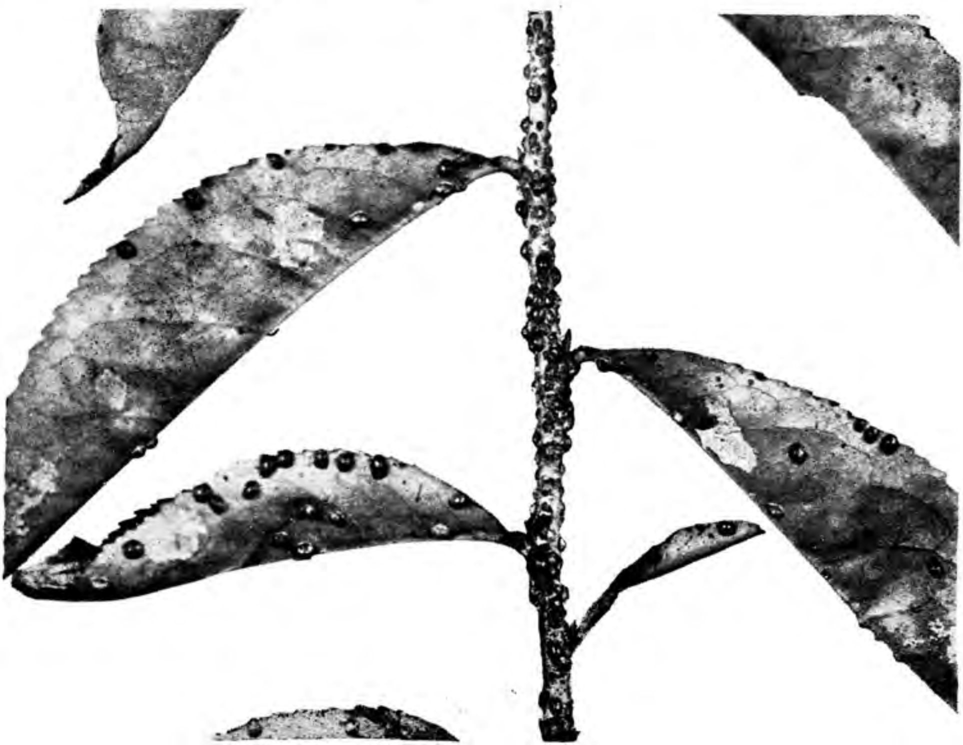


FIGURE 20—Line-drawings showing four sucking pests of tea, greatly enlarged: A & B—*Helopeltis theivora*, adult; C—*Lygus viridanus*, adult; D—Thrips, adult female; E—Aphis (*Toxoptera aurantii*), wingless female (Drawings by E. F. W. Fernando).

FIGURE 21—Tea Aphis (*Toxoptera aurantii*) clustered on young tea shoots.

FIGURE 22.—Brown Bug (*Saissetia coffeae*)—heavy infestation on tea stem and leaves.



to die, and the recently-made punctures show up as tiny brown necrotic spots on the flush. As the leaves grow and expand, the old feeding punctures tend to become small holes and the leaves become ragged and deformed. The effect on the younger leaves has been called 'corroded flush' (Figure 18). The damage may be noticed on the upper maintenance foliage after the attack is over; examination of the youngest leaves and buds for fresh feeding punctures will show whether the attack is still going on.

Lygus bug flourishes in moist shaded conditions and generally prefers low-jat tea. Reduction of shade will often greatly help, but even more important is the ground cover; clean cultivation will often end the attack without recourse to chemical control. If attacks occur near weedy jungle boundaries or ravines, it may be necessary to cut down the weeds there.

Chemical control—Lygus can be controlled by spraying with a DDT E. C. at 4-6 pints in 50-70 gallons water per acre applied by knapsack sprayers or in 10 gallons water applied by mist-blowers. One spraying round at a time is generally sufficient but the pest may recur after several weeks where conditions are favourable.

6.2. TEA MOSQUITO BUG (*Helopeltis* spp.)

Helopeltis is another common genus of mirid bugs. In N. India and in the Travancore (Kerala) districts of S. India, *Helopeltis theivora* Waterhouse was, until the advent of DDT, a very serious pest of tea causing extensive loss of crop, and engaging the attention of scientific workers and planters from the earliest days of tea planting. In Ceylon, however, attacks were, much less severe and largely confined to the Morawak-Korale district in the low country. Severe attacks have not been reported at all in recent years. Earlier attacks in Ceylon were attributed to *Helopeltis antonii* Kirby, another common species, which also attacks cacao; very little work has been carried out on *Helopeltis* on Ceylon tea, and possibly both *H. theivora* and *H. antonii* occasionally attack it.

As with *Lygus*, the eggs are embedded in tender green stems, in this case usually two or three eggs in a group. The protruding egg cap carries two filamentous threads. There are five nymphal instars and the orange coloured nymphs are superficially ant-like in appearance. The adult bug is longer and narrower in form than *Lygus*, up to 3/10th inches in length, the general colour black, relieved by the reddish thorax and black and white abdomen; when resting or running on the leaves, the greenish-brown wings are folded close to the abdomen (Figure 20). Just behind the thorax (on the scutellum) is a single, knobbed, erect process, rather like a short pin with the head upwards. The life-cycle takes about 3-weeks in the low country.

The brown necrotic spots of dead tissue around the feeding punctures of *Helopeltis* are larger than those caused by *Lygus* (Figure 19). The tender stems as well as the leaves may be punctured and stripes of corky tissue develop around the lesions. In severe attacks the whole flush is blackened and corroded, and the loss of crop can be total.

Helopeltis prefers moist, warm conditions and attacks low jat tea preferentially. Unlike *Lygus*, attacks are not associated with weeds and cover crops.

Chemical control—Helopeltis can be controlled with DDT at the rates recommended for *Lygus*. In India, the use of DDT for the control of this pest was extraordinarily successful; numbers appear to have been so reduced that much less frequent spraying was necessary thereafter.

6.3. TEA APHIS (*Toxoptera aurantii* Boyer de Fonseca)

The Aphididae (order Hemiptera) are the common greenfly and black-fly pests of many crops and gardens. Only one species occurs on tea; this is the almost cosmopolitan *Toxoptera aurantii,* which occurs on citrus in most countries where it is grown, and also on cocoa, coffee, mango, rambutan, soursop, etc.

Clusters of the small dark brown aphids occur on the buds and youngest leaves of tea (Figure 21), and since these are removed by plucking the insect is a pest chiefly on young tea in the field and in nurseries, and mature tea recovering from pruning . However, although a few serious attacks have been reported years ago, the author has never seen a really serious outbreak in the last seven years in Ceylon.

Winged females, which disperse far and wide in the wind and convection currents, arrive on the shoots and produce colonies of tiny living young, i.e., no eggs are laid and female gives birth to live young—this is termed 'vivipary'. Reproduction is also parthenogenetic, i.e., without fertilization by male insects, which are in fact unknown in Ceylon. The offspring mostly develop as wingless females which also reproduce viviparously and parthenogenetically, but some winged females may also be produced and fly off to start colonies elsewhere.

The wingless females (Figure 20) are 1-2 mm long, dark brown in colour with a flask-shaped body narrowed somewhat in front and terminated behind in a short pointed cauda . Dorso-laterally the abdomen (on the 6th segment) carries a pair of cornicles; these are tube-like protuberances characteristic of aphids which serve as channels for secretion of a waxy substance said to act as a deterrent to predators.

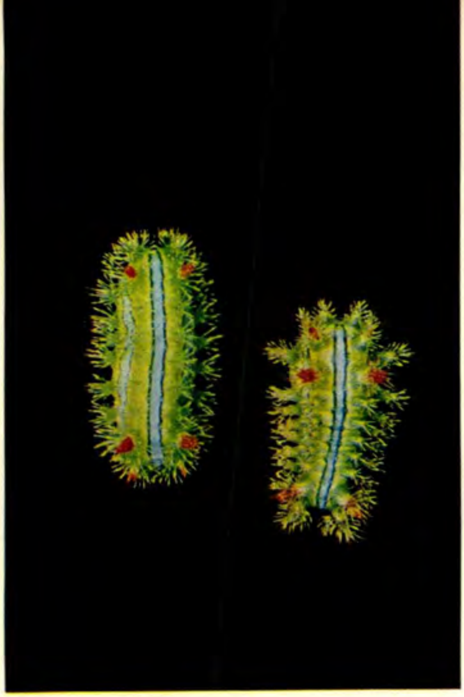


Plate 13. Blue-striped Nettle Grub, *Parasa lepida* (Cram.). The full-grown larva is $1\frac{1}{4}$ inches to $1\frac{1}{2}$ inches in length.

Plate 14. Fringed Nettle Grub, *Macroplectra nararia* (Moore), larvae and cocoons. Full-grown larvae are $\frac{3}{8}$ to $\frac{1}{2}$ inch in length.

Plate 15. Saddle-backed Nettle Grub, *Thosea cervina* Moore, larvae and cocoons. Full-grown larvae are 1 to $1\frac{1}{4}$ inches in length.

Plate 16. Morawak-korale Nettle Grub, *Thosea recta* Hmps., larvae and cocoon. Full-grown larvae about $\frac{5}{8}$ inch.

Aphids feed by sucking the sap of the host plant; the affected leaves tend to curl and become distorted. They excrete 'honey dew', containing excess water and sugars in their diet, through the anus; this spreads over the leaves and falls on leaves below and encourages the growth of a black sooty mould. The latter is not a parasitic fungus but purely a surface growth on the deposited honey dew and can be rubbed off the leaf surface; but, if growth of it is heavy, it interferes with photosynthesis in the leaves. Aphids are generally attended by ants which imbibe the honey dew. This symbiotic relationship has been likened to the ants keeping the aphids like cows which are 'milked'; to a certain extent the ants protect the aphids and carry individual aphids to other shoots to start up colonies.

Recorded parasites of *T. aurantii* in Ceylon are *Eurytoma* sp. (Eurytomidae), *Alictus* sp. and *Aphidius* sp. (both Braconidae).

Chemical control.—If sufficient numbers occur to merit spraying young tea in the field or in nurseries, Tea Aphis can be controlled by spraying with a malathion 50% E. C. at a concentration of 10 fl. oz. in 25 gallons of water, wetting the shoots thoroughly.

If control is required on mature tea recovering from pruning, an effective dosage is 1½ pints malathion 50% E. C. in 50-70 gallons of water per acre applied by knapsack sprayers.

6.4. SCALE INSECTS

The common scale insects on tea belong to the families Coccidae and Diaspididae (order Hemiptera). They are small sucking insects in which the females are degenerate, wingless, obscurely segmented and scale-like in appearance, with the legs and antennae atrophied. The first-stage nymphs ('crawlers') are provided with functional legs and their mobility ensures dispersal; subsequent nymphal instars and the adult females are stationary, being attached to the food plant by their sucking mouthparts. The males develop as scale-like nymphs but the adults are active and usually winged, tiny, fragile insects. As with the aphids, scale insects excrete honey dew and are generally attended by ants (Das, 1959); similarly 'sooty mould' growing on the honey dew is characteristic of their occurrence.

The group contains a very large number of species of which those occurring on a wide range of host plants in Ceylon were the subject of an excellent monograph by Green (1896-1922). Several species are liable to occur on tea, affecting a few bushes here and there. Only two species have appeared repeatedly as significant localised pests over the years affecting several acres of tea at a time; these are commonly called Green Bug (*Coccus viridis* Green) and Brown Bug (*Saissetia coffeae* Walker); both belong to the family Coccidae.

Other fairly common species, but generally affecting only small groups of young plants, are *Hemiberlesia rapax* Comstock (= *Aspidiotus camelliae* Signoret) and *H. lataniae* Signoret (= *Aspidiotus transparens* Green) (both family Diaspididae). Scale insects do not usually occur in numbers on healthy vigorous plants and their presence would seem to indicate an imbalance in nutrition or water uptake.

Green bug (*Coccus viridis* Green).—This species was recorded as *Lecanium viride* by Green. It occurs in many countries on a wide range of host plants. It was a major scourge on coffee in Ceylon in the years 1882-1886 and also attacks *Cinchona*, *Citrus*, Guava, para rubber, cassava and numerous garden shrubs. On Ceylon tea it can appear in numbers at all elevations but is more common in the high-country, outbreaks usually occur in March-June in the S. W. Monsoon zone, and April to October in Uva, and diminish with the rains.

The scales occur clustered on the tender green shoots and undersides of the leaves along the mid-rib and veins (Colour Plate 24). The adult female scale is yellowish-green, roughly oval in outline, the anterior end slightly more pointed and showing two minute black eyes (seen under 10 x hand lens). The scale is moderately convex but much less so than Brown bug. The length is 2.5-3.25 mm. and the breath 1.5-2 mm. In Ceylon, males are unknown in any stage. Reproduction is therefore pathenogenetic, i.e., unfertilized eggs develop; and it is also 'ovo-viviparous', the eggs being hatched at the time of, or just after, exclusion under the adult female scale. Under a mature female, a mass of empty egg-skins will be found. A constant succession of larvae are produced during the adult life of the female.

The tiny newly-hatched crawlers can be seen with a hand lens; they are 0.35 mm long, very pale green, broadly oval and very flat, with antennae, three pairs of legs, a pair of conspicuous black eyes, and a pair of setae which are about half the length of the insect protruding posteriorly. The female of the second stage is similar to the adult but smaller, narrower and flatter. Development is fairly rapid, about 4-6 weeks, but varies considerably with climatic conditions; the females produce young over an extended period and generations are therefore overlapping.

There has been no detailed study of the parasites and predators of Green Bug in Ceylon. Certain Coccinellid beetles, both adults and larvae, are predacious on them. Parasitism by minute chalcid wasps is common, the species include *Aneristus ceroplastae* Howard (Aphelinidae), *Anicetus ceylonensis* Howard (Encyrtidae) and *Microterys flavus* Howard (Encyrtidae).

FIGURE 23.—Diaspine scales (*Hemiberlesia rapax*) on tea leaf, very greatly enlarged.

FIGURE 24.—Green Bug (*Coccus viridis*) on tea leaf, killed by fungal disease (*Cephalosporium lecanii*). Note the greyish-white fungal mycelium covering the scales (*see also* Colour Plate 24).

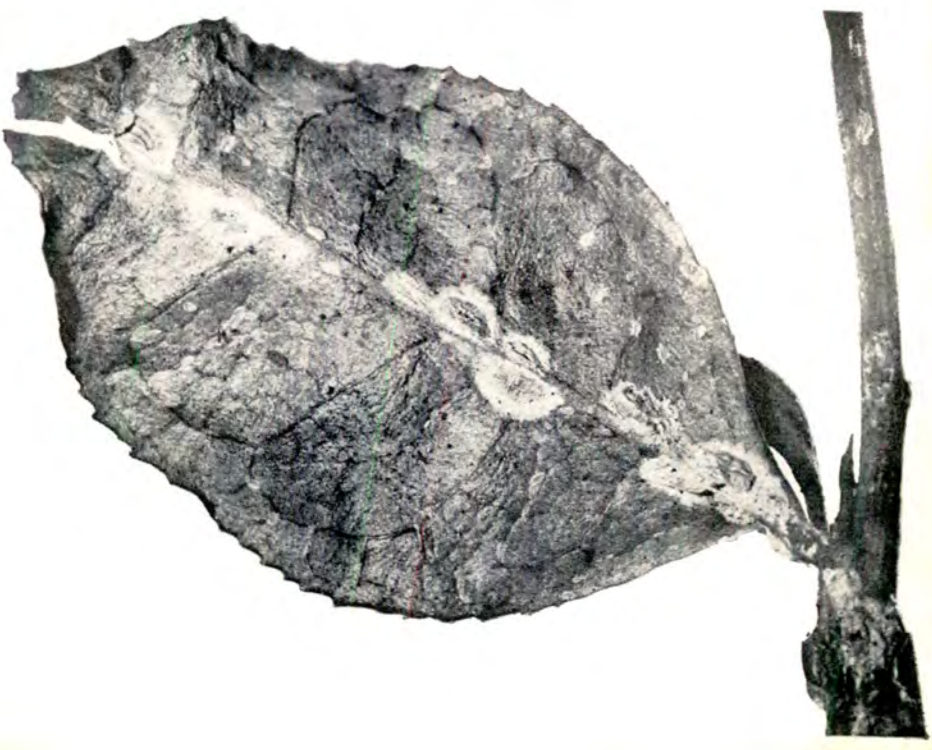


FIGURE 25.—Tea shoot damaged by thrips.

FIGURE 26.—'Sewing Blight'—oviposition punctures caused by an *Orasema sp.*

In humid rainy weather, outbreaks of Green Bug are subject to an epidemic fungal disease, *Cephalosporium lecanii*, which kills off a very large proportion. The scales shrivel and are covered with the greyish-white fungal mycelium (Figure 24). This appears to be an important factor in natural control.

Brown Bug (*Saissetia coffeae* Walker)—This species was recorded as *Lecanium hemisphaericum* Targ. by Green. It is a nearly cosmopolitan species with a wide range of host plants. It was, like Green Bug, a severe coffee pest in Ceylon, and was studied by Nietner (1861). It occurs also on cinchona, guava, *Adiantum* and other ferns, asparagus, gardenia, *Loranthus* and many garden plants. On Ceylon tea, outbreaks occur mainly in the high country from 4000-6500 feet and the seasonal occurrence is similar to that of Green Bug. The two species not uncommonly occur together.

The scales occur on the shoots and under-surfaces of leaves; in heavy attacks the stems may be completely encrusted with mature scales (Figure 22). The mature female scale is at first pinkish-yellow (fulvous) and changes to a deep chestnut-brown, and is roughly oval in outline but strongly domed so that it is almost hemispherical in shape with a marginal rim, 2-3 mm in length 1.25-2 mm wide.

Winged males have been noted in this species but they are rare and reproduction must generally be parthenogenetic. Unlike Green Bug, a mass of tiny fulvous eggs is laid under the mature female scale and from these the crawlers hatch later, more or less at the same time, and disperse.

Recorded parasites of *Saissetia coffeae* in Ceylon are as follows:—Pteromalidae—*Cephaleta purpureiventris* Mots., *Scutellista cyanea* Mots.; Encyrtidae—*Diversinervus paradisicus* Mots., *Encyrtus infelix* Embleton; Aphelinidae—*Aneristus ceroplastae* How., *Coccophagus flavescens* How. and *Marietta leopardina* Mots.

Brown Bug is also subject to an epidemic fungal disease which appears to be the same as that which attacks Green Bug.

Hemiberlesia rapax.—This species has a wide distribution in the world. In Ceylon it is noted on the stems and leaves of tea, *Cinchona*, *Acacia* and other plants. It chiefly attacks young tea plants, greatly hindering their growth.

The mature scale (Figure 23) resembles a diminutive oyster and shows concentric rings of growth; the colour is yellow with a darker brown centre surmounted by a white 'boss'; the size is 1½ to 2 mm by 1 mm. The younger individuals are clustered around the older ones, resembling 'oyster-spat'.

Hemiberlesia lataniae.—This species occurs in Ceylon on tea, certain species of palm, and various shrubs. It is a diaspine species rather similar in size and form to *H. rapax*, but the scale is flatter, less regular in shape and does not show concentric rings of growth; the centre is pale yellow but the outer part colourless and transparent. It feeds on the stems and on the undersurface of the leaves; the presence of each larger scale shows characteristically as a yellow spot on the upper leaf surface. It is most damaging on very young tea plants.

Chemical control of scales.—Recent trials have shown that good control of both Green Bug and Brown Bug can be obtained with Sevin (carbaryl) applied at 2 lb 'Sevin 85% sprayable' (*ex* Shell Co. of Ceylon) in 70-80 gallons water per acre applied by knapsack sprayers as a 'run-off' spray to wet the shoots and leaves thoroughly, A second spray may be necessary after 14 days. This has been shown to be far superior to the use of 1% white-oil emulsions which were recommended previously. It has not, however, yet been tested against the diaspine scales *H. rapax* and *H. lataniae.*

6.5. MEALY-BUGS

The mealy-bugs (family Pseudococcidae) are coccoids related to the scale insects. The adult females are not so degenerate; they are wingless, but they have functional legs and segmentation is well defined. They are covered in either a mealy or filamentous waxy secretion which may be extended into lateral or terminal filaments. Winged males may occur but parthenogenesis is common.

These are very occasional pests on tea and the species occurring have not been determined. Examples have been noted of an occasional bush or two (usually young tea) carrying a dense infestation of a mealy bug on the stems and leaves. More commonly recorded is a root-feeding mealy bug on rooted cuttings and young plants in nursery beds. Their presence has been found to be indicative of bad drainage conditions and correction of the latter will generally control the mealy bugs. A quick control can be obtained by watering the soil of the nursery beds with 1 fl. oz. of a malathion 50% E. C. in 2-3 gallons of water applied to 30 sq. yards of nursery bed, followed by normal watering of the beds to wash the insecticide into the soil.

6.6. THRIPS (*Thysanoptera*)

These are tiny sucking insects which are very minor pests of tea in Ceylon; they have so far received little attention, so that the species involved are not certain. They merit more attention, however, since in recent years they have attained the status of a major pest in S. India (Ananthakrishnan, 1963a), where *Scirtothrips bispinosus* (Bagnall) is reported as the main species involved. *Taeniothrips setiventris* Bagnall is a serious pest in the Darjeeling district of N.

India, but on the plains of N. India the common thrips on tea is *Sericothrips dorsalis* Hood which rarely causes appreciable damage (Das, 1965).

The adults are very small, narrow insects, less than one-tenth of an inch long, the narrow strap-like wings fringed with long hairs and folded close down the back when not in flight. The eggs are laid on tender foliage. In development, there are four nymphal stages; the first two are active nymphs which feed on the foliage, rather like the adult in form but wingless. The two later stages, the 'pre-pupa' and the 'pupa', are non-feeding stages of metamorphosis to the adult. The last is generally passed in a tiny earthen cocoon in the surface of the soil or in leaf debris. With the species that occur on Ceylon tea, few adults are found on the leaves; they generally feed in the flowers. The tiny pale-yellow nymphs can be found on the under surfaces of the younger leaves and are just visible to the naked eye. The mouthparts are a combination of the sucking and biting type, they penetrate the surface cells of the leaf and suck the sap. Attack often begins on the folded bud, and when this unfolds it carries two corky lines of 'scar tissue', parallel to the mid-rib, on the under-surface and these are pressed out on the upper surface of the leaf. This effect is very similar indeed to that caused by Yellow Mite feeding on the bud; in fact thrips and Yellow Mite frequently, though by no means invariably, occur together. However, with the latter, the corky feeding area generally completely covers the mid-rib and may cover all the lower surface of the leaf (Colour Plate 4).

Thrip damage does not cause the leaves to curl up as with Yellow Mite. The leaves tend to be rather puckered, hardened and deformed; a typical example is shown in Figure 25. Since thrips feed mainly on the youngest leaves, plucking is a partial control measure and attacks in Ceylon occur only on young tea and on mature tea recovering from pruning. Attacks seldom last for more than a few weeks, generally occurring in the drier months, and the plants seem to grow out of the damage quite quickly; such mild attacks have been noted in the high country and mid-country districts fairly frequently.

Chemical control.—If this is necessary, DDT gives effective control when used at 4 pints DDT E. C. in 50-60 gallons water per acre (applied by knapsack sprayers) or in 10 gallons water per acre applied by mist-blowers. Malathion can also be used on tea not in plucking at 1 pint Malathion 50% E. C. per acre.

CHAPTER 7

WHITE GRUBS (COCKCHAFER LARVAE)

7.1. INTRODUCTION

The larvae of various Scarabaeid beetles (chafers or cockchafers), which develop in the soil, are commonly known as 'white grubs'. They are fat, mostly white or cream-coloured grubs, with the body curved in the form of a letter 'C', with three pairs of thoracic legs and a brown sclerotized head with prominent mandibles (Figure 29). Several species are commonly found in tea soils and in the patnas of the Ceylon hills; the full-grown larvae of these vary in size from ¼ inch to 3 inches in length. Some species feed on dead organic matter, some live on organic matter and occasionally attack living plant roots, and one or two habitually feed on living plant roots, particularly of grasses.

Damage by white grubs to young tea plants has been noted from the earliest days of tea planting, especially in the 1880's when vast areas of the hill patnas were being planted up. Occasional serious attacks have been recorded over the years, and vaguely attributed to an *Anomala* sp. Following a few severe local attacks on clonal new clearings in 1959-1962. investigations were carried out on the species occurring, their biology and control. These studies showed that instances of severe damage to the roots of young tea were caused very largely by only one species, *Holotrichia disparilis* Arrow. Several other species are very common beetles and their larvae often occur in numbers in tea fields, but they feed on dead organic matter and do not injure the living roots of tea. Identification of the species occurring is therefore important; these belong chiefly to two families, the Melolonthinae and the Rutelinae. Common melolonthine species are *H. disparilis*, *Microtrichia costata* Walker, and *Leucopholis pinguis* Burmeister. The ruteline species include *Anomala walkeri* Arrow, *Anomala dussumeri* Blanchard, and *Mimela mundissima* Walker; these are not associated with damage to tea roots. *Anomala superflua* Arrow has been noted on low country estates and may occasionally damage tea roots; it does attack young teak and other trees in forest nurseries.

Damage by white grubs in new clearings naturally causes concern, since it may endanger the replanting programme. In point of fact, however, instances of severe damage have been very few. Failures due to deep planting and subsequent collar rot have often been wrongly attributed to white grubs—although these grubs may in fact feed secondarily on the rotting bark of the collar (see below).

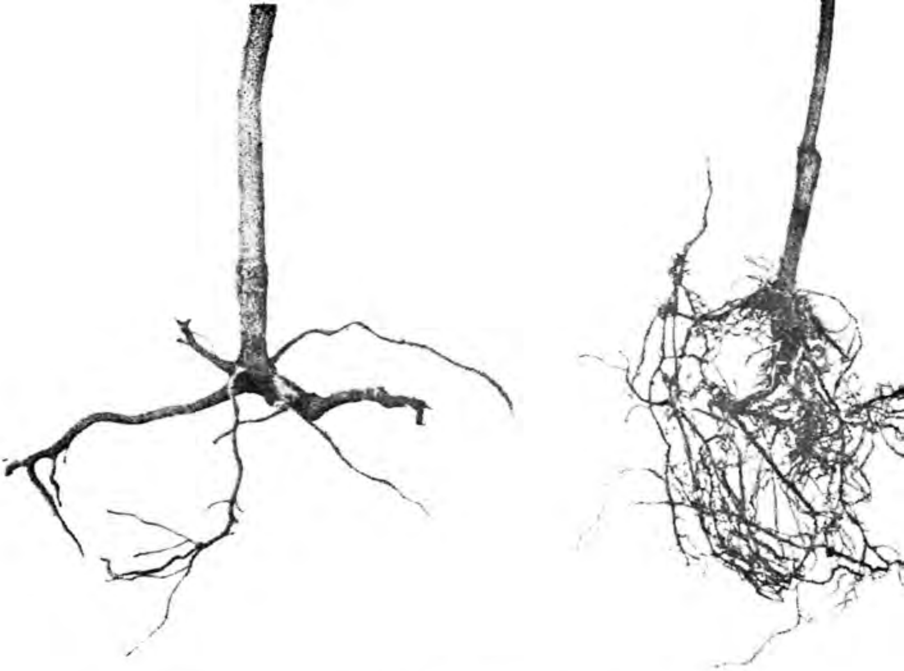


FIGURE 27.—Damage by white grub (*Holotrichia disparilis*). Left—root system of young tea plant with the smaller roots bitten off by white grubs. Right—root system of young plant largely undamaged.

FIGURE 28.—Young tea plants showing effects of planting too deeply. Collar rot has set in and the dead or moribund bark has been cleaned up by white grubs (*Microtrichia sp.*). The root system has not been damaged.

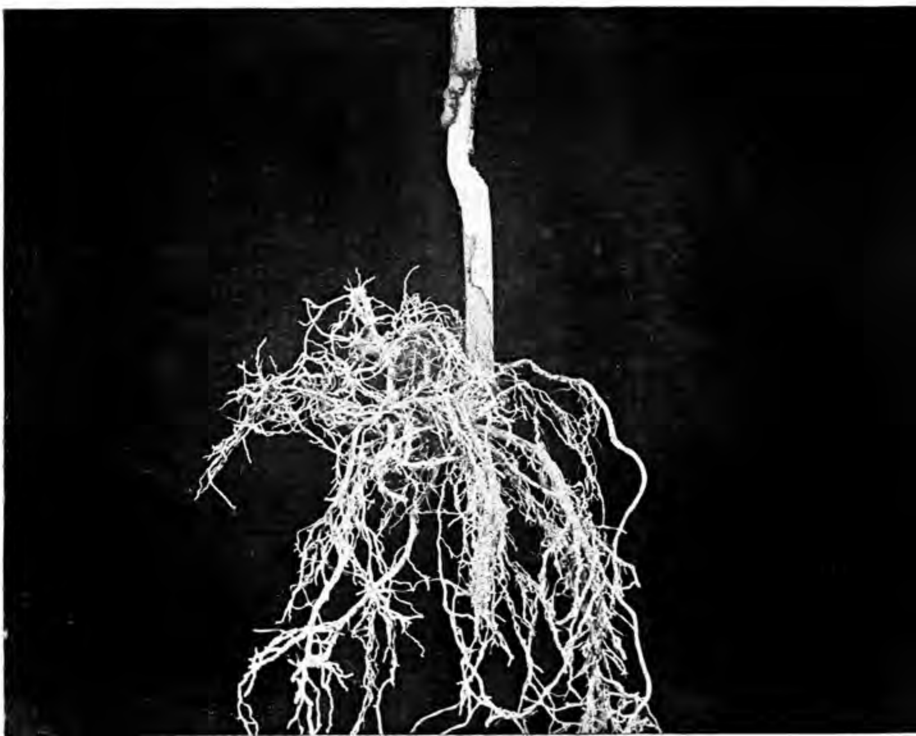


FIGURE 29.—White grub—full-grown larva of *Holotrichia disparilis* (Natural size 1½ inches long when extended).

FIGURE 30—Newly-formed pupa of *H. disparilis* on soil.

FIGURE 31.—Adult chafer beetle. *H. disparilis*.

7.2. HOLOTRICHIA DISPARILIS

This species occurs in up-country districts above about 3,000 feet and is more commonly noted above 4,000 feet, particularly in Kandapola, Maturata, Hewaheta, Udapussellawa and Dimbula.

Guatemala and Mana grass areas are undoubtedly attractive for white grubs; *Holotrichia* is commonly found there but often as a small minority among several species. It is also common, in lawns, patnas and in mature tea fields. Presumably it may feed on the tender roots of mature tea but the damage appears to be insignificant.

There is one main generation per year. The adults (Figure 31) are typical chafer beetles, mostly brown in colour and ¾ inch long. The peak adult emergence period occurs from March to May, when the adults fly nocturnally and are attracted in numbers to lights, along with other chafer species. Smaller numbers of adults are, however, found in the later months of the year, and there would appear to be a less numerous overlapping generation. The adults feed on the foliage of trees including *Acacia*, *Albizia* and dadap but rarely cause severe damage. By day they rest in leaf litter and in the surface soil.

The eggs are laid in the soil. They are soft, ellipsoid, off-white and about 1 mm. on the longest axis; they may be confused by planters with the much larger earthworm cocoons common in some tea soils. Newly-hatched larvae appear in June-July. There appear to be four larval instars in *H. disparilis* (usually in chafer larvae there are three) which are similar in structure and form and increase in size with each successive moult. The larvae feed on plant roots and organic matter in the soil. They are mostly found in the top six inches of soil except when soil conditions are very dry, when they move deeper. They reach maturity in November to December and pupate in the soil in December and January. Before pupation the larva becomes an opaque off-white or yellowish colour, ceases to feed, and the body is less strongly curved. It hollows out an earthen cell, generally found several inches below ground, and pupates. The pupa (Figure 30) is at first soft and yellow-brown in colour with the primordia of the mouthparts, legs and wings 'free' and not enclosed in a pupal case as in Lepidoptera. It hardens and becomes darker in colour. The adults emerge mostly from March onwards.

7.3. RECOGNITION

Grubs—There are many species of white grubs which occur in tea soils; most of them are not injurious to tea. The grubs of *Holotrichia* are about 1½ in. long when full-grown; a characteristic of the species is the extrusion of black vomit from the mouth when handled. If this occurs, the species is probably *Holotrichia*, but it is best to send specimens to the Institute for identification. If they are sent with soil in a box, grubs usually die and disintegrate overnight. Unless they can be delivered the same day, it is best to 'pickle' them in a small bottle of surgical spirit (from a dispensary), or of methylated spirit, and send them in this.

A structural feature which provides a means of identification of the species is the 'raster', an arrangement of spines and hairs on the ventral side of the last abdominal segment. This is characteristic of the species and the rasters of six white grubs common in tea soils are shown in Figure 32. Examination requires a 10 x hand lens. In *H. disparilis* there is a close double row of heavy spines (palidia) in the ventral mid-line, which to the naked eye looks like a slit.

Damage—This is usually serious only in first-year new clearings and in nurseries. It is noticed that some plants are yellowing, defoliating, or dying back, and investigation shows that the roots have been chewed off (Figure 27) . Often the grubs have moved on to other plants. *Holotrichia* will often chew the roots off completely, leaving a callused stump from which the plant attempts to put out new roots. 'Ring-barking' of the stem at soil level can also occur, but commonly this has been confused with 'collar-rot' due to deep planting, fungus attacks and other causes. Where 'collar-rot' occurs, white grubs may feed on the dead and moribund bark of the collar, bringing about a secondary effect of ring-barking (Figure 28). This type of secondary damage is not associated with *H. disparilis* but with *Microtrichia* spp. Damage by *H. disparilis* occurs chiefly from August to December in both the N. E. and S. W. monsoon zones, but the effects of root damage will often become more pronounced during dry weather spells from January to March. This may give the impression that the damage is being done then when in fact the grubs have pupated and ceased to feed.

Fortunately there have been few instances of serious damage, although the grubs are very common and widely distributed. In new clearings, the first year after planting is the danger period; from the second year on, plants are usually able to outgrow the root damage caused. Certain damage to second-year and older plants has been reported very rarely and this appears to be due to other species of white grubs, not yet determined.

7.4. CULTURAL FACTORS AND THE INCIDENCE OF DAMAGE

For reasons which are not understood, dense populations of *Holotrichia* grubs, say of 1 or 2 grubs per sq. foot of soil surface, sometimes cause severe plant losses (in the worst case 40-50%) and sometimes very little at all. It would seem likely that this is

Plate 17. Small Gelatine Grub, *Narosa conspersa* Wlk., larvae and cocoons.

Plate 18. Large Gelatine Grub, *Belippa laleana* Moore.

Plate 19. Early stage of severe attack by Fringed Nettle Grub.

Plate 20. 'Red Slug', larvae of *Eterusia aedea cingala* Moore.

connected with the amount of other available organic matter in the particular soil; the species is by no means an obligate feeder on live roots.

There is a close association between soil organic matter and the occurrence of white grubs. In a given field, the grubs will be found in the areas where the soil has a high organic matter content, and very few where the soil is more sandy and gravelly. The addition of natural manure to the planting hole, or of tea fluff to nursery beds, is attractive to white grubs.

There is no clear cause-and-effect relationship between rehabilitation under Guatemala and the subsequent occurrence of *Holotrichia* grubs damaging the young tea. It is usually the generation of grubs developing after planting-out that does the damage; the eggs are laid by chafers that can fly considerable distances and may come in from local patna, etc.

In so far as rehabilitation improves the organic matter content of soils, it may render them more attractive to white grubs, but severe attacks have been noted in new clearings which were not rehabilitated.

Similarly, although grubs are often abundant close to the surface under grass thatch, severe attacks have occurred in unthatched new clearings. It is not likely that the incidence can be reduced by not thatching. The conditions under thatch, moist and rich in organic matter near the surface, are clearly attractive to grubs, but later in the season more grubs are found under the tea plants themselves.

The season of planting does not appear to offer a means of avoiding damage. One would expect that the larger the plant, and the better established, the better it would withstand attack when it occurs. This is probably so, but at one site (in Kandapola) where large plants in baskets were planted out in February, damage later in the year was, nevertheless, very severe.

7.5. CONTROL MEASURES

The grubs of *H. disparilis* have proved abnormally resistant to chemical control. In field tria's, all the insecticides which commonly provide effective control of white grubs elsewhere in the world have been tested e.g. aldrin, dieldrin, Telodrin, B.H.C., DDT, chlordane, and several others. These have been tried by various methods of application including soil drenches and soil injection, and at very high dosages, but treatment rarely gave more than 50-60% control of the older grubs, which is not economically useful if severe root damage is occurring. Of these materials, B.H.C. was the most promising, and in one trial it gave an 80% reduction in white grub numbers when applied at a high dosage (30 lbs. 'Gammexane'

36% D. P. per acre=7.5 lb. gamma isomer of B. H. C.) and worked into the soil with mammoty forks.

The young grubs are likely to be more susceptible and prophylactic soil treatment before planting may afford more efficient control. It has been found that 'Shell D-D' soil fumigant at the dosage used for control of Meadow Nematode (*Pratylenchus loosi*) will provide a high percentage kill of white grubs. However, this is expensive and, since the incidence of white grub damage is so occasional, it is not a practical proposition as a routine treatment. In the present state of our knowledge, planters should seek advice from the Institute on specific occurrences of white grubs.

Where the plant root systems are still small, it is possible to resort to digging out the grubs between the rows and collecting by hand. It is of course impossible to remove the grubs from under the plants, and excessive disturbance to the plant roots *must* be avoided; experience suggests that 80-90% of the grubs can be removed in this way, which is useful.

The soil around the plants should be sufficiently but not excessively firmed down after planting; the effects of root damage are far worse in 'loose' soil.

In nurseries, although damage has been caused very occasionally to plants in polythene bags (and the grubs can chew through thin polythene sheet), the use of the latter largely avoids the damage that is common in nursery beds.

Control of other species.—There is the possibility that certain of the other species can cause damage to tea. These species may be perfectly well controlled by aldrin, B.H.C. etc. but we do not know for certain. In these instances, please consult the Institute for specific advice.

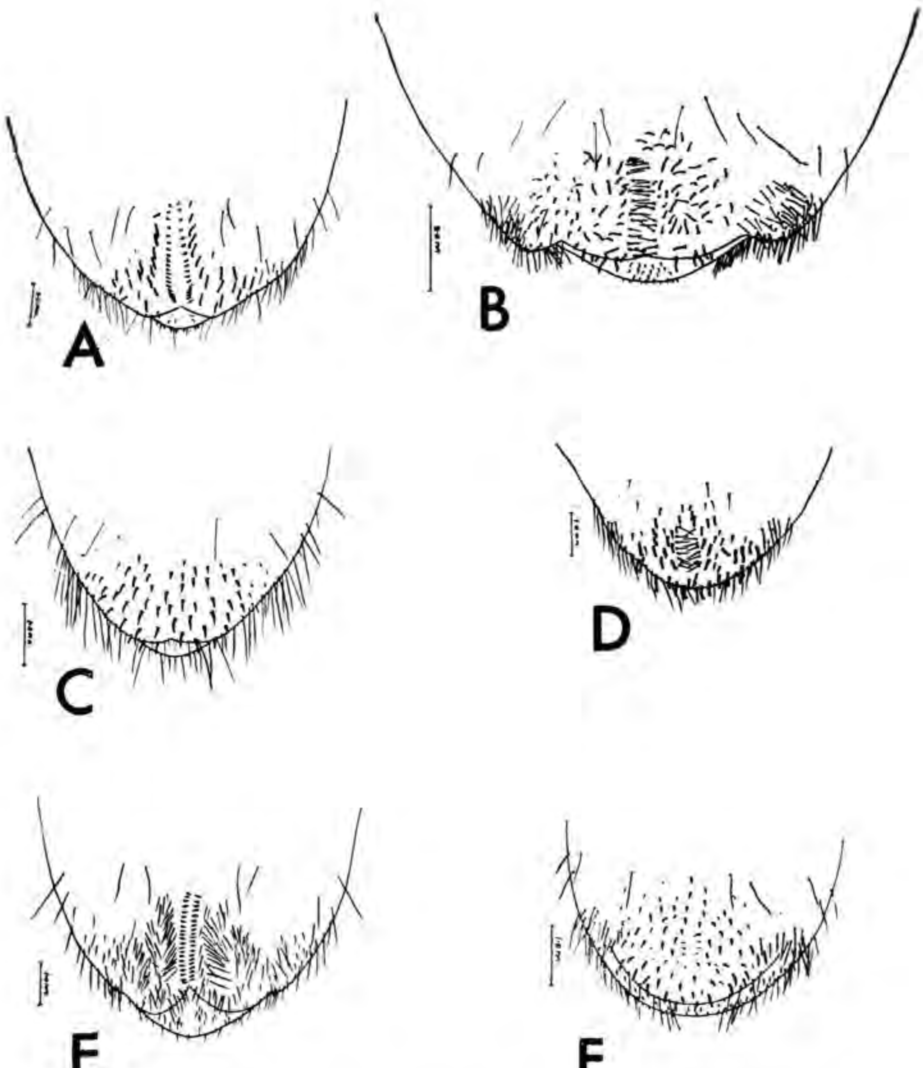


FIGURE 32.—'Rasters' of six species of white grubs (i.e., setation of the ventral surface of the last abdominal segment);—(A) *H. disparilis*; (B) *Leucopholis pinguis*; (C) *Microtrichia costata*; (D) *Mimela mundissima*; (E) *Anomala superflua*; (F) *Anomala walkeri*. (Drawings by E. F. W. Fernando).

FIGURE 33.—Vertical section of a tea bush hollowed out by *Neotermes militaris*.

FIGURE 34.—Vertical section of a tea bush showing small galleries made by *Glyptotermes dilatatus* in wood above soil level.

CHAPTER 8

TERMITES

Termites are occasional pests on tea estates and may be considered in three main groups according to the nature of the damage they cause. The species in Ceylon have recently been reviewed by Ranaweera (1962).

1. Firstly, there are live-wood termites, directly injurious to tea and shade trees; these form nests within the live-wood of healthy plants and are regarded as primary pests of tea.

2. Secondly, there are scavenging termites indirectly injurious to plants. Nests are formed in the soil outside the plants, in mounds or underground, and the termites come out to feed upon dead and rotton wood, diseased bark, dead snags, tree stumps, decaying roots and like material. These termites are essentially secondary pests of tea.

3., Thirdly there are termites which attack structural wood-work in bungalows and tea factories.

8.1. BIOLOGY

Termites are often known as 'white ants', but they belong to the relatively primitive order Isoptera not to the highly developed order Hymenoptera of ants, bees and wasps. The similarity of social organisation of the two orders has been responsible for this misnomer, but in structure and development the termites differ greatly from the true ants.

The size and composition of the termite colony varies greatly. In the highly organised colonies of the family Termitidae, many of which build the well-known termite mounds, the numbers in one colony may run to hundreds of thousands, with several well-defined castes. In the more primitive Kalotermitidae, or dry-wood termites, the colony may never be larger than a few hundred individuals.

Generally, a colony is started by a winged pair. The winged forms emerge in large numbers from the parent nest at certain seasons of the year, usually after the commencement of the rainy season. Those few which escape the many birds, reptiles and other predators which feed on them come together in pairs, shed their wings, and find a suitable site to found new colonies in the soil or in cracks of dead branches or in structural timber, according to the habit of the species. After mating, the female of the pair starts to lay eggs which the parents look after until the nymphs develop. In a typical termite colony, the main types or castes met with are workers, soldiers and reproductive forms.

At first, all the larvae develop as workers which are blind and apterous (wingless), with whitish soft bodies but with efficient jaws, since it is their function to collect food, feed the other castes and construct the dwelling. The Kalotermitidae have no distinct worker caste; the work of the colony is done by nymphs whose development to the winged adult stage is controlled according to the needs of the community. In this family the parent queen undergoes very little or sometimes no increase in size. In the Termitidae, the parent queen develops an enormously distended abdomen to accommodate her massive ovaries so that she has the appearance of a large white grub.

As the colony develops, some of the nymphs develop into soldiers, which are also wingless but may easily be recognised by their larger chitinised heads and powerful jaws. Their main function is to defend the colony against invasion by enemies. Though represented by both sexes, they are sterile. The shape of the head and jaws of the soldier caste is an important diagnostic character for identification of the species.

Ultimately, when the colony is well-established, some larvae develop with wing pads on the thorax. These are the nymphs which will become winged termites, and at certain times of the year, prior to the swarming season, large numbers of the adult winged reproductive castes may be found in the nest. There may also be 'supplementary reproductives' or neotenic forms present, which are sexually mature but unable to fly out. They are light brown in colour, paler than the winged reproductive forms, and may be either without wings or possess short wings. It is one of the characteristics of the termite colony that should either parent be lost or lose its powers, the development of some nymphs as supplementary reproductives is hastened, so that they may take over. The females of this form do not become greatly enlarged and each lays fewer eggs than the old queen but the combined total may be much greater. They may also be found in subsidiary colonies which have developed from sections of the original colony by accidental separation.

Termites feed on sound or decaying wood and on other plant materials such as humus, grass, fungi, etc. This is practised by the workers of all families that possess them, by the young reproductive forms of the Kalotermitidae and the older nymphal stages of most species. Other castes, including the soldiers, many reproductive forms, and young stages, are fed by the workers by regurgitation

Plate 21. Red Borer, larva of *Zeuzera coffeae* Nietn., within gallery in split tea stem (full-grown larva is two inches long).

Plate 22. Attack by live-wood termites, *Neotermes greeni* (Desn.) in a split trunk of *Grevillea robusta*.

Plate 23. 'Looper', larva of *Buzura suppressaria* (Gn.) on tea stem (full-grown larva is over two inches long).

Plate 24. Green bug, *Coccus viridis* (Green), on tea shoot.

of half-digested food or extrusion of it from the rectal pouch. Many species possess in their intestines a rich fauna of symbiotic Protozoa which can digest the cellulose in wood.

Termites play an important role in the breakdown of dead woody plant materials and the return of nutrients to the soil. The role of subterranean termites has also been compared to that of earthworms, in that by means of their underground activities they keep the soil in constant circulation, rendering it permeable to air and moisture. They are by no means, therefore, solely injurious to the agriculture and buildings of man.

8.2. TERMITES DIRECTLY INJURIOUS TO LIVING PLANTS

Family Kalotermitidae (Dry-wood termites) The species of this rather primitive termite family unlike those of the highly specialised families Termitidae and Rhinotermitidae, do not nest in the soil; nor do they travel through soil or under covered runways to reach their food supply outside the nest. They make a series of galleries inside living or dead woody plants, or in logs or structural timber, without constructing a separate nest.

Of the genera recorded in Ceylon, *Neotermes* and *Glyptotermes* damage tea bushes and shade trees and *Cryptotermes* damages structural timber on tea estates.

Neotermes militaris Desneux (=*Calotermes militaris* Desn.).—First noted by Green (1890), this species is the most damaging live-wood termite of tea, and occurs mostly at elevations between 3,500 and 4,500 feet, particularly in the Maskeliya district; hence, it is commonly known as the 'Up-country Tea Termite'. It has, however, occasionally been recorded attacking tea and *Grevillea robusta* at somewhat lower elevations. The wide galleries made in the heart-wood of the main branches of bushes are unmistakable when exposed during pruning. The damage caused to tea was considered very serious at one time and investigations on the biology and control were carried out by the Department of Agriculture from 1925 (Jepson, 1930). However, King (1937a) and later Austin (1958) produced clear-cut evidence that the damage had been greatly over-estimated.

The occurrence of *militaris* in tea is thought to have originated when jungle was cleared for planting and infested tree stumps were left in the tea fields. Green (1907) considered that the spread of *militaris* occurred from bush to bush through roots and this view was later supported by the evidence of King. Attacked bushes occur in groups, averaging about ten in a group but sometimes many more. In the many hundreds of tea bushes examined, no entrance holes were found in branches or main stems above ground; although in shade trees the entrance point has sometimes been traced to a weak spot in a branch or the trunk. Colonies in tea bushes appear always to originate in a root and the termites then extend their galleries upwards into the main root and stem and into other roots and branches. Only the heartwood is consumed; the sapwood is untouched and carries on the functions of the plant. Thus, attack passes unnoticed until wide galleries are made in the branches and exposed at pruning. The galleries contain a lot of termite faecal matter which is used to block the galleries when they are exposed. The bushes show no external signs of injury until a very late stage of the attack, which usually continues until the heartwood is almost completely destroyed and the bush is just a hollow shell. Sometimes, for unknown reasons, the termites abandon a bush only partly excavated. The development of colonies is extremely slow, however, and takes many years.

A colony of *N. militaris* may contain 3000 to 5000 individuals, a relatively small number for termites. The queen is brown in colour and only slightly larger than the other castes; she moves freely inside the colony and egg-laying is not confined to any particular part of the galleries. In well-established colonies there are usually a fair number of 'supplementary reproductive' forms, both wingless and short-winged forms. The fully-winged reproductive forms are very rarely found. It is believed that groups of the termites at times migrate to the roots of adjacent bushes, founding separate colonies with the aid of the supplementary reproductive forms; this would account for the occurrence of attack in groups of adjacent bushes.

Tea appears to be the favourite host plant but attack has also been noted on *Acacia decurrens*, *Albizia falcata*, *Casuarina* sp., *Cedrella toona*, *Crotalaria anagyroides*, *Erythrina lithosperma*, *Eucalyptus* sp., *Grevillea robusta* and *Tephrosia vogelii.*

Control measures—One of the earliest measures adopted for control of *N. militaris* was to pour kerosene, liquid fuel or 'Brunolineum' into the galleries exposed in the branches at pruning time. As noted, however, the galleries are often blocked up with the soil-like faecal matter which prevents such fluids from affecting more than part of the colony, and these measures were not effective.

Jepson (1929) first experimented with the blowing-in of Paris Green, (copper acetoarsenite); the method was to bore a small hole in the main stem of an affected bush and introduce about one-twelfth of an ounce of Paris Green with the aid of a rubber enema, and then to plug the hole with putty or asphaltum. Jepson claimed that the dose was spread through the whole colony by termites eating those which had already succumbed to the poison. However, this method did not work well in practice and the use of Paris Green was hazardous.

Since the faecal matter in the galleries appeared to contain some particles of soil it was thought that the termites must come in contact with the soil at some time or other. Hence, in 1954, the first experiments with organic insecticides involved treatment of the soil around infested bushes with dieldrin and Chlordane.

These soil treatments, however, proved totally ineffective and efforts were then transferred to working out a practical method of forcing insecticide into the galleries.

The method worked out by Austin (1957) is as follows. At pruning time, the branches of bushes showing galleries are cut back in at least two places per bush to make sizeable entrance holes, large enough to insert the spray nozzle of a knapsack sprayer. Application of the insecticide is done on the same day immediately after cutting back, because termites quickly block the holes so formed with faecal matter. Diluted dieldrin (or Chlordane) emulsion at the rate of one or two pints per bush is forced into the galleries at about 70 lb. pressure, using a pressure-retaining knapsack sprayer fitted with a nozzle with the swirl plate removed so as to force a thin jet of liquid down. This usually has the effect of cutting through the termite 'earth' so that the insecticide is forced into the central galleries. Austin reported good results with this method and it has since worked well in practice. It is usually practicable to treat the small percentage of attacked bushes in an affected field. Dieldrin is effective at a concentration of 1 pint 20% E. C. in 25 gallons of water, using one or two pints per bush.

Neotermes greeni Desneux was named after E. E. Green from material collected from Ceylon tea; there appear to be no records from other countries. It has a wide distribution on estates up to 3,500 feet and occurs very occasionally at somewhat higher elevations. With this species, entry into the host plant appears always to be made by a winged adult pair at a weak spot in the trunk or a branch. In the development of the colony, the heartwood is eaten away in a regular honeycomb-like network of galleries which are much narrower than those of *militaris*; the heartwood is never completely hollowed out. Galleries rarely extend below soil level. In the advanced stages of an attack the sapwood and bark are also attacked after killing the plant. The size of the colony is about the same as in *militaris* but the number of supplementary reproductive forms is conspicuously low, there being not usually more than half a dozen per colony. As the galleries are small, it is not possible to force in insecticides as for *N. militaris*. Fortunately, attack on tea is usually confined to a few isolated bushes (sometimes in small groups) and is uncommon. *Grevillea robusta* is a favourite host plant; full-grown trees are sometimes killed and die back from the tops. *Albizia falcata* and *Erythrina lithosperma* also are occasionally attacked.

Glyptotermes dilatatus Bugnion & Popoff (=*Calotermes dilatatus* B. & P.) is the smallest of the three termite species that eat into the heartwood of living bushes. It is widely distributed below 3000 feet and is commonly known as the 'Low-country Tea Termite'. As with *N. greeni*, entry into the host plant is made above ground and the colony is formed in the larger branches and main stem of the bush; the galleries are small like those of *N. greeni* but much less regular in size and pattern. Colonies are often quite small and two or more independent colonies may exist in the same bush. In the advanced stages of attack, this species may attack the sapwood and bark causing the death of large branches or the whole bush. *G. dilatatus* mostly attacks debilitated bushes, those showing wood-rot and die-back and recovering poorly after pruning, and often those with *Ustulina* root disease. Thus it can be regarded mainly as a secondary pest which accelerates the death of unhealthy bushes. Attacked bushes are usually scattered throughout a field and not in distinct groups. This termite also attacks *Albizia* spp, *Erythrina lithosperma* and *Grevillea robusta.* As with *N. greeni* the galleries made by *G. dilatatus* are so small that it is not possible to force in insecticides. When colonies are confined to branches, the affected portions can be removed and burned. However, replacement of the affected bushes is often called for.

Family Rhinotermitidae (Moist-wood termites)— Members of this family have a more highly developed social organisation than the Kalotermitidae, with thousands of individuals in a colony, consisting of all the three normal castes—workers, soldiers and reproductive forms. They nest in the soil or in old tree roots well below ground and are not known to build mounds in Ceylon, although some species do so in other countries.

Coptotermes formosanus Shiraki.—Ahamed (1953) has recorded this termite as a recent introduction to Ceylon. It is one of the most destructive termites of the Orient and, unlike other subterranean termites, can live without ground connection when there is a suitably located constant water supply above ground.

Coptotermes ceylonicus Holmgren.—This is principally a scavenging termite which also attacks buildings in Ceylon. It is included in the group of termites directly injurious to living plants because it attacks healthy tea bushes rather severely at times, eating away healthy roots and branches. It is generally a low-country termite working below an altitude of 3,000 feet but has occasionally been found at elevations up to 4,500 ft. It has also been recorded in South India as a pest of living tea bushes (Ananda Rau, 1939). When disturbed, the soldier characteristically ejects a milky-white fluid from a gland in the head.

8.3. SCAVENGING TERMITES

The scavenging termites on tea estates belong mostly to the family Termitidae, which form their highly specialized colonies in the ground, or in mounds above ground, or in 'carton nests' in hollow tree trunks. The workers forage for dead and decaying wood and other food outside the nest, moving along tunnels in the surface soil and under cover of the earthen runways they construct above ground. The dead and moribund wood to which they are attracted on tea bushes is associated with sun-scorch, die-back after pruning, wood-rot, branch canker and mechanical damage; these weaknesses may be brought about in various ways but are involved particularly in the cycle of secondary effects of Shot-hole Borer attack (see section 2.3). Scavenging termites are most common at elevations below 3500 feet and particularly in fields with a long history of severe borer attack.

Essentially they are secondary pests as they do not normally attack healthy live wood, but they do sometimes greatly aggravate other effects. They usually encase dead and moribund portions of the bushes with soil in order to protect themselves as they feed underneath, and this aggravates wood-rot. They clean up the dead wood but in so doing tend to expose fresh surfaces of live wood on which the callusing tissue is attacked before a healthy callus can form. The dead wood on the upper surfaces of branches affected by sun-scorch is eaten away and the furrows so formed are filled up with earth, thus encouraging further wood-rot in wet weather and resulting in time in the formation of very deep furrows in the branches. Similarly where wood-rot occurs inside the stems around borer galleries that do not heal, the termites eat away the rotten wood and bring in soil and this again enhances wood-rot and eventually results in wide galleries inside the stems. (Fig. 7).

The activities of scavenging termites can also sometimes be of consequence in new clearings, aggravating the effects of collar-rot caused by deep planting, of damage by white grubs, and of unhealthy root systems caused by drought or waterlogging. In dry seasons they are sometimes forced to obtain moisture from succulent rootlets, causing serious damage or even killing young plants.

The commoner species of Termitidae involved are as follows. *Hospitalitermes monoceros* Koenig, commonly known as the Black Termite of Ceylon, makes carton nests in the hollows of tree trunks or, sometimes, attached to branches. They have the unusual habit of foraging over open ground, unprotected by earthen galleries, particularly at night. *Hypotermes obscuriceps* Wasmann and *Odontotermes redemanni* Wasmann are two common species of mound-building termites in the low and mid-country. Termite species which form their nests in the soil without building mounds are *Nasutitermes ceylonicus* Holmgren, *Odontotermes ceylonicus* Wasmann, *O. horni* Wasmann, and *Microcerotermes greeni* Holmgren. Of these, *O. horni*, although predominantly a scavenging species, has been noted on several occasions attacking the tender roots of young plants in nurseries and new clearings. A species of *Microcerotermes* has been recorded in N. India (Das, 1958) attacking the live wood of tea, but there is no evidence of this genus attacking live wood in Ceylon.

Control measures.—Scavenging termites cause negligible trouble on bushes maintained in a healthy, vigorous condition, free of wood-rot, die back, and sun-scorched branches, etc.

Mound-building species can be controlled, by locating the mounds, breaking them open, and forcing 0.1% aldrin or dieldrin emulsion into the inner galleries. The nests of subterranean species are difficult to locate but, if found, insecticidal treatment can be applied in the following way. The soil around the base of each bush for about one foot radius is sprayed thoroughly with 0.2% aldrin emulsion (4 pints of 20% E. C. in 50 gallons of water) using two or more gallons of spray for every 100 bushes. This limited treatment of the soil with aldrin should not cause a build-up of Tea Tortrix or other pests.

This type of treatment may also be necessary where *Odontotermes horni* or other termites cause damage to young plants in new clearings. Where attack occurs in nursery beds, the soil of the beds can be sprayed, employing 1 fl. oz. of 20% aldrin E. C. in 2-3 gallons of water applied on 30 square yards of bed; this treatment is also effective as a preventative soil treatment before planting the beds.

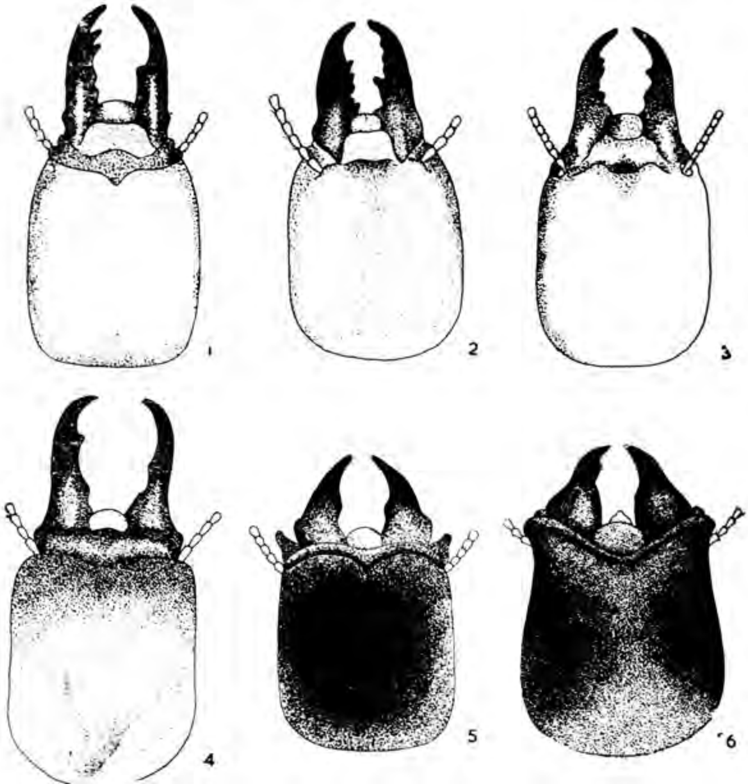
8.4. TERMITES ATTACKING STRUCTURAL TIMBER

Termite damage to woodwork in factories and bungalows is quite common on estates up to 3000 feet in elevation, and occasionally at higher elevations. Two types of attack are involved.

The first type is by certain dry-wood termites (Kalotermitidae) which are able to thrive in dry wood without any communication with the ground for moisture. The colony is started by an adult reproductive pair which, after dispersal and mating, shed their wings and secrete themselves in a crevice close to wood-work; from there they slowly eat their way into the woodwork. Colonies are small and the development of the damage is slow compared to that caused by subterranean termites. Species of the genus *Cryptotermes* are mainly involved on Ceylon estates. *C. dudleyi* Banks is the commonest and most destructive; it is the largest of the dry-wood

FIGURE 35.—The effect of scavenging termites on a tea bush that has suffered from sun-scorch and wood-rot. Note the deep furrows in the main branches where the termites have cleaned up dead wood.

FIGURE 36.—Heads of soldier termites (not to scale). 1. *Neotermes militaris*; 2. *Neotermes greeni*; 3. *Glyptotermes dilatatus*; 4. *Cryptotermes dudleyi*; 5. *Cryptotermes ceylonicus sp.* n.; 6. *Cryptotermes perforans*. (Drawings by D. J. W. Ranaweera (Ranaweera, 1962)).



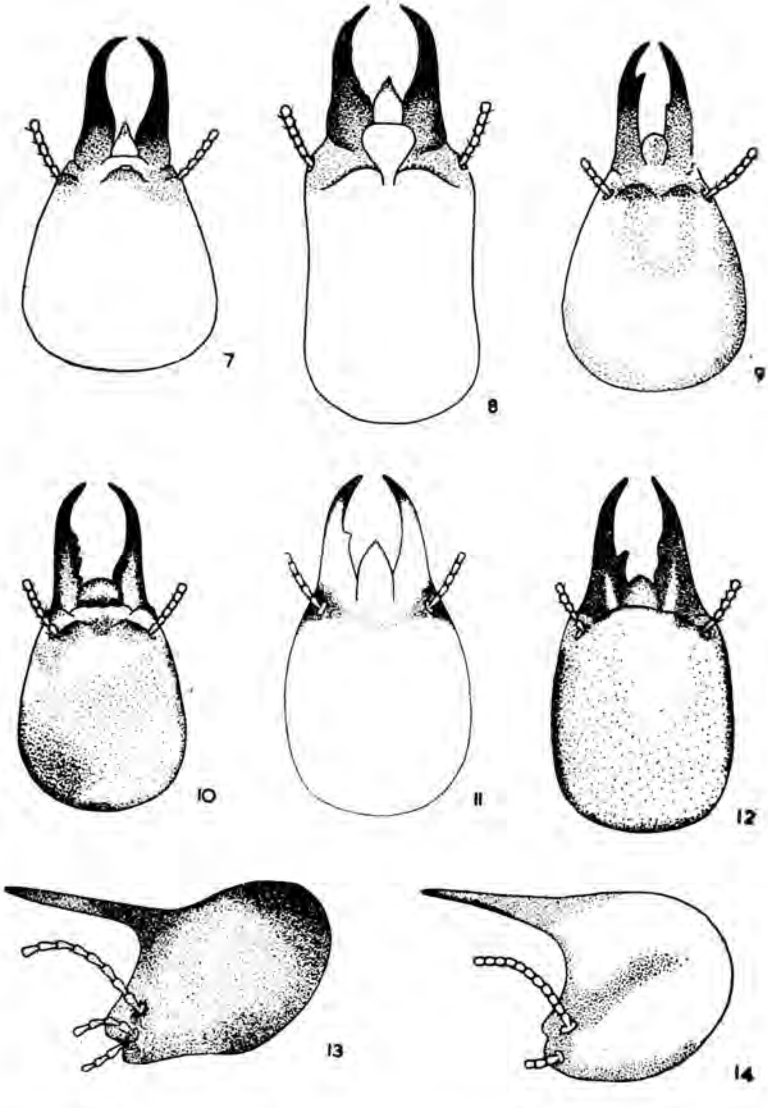


FIGURE 37.—Heads of soldier termites (not to scale): 7. *Coptotermes ceylonicus*; 8. *Heterotermes ceylonicus*; 9. *Odontotermes redemanni*; 10. *Hyptotermes obscuriceps*; 11. *Odontotermes ceylonicus*; 12. *Odontotermes horni*; 13. *Hospitalitermes monoceros*; 14. *Nasutitermes ceylonicus*. (Drawings by D. J. W. Ranaweera (Ranaweera, 1962)).

termites and has larger colonies than the other species. *C. perforans* Kemner and *C. ceylonicus* sp. n. (Pinto, 1941) have also been recorded.

The other type of damage is caused by subterranean and mound-building termites which invade buildings to feed on structural timber whilst maintaining uninterrupted connection with the ground to obtain sufficient moisture. The nest may be under the building or as much as 100 yards away. These termites gain access to the building through cracks in the foundation or walls; they can penetrate poor grades of mortar and plaster, and build their earthen galleries over solid barriers to reach wooden window frames, doors, floors and roof timbers. The attack generally proceeds much faster than that caused by dry-wood termites. *Coptotermes ceylonicus* (Rhinotermitidae), mentioned earlier, is probably the commonest subterranean species damaging structural timber; it has been noted that the main nest may be far away from the building they invade. *Hypotermes obscuriceps*, *Nasutitermes ceylonicus*, *Odontotermes redemanni*, *O. horni*, and *O. ceylonicus* are species of the Termitidae commonly involved.

The preventative and curative measures for termite attack in buildings have been dealt with by several authors (including Jepson, 1929; Harris, 1961) and the detailed treatment necessary is outside the scope of this book. The preventative measures include treatment of the building site with persistent insecticides, termite proof construction of the building, and the use of termite-resistant timber or the impregnation of all structural timber with preservatives. Certain Colombo firms offer a contract service to eliminate termites in buildings. A special problem in tea factories is that the floors and tat frames of withering lofts must not be treated with any preservative that is liable to cause taint or insectcide residues in made tea.

8.5. IDENTIFICATION KEY TO SOLDIER TERMITES

(This is to be used in conjunction with the illustrations of the heads of soldier termites. 'Head 1', 'Head 2', etc. refer to the numbering of the fourteen species illustrated in Figures 36 and 37. Examination requires a low-power microscope.)

1. (a) Head drawn out in front in a nose-like projection......2
   (b) Head not so drawn out; mandibles visible, pincer-like and large..3
2. (a) Top of head making an obtuse angle with the 'nose' in profile. Head constricted behind the antennae. Segments of the antennae long, cylindrical, dark brown. Mandibles clearly visible under a lens..*Hospitalitermes* (Head purple-brown......*Hospitalitermes monoceros* (Head 13))

(b) Top of head and 'nose' forming a straight line in profile. Head not constricted behind the antennae; segments of the antennae rounded, yellow. Rudimentary mandibles, not visible...... *Nasuititermes* (Head yellow-brown..... *Nasutitermes ceylonicus* (Head 14))

3. (a) Pronotum (neck-shield) as broad or broader than the head, more or less rectangular. Termites living in live wood of tea or shade trees, or dry-wood termites in buildings.......................................4
   (b) Pronotum not as broad as head, and not rectangular....9

4. (a) Head cylindrical, hollowed out in front, with a rough surface, dark brown to black...... *Cryptotermes*......5
   (b) Head more or less flattened, ovoid or rectangular, yellow to dark brown.....................................7

5. (a) Mandibles short and stout, one-third of the length of the head; head black...............................6
   (b) Head brown at base, black towards the mandibles. Mandibles black, about half the length of head. Left mandible with one tooth not more than half way from the tip. Right mandible with one small tooth...... *Cryptotermes dudleyi* (Head 4)

6. (a) Mandibles with no teeth...... *Cryptotermes ceylonicus* sp. n. (Head 5)
   (b) Left mandible with one tooth about one-fourth of the way from the tip; right mandible not toothed...... *Cryptotermes perforans* (Head 6)

7. (a) Antennae with 15-17 segments; large species 3/8th of an inch long or more...... *Neotermes*..............8
   (b) Antennae with 11-12 segments; small species about one quarter of an inch long...... *Glyptotermes* (Head slightly raised between the antennae to form two points. Mandibles brownish-black. Left mandible unevenly toothed. Right mandible with one tooth not more than half-way from the tip and serrated below...... *Glyptotermes dilatatus* (Head 3))

8. (a) Mandibles straight at base, black only towards the tip. Left mandible with two prominent teeth, the first not more than one-third of the way from the tip, and with two serrations below the second tooth. Right mandible with one tooth half-way from the tip and the rest of the margin smooth...... *Neotermes militaris* (Head 1)

(b) Mandibles black, broad at base. Left mandible with two teeth, the first tooth not less than one-third of the way from the tip, and with three serrations below the second tooth. Right mandible with a single tooth half-way from the tip and the margin above the tooth with small serrations...... *Neotermes greeni* (Head 2)

9. (a) Opening of the frontal gland large and conspicuous. Labrum (upper lip) pointed, Pronotum oval.......... *Coptotermes* (In *Coptotermes ceylonicus* the mandibles are brown, slender and sickle-shaped, without teeth ......(Head 7))

(b) Opening of frontal gland small, pronotum not oval 10

10. (a) Left mandible with three teeth on inner margin......11

(b) Left mandible with a single tooth..................12

11. (a) Head creamy-yellow, rectangular in shape; the three teeth on the left mandible are very small and near the base of the inner margin...... *Heterotermes ceylonicus* (Head 8)

(b) Head light-brown, oval; the three teeth on the left mandible are prominent and near the middle of the inner margin...... *Hypotermes obscuriceps* (Head 10)

12. (a) Head brown, near rectangular in shape; mandibles brownish black. Left mandible with a single prominent tooth two-thirds of the way from the tip. Right mandible not toothed...... *Odontotermes horni* (Head 12)

(b) Head brown, broad behind, narrowing sharply towards the front. Mandibles brown. Left mandible with a single tooth less than one-third of the way from the tip. Right mandible with a small tooth half-way from the tip .... *Odontotermes redemanni* (Head 9)

(c) Head light brown, rectangular in shape. Mandibles brown. Left mandible with a single tooth half-way from the top. Right mandible not toothed...... *Odontotermes ceylonicus* (Head 11)

CHAPTER 9

OTHER PESTS OF TEA

The pests here described are a miscellaneous assembly of those which cannot be placed under the headings of preceding chapters.

9.1. RED BORER (*Zeuzera coffeae* Nietner)

This pest belongs to the family Cossidae (Goat moths and Carpenter moths) of the order Lepidoptera, the larvae of which are pith or wood borers of large size with powerful mandibles for boring. It is a widely distributed species in India and Ceylon with many host plants including tea, coffee, cacao and many forest trees. It is not uncommon in low numbers, which on mature tea result only in the death of the odd branch here and there. It is of significance mainly on young tea where the main stem may be bored; it is commonly reported from new clearings in the mid-country and low-country, sometimes causing alarm, but it is nearly always found that only a very small percentage of the plants are affected.

The boring caterpillar is dark red in colour and 1½ - 2 inches long when full grown (Colour Plate 21). The head is rather small and horny with large mandibles and the first thoracic segment and anal segment carry heavily-sclerotized black shields. The cuticle is tough and carries rows of black warty tubercles on the body.

The eggs are deposited in ropy masses, like strings of minute amber beads, in crevices in the stems. The newly-hatched caterpillars spread out and many are dispersed by wind. Each young caterpillar then bores into a tea stem, at first into smaller shoots, and bores a tunnel in the pith and inner wood. As the larva grows, the gallery is widened and extended into the larger branches and may reach for two feet or more from the point of entry. Holes are made at intervals for air supply and for ejecting the frass (excreta); the presence of the frass, like large pellets of saw-dust, on the ground below, often calls attention to the attack. An affected branch may be completely hollowed out, leaving just a thin shell of bark and wood; typically, the leaves brown and wither but remain attached to it. In young plants the gallery often extends into the main stem, even below ground level, and the plant may die as a result.

The mature larva pupates inside the gallery in a carefully constructed chamber, with the future exit hole marked out as a thin skin of bark not completely severed. The pupa is about 1 inch long, chestnut-brown in colour. The pupa finally wriggles half out of the exit hole and the moth emerges. The moth is large and attractive, a strong flier; the wings are white, speckled with black and steel-blue spots, with a span of up to 1¾ inches.

Development is rather slow and the life cycle may take 4-5 months in the low country or up to a year at higher elevations.

A *Bracon* sp. and a *Microbracon* sp. have been recorded as parasites of the larvae of *Z. coffeae* in Ceylon.

Control—In new clearings, since attacks generally involve only a small percentage of plants, it is practicable to search out the affected plants, looking for withered branches and frass on the ground, then to prune affected branches below the gallery and burn them.

On young plants this may involve cutting the main stem to ground level, and the plant may not recover. If the attack is found soon enough, it may be possible to treat these by finding the frass ejection hole and injecting a squirt of aldrin solution into the hole. Aldrin E. C. should be used at a strength of 1 part in 200 parts of water; a small scent spray with a narrow nozzle is required for injecting the insecticide.

9.2. TEA LEAF MINER (*Melanagromyza theae* de Mejere)

The leaf mine of this tiny dipterous fly (family Agromyzidae) is commonly seen on tea foliage (Figure 40) and though never sufficiently numerous to be considered a pest of mature tea, it is occasionally so on young tea plants in new clearings and nurseries.

The adult is a small, active, winged fly of which the female lays eggs singly on the upper leaf surface, inserting them just below the upper epidermis. Usually not more than two eggs, but occasionally up to five, are laid on one leaf. The larva mines just below the upper epidermis, never on the lower side of the leaf. The mine is seen as a winding white line gradually widening as the tiny maggot-like larva grows. The full grown larva pupates at the end of the mine with breathing tubes exposed. Larval development takes about 11 days and the pupal period is 14-16 days. Tea Leaf Miner is commonly heavily parasitised in the pupal stage, expecially by *Closterocerus insignis* Wtstn. (*Eulophidae*) and less commonly by *Trigonogastra joachimi* Fernando (Pteromalidae).

Chemical control—Where control is required on young plants in the nursery and in new clearings, DDT E.C. can be applied at a strength of 1 pint in 25 gallons water by knapsack sprayers to wet the foliage thoroughly.

9.3. LEAF-EATING WEEVILS

Certain species of leaf-eating weevils (Curculionidae: Order Coleoptera) cause damage occasionally to tea foliage and to dadap, and leave a typical saw-edged appearance of the leaves (figure 38) that cannot be mistaken for the damage caused by any other defoliating pest. *Myllocerus curvicornis* Fabricius is a common species. Light (1928) recorded also the species *Leprosus immunis* Walker and *Leprosus apicatus* Marshall (these species were recorded by Light in the genus *Astycus*, which is pre-occupied). No detailed work has been carried out on these weevils or their life-history.

The eggs are laid in the soil and the larvae, which are white legless grubs, appear to develop principally on decaying plant roots and other organic matter. They pupate in a small earthen cell. The adults are typical weevils (Figure 39) with the head protruding forward in a short snout which bears the mouth-parts and antennae. In *Myllocerus curvicornis* the integument is very dark brown, almost black, but densely clothed in patchy, white pubescence so that they appear ash-coloured to the naked eye; the females are 0.3 inches long, the males about 0.2 inches.

Weevils can be readily controlled by DDT spraying, employing the dosages used for Tortrix and other pests.

9.4. 'SEWING BLIGHT'

The origin of a peculiar type of damage to the foliage called 'sewing blight', noted occasionally in both India and Ceylon, has been established by Das (1963b) at Tocklai. The characteristic symptoms are a series of incisions in several rows along the length of the leaf, giving the appearance of stitches made by a sewing machine (Figure 26). These incisions might be taken to be the lesions around the feeding punctures of a sucking bug similar to *Lygus viridanus* or *Helopeltis* spp., but no bug feeds in such a regular, precise fashion. The incisions are in fact made by a tiny wasp of the genus *Orasema* (Eucharitidae: order Hymenoptera) for oviposition. Das studied the biology of *O. assectator* Kerrich in Assam, and found that *O. initiator* Kerrich was also responsible for this type of damage, but the species present in Ceylon have not been determined.

The life-history is unusual. With *O. assectator*, Das found that the eggs were laid singly in the incisions made on the under-sides of the leaves. The newly-hatched larvae exist as free-living 'planidia' on the leaf surface, whence they are carried by unknown means into ants' nests (of *Pheidole* sp.) in the soil beneath the tea bushes. Within the ants' nest the larvae develop parasitically on the larvae and pupae of the ant; and, curiously, the free mature larvae and pupae of the parasite are cared for and protected by the worker ants, although the newly emerged adults were often prevented from escaping from the nest.

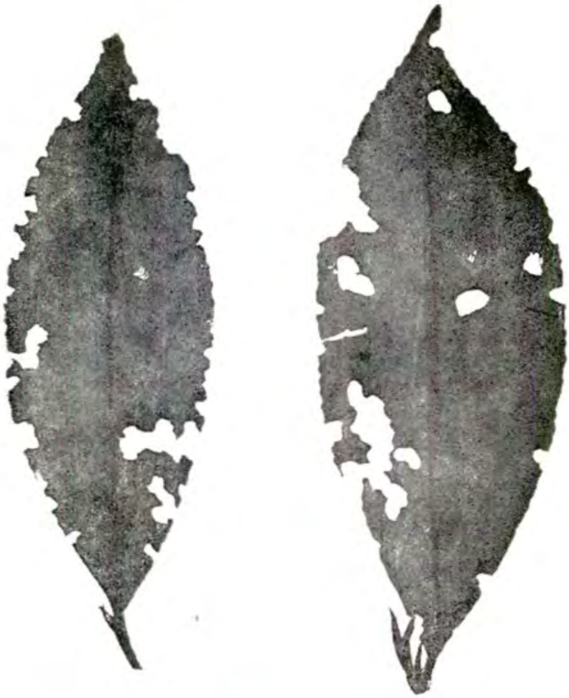


FIGURE 38.—Leaves damaged by weevils (*Myllocerus curvicornis*) showing typical saw-edged appearance.

FIGURE 39.—Leaf-eating weevils (*M. curvicornis*)—left, male, right, female. (Natural size 0.2 and 0.3 inches.)

FIGURE 40.—Tea leaf damaged by Tea Leaf Miner (*Melanagromyza theae*)

FIGURE 41.—Nest of Red Ant (*Oecophylla smaragdina*)

In one instance in Ceylon, clonal plants were affected over about an acre or so of a new clearing; clone Diyagama N was much more affected than other clones. Whether or not there was a clonal preference is uncertain; the occurrence of the parasitic wasp must be related to the presence in the soil of the nests of a suitable ant host. The damage noted was not severe; the leaf tissue around each puncture turns brown, leaving a minute cavity in the middle. The growth of the shoots was definitely checked.

'Sewing blight' has been noted only on very few occasions in Ceylon, affecting very limited areas. Control measures have not been required.

9.5. RED ANT (*Oecophylla smaragdina* Fabricius)

This fairly large species of reddish-brown ant is distributed over most of tropical Africa and Asia, and eastwards as far as New Guinea and Australia. It is a nuisance in tea fields, as in some other perennial tropical crops, because it is very pugnacious and bites severely, and forms its nest from tea foliage in the bushes. The nest (Figure 41) is made by spinning together a number of leaves with silk in an irregular bundle. This is performed in a peculiar way. Worker ants hold the leaves together whilst others carry some of the ant larvae to and fro, and the latter secrete the silk threads by which the leaves are spun together. In addition to the main nest there are usually subsidiary nests containing stored food material. The species is predacious on other insects and is thus partly a beneficial insect, but it also tends scale insects for honeydew, sometimes keeping them within the nest.

The webbed-up leaves and shoots die back, although the injury to the bushes is negligible; the ants are troublesome chiefly because they deter labourers from carrying out plucking and other operations in the tea. In the past, the usual control measure was to burn the nests with a kerosene torch, doing this at night when the ants are in the nests. It is less damaging to spray the nests with aldrin E. C. (at a dilution of 1 in 200 parts of water) which can also be done just after dusk by the light of kerosene torches. Treated bushes should be marked and not plucked for three weeks after spraying, to avoid any aldrin residues in made tea.

9.6. CRICKETS (*Brachytrupes portentotus* (Licht.))

Damage by crickets to very young plants in nurseries and new clearings has been noted only rarely in Ceylon. It is reported to be fairly common in N. India (Das, 1965). The species involved is generally *Brachytrupes portentotus* (Licht.) (=*B.* achatinus (Stoll.)) a large blackish-brown cricket 1¾ to 2 inches long which makes a 'burrow' or tunnel in the ground up to a foot or more deep. The crickets come out of their burrows at night to feed on tender stems and foliage and probably also on decaying plant material. During the day time the cricket stops the entrance to the burrow, often by pulling a leaf or leafy shoot into the mouth of the burrow and pushing up soil from below. Occupied burrows can be recognised because they are 'plugged' in this way and show freshly turned-up soil around the entrance hole. Unoccupied burrows are left open unless accidentally blocked with soil.

There appears to be an annual generation with the breeding season in the later months of the year. Eggs are laid embedded in the soil at the bottom of the burrow; the newly hatched nymphs remain for a short time in the parent burrow and later disperse and make small burrows of their own. Development to the adult stage takes several months. The adult males 'stridulate' after dusk producing a shrill piping sound, usually whilst sitting at the mou h of the burrow. The sound is made by two modified areas of the fore-wings, forming a 'ridge' and a 'file', which are rubbed together and set the wings in vibration. Stridulation is used to attract the female but may often be the spontaneous song of sexually mature males long before mating begins.

With young tea, the crickets bite off tender shoots and even bite through main stems about an inch or so above grouud level, feeding on the felled shoots and often dragging them inside the burrows.

Control—In nurseries it is practical to spray the young plants and the soil of the beds and paths with aldrin, employing 1 fl. oz. of aldrin 20% E. C. in 3 gallons of water on 30 square yards of nursery bed. Where crickets are known to cause trouble it may be desirable to use this as a prophylactic treatment on the prepared beds, spraying the soil surface and working it into the top few inches of soil.

Control in new clearings may be best tackled by searching out and treating the individual burrows which can be recognised as noted above. It is necessary to prod through the soil plugging the entrance hole and pour insecticide down the hole. Aldrin E. C. can be used at a dilution of 1 in 200 parts water (1 pint in 25 gallons of water) using about one-quarter pint per hole. This usually forces the cricket out of the hole and it dies shortly afterwards. Treatment should be carried on until no further burrows can be found.

CHAPTER 10

PESTS OF SHADE TREES AND GREEN MANURE PLANTS

In this chapter a brief account is given of the commoner insect and mite pests of the shade trees interplanted in tea and of the green manure plants grown as cover crops in new clearings or, as with Guatemala grass, for rehabilitation. Many of these pests were described by Hutson (1932a).

10.1. 'DADAP' (ERYTHRINA LITHOSPERMA)

The Spotted Locust, *Aularches miliaris* F. (Acrididae) is an occasional pest of dadap in the low and mid-country which strips the leaves and tender bark. It is a brightly-coloured, gregarious grasshopper which has a wide distribution in S. E. Asia from India to Java, and which feeds on many species of trees and shrubs and on vegetables. It does not feed on tea. The adults are 2 to 2½ inches long, mostly olive-brown in colour and with large wings, the fore-wings greenish-bronze with large white or yellow spots, and the hind wings smoky; dorsally the thorax is heavily dentate. There appears to be an annual generation (Hutson 1932a), with the adults maturing in July to September and laying their eggs in 'pods' of 50-100 in holes in the ground in October to December. The eggs hatch in February to April and the young nymphs or 'hoppers' congregate on low vegetation; if they are found on dadap at this stage they are usually on the lower branches. There are five nymphal instars, similar in form to the adult but wingless.

Infestation on dadap usually occurs by migration of the winged adults from nearby vegetable cultivation, and it is usually sufficient to collect and destroy the adults. Hutson recommended spraying soap solution for the control of the young hoppers.

Two species of hemipterous bugs are occasionally found feeding on the tender shoots of dadap. *Cyclopelta siccifolia* Westw. (Pentatomidae) is a rather large 'shield bug', a little over half an inch long and oval in outline, mostly very dark brown in colour, but lighter brown on the membranous parts of the fore-wings and the abdomen red and black. The nymphs are brown with red markings. Adults and nymphs feed in large groups on the green twigs and branches of dadap and on *Indigofera* spp., sometimes causing the injured portions to wither. The bugs have a strong odour and can eject a liquid that produces a smarting sensation on the skin. This pest can easily be collected by hand if necessary.

Anoplocnemis phasiana F. (Coreidae) is another large sucking bug found on dadap. The colour is light brown; the femora of the hind legs are greatly swollen, especially in the male, and provided on the inner side with a large spine. This species feeds also on cacao and the shoots and young fruits of various leguminous plants.

Pseudococcus lilacinus Cock. (=*crotonis* Green) is a rather large mealy bug which occurs on dadap and on many other plants including cacao. The body is red-brown in colour but entirely covered in the white waxy secretion typical of mealy bugs; length about 3 mm. The species is viviparous. It occurs in clusters on the young shoots but the damage done is of slight importance.

Various species of defoliating caterpillars occur on dadap, including occasionally Tea Tortrix and Fringed Nettle Grub. A common species is the tussock moth, *Notolophus posticus* Wlk. (=*Orgyia postica Wlk.*) (family Lymantriidae), a brightly-coloured hairy caterpillar. The full-grown caterpillar is 1½ inches long, mostly black and yellow in colour, with a reddish head, and along the mid dorsal line there are four closely-set short tufts of yellow hairs. There are also paired pencils of long black hairs on the thorax which project forward on either side of the head, and a pair of long brown tufts extending backwards from the last segment. This form is typical of the tussock moth family Lymantriidae, and other species found on dadap include *Dasychira horsfieldi* Saunders and *Euproctis flava* F. These caterpillars may also occur in small numbers on the tea bushes beneath the shade trees.

Other hairy caterpillars on dadap may be those of the eggar moth family Lasiocampidae; these are large caterpillars with a prominent lateral fringe of hairs and also dorsal tufts of hairs which are often irritating to the skin. *Suana concolor* Wlk. grows to four inches in length; it is covered with dense grey-brown pubescence with darker streaks, and has two bands of irritant jet black hairs on the thorax and lateral fringes of much longer hairs. *Taragama dorsallis* Wlk. is another lasiocampid caterpillar of rather similar appearance and size that occurs on dadap, *Albizia*, rubber and cacao.

Caterpillars of the hawk moths (Sphingidae) *Acherontia lachesis* F. and *A. styx* Westw. may also be found on dadap. These are also large, but smooth and sleek with a horn-like dorsal projection on the last abdominal segment. They are green with oblique yellow stripes at the sides; in *A. lachesis* these are edged with blue above. *A. lachesis* grows to 4 inches or more in length, and *A. styx* to about 3 inches. The adult of the latter species is the well-known 'Death's Head Hawk Moth' with a white marking on the thorax which resembles a skull.

Agathodes ostentalis Hubn. (Pyralidae) is the Dadap Leaf-Folder. The young larvae feed inside the undeveloped leaves protecting themselves with a fine web, and the more mature larvae feed within a fold spun together with silk on mature leaves. Pupation occurs inside a cocoon formed in a crevice in the bark or inside empty tunnels of the dadap shoot borer.

The larva of the moth *Terastia meticulosalis* Gn. (Pyralidae) is the Dadap Shoot Borer and bores in the green shoots of dadap. This is the most serious pest of dadap. The eggs are laid singly at the bases of tender leaf stalks and on hatching the young larva bores into an immature leaf. After about two days it enters a young shoot near the tip and tunnels down the centre, gradually causing the shoot to die back. A mass of excrement (frass) usually protudes from the tip of an attacked shoot. The larvae is full grown in about a month and pupates inside a cocoon within the hollow decaying shoot. Lopping and burning of the loppings may occasionally be necessary to keep this pest within bounds.

Leaf-eating weevils, *Leprosus* spp. (Curculionidae), and *Myllocerus curvicornis* F. which are also minor pests of tea, may occasionally do considerable damage to dadap. The adults of various species of chafer beetles (Chapter 6) may also feed on dadap.

10.2. GLIRICIDIA SEPIUM

Cyclopelta siccifolia, noted as a pest of dadap, occur also on *Gliricidia*. Infestation by Green Bug (*Coccus viridis*) may occur, and also an unidentified green aphid; the sugary secretion of both these species results in the growth of sooty moulds on the leaves. Of defoliating caterpillars, Tea Tortrix may occur, and sometimes bagworms, of which the commonest is *Acanthopsyche subteralbata* Hmpsn.

10.3. ALBIZIA SPP.

The species of *Albizia* commonly interplanted in tea in Ceylon are *Albizia falcata* (=*A. moluccana*) and *A. sumatrana*. These frequently suffer severe attack by various pests, many of which are also tea pests. As shade trees, however, *Albizia* spp. are now much less in favour.

Infestations of Tea Red Spider Mite and of Scarlet Mite are common, especially on *A. falcata*. Scarlet mites appear to be mostly *Brevipalpus californicus*, as on tea, but *B. phoenicis* has also been noted. The infested leaves fall on to the tea bushes beneath.

Albizia may suffer severe attacks of Tea Tortrix, occasionally. Heavy infestations of bagworms and faggot-worms have also been quite commonly recorded in low and mid-country districts over the last sixty years, and all the common species on *Albizia* may infest tea as well:—*Clania cramerii*, *C. variegata*, *Manatha* *albipes*, *Chalioides vitrea*, *Acanthopsyche subteralbata*, and *Kotochalia doubledayi* (see Section 5.3). The tussock moth caterpillar *Notolophus posticus* may occur in numbers, and also a geometrid 'looper' caterpillar, *Macaria pluviata* F., a species which does not occur on tea.

Also common on *Albizia* are the caterpillars of the common yellow butterflies *Eurema hecabe* L. and *E. silhetana* Wall. (Pieridae), which can defoliate large trees and which are also common nursery pests which can defoliate and kill young plants of *Albizia*, *Acacia* and *Sesbania*. The caterpillars are dull pale green with paler lateral stripes; the head is black in *E. silhetana* and green in *E. hecabe*. The larvae of *E. silhetana* are gregarious, those of *E. hecabe* feed singly. The 'boat-shaped' chrysalids are formed on the host plant and hang pendant attached at the tail end by a silken girdle; they are brown to almost black in *E. silhetana* and pale to dark green in *E. hecabe*. On nursery plants both species can be readily controlled by DDT at the strength of 1 pint of 20% E. C. in 25 gallons of water.

The Bark-eating Borer, *Indarbela quadrinotata* Wlk. (Metarbelidae), is very common on *Albizia* especially after pollarding, and also occurs on *Acacia* spp., *Cassia* spp. *Grevillea robusta* and many other trees. The eggs are laid in clusters of 15-20 on the bark. The larva bores a short tunnel downwards into the wood which is used during the day; at night the larva comes out to feed on the outer surface of the bark, which it does under the protection of a shelter gallery composed of fragments of bark and frass spun together with silk. This gallery may extend several feet and in severe attacks the whole tree trunk may be covered with such galleries and a large part of the surface of the bark may be eaten away. Although the trees look very sick when so damaged after pollarding, they usually recover surprisingly well when the attack is over. Control measures can be applied on pollarded trees by rubbing off the frass galleries and plugging the holes of the tunnels with a little bitumen. A related species, *Indarbela theivora* Hmps. is recorded on tea in N. E. India (Das, 1965) but this has not been noted in Ceylon.

Neotermes militaris, the live-wood termite of tea in the high country, also occurs on *Albizia*.

10.4 GREVILLEA ROBUSTA

This shade tree very commonly carries infestations of Scarlet Mite, which appear to be mostly *Brevipalpus phoenicis*, and sometimes Tea Red Spider Mite also. Also, in common with *Albizia*, *Grevillea* is liable to be attacked by *Neotermes militaris*, but more commonly by another live-wood termite, *N. greeni* (*see* Colour Plate 22). Bark-eating Borer, *I. quadrinotata*, occurs on *Grevillea* though much less commonly than on *Albizia*; and also the Red Borer, *Zeuzera coffeae*, which occurs on tea. Young trees have occasionally been seen to be severely stunted by *Lygus viridanus* where this pest occurs on tea and cover cops.

Defoliating caterpillars are relatively few. Tea Tortrix may occur, but usually in small numbers. The eggs of Twig caterpillar *Ectropis bhurmitra* Wlk., are commonly laid on the rough trunks of *Grevillea* which is a favourite host plant for the larvae; instances have been recorded where trees were completely defoliated by this pest.

10.5. ACACIA PRUINOSA AND A.DECURRENS

These *Acacia* species are not greatly troubled by insect pests. Defoliating caterpillars which may occur include those of the yellow butterflies *Eurema hecabe* and *E. silhetana* (*see Albizia*), *Suana concolor* and *Dasychira horsfieldi* (*see* dadap), and Tea Tortrix. Attacks by *Neotermes militaris* may occur.

An unusual pest, not noted on any other shade tree species on tea estates, is the root-feeding ant *Dorylus orientalis* Westw., which attacks the roots of *Acacia* (Hutson, 1933). It is known throughout S. E. Asia as a pest of vegetables, gardens and forest tree nurseries and appears to be entirely herbivorous, unlike the fierce driver ants of the same family, the Dorylinae. The nest is formed below ground and contains the very large apterous queen. The workers are blind with the head much broader than the thorax and the legs short; they are chestnut in colour with a paler abdomen, and up to 5 mm in length. The winged males are much larger, superficially wasp-like in appearance, and are commonly attracted to artificial lights at night.

The very large mealy bug, *Icerya purchasi* Mask., is occasionally seen on *Acacia*, and sometimes on *Tephrosia candida*. This is the Fluted Scale, at one time a serious pest of citrus in California; successful biological control was achieved by importing the predacious ladybird beetle *Novius cardinalis*. Also introduced into Ceylon, *I. purchasi* caused concern as a pest of *Acacia* in 1916-1918 but it was found to be kept under natural control by a fungus disease and native predators (Hutson, 1920).

10.6. CROTALARIA SPP.

Crotalaria may sometimes be severely attacked by the caterpillars of the moths *Argina argus* Koll. and *Argina syringa* Cram. (family Arctiidae). These are conspicuous hairy caterpillars; those of *argus* up to two inches long, black but with a line of white spots on the mid-dorsal line, and those of *syringa* dull greenish-grey with transverse narrow black bands, three on each segment. They feed on the leaves and flowers and sometimes bore into the pods to eat the seeds; they can also girdle the stems.

The larvae of the Legume-pod Moth *Etiella zinkenella* Treit. (Phycitidae) bore in the pods and eat the seeds of *Crotalaria* and are a common pest of various legumes throughout the tropics. They are small green caterpillars, a little over half an inch in length full-grown; when mature they have a pink tinge and are darker dorsally. Another pod-borer on *Crotalaria* is the green slug-like larva of the Small Pea-Blue butterfly *Lampides boeticus* L. (Lycaenidae). These two pests are only of consequence where *Crotalaria* is grown for seed.

The most severe pest, when trying to interplant *Crotalaria* as a cover crop in tea new clearings, is the mirid bug *Ragmus importunitas* Dist. which damages young *Crotalaria* in the way that tea is damaged by the mirids *Lygus viridanus* and *Helopeltis* spp, resulting in very ragged foliage and often stunting growth completely when the plants are still very small. For this pest, spraying is often essential, and DDT is effective at the strength of 1 pint in 25 gallons of water, using enough to wet the plants thoroughly.

It has also been observed that severe damage may be caused by an unidentified species of 'flea beetle' that peppers the leaves of the newly-emerged seedlings with tiny holes. This is a small shining chrysomelid beetle (sub-family Halticinae) with enlarged femurs that enable it to leap like a flea. Control can be obtained by DDT spraying as for *Ragmus*.

10.7. TEPHROSIA CANDIDA

The pods of *Tephrosia* are often attacked by *Etiella zinkenella* (*see* Crotalaria) and also by a similar species *Maruca testulalis* Geyer and by the beetle *Araecerus fasciculatus* De Geer. The leaves may be attacked by a spider mite, an *Eotetranychus* sp. The mealy bug *Icerya purchasi* noted as a pest of *Acacia*, may also occur.

10.8. SESBANIA CINERESCENS

The green caterpillars of the yellow butterflies *Eurema hecabe* and *E. silhetana*, noted above as serious pests of *Albizia*, also commonly occur on *Sesbania* and may defoliate plants completely.

10.9. INDIGOFERA ENDECAPHYLLA

A common pest on *Indigofera* is the caterpillar of the moth *Dichomeris ianthis* Meyr. (Gelechiidae). This is a small green caterpillar which webs the leaves together and feeds within the webbed masses of leaves. The cocoons are formed within masses of shrivelled leaves on the plants or within individual fallen leaves.

The adult is a small grey-brown moth. This pest can be controlled by DDT spraying.

10.10. GUATEMALA GRASS (TRIPSACUM LAXUM)

Pseudaletia (*Cirphis*) *unipuncta* Haw. is a noctuid caterpillar, like the cutworms or army-worms, and feeds on the leaves of Guatemala grass. It has been noted on a few occasions stripping the plants badly over several acres. It can be controlled by DDT spraying.

An unidentified stem-boring caterpillar has been noted once on St Coombs but has not re-appeared.

CHAPTER 11

INSECTICIDES AND THEIR USAGE ON TEA ESTATES

11.1. INSECTICIDES

Over the last twenty years or so, chemical industry has developed a large range of powerful, synthetic, organic insecticides. A recent tally showed that 236 pesticidal chemicals, including 66 insecticides, were available commercially in the U. S. A. Considerably fewer are available in Ceylon, but since there are often several proprietary formulations of each insecticide sold under various trade names, the layman is faced with a welter of names.

Names—Each active insecticide has a full chemical name and, for convenience, a short 'common name' e.g.

> 1,1,1, - trichloro-2, 2-bis (p-chlorophenyl) ethane (alternatively dichloro-diphenyl-trichloroethane)

is abbreviated to DDT, and the latter is the 'common name' of this insecticide. As the number of chemicals increased, it became confusing to use abbreviations based on the first letters of the full names (e.g. DDT and related insecticides such as TDE and DTT) so that common names such as 'aldrin' and 'lindane' were coined.

DDT is a white crystalline solid and—like the many organic insecticides—virtually insoluble in water, so that for practical use it has to be 'formulated' as an emulsifiable concentrate, a dispersible (wettable) powder or a dust, etc. Each proprietary formulation marketed by the various manufacturers or agents is sold under a trade name e.g. emulsifiable concentrates of DDT available in Ceylon are 'Didimac', 'Deenol', 'Arkotine D18' and 'Sillortox'. Hence, for each insecticide, there is a chemical name, a common name and one or more trade names for the formulations; the planter need not concern himself at all with the full chemical name but with various trade names he should be able to identify the active insecticide. Table 4 gives a list of the common names of the active insecticides available in Ceylon and the trade names of the various proprietary formulations.

Chemical types of insecticides—Before the second world war, the main categories of insecticides in use were as follows:

(1) Those of botanical origin e.g. nicotine, pyrethrum and rotenone (derris);

(2) inorganic chemicals including sulphur and lime sulphur, lime, and various arsenicals such as lead arsenate and Paris Green (copper aceto-arsenite);

(3) Oil fractions from the fractional distillation of petroleum and coal tar, generally used as oil-in-water emulsions such as 'white-oils,' 'summer-oils', and 'tar-oil winter washes'.

The synthetic organic insecticides developed over the last two decades fall mostly into the following categories:

(4) organo-chlorine or 'chlorinated hydrocarbon' compounds. This group includes DDT and related compounds, such as TDE, methoxychlor, Perthane, and the acaricides Chlorbenzilate and Kelthane. It also includes the chlorinated aryl hydrocarbons, such as B.H.C., chlordane, heptachlor, aldrin, dieldrin, and endrin.

(5) organo-phosphorous compounds or 'O.P.'s'. This has been a particularly prolific group, and includes non-systemic insecticides such as parathion, malathion, trichlorfon (Dipterex),fenitrothion and ethion, and many systemic insecticides such as dimethoate (Rogor), methyldemeton (meta-systox), demeton (systox), Dimecron, and Phosdrin.

(6) carbamates such as carbaryl (Sevin) and 'Matacil'.

(7) Sulphides, sulphones, etc, which are chiefly used as acaricides such as tetradifon (Tedion).

Some properties of insecticides.—With the older materials it was possible to distinguish fairly clearly between (1) 'contact' poisons which act through the integument of the insect, e.g. pyrethrum, (2) stomach poisons, which have to be ingested, e.g. lead arsenate, and (3) poisons with a strong fumigant action through the respiratory system, e.g. nicotine. These distinctions are not very useful with the organic insecticides, most of which can act both as contact and stomach poisons and often, if they are fairly volatile, in the vapour phase as well.

Insecticides vary greatly in persistence on plant surfaces or in plant tissues. Some have a short residual life because they are quickly hydrolysed i.e. decomposed by water (e. g. many organo-phosphates), others because they have a high volatility (e.g. aldrin and B. H. C.), whilst some are unstable in daylight (e.g. pyrethrum). The most persistent are the highly stable compounds with a relatively low volatility e.g. DDT, dieldrin and Kelthane. Many of the organo-chlorine compounds are, like these, highly persistent. The organo-phosphates are, in general, much less persistent and are hydrolysed or decomposed fairly rapidly.

Even the insecticides with the widest 'spectrum of activity' are not equally toxic to all insects and show some selectivity of action.

DDT, for instance, has a very low toxicity to certain locust species; and although toxic to most lepidopterous caterpillars, the difference in response between species of the same family or genus can be very marked. Unwanted side-effects arise because insecticides are lethal to beneficial insects as well as pest species; hence materials with a more selective toxicity can be useful, but they must have sufficient usage to render it economic to develop and manufacture them. The most notable success of this nature so far has been the development of acaricides such as Kelthane and Tedion which are toxic to the mite pests but not to insect predators of the mites.

Certain insecticides have 'systemic' properties, i.e. they are absorbed through the roots or leaves and transported in the vascular system to other parts of the plant. Sucking insects or mites ingest them with the sap or tissues of the plant. A few compounds act solely in this way and have little or no contact or fumigant action; this represents another type of selective toxicity, since the insecticide is toxic to the sucking pests but not to predators and parasites of them. However, most insecticides that show systemic properties-mostly organo-phosphates—have a marked contact action or a fumigant action as well. They have not so far been of particular value on tea, and some of them involve complex problems of residues, since the decomposition products may also be toxic.

Apart from systemic action, organic insecticides do not behave as inert materials on plant surfaces. Most of them have a high lipoid solubility and dissolve rapidly in the waxes of the plant cuticle. Further, many have the property of diffusing across or through leaves. The mechanism of this 'trans-laminar' action is not well understood, but it can be important in practice. Insects and mites feeding on the undersides of leaves, where it is difficult to obtain spray coverage, may be killed by spray deposits on the upper surfaces of the leaves.

11.2. PRECAUTIONS

These safeguards are for the protection of labourers using insecticides, of animals and wild-life, and to prevent contamination of made tea.

Insecticides vary in the hazards they present for man and animal but most of them can be hazardous if not used correctly. Use them only when needed and handle them with care. Follow the instructions and heed all precautions on labels and leaflets.

Insecticides should be kept in closed, well-labelled containers locked in a dry store where they will not contaminate food or animal feed, and where unauthorized persons, children and animals cannot reach them. Empty cans should be punctured and buried so that they cannot be used for drinking water.

Protection of Labourers

Rule 1. When handling or mixing, avoid spilling the concentrate on the skin and keep it out of the eyes, nose and mouth If any is split, wash it off the skin with soap and water and change contaminated clothing immediately. Rubber gloves can well be used for handling the more toxic materials; if the insides of the rubber gloves become contaminated, however, it can be more dangerous than not having gloves.

Rule 2. Wash thoroughly with soap and water before eating and smoking and at the end of the day's work.

Rule 3. It is highly desirable to provide labourers with spraying clothes (light cotton) which they change after work, and to have these washed regularly. A piece of jute hessian tied round the waist to cover the legs will prevent a good deal of skin contamination; this must be discarded or washed every few days.

Rule 4. If there is prolonged working exposure to Class 2 compounds it is recommended to switch spraying gangs after a month: the relieved gang should then be out of contact with the insecticide for a month before being put back on spraying.

Prevent contamination of water sources

Rule 5. To prevent poisoning of fish and wild-life and possibly people, be careful not to contaminate streams or ponds with insecticides. Do not clean spraying equipment or dump excess spray solution near such water; dig a deep hole and bury it.

Relative toxicity of insecticides

Table 2 (below) gives an assessment (inevitably somewhat arbitrary) of the relative hazards to persons handling insecticides of those which may be offered for sale to tea estates.

Class 1 ('Safe')—these materials can be used safely as diluted sprays. Observe Rules 1 and 2 above.

Class 2 ('Intermediate')—these materials require more special care and attention. They can be absorbed directly through the skin, possibly in harmful quantities, but normally a serious hazard exists only from:

(a) gross skin contamination (Observe Rules 1, 2, & 3);

(b) prolonged working exposure (Observe Rule 4).

Class 3 ('Hazardous')—these materials are not generally recommended for use on tea estates. They are very poisonous and may be fatal if swallowed, inhaled or absorbed through the skin. For proper protection of the spraying labour they usually require waterproof protective clothing which is not practicable under conditions on tea estates.

TABLE 2

TOXICITY OF INSECTICIDES

(The active insecticides are listed here, using the names current in Ceylon; for proprietary formulations of these insecticides, *see* Table 4)

Class 1	Class 2	Class 3
'Safe'	*'Intermediate'*	*'Hazardous'*
Akar (Chlorbenzilate)	Aldrin	Dimecron
B.H.C., lindane	Chlordane	D.N.O.C.
DDT	Dieldrin	Endrin
Dipterex	Diazinon	Nicotine
Fenitrothion	Heptachlor	Nicotine sulphate
Kelthane	Metasystox	Parathion
Malathion		Phosdrin
Rogor (dimethoate)		Systox
Sevin		Telodrin
Sulphur		
Tedion		
White-oil emulsions		

Treatment for poisoning

If an insecticide is swallowed, induce vomiting by giving one tablespoonful of salt in a glass of warm water; repeat until the vomit fluid is clear or the odour of solvent is gone. Have the victim lie down and keep quiet, and call a physician immediately.

Avoid taint and insecticide residues in made tea.

Taint or off-flavour in made tea can be caused by certain insecticides, particularly (of those likely to be used on tea) benzene hexachloride (B.H.C), sulphur and malathion.

Quite apart from a taint effect, it is essential that residues of pesticides in made tea should be below levels acceptable to importing countries; this is vitally important since a single objection from an importing country could have serious repercussions on the prestige of Ceylon teas.

Residues of some pesticides disappear quickly, others are more persistent. The rapid growth of the flush, and often heavy rainfall, are factors which help to reduce residues; the processes of manufacture result in a further loss of residues. In addition, it is usually necessary or practicable to spray only a fraction of the acreage of an estate in any week; thus, tea made from sprayed leaf will generally be bulked with several times as much tea made from unsprayed leaf. Provided this bulking is well done, this is a valuable means of keeping residues at very low levels in commercial consignments of tea.

To avoid taint and objectionable residues in made tea, observe the following rules:—

Rule 6. Do not exceed the recommended dosages.

Rule 7. Observe carefully the 'safe interval' required between spraying and plucking for manufacture and the requirements for bulking of made tea.

Rule 8. Avoid drift of insecticide sprays on to nearby tea in plucking, particularly if spraying with a motorized mist-blower. It is not wise to mist-blow materials which taint badly, eg B.H.C., sulphur, malathion.

TABLE 3

SAFE INTERVALS

The following are the minimum safe intervals required between spraying and the next plucking for manufacture in order to avoid taint and undesirable residues in made tea:—

Tedion—7 days

DDT —7 days, provided the tea made from sprayed areas is bulked with about ten times as much tea made from unsprayed areas. If such bulking is not possible, allow 14 days, either by discarding one plucking round or by resting the tea.

Dipterex, Sevin, Kelthane and Akar—7 days, provided the tea made from sprayed areas is bulked with five times as much tea made from unsprayed areas. If such bulking is not possible, allow 14 days.

Malathion—to avoid taint, allow 21 days, either by discarding one or two plucking rounds or by resting.

Wettable sulphur—to avoid taint, allow 28 days, either by discarding two or three plucking rounds or by resting.

TABLE 4

PROPRIETARY FORMULATIONS OF INSECTICIDES MARKETED IN CEYLON

This list is not necessarily complete, nor does it imply that a given formulation is currently available. It is intended chiefly to reduce confusion over proprietary names, and to help planters identify the active insecticide in each product.

There are the following types of formulations involved:—

E. C.—emulsifiable concentrate, a liquid formulation containing the insecticide dissolved in a solvent, which forms an 'oil-in-water' emulsion on dilution with water.

W. P. = wettable powder. This type of formulation contains the insecticide with an inert diluent, together with dispersing and wetting agents, etc. On dilution it gives a fine dispersion of the insecticide in water.

Dust = the insecticide with an inert diluent, for dry dusting and not for dilution with water. Not recommended on tea.

Common names of insecticide or acaricide		*Proprietary formulations and local agents*
Aldrin	E. C's	'Aldrex 2' (20%) (Shell)
		'Baur's Aldrin 25% E. C.' (Baurs)
	W. P.	'Aldrin 40% W. P.' (Shell)
	Dust	'Aldrin dust' (Shell)
B. H. C. (Benzene hexachloride and lindane)	E. C's	'Gammalin 20' Misoible liquid (20%) (C. I. C.)
	W. P's	'Gammexane' 26% W. P. (C. I. C.)
		'Hexidole' W. P. (Fisons)
	Dusts	'Gammexane' dusts (C. I. C.)
		'Hexidole' dusts (Fisons)
Chlorobenzilate	E. C.	'Akar 338' (25%) (Baurs)
Chlordane	E. C.	'Intox 8' (Baurs)
D. D. T.	E. C.'s	'Arkotine D 18' (18%) (Shell)
		'Deenol' (25%) (Baurs)
		'Didimac 25' (25%) (C. I. C.)
		'Sillortox' (25%) (Fisons)
	W. P.'s	'Shell DDT W. P.' (Shell)
		'Guesarol' 550 W. P. (50%) (Baurs)
		'Didimax 75 W. P.' (C. I. C.)
	Dusts	'Shell 5% DDT dust'
		'Shell 10% DDT dust'
		'Baurs 5% DDT dust'

Dieldrin	E. C.'s	—	'Dieldrex 20' (20%) (Shell) 'Dieldrex Extra' (20%) (Shell) 'Baur's Dieldrin 20% E. C.' (Baurs)
	W. P.	—	'Shell dieldrin 50% W. P.'
	Dust	—	'Shell dieldrin' 1% dust
Diazinon	E. C.	—	'Diazinon 60 E' (60%) (Baurs & Fisons)
	W. P.	—	'Diazinon 40% W. P.' (Baurs & Fisons)
Dipterex (trichlorphon)	W. P.	—	'Dipterex S. P. 80' (80%) (Hayleys)
Endrin	E. C.'s	—	'Endrex 20' (20%) (Shell) 'Baur's Endrin 20% E. L.' (Baurs)
Fenitrothion	E. C.'s	—	'Sumithion' 50% E. C. (Shell) 'Folithion' 50% E. C. (Hayleys)
Kelthane (dicofol)	E. C.	—	'Kelthane M. F.' (36%) (C. C. & F) & (Shell)
Malathion	E. C.'s	—	'Shell Malathion 50% E. C.' 'Malacide 50 E. C.' (C. I. C.) 'Malatox 50 E. C.' (Fisons) 'Millathion 50 E. C.' (Millers)
Metasystox (methylde-meton)	E. C.	—	'Metasystox' (Hayleys)
Parathion	E. C.'s	—	'Folidol E. 605 conc.' (46.7%) (Hayleys) 'Ekatox 50% E. L.' (Baurs) 'Fosferno 50' (50%) (C. I. C.)
Phosphamidon	E. C.	—	'Dimecron' (50%) (Baurs)
Roger (dimethoate)	E. C.	—	'Rogor 40 E. C.' (Fisons)
Sevin (carbaryl)	W. P.	—	'Sevin 85% sprayable' (Shell)
Sulphur	W. P.'s	—	'Shell dispersible sulphur' 'Thiovit W. P.' (Baurs) 'Spersul W. P.' (C. I. C.)
Tedion (tetradifon)	E. C.	—	'Tedion V. 18' (8%) (Lewis Brown)
Telodrin (isobenzan)	E. C.	—	'Telodrin 15% E. C.' (Shell)
White-oil emulsions		—	'Albolineum' (C. I. C.)

AGENTS (Abbreviations used in the above list)

'Baurs'	—	A. Baur & Co. Ltd.
'C. C. & F.'	—	Colombo Chemical & Fertilizer Co. Ltd.
'C. I. C.'	—	Chemical Industries (Colombo) Ltd.
'Fisons'	—	Fisons (Ceylon) Ltd.
'Hayleys'	—	Hayleys Ltd.
'Lewis Brown'	—	Lewis Brown & Co. Ltd.
'Millers'	—	Millers Ltd.
'Shell'	—	Shell Company of Ceylon Ltd.

11.3. NOTES ON SPRAYING

To obtain good results with insecticidal spraying it is essential to use the full recommended dose in an adequate volume of water and to ensure that spray coverage is good. The spraying machines, both conventional knapsacks and motorized mist-blowers, should be properly maintained and frequently checked, and thorough supervision of spraying is vital. Inadequate spray coverage is doubly wasteful since it results in loss of crop from the pest and waste of money on the insecticide and labour.

The dosages for mature tea are given as pounds or pints of the insecticide formulation per acre and these are to be used in the volume of water recommended for spraying by conventional knapsacks or, alternatively, by motorized mist-blowers (where no volume has been suggested for mist-blowing, it is not recommended).

With knapsack spraying, the volume required varies with the type of spraying e.g. to control pests of the flush such as yellow Mite or *Lygus* bug, 50 gallons is usually sufficient; but for thorough coverage of the maintenance foliage, as for Scarlet Mite, 100 gallons may be required. The volumes noted are a guide to those generally needed for adequate spray coverage on mature tea; naturally, this will vary somewhat with the stand and size of the tea bushes and the spray nozzles used, etc. Nozzles giving a cone of spray are more suitable for insecticide spraying than fan jets (as used for blister-blight control). Labourers must not be allowed to enlarge the orifice in the nozzle discs; ceramic nozzle discs are useful in this respect because they break if this is attempted. Pressurized knapsacks, preferably with pressure-regulating valves, are the best type for ensuring uniform output and coverage.

Motorized knapsack mist-blowers provide the most convenient and economical means of spraying, especially where the bush frames are large and/or the bush density is high, and the advantages include greater speed of operation and a reduced labour cost per acre. Certain insecticides, however, are not suitable to be applied with mist-blowers and therefore mist-blowing should be done only when recommended. The average volume recommended is 10 gallons per acre (a tank of 2 gallons of spray on one-fifth of an acre) and this is not appreciably affected by the stand and size of the bushes. For certain pests and insecticides up to 15-20 gallons per acre has been found advantageous; the larger mist-blowers (machines of 2-3 h.p.) are required to apply these volumes efficiently. The type of mist-blowing used for control of Blister Blight is not adequate for insect and mite control; these larger volumes are required and the spraying operator should generally travel up and down on alternate rows directing the spray blast from side to side and slightly downwards into the bushes. It must be remembered that the aim in mist-blowing is not to wet the bushes thoroughly but to obtain a fine cover of discrete droplets. It is important that there should be a uniform output, controlled by a device such as a reducing jet which the labourer cannot readily alter; similarly, the labourer should move at a uniform pace and not rush the work.

New clearings and nurseries—For spraying small young plants in new clearings and nurseries it is better to use a standard dilution of the insecticide rather than a dose per acre and to use sufficient of the spray to wet the plants to 'run-off'. The standard dosages recommended for various insecticides are as follows:—

Insecticide	*Dose in 25 gallons of water*
DDT E. C. (18-25%)	1 pint
Kelthane M. F. (36%)	5 fluid ounces*
Tedion V. 18 (8%)	10 fluid ounces*
Akar 338 (25%)	10 fluid ounces*
Wettable sulphur	1 lb
Malathion E. C. (50%)	10 fluid ounces*
Sevin 85% Sprayable	½ lb
Aldrin E. C. (20%)	1½ pints

*1 pint=20 fluid ounces.

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