# SHOT-HOLE BORER: BIOLOGY AND CONTROL.
# NOTES FOR PLANTERS, 1963.

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Recommendations for the chemical control of Shot-hole Borer, by dieldrin spraying soon after pruning, were given in the Tea Quarterly in December 1961 (Cranham, 1961). Rough estimates of the acreage sprayed show that about 6,000 acres were sprayed in 1961, 12,000 acres in 1962 and, on the trend of the first few months of the year, 30,000 acres may be sprayed in 1963. The pest is prevalent on at least 150,000 acres of tea. Many more planters have become convinced of the benefits to be derived from spraying, in spite of the temporary, though troublesome, Tortrix side-effect. Clearly the industry is prepared to invest a considerable sum of money on borer control in anticipation of a fair return for it.

In these circumstances, it is important that the Institute should do all it can to guide planters in the correct, safe and effective usage of dieldrin. The purpose of this article is to inform planters of our conclusions from trials and observations on current estate experience, as a concise summary of the answers to questions we are asked, plus sufficient explanation. For the sake of lucidity, I shall not attempt to include the detailed evidence and trial data in support of statements. This will be recorded in later papers.

We have reached the stage when our knowledge of Shot-hole Borer begins to form an integrated general picture of the life-history and habits of the pest, of the factors which control it's numbers, of the manner and extent of the damage that it causes, and of the inter-relations with the tea bush and cultural practice on the crop.

I must ask the reader to note the caution with which certain statements are phrased. In order to make my general picture better integrated and more understandable I have included some personal opinions and tried to make it quite clear when I have done so. Especially when dealing with the pest in relation to the complex agronomy of the crop, to the health of the tea bush, and the effect of cultural practices such as pruning and manuring, the interpretation I place on the facts, and on my own observations, is a personal one.

## Biology

The Shot-hole Borer of Ceylon tea is a small beetle of the Scolytidae, a family which contains serveal 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 (1947) succeeded in rearing larvae through to maturity in the laboratory on artificial cultures of the fungus.

In *X. fornicatus*, as in the *Xyleborus* genus generally, the male beetles are much smaller than the females and the wings are undeveloped, so that they are flightless. At any time, the males which have a shorter adult life, average about 10% of the adult population; the true sex ratio in the broods is probably nearer 4 : 1, females to males.

Galleries are made only by the female beetles. The young mature female beetle, a few days after emergence from the parent gallery, makes a new gallery in the wood of a young stem and introduces the ambrosia fungus on the walls of the gallery. 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, hatch and feed on the ambrosia fungus, pupating in the gallery after three development instars and successive moults. The young female beetles emerge from the pupal stage and remain in the parent gallery for a few 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 at the same time, 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 the first female offspring took about 45 days at Passara (3,500 feet). 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 never 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.

Our knowledge of adult emergence and behaviour is still poor. We do know that the females fly in the middle of the day, not at night as many Scolytidae do, and that the flight is weak and probably short. Judenko (1958), using sticky traps, caught roughly two-thirds of the beetles trapped in flight below 7′ 1″, and over a third of the catch below crop level. A better knowledge of the flight and dispersal of the beetles would be valuable in relation to understanding the spread of infestation, the build-up of infestation after pruning, and the reinfestation of sprayed areas.

*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 be able to raise broods successfully. The shade trees commonly interplanted in Ceylon tea contains several other species of Scolytidae including other *Xyleborus* species very similar to *fornicatus* to the untrained eye; but Judenko (1961b) found that only *Albizzia moluccana*, 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. moluccana* could breed successfully in tea. What effect in practice this has on infestation in tea is as yet undetermined.

**What damage does the borer cause?**

Austin (1956) summarised his views on the damage caused by Shot-hole Borer as follows:—"*Damage to the tea bush is assessed as follows:—Primary damage is caused during the construction of galleries in the stems. This of itself would be of little importance were it not for other consequences which result more or less accidently from the presence of the galleries. The consequences, really secondary damage, are:*—(1) *die-back,* (2) *wood-rot,* (3) *branch breakage. The last named is the most important as it leads to the greatest loss of crop*".

It is evident that Gadd too regarded branch breakage as the main cause of the immediate loss of crop during attack, apart from secondary insidious effects debilitating the bushes. In the Passara trial (Gadd 1944), he assessed the immediate loss of crop due to borer attack by counting the number of broken branches.

It is only since we have had an effective control for the borer, that we can make some assessment of the size of the direct loss of crop due to current attack. The results of yield trials (*see* section 7 and Figs. 3 & 4) show that there is a very large direct loss of crop over the period when infestation and current attack are highest. Considered month by month, the size of the loss is closely correlated with the degree of infestation and current attack, and in the months of peak infestation the losses are so large (*e.g.* at Hantane, about 30% over the second year) that we cannot believe they are entirely due to branch breakage. The facts strongly suggest that the most important factor causing loss of crop is the direct effect of recently-formed galleries in the young wood of the stems in restricting the supply of sap and nutrients to the foliage. This loss of crop can be quite appreciable even from a very moderate infestation in the peak months, *i.e.* without it showing up in numerous breakages and the pronounced symptoms of chlorotic foliage, defoliation and die-back of the shoots which are often associated with a severe attack.

There is a further point about this phenomenon which is worth stressing. As the infestation declines, the direct loss of crop declines (Figure 3), *i.e.* the loss is not then correlated with the accumulated total number of galleries which includes all those vacated, but it is correlated throughout the whole cycle with the infestation and the occupied galleries of the current attack. This strongly suggests that it is some feature of the occupied gallery that interferes most strongly with the flow of sap, perhaps the growth the ambrosia fungus of the youngest wood near to the cambium. Since the accumulation of old vacated galleries does not appear to add very much to the direct loss of crop, we may presume that the bush is able to repair the main damage done internally, presumably by proliferation of new xylem (wood) peripheral to the old galleries.

Turning now to the secondary and chronic effects of the borer, Figure 1 attempts to show some of the interactions of factors which result in debilitation of the bushes. The direct effect of new galleries on sap flow which affects the yield also leads, in severe attacks, to defoliation and some die-back of shoots. Chlorotic symptoms in the foliage may be more pronounced. Primary breakages, due to occupied or recent galleries, occur mostly in shoots about a quarter of an inch thick. These factors all contribute to impoverishing the bush frames and the maintenance foliage, which on the one hand gives the bushes less chance to maintain good starch 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 starch 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.

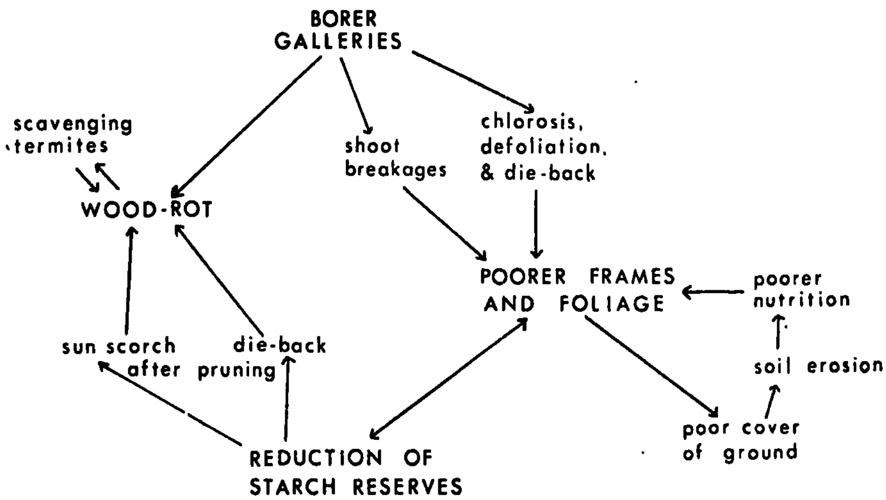



Figure 1. A schematic representation of the secondary effects of shot-hole-borer damage and some of the interactions which result in chronic debilitation of the bushes.

I have described this 'vicious circle' to show how borer damage is linked with cultural factors that cause chronic debilitation of tea. The good health of the bush is dependent upon a good frame, maintenance foliage and good starch reserves. Obviously, *any* factors which injure these will debilitate the bushes. *Any* type of wound will tend to enhance wood rot. Mineral deficiencies may themselves directly result in different types of chlorosis and in defoliation and may affect recovery from pruning.

I do not suggest that the borer is the 'root of all evil' but few would doubt that it is a very important factor. Control will give us a very much better idea of how important it has been and also may help to clarify the relation between borer damage and the nutrition of the bush.

### What is the usual pattern of attack?

In mature tea, heavy attacks follow a chronological sequence within the pruning cycle. From the first year, the number of borers (infestation) increases steadily to a peak in the latter half of the second year and then declines at much the same rate as that at which it grew. In all heavy attacks studied, this pattern has been substantially the same so that we now speak of the growth, peak and decline phases of infestation. Graph I in Figure 2 is plotted from the average counts per 100 sample units of all live borers (eggs, larvae, pupae, and adults) from the unsprayed plots of eleven trials on mature tea.

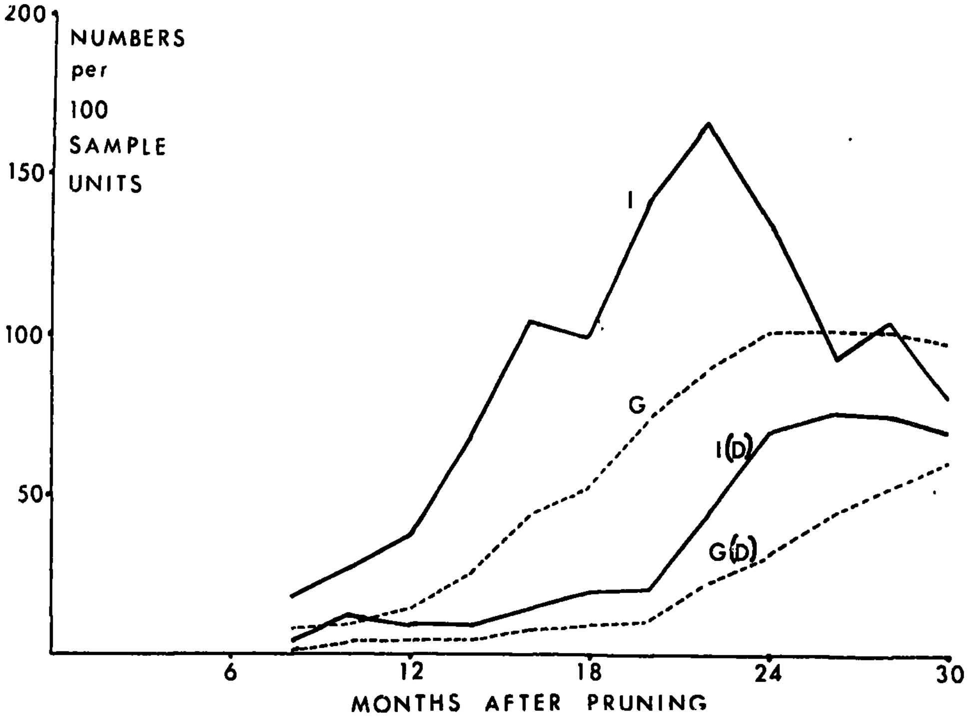



Figure 2. The average results of borer control with dieldrin on eleven large-plot trials, to the 30th month after pruning: the number of live borers (I) and of galleries (G) per 100 sample units on the unsprayed plots; and the number of live borers (I(D)) and of galleries G(D) on the dieldrin-sprayed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

It is important to note that the number of galleries (Graph G) does not decline with the infestation. Galleries do not heal up internally in the wood but remain permanently, and incidentally provide us with a record of past attack. The number of galleries per sample is a useful measure of the accumulated total of the attack. In healthy wood, the openings of the galleries heal over externally by growth from the cambium; thus, the number of open galleries is usually closely correlated with the number of borers present. However, in older wood, or in tea badly damaged by borer attack, the openings may not heal over.

If we now revert to the beginning of the cycle, pruning removes much of the wood that contains live beetles and young; thus, the lighter the prune, the more are left in the pruned frame. If pruning is hard and such that most wood under half-an-inch in thickness is removed, very few borers will be left in the frame. Harder or cleaner pruning may possibly be a factor, additional to temperature, which affects the incidence of borer at the upper limits of it's distribution (around 4,000 feet). However, the subsequent build-up in numbers depends not only on the numbers left on the field but also on the numbers of beetles immigrating into the field from neighbouring fields. In the mid-country, hard pruning is hardly ever advisable and it is not likely to make much difference to borer incidence.

The number of beetles and young left in the pruned frames declines very markedly in the months after pruning. Evidently, conditions become unfavourable for brood rearing. The reasons for this are not known; it may be the sudden reduction of sap flow, or that temperatures in the wood, exposed to the sun, rise above the critical. Because conditions in the bush frame remain unfavourable until the growth of the new wood, beetles emerging from the prunings cannot successfully recolonise the pruned bushes. The prunings dry up fairly quickly so that most of the young stages fail to develop.

Conditions become favourable again with the growth of the new wood and as soon as this is thick enough (3/16th to 1/4 inch) to render it mechanically possible for borers to make galleries the attack of the new cycle starts to build up. Sometimes this thin new wood will suffer a remarkably heavy attack by the end of the first year, but more generally the attack is not really noticeable until the 15th month and the numbers then increase steadily to a peak between the 18th and 24th months. By the 30th month the numbers have usually declined substantially, and where tea is run for longer cycles the numbers remain at a rather low ebb until the end of the cycle.

In light attacks, the numbers may rise slowly to a flat 'peak' in the third year and then decline slowly.

It is normally during the second and early third years that the tea suffers the most severe loss of crop and breakages. After this, in three or four year cycles, infestation and fresh attack are relatively small. Often the tea improves, but sometimes planters may see bad damage (thin foliage, die-back, breakages) in the third and even the fourth year of longer cycles and assume that the pest is very active. In fact the numbers have declined, and in these cases we are seeing more of the accumulated effect of past attack.

It will be readily seen that the number of borers left at the end of the cycle is influenced by the cycle length. After 18 or 24 months, the numbers left are relatively high—and, although the numbers left in the pruned frames decline, the potential carry-over to the next cycle is heavier. At the end of a three-year or four-year cycle the potential carry-over is very much less.

**What controls the numbers of borers?**

What factors determine the typical rise and decline in numbers, and the chance of each female beetle to survive and multiply? There is strong evidence that the chief factor involved, within the range of suitable climatic conditions, is the amount of wood in which conditions are favourable for gallery formation and the growth of the ambrosia fungus and, consequently, for brood rearing. Gadd (1949) produced evidence that the rate of reproduction declined steadily as the wood aged after pruning and he concluded that conditions became progressively less suitable for brood-rearing. Analysis of the data from the unsprayed plots of our trials confirms much the same thing from a wider variety of sites:—a decline in the number of inmates per open gallery and also in the proportion of young in the population, the effect of both being marked after the 16th-18th month when the number of galleries has reached a certain density.

Is it that the wood becomes less suitable with age after pruning, or as the result of accumulated borer attack? Perhaps the effect of borer attack on the wood is to age it prematurely. In heavily attacked fields, where the population rises to a normal peak in numbers, there is a ceiling on the number of galleries which the wood will carry, a *saturation density* usually between 1.0 and 1.5 galleries per 4-inch sample unit. On the face of it there is room for more galleries between those already made, but long before the *saturation density* is reached the wood has lost the fresh sappy appearance of new wood and has become dull and drier in appearance. Unattacked wood of the same age has not. It seems highly probable, therefore, that the decline in numbers is brought about by the accumulated attack itself rendering the wood less suitable. Populations may in this sense be self-regulating. We note that if the growth of the population is much slower, numbers can go on rising into the third year to a low extended peak and a gradual decline. At this stage it is likely that the natural aging of the wood begins to take effect.

What is it in the condition of the wood that makes it suitable or unsuitable for the growth of the ambrosia fungus? We may presume that the sap flow must be adequate; and that the decline in borer numbers after pruning or in young tea during a severe drought (Cranham, Danthanarayana and Ranaweera 1962) is brought about by an inadequate flow of sap, directly or indirectly. But we also have to explain why it is that wood generally becomes less suitable as it ages even in the absence of borer attack, and why it is that some bushes, clones, and fields can be exposed to infestation and develop very much less than others. We may suppose that changes or differences in the chemical constituents of the wood can render the wood less acceptable or less suitable, but we have no knowledge of this. The subject certainly merits investigation, but is likely to involve complex biochemical and physiological considerations; and even if we knew what makes some wood unsuitable, it does not follow that we could make practical use of the knowledge.

In the present state of our knowledge, it is an essential point to remember that it is the young wood on vigorous bushes that offers the most favourable conditions for borer development. There are many pests which go particularly for bushes that are unhealthy, senile, or in some way below par. Scarlet Mite and Scale insects are good examples. Actually, many *Xyleborus* species and other related beetles of the family Scolytidae come in this category, but *Xyleborus fornicatus* definitely does not. It is well known that the more vigorous high-yielding fields—which get more manure—usually carry the heaviest borer attacks. Unfortunately, cultural practices that promote the growth of young wood (and thus more crop) foster borer development. Pruning itself does this, and continually recreates the conditions favourable to attack. Nitrogenous (NPK) manuring also promotes more young wood, and therefore generally creates more scope for borer development.

### Manuring, Shot-hole Borer and Yields

It is generally considered that the borer has increased markedly over the last decade or so. I believe it is highly probable that the main reason for this increase is that the greatly increased manuring, in promoting more wood and more crop, has *ipso facto* created better conditions for the borer.

This statement is usually met by planters with some puzzlement if not consternation. Planters are inclined to say 'but in the past, the answer to borer attack was to increase manure'. It is important here to distinguish between the effects of the borer and the actual numbers of borers. By giving more manure, we alleviate the effects of borer attack—we enable the bushes to maintain and quite often even produce more, but we do not reduce the numbers of the borer, we usually increase them.

The situation is something like a dog with tapeworms which keep the dog thin. By luxury feeding we may be able to fatten the dog a little, and the worms. Starvation may help to starve the worms, but the dog will lose weight, and eventually die.

Probably in time, however much food we give, the dog will remain rather thin and it's weight be fairly static. If however we get rid of the worms by treatment, then we can fatten up the dog by good feeding. An analogy such as this should not be taken too closely but it may help understanding.

In relation to Shot-hole Borer, the crucial question is 'what better response to manure might we have got in the absence of the borer?' Like the worms in the dog, the borer (the 'worm in the wood') has the effect of 'taking' part of the food we give and part of any extra food we give. Fresh borer galleries interfere in some way with the utilisation of nutrients and the effect is to reduce the yield response to manure. To take a purely hypothetical example:—if, on a borer-attacked field, we get 2 lb of extra crop per extra lb of nitrogen in an NPK manure, it might be that in the absence of the borer we would get 4 lb of extra crop per lb of nitrogen. If the response falls below a certain level, in terms of extra crop per lb of nitrogen, it becomes uneconomic to increase the manure. We *may* able to go on pushing up the yield in spite of borer attack; on the other hand if the borer attack increases too greatly under the more favourable conditions created by more liberal manuring, we may end up with a static yield or even one that declines.

There is a quite widespread belief that heavy potash manuring, sometimes even more than is given in the T. 750 mixture, will reduce borer incidence. This is unlikely to be true, but here again we must distinguish between the effects of the borer attack and the actual numbers of borer. We might expect potash to have an important role in helping to alleviate the effects of the borer, in the repair of damage, and in recovery after pruning. We have no experimental evidence, however, as to the levels of potash manuring which can prove beneficial in this way, and at present planters can only be guided by practical experience.

**What is the effect of dieldrin spraying on borer numbers?**

There is now abundant evidence that dieldrin spraying after pruning will nearly always bring about a marked reduction of the second-year infestation and attack, provided that the spraying is initially well done on dry bush frames. We are now chiefly concerned with the duration of control. Will control last for a three or four-year cycle? Will it be necessary to respray at each successive pruning?

I will first deal with the summarised results of the large plot trials started in 1960-1961 (Cranham, Danthanarayana and Ranaweera, 1962). For eleven trials which have run for over two years, Graphs I (D) and G(D) in Figure 2 show the average counts for infestation and galleries on the dieldrin-sprayed plots, by comparison with Graphs I and G for the unsprayed plots referred to earlier. Most of the sprayed plots were 5-10 acres in size and received 1.5 lb actual dieldrin, either as two rounds of 3 pints of 'Dieldrex' or one round of 6 pints of 'Dieldrex' per acre.

The control achieved from dieldrin within a two-year period was generally good. At the end of two years, the accumulated attack, as represented by the number of galleries, was reduced by more than two-thirds on an average. But at the end of the second year and into the third year the infestation of the sprayed plots is building up. Does spraying only postpone the build up by 10-12 months to just as bad an attack in the third year of a 3 or 4-year cycle? We still need more information from the third year of trials to answer this, but so far, as will be seen from the graphs, there is a build up in the third year but on average it appears to be about half that which occurred earlier on the usprayed plots. It looks as though the age-of-wood factor is having some effect in the third year but that it varies greatly, as one might expect, in different types and conditions of tea.

It is clear, however, that in these trials a totally different factor has influenced the duration of control on the sprayed plots, namely reinfestation by immigration of beetles from outside. The results referred to above and illustrated in Figure 2 were from plots mostly of 5-10 acres in size and adjacent to unsprayed plots which became heavily infested. Under such conditions, reinfestation is much more marked than when the whole field or larger groups of fields are sprayed. Specific studies on the pattern of reinfestation in the Rye and Demodera trials, and general observations elsewhere, strongly suggest that reinfestation works in progressively from boundaries adjacent to infested tea, and that it normally works in rather slowly; it does not develop equally all over the field at once. We do not yet know enough about the flight and dispersal of *X. fornicatus*, but the general indication that the flight is weak and short fits in with this.

This observation on reinfestation is important in relation to practical control. The duration of control may be greatly improved when whole divisions or estates are sprayed, *i.e.* to the limit of such time as it takes for the few survivors on a sprayed area to build up again in numbers.

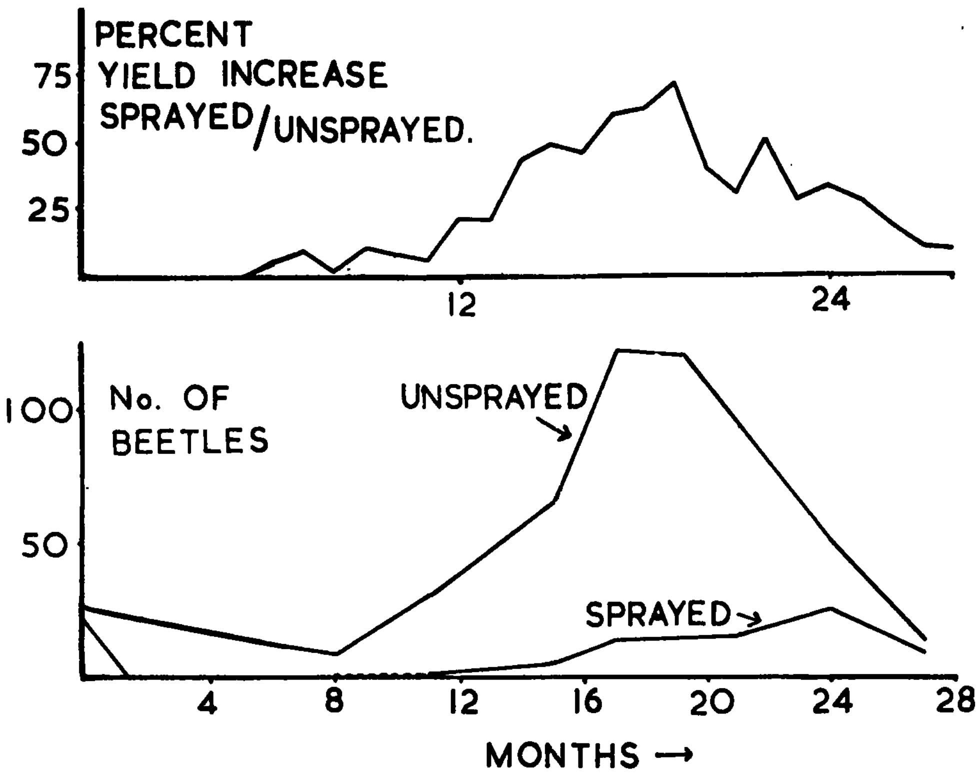
Whether or not it will be necessary to repeat spraying after each pruning will hinge upon the extent of spraying and the effect upon reinfestation. This question can only be answered in time from practical experience on estates, but at present there appears to be a fair chance of control lasting for two short cycles of 18-24 months when large groups of fields have been sprayed.

In practice, the planter will wish to make a decision on whether or not to respray certain fields. The simple method, described in section 11, for assessing the degree of attack can be used at the end of the first cycle after spraying. In sprayed fields in which a moderate or heavy attack has developed by the next pruning, it will clearly be useful to repeat spraying. Difficulty over a decision will arise in those fields in which good control has lasted for the whole of the first cycle. Will a build-up occur in the next cycle? It will probably never be possible to predict, with any certainty, what will happen in individual fields. However, if a field is surrounded by infested fields, full reinfestation in the second cycle is probable. If, on the other hand, the borer has been reduced to a low level over a large area (*i.e.* several fields in a group, a division, or a whole estate), control may well last for the second cycle.

**What yield increases may follow control?**

In the first cycle after spraying, if the control is good, there is usually a substantial increase of crop in the second year and early third year, when borer attack would normally be most damaging. The size of the increase is roughly proportional to the degree of attack previously suffered, which we have controlled. In different fields and estates other factors will affect the size of the response, but obviously we cannot expect a large response from controlling a mild infestation.

In three replicated plot trials started by Dr Judenko (Judenko, Shanmugam and Hasselo, 1962) we compared dieldrin-sprayed and unsprayed plots, and we assessed the yield and the borer attack. We have assessed the monthly yields on the sprayed plots as percentages of the yields on the unsprayed plots, which gives us a percentage increase or decrease each month. The data of the Hantane trial, plotted in Figures 3 & 4 shows how the monthly percentage yield increase was closely correlated with the difference in infestation. The biggest difference in yield occurred when there was the biggest difference in infestation and current attack in the second year.




Figures 3 & 4. The results of the Hantane 1/60 trial showing the close inverse correlation between (Fig. 3, above) the percentage yield increase on the sprayed plots, and (Fig. 4, below) the difference in infestation on the sprayed and unsprayed plots. The difference in yield between sprayed and unsprayed plots is here graphed as an increase (sprayed on unsprayed). In section 2 of the text we deal with it as a loss (borer-attacked against borer-controlled; the corresponding losses are smaller percentages e.g. a 50% increase corresponds to a 33% loss.

On the unsprayed plots, infestation at Bandarapola was much lighter, with a low second year peak. At Kirimetiya, the infestation remained rather low throughout both years. A comparision of the data for the three trials show how the size of the yield increase on the sprayed plots was related to the degree of infestation controlled.

TABLE 1

| | *% increase in yield on sprayed plots* | | *Maximum number of adult borers per 100 sample units on the unsprayed plots* | |
|---|---|---|---|---|
| | 1st year | 2nd year | 1st year | 2nd year |
| *Hantane* | 5% | 42% | 30 | 122 |
| *Bandarapola* | 5% | 27% | 19 | 48 |
| *Kirimetiya* | 14% | 14% | 31 | 30 |

In these trials, the manurial dosage, shade, and other cultural factors were the same for the sprayed and the unsprayed plots. The trials should give us a measure of the direct effect of borer control over the first two years after spraying, uncomplicated by other factors. We have other evidence on the size of the effect and generally when we control heavy attacks there is an increase of about 15%-20% over the first two years with most of it coming in the second year.

There is very little evidence yet on what will happen in subsequent cycles if we maintain control. However, in practice on estates, even in the first cycle, the response may be influenced by other factors, especially by increased manure.

We are finding examples on estates of dieldrin-sprayed fields in which the second-year increase in yield, compared with previous cycles is extremely good (*e.g.* over 40%) and rather more than we would expect purely from borer control. In some cases it has been the policy to increase the manure by 10% or 20% irrespective of yield. In these cases, if borer has been the factor limiting the yield response to increased manure, we *may* be getting an improved response to the increase, additional to the effect of borer control *per se*.

In some other cases where it has not been the policy to increase the manure except in proportion to the crop, I believe things may work as follows. We get initially an increased yield in the second year due to borer control, and the estate gives more manure in proportion. The response to this increase of manure is better because of borer control. This may push up the yield further and stimulate another increase of manure to which the response may also be good. This gradual increase of manure in proportion to the response of the crop is of course no more than what has been happening over the years on many estates where the response is good. Control of the borer may enable us to do the same thing on many fields where the response has not been good, or to improve it where it has been fair, if in fact the borer has been the key limiting factor on those fields.

Evidence on this, of course, is in the early stages, but on many mid-country and low-country estates we may get much more out of borer control than the immediate and direct effects.

**Poor fields**

I have pointed out that the heaviest infestations of the borer usually occur in the better fields, usually high-jat fields which probably already give a fair yield in response to fairly liberal manuring. These fields tend to respond well after control of the borer.

There are, however, many fields in the mid-country with very poor yields based on poor bushes, often low-jat, with a lot of vacancies. These fields usually carry only low infestation and current attack. Possibly many of them in the past gave better yields but the evidence suggests that Shot-hole Borer and the secondary effects have progressively reduced them to a poor state in which they now support only mild infestations of the borer. We can come to the point where the secondary effects are more important than the pest itself which originally caused this condition.

We cannot reasonably expect that these fields will respond so quickly to borer control or that the response to manure will be so much improved. Recovery from the accumulated damage of many cycles is likely to be a slow business. If the fields are not so bad that replanting provides the only real answer, dieldrin spraying may give an economic return, and certainly it provides a desirable prerequisite for improving such fields.

If it can be successfully done, infilling of the vacancies can improve matters a lot. It appears that, so far, few planters in the mid-country and low-country have carried out infilling successfully on any scale. Dieldrin spraying provides the means to protect supplies from early borer attack, which has been one factor in survival, but experiments are required to see how we can best cope with competition from the older plants and other factors.

Resting of the poorer fields can prove to be very beneficial, especially if the borer has been controlled, and the consequent improvement in the frames by the next pruning quite astounding. Resting is not the popular practice it deserves to be, for obvious reasons when the crop is none too good; this is equivalent to putting some of your income into a savings account when the income is none too large. However, if, following large-scale dieldrin spraying on an estate, we get a substantial increase in crop it may prove more opportune to rest the poorer fields. Indeed, there have already been results from extensive spraying on estates where the intake of green leaf, in the second year after spraying, has been more than the factory can cope with; so that, until this could be remedied, resting of some fields was the logical answer. The long-term benefits are likely to be considerable.

**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. We have seen galleries even in green stems if they exceed a quarter of an inch in thickness—which on the more vigorous clones they will sometimes be.

How soon the attack starts on susceptible plants depends very much on sources of infestation. If a new clearing is isolated from infested mature tea, the borer will usually take longer to develop. Commonly the attack is noticed about 12-18 months after planting and is often really heavy by the third and fourth 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 bushes 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.

Because of the intensive programme of work on chemical control we have not been able to make a detailed study of the susceptibility of clones. However, most clones are susceptible, some more so than others. The relative susceptibility of clones exposed to attack in several places appears to vary widely *e.g.* on one site Clone A may be more markedly attacked than Clone B, and on another site vice-versa. The facts suggest that the (physiological) condition of the bushes as influenced by local conditions is a very important factor, over and above the genetical character, affecting the susceptibility to borer attack.

With an efficient chemical control for the borer, it would hardly seem justified to screen clonal material for resistance or tolerance to Shot-hole Borer, as is being done for Meadow Nematode (*Pratylenchus loosi* Loof) (Hutchinson, 1960). More widely-gathered information on the susceptibility of popular clones with the desired cultural characters would be worth having.

Young clearings which are not yet in plucking can be protected by spraying the frames at any time without pruning (*see* Cranham, 1961). On estates where early attack is common, it may well be wise to spray routinely soon after planting out, or even in the nursery just before planting out. This will prevent damage from the beginning, and the cost of the first spray will be small (*i.e.* employing a dilution of six pints or dieldrin 20% E.C. per 100 gallons, probably 25-30 gallons of spray fluid per acre will be sufficient for thorough spray coverage of young plants). The protective effect of this first spraying should last for 12-18 months. It must be strongly stressed that Tortrix can quickly defoliate very young plants, often with fatal results, so that it is especially necessary to keep it under control.

If the clearing is in plucking it will be necessary to rest it for at least two months after spraying to avoid dieldrin residues in made tea; the rest is also beneficial to the bushes.

If the foliage hides the frames it will be more convenient to spray after pruning but great caution should be exercised when deciding whether to prune. If the bushes are severely damaged it will often be beter to cut away only the side branches to facilitate spraying. After the bushes have recovered from the attack they will be in better shape for pruning.

**Points about dieldrin spraying**

The details of dieldrin spraying were given in the 1961 Tea Quarterly article. There are no substantial changes or innovations in technique and I wish here only to stress a few points.

Purely from the point of view of insect control, the ideal time to apply dieldrin would probably be when the attack is starting to build up, say 9-15 months after pruning; but the time between pruning and bud-break was chosen for other important reasons. Firstly, dieldrin residues in made tea must be avoided. It is one of the most persistent insecticides and in practical terms the amount allowed in made tea is NIL, so that even trace contamination of the flush, coincident on spraying the frames of tea in plucking, would be serious. Even if we spray only the frames of bushes in full foliage it is necessary to rest for a minimum of eight weeks after spraying.

Secondly, it is usually so much easier, after pruning, to obtain good spray coverage of the bush frames. Although it is possible to spray the frames of thin tea in full foliage, it would be very difficult on bushes with full 'skirts' of foliage.

Thirdly, we might get worse Tortrix trouble by spraying bushes in full foliage, and it will tend to be worse if we rest the tea after spraying.

The chief practical disadvantage of spraying after pruning is that since we usually prune in wet seasons it is not always easy to find days when the frames are dry. Results indicate that so long as we spray on dry frames and the spray dries on before rain, control is not very much affected by even heavy rain soon after spraying; so that we can safely spray on dry mornings without fear of the consequence of heavy rain later in the day.

The results from trials and fields mist-blown with dieldrin in 1960-61 are generally about as good as the results from high-volume spraying with conventional knapsacks. The value of the technique described previously has been confirmed. This method enables us to get ahead much faster on the available dry days and effect a saving in labour costs, and other points about it have been given previously (Cranham, 1961).

The effect of including lime (Limbux) in the dieldrin spray has been studied in a detailed trial at Kataboola. There has so far been no reduction in the control obtained. This method has been used by several estates and the results appear to be generally good.

Some planters have altered their months of pruning to try to get better weather for dieldrin spraying, and some have altered even the type of pruning. We have not suggested this, nor do we now, since it could be very dangerous to attempt to give any general advice about such an individual matter. The length of the cycle, the time and the type of pruning, are all vitally important in relation to the health of the bushes, especially so in borer-attacked fields. The pruning should be culturally suitable and not altered to suit the spraying if there is a danger in so doing.

Having stressed this warning, I will venture to report that several estates have brought pruning forward to a month or two before the rainy season and found that recovery was at least as good and sometimes better.

From the point of view of borer control, there is no reason at all for making pruning harder or cleaner—it will not improve the degree of control obtained. In borer-attacked fields in the low and mid-country, the bush reserves are often marginal. It seems sensible when dieldrin is used for the first time, not to tax the reserves of the bushes. Experience suggests that, with the borer controlled, the bushes will usually recover fast and well from a light prune. We can anticipate that after another cycle the bushes, freed from borer attack, will be in better heart, so that it should be possible to commence a programme, not of hard, but of selective, pruning over successive cycles, to rebuild the frames more or less completely. It will not matter, if, due to a light prune, the first cycle after spraying has to be shorter than you may consider desirable. This is only the first phase, and the possibilities which borer control may open up for running longer cycles than are possible in attacked fields can be approached gradually.

We do come across badly-attacked fields below 3,000 feet which are run for 3 or even 4-year cycles, even though the effect of borer damage is very pronounced in the third and fourth years. Some planters have decided to cut short such cycles, in order to bring the borer under control with less delay, and this would seem sensible. An alternative in thin tea, is to spray the frames without pruning and to rest the tea for a few months before pruning (with special care about Tortrix control). In one young field where this was tried the improvement in the frames and in the general vigour of the tea by the next pruning was very great. It resulted in a temporary loss of crop but this should be more than made up.

**Assessment of borer attack**

The following method is a simplification of the 'sample unit' method used by the T.R.I. which can easily be used by planters themselves. On a large estate with a bad shot-hole borer problem it might well be worth training an assistant to use it, both for estimating when spraying is likely to be worth while and for judging the results after spraying.

*Sample units*—Sample units of branch, cut to 4 inches in length, should be taken from 'new' wood that has been formed since the last pruning (the bark of new wood is striped until it ages). The wood of sample units should average about 3/8 inches, and be within the limits of ¼-inch to ½-inch in thickness (diameter); within these limits there should be no particular selection of units, which can be with or without side twigs (the latter are cut off).

*How to sample*—The sample should be taken more or less at random from bushes all over the field or plot—a minimum of 100 units from 100 different bushes. For a large field, four or more lots of 50 units from the different sections is better. Do not pick out bushes and branches because they look attacked; take any bushes and any branches quickly without selection.

*When to sample*—The peak of borer attack normally occurs between 18-21 months after pruning and consequently the samples are best taken at the end of the second year or at least between 18-30 months from pruning. Samples taken towards the end of a 3- or 4-year cycle can also give some idea of the previous peak of attack.

*Percentage of units with galleries*—Split each unit down the middle and count the number showing any galleries at all in the wood. This is *not* a count of the actual number of galleries, but of the number of units with galleries, whether a unit contains 1, 2, or 3 galleries or only part of one gallery.

We now have a figure of the 'percentage of units with galleries' (number per 100 units), which is a sound measure of the accumulated total of the attack.

Our knowledge of the yield increases and other benefits to be gained by controlling the borer is still in the early stages so that it is possible to give only a provisional assessment as a guide to the likelihood of when spraying is worth while. The following table summarises the provisional assessment for *mature tea:*—

**Degree of attack (after 24 months)**

**% of sample units with galleries**

| | | |
|---|---|---|
| 50–100% (heavy) | ... | spraying considered worth while |
| 25–50% (moderate) | ... | spraying probably worth while |
| 15–25% (light) | ... | spraying probably not worth while |
| Less than 15% (very light) | ... | spraying considered not worth while |

This assessment may well have to be modified in the light of further experience but it is useful at this stage to have some idea of what is a heavy and what is a light attack. If an estate is generally heavily attacked but with some fields lightly attacked; it may well be worth spraying the latter as well, in order to minimise reinfestation of sprayed areas. However the borer cannot be eliminated from an estate and it is fairly certain that the control of very light attacks is not economically justified.

The above assessment applies to mature tea, and on young new clearings, especially when there are long sappy branches, even a light incidence (15–25%) can cause an excessive number of breakages, and this is best judged from the appearance in the field.

## Tortrix control

At present we have to regard control of the side effect of Tortrix infestation as an integral part of shot-hole-borer control.

Detailed advice on DDT spraying has been given previously (Cranham, 1991) and remains the same except for the following points:—

1. Recent work enables us to give a revised recommendation for the use of DDT so that it can be used on tea in plucking without losing crop:—DDT will not taint or affect quality if there is a one-week interval between spraying and plucking. Nevertheless, in order to minimise DDT residues if you pluck after one week, you should bulk the tea from sprayed areas with ten times as much unsprayed leaf. If such bulking is not possible allow a two-week interval between spraying and plucking either by discarding one plucking round or by resting the tea for one round.

2. DDT will sometimes increase the numbers of Red Spider and Scarlet Mite on tea. Full details for the use of Dipterex, as an alternative insecticide that does not increase the numbers of these mites, have been published in the Tea Quarterly (Cranham, Ranaweera and Rajapakse, 1962).

In districts where Red Spider is not prevalent, the risk of a mite build-up is small especially when spraying is done in the wet weather or with the monsoon one or two months ahead. The maximum risk occurs when spraying is done at the beginning of the dry weather. Wider estate experience has recently shown thas Dipterex will generally give satisfactory control but is not so persistent in effect at DDT, and the latter is preferable where there is little risk of a mite build-up.

Some estates have had an excessive amount of trouble with Tortrix and have had to spray two or three times over a period of up to six months after pruning. Some of the worse instances have occurred in low-country districts where natural outbreaks of Tortrix are unknown; in these cases it may be that initially the numbers of *Macrocentrus homonae* are extremely low and take more time to build up. It seems to be quite often found that attacks are worst in the first year when wide-scale spraying is started, and that subsequent experience is not so bad, which may result from a somewhat higher general incidence of Tortrix and consequently of the parasite. Experience also shows that Tortrix is often worse in low-jat tea, where control also appears to be more difficult. Hence, when a wide-scale programme of dieldrin spraying is started, it may be good policy to start with the high-jat fields (which also tend to respond better to control of the borer) and to leave the low-jat fields to last.

Our impression is that it is hardly ever necessary to spray for Tortrix more than twice if spraying is well done and properly timed. The first spray should come after tipping unless there is a build up before that; DDT should maintain control for 6-8 weeks if the initial control has been good. Some failures in Tortrix control were believed to be due to one or more of the following reasons:—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 can spread and get out of hand. For this reason also, spraying only the bad patches in a field is not to be recommended. A further complication is that dieldrin spraying of tea can also result in outbreaks of Tortrix in shade trees—especially *Albizzia moluccana* and *Gliricidia.* The shade trees can act as a source of heavy reinfestation of the tea beneath unless the pest can also be controlled in the shade trees. Trees up to 20 feet in height can be tackled by mist-blower applications.

We are sometimes asked whether we cannot make releases of the parasite *M. homonae* or prescribe measure to foster it. The surprising fact is that the parasite is always present and sooner or later resumes control; even when the incidence of it is low, the numbers present per acre are far higher than we could hope to release artificially. We know of no way of helping it to regain control more rapidly.

**New experiments with aldrin and Telodrin**

The insecticides aldrin and Telodrin have shown promise in short-term field trials for the control of Shot-hole Borer. The reduction in the numbers of the borer within the first few weeks was faster than with dieldrin and quite as good.

We have therefore arranged sufficient large-scale trials to evaluate these insecticides by comparison with dieldrin for (1) Tortrix side-effect and (2) duration of control. Because they give a good initial control it does not follow that they will give as good long-term control as dieldrin. The duration of control is probably influenced not only by the initial percentage mortality but also by residual effects and by the rate of reinfestation. Our knowledge of the last two factors is far from adequate.

Until we have proof of the long-term value of these materials, we would not suggest that estates experiment with them on their own account. We have arranged sufficient trials on mature tea, but we should be glad to arrange more trials on young new clearings if planters will contact us.

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