

THE CHEMICAL CONTROL OF SHOT-HOLE BORER WITH DIELDRIN; INTERIM REPORT ON ESTATE TRIALS, 1960-1961

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Shot-hole Borer (*Xyleborus fornicatus* Eichh.) is by far the most serious insect pest of tea in Ceylon. Provisional recommendations for chemical control measures, by spraying the insecticide dieldrin soon after pruning, have been made in a recent paper (Cranham 1961), in which reference was made to the large-scale trials which were started by estates in conjunction with the T.R.I. in 1960 and 1961.

The present paper is intended as an interim report on the progress of these trials, and it is not concerned with making recommendations. As mentioned previously, there is still doubt about the length of time for which control will be obtained under a wide variety of conditions and the present series of trials has not run for sufficiently long to reach conclusions on this point. Such trials must run for one pruning cycle of two or three years, or perhaps even beyond that.

Mention has been made previously (Gunn 1961, Cranham 1961) of the purpose of these trials: (1) to assess the effects of dieldrin on large plots of tea, both as regards the control of Shot-hole Borer and the side-effects, including outbreaks of Tea Tortrix (*Homona coffearia* Nietn.); and (2) to assess the results which could be obtained by estates in practice. For this reason, the spraying was done by each estate without supervision by us, but following advice on the type of spraying required.

It was decided that the area of each trial should be not less than about eight acres and preferably a whole field of 20 to 40 acres in size. The area would be divided into four quarters (plots), using natural boundaries, or marked rows of shade trees, to give roughly equal quarters. Two plots would be sprayed with dieldrin, two plots would be unsprayed. To test the use of DDT for the control of the Tortrix side-effect (Cranham 1961, 1961a), each dieldrin-sprayed plot would be sub-divided into two roughly equal sub-plots of which one would be sprayed with DDT at 2 lb. per acre (6 pints of 25% emulsifiable concentrate of DDT). There would thus be duplicate dieldrin-treated and untreated plots, and DDT-treated and untreated sub-plots of the dieldrin plots in each trial. Some variation on this design was allowed, to meet local circumstances and special needs. The assessment of shot-hole-borer control, the Tortrix side-effect, and any other side-effects, were carried out by us on routine periodic visits to the trials. Although it would have been desirable to have assessed the possible increases of yield resulting from controlling Shot-hole Borer with dieldrin, this was not practicable on these trials, and in many cases the essential pre-assessment of yield before treatment could not be carried out. The effect on yield is being studied separately in other trials not reported here.

The design of such trials does not permit the statistical analysis of each trial. However, the overriding requirement was that the plots should be large and so could not readily be more than duplicated at each site. Nevertheless, given sufficient sites, the whole series can be combined and analyzed as one large trial which should give a picture of results under a wide variety of conditions. It was clearly necessary to have as large a number of trials as could reasonably be handled, and to site them in the different districts suffering from Shot-hole Borer.

Alternatively, we might have confined our work to well-replicated small-plot trials. Such trials might well produce results in which highly significant differences appeared in the statistical analysis; nevertheless the results might be unrepresentative of what could be achieved generally, and—more important—would be likely to be unsound in relation to the results to be obtained from spraying whole fields. That is to say, the duration of control of the borer on large plots may be better, and the intensity of the Tortrix side-effect also much greater.

In all, fifteen trials were started between June 1960 and June 1961, and these give comparisons between dieldrin-sprayed and unsprayed plots in the same field. Of these, ten trials have run for about twelve months or more and are reported in this paper. In addition, three other trials, which did not include unsprayed areas, were carried out to study the value of DDT in the control of Tortrix.

Some variation has occurred in the treatments applied. When these trials were planned, Judenko (1960) had already shown that doses of dieldrin down to 1.1 lb. per acre usually gave good results when applied to dry bark on the basal parts of tea in plucking. It did not follow that this minimal dose was the best dose on which to standardize for post-pruning applications. Accordingly, in the first four trials, we planned to test 1.5 lb and 3 lb of dieldrin per acre. Later in 1960, it had become clear from the results of sampling fields sprayed by estates in 1958 and 1959 that the lower dose of 1.5 lb per acre could be expected to perform well when sprayed on dry bark, and that the higher dose, apart from the extra cost, might induce worse Tortrix outbreaks. From this time on, therefore, we used 1.5 lb dieldrin per acre, either as two spraying rounds of three pints of 'Dieldrex' or one round of six pints of 'Dieldrex', each round in 70–100 gallons of water per acre. Messrs Shell Co. of Ceylon Ltd., supply two emulsifiable concentrates of dieldrin, called 'Dieldrex 20' and 'Dieldrex Extra'. Each contains 2 lb of dieldrin per Imperial gallon and the latter formulation contains an additional resin.

There are reasons for using two or more spraying rounds of a chemical instead of one spraying round if the persistence required for control is greater than the persistence of effect attained, or if in practice two rounds can be expected to give better spray coverage than one round. In fact, evidence has accumulated of an extraordinary persistence of effect from dieldrin; and in practice it was much easier to find one dry spell of weather for spraying dieldrin than to find two such dry periods. Our standard application has therefore become one thorough spraying round of six pints of 'Dieldrex' per acre. This has been arrived at empirically, but when we consider the length of time for which trials must run to yield results, there is at present no alternative to an empirical basis.

In late 1960, our interest was aroused in the possibilities of applying dieldrin in a much smaller volume of water by knapsack mist-blowers—a method which would have several advantages over the tedious applications of 100 gallons of spray fluid per acre. Plots treated by this method were included in two of the trials reported here, No. 8 and No. 10. The suggestions on mist-blowing dieldrin given in a recent paper (Cranham 1961) represent a technique worked out after trials No. 8 and No. 10 had been carried out.

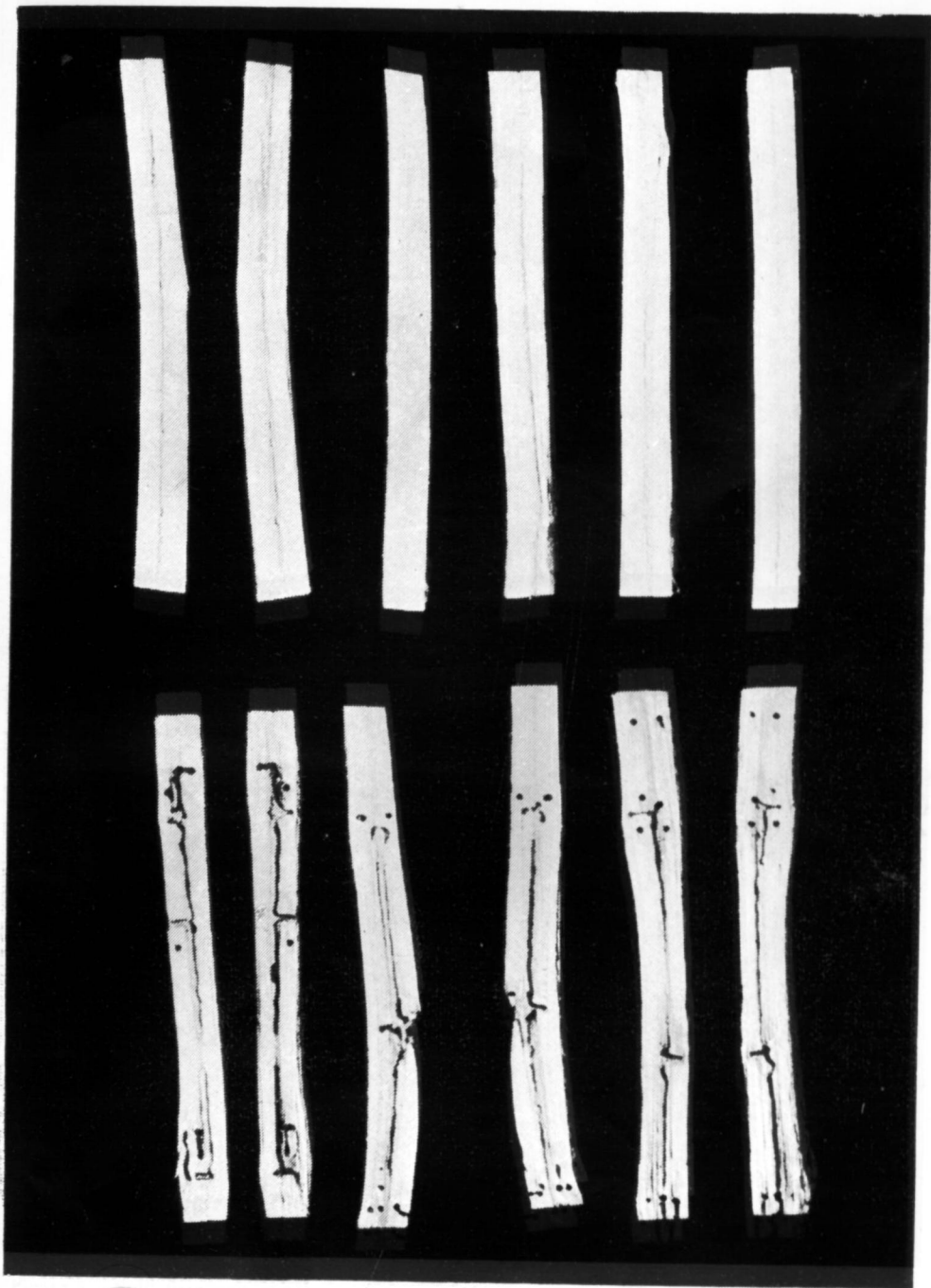


Figure 1. Split four-inch sample units from dieldrin-sprayed bushes (top) and unsprayed bushes (bottom) at two years after spraying. Note the borer galleries and the difference in colour of the wood which looks much older in the infested units.

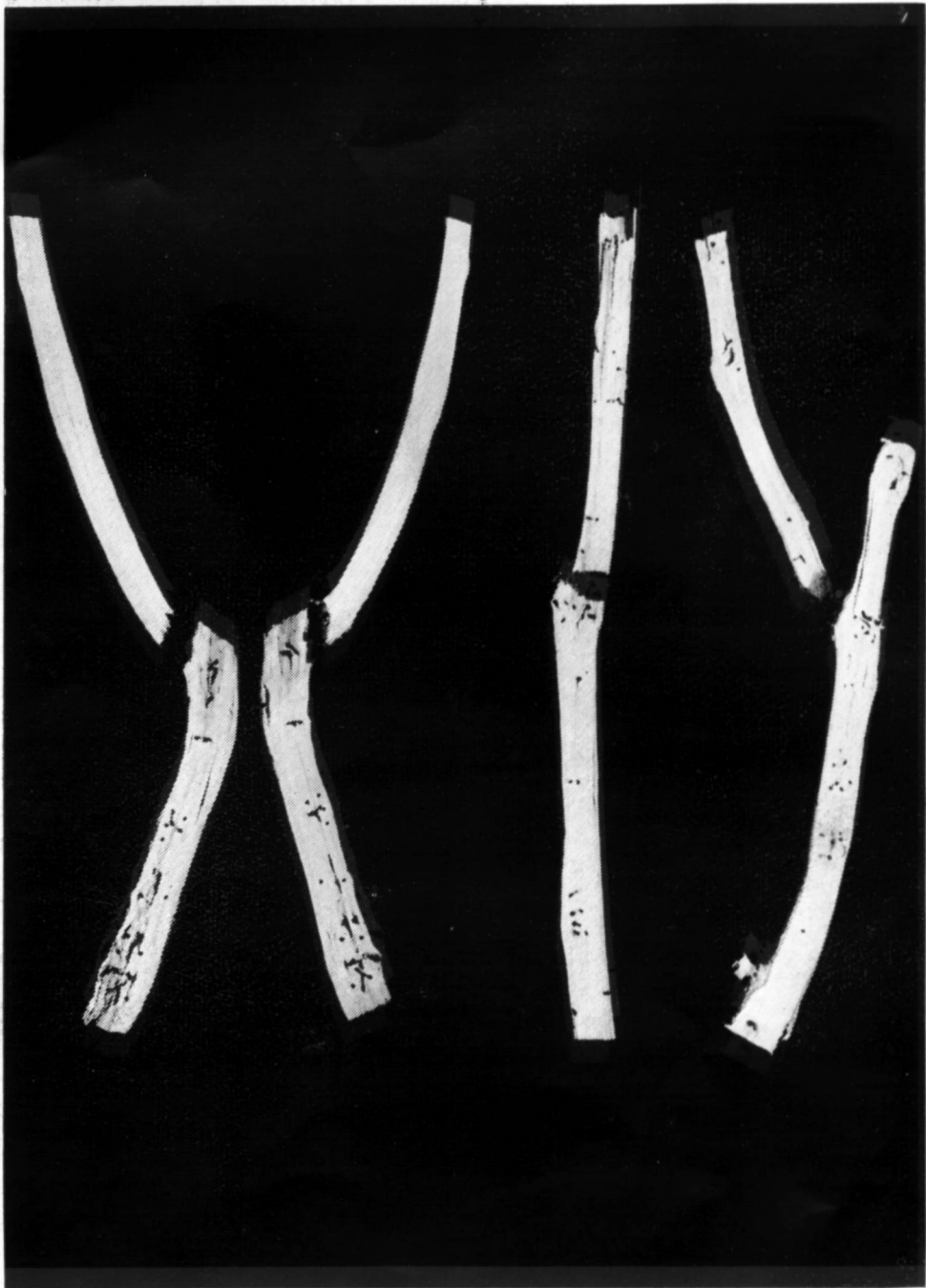


Figure 2. Split branches from dieldrin-sprayed bushes (left) and unsprayed bushes (right) at two years after spraying. The junction of the new wood (growth of the present pruning cycle) with old wood (of the previous pruning cycle) has been marked in ink. Note that old galleries occur in old wood in both cases but the effect of spraying is to reduce infestation and galleries being made in the new wood.

A possible alternative insecticide was included in one trial (No. 6). This was the formulation 'Gammalin 20' (Imperial Chemical Industries (Export) Ltd.) containing 20% of lindane.

Assessment of Shot-hole-borer Infestation and Attack

Judenko (1958) has previously described a method of sampling Shot-hole Borer by taking 'standard units' of wood which he defined as 'a piece of live branch, four inches long, 6/16th of an inch in diameter at base and top, and free of any secondary branch or green shoot'. Investigations by us (Cranham, 1962) have shown that it is advantageous to take less stringently selected 4" sample units of branches, falling within the wider range of 5/16th to 7/16 inches in thickness, which may or may not have side branches and twigs. This wood represents a large part of the wood that contains active shot-hole-borer infestation; and soon after pruning, when the new wood has not yet attained a thickness of 5/16th of an inch, wood is accepted that is even only a quarter of an inch thick. Wood thinner than this does not contain galleries. By this method, there is very little selection involved; most new wood that is likely to contain infestation is accepted in the sample. These units will be referred to as 'sample units' (Figure 1).

In sampling the plots of these trials, one sample unit is taken from each of a 100 bushes. The bushes are taken freely without conscious selection to give a more or less systematic coverage of the plot. Collection is usually done by a team of three men in each plot. A method of truly random collection of branches from a random sample of bushes would be so tedious as to be unworkable.

In each case, the sample units are brought to the laboratory where they are split and carefully dissected to assess the number of borer galleries (open and healed), and the numbers of eggs, larvae, pupae, and adults, of the borer, here termed the infestation.

Pruning usually removes much of the wood that contains live Shot-hole Borer but a proportion of the population usually survives in the younger wood left on the bush frames. At this stage, there are usually far more empty galleries than beetles. In the months after pruning, the beetle population usually declines, often markedly, and it is not until new growth has produced wood of a thickness of a quarter of an inch or more, and the female beetles can make galleries in it and produce large broods, that the borer population again increases.

It should be noted that the entrances of galleries that have been vacated after use are often closed and healed over by the growth of the cambium, but the galleries remain internally. These galleries are evident on dissection of the old wood. The effect of spraying is greatly to reduce the formation of galleries and the number of beetles to be found in the new wood formed after pruning. Figure 2 compares split branches from sprayed and unsprayed plots at two years after spraying. Galleries, mostly healed but some still open, are found in the old wood of the previous pruning cycle in both sprayed and unsprayed bushes; but the new wood of the current cycle is free of galleries only in the sprayed sample. Hence, it will be clear that the effect of spraying can best be assessed by sampling new wood only; this cannot be done until the new wood is thick enough, usually six to nine months after pruning. In a sample taken after this time, the number of galleries in new wood is a measure of the accumulated attack. The number of beetles represents the attack going on at that time. Up to that time, the effect of dieldrin in reducing the numbers left in the pruned frames can be assessed by sampling the wood of the previous pruning cycle.

It has been shown by Gadd (1949) that the infestation reaches a peak usually 18 to 24 months after pruning; it then declines. The number of galleries increases cumulatively and cannot decline unless galleries heal up completely; if it happens at all, such healing must be rare. Thus, though we might expect a correlation between the number of occupied galleries and the infestation, we cannot expect to find a correlation between infestation and the total number of all galleries, open and closed. It is for few pests, however, that we have a measure of accumulated attack, which is given us in this instance by the total number of galleries.

In these trials, with a few exceptions, sampling was first carried out when the new wood was thick enough to support infestation and was repeated about every two months after that. The life-cycle of the borer lasts from forty to sixty days (Gadd, 1949a) and bi-monthly sampling seems to be an adequate frequency for the purpose of studying population trends.

Results (Shot-hole-borer control)

The results for each trial that has run for about one year or longer are given below. Some of the results are illustrated in the figures in the form of histograms. The infestation (*i.e.* the number of live beetles—all stages including eggs, larvae, pupae and adults) is shown by the fully shaded histograms, and the number of galleries is shown by the stippled histograms, all expressed per 100 sample units.

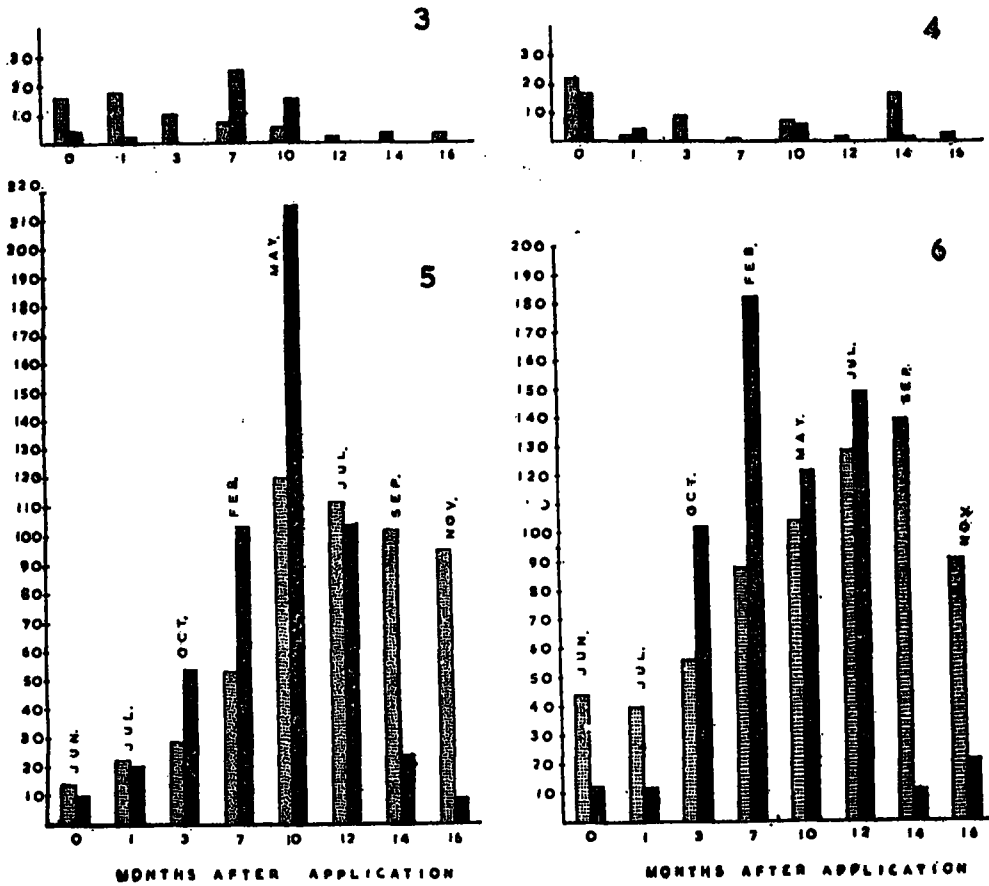
TRIAL No. 1. (Uva Ketawella Estate, 1956 new clearing; 8½ acres). This four-year-old new clearing was divided into four plots; Plots 1 and 3 were untreated controls. It was intended to compare on the treated plots two spraying rounds of 'Dieldrex' at 3 pints and two rounds of 6 pints per 100 gallons of water per acre. The plants were not large and the Superintendent found that only 60 gallons of the diluted spray per acre were needed for good coverage of the bush frames. Thus, the actual dosages per acre were 0.9 lb of dieldrin (Plot 2) and 1.8 lb dieldrin (Plot 4) instead of the 1.5 lb and 3 lb of dieldrin which was intended. Spraying was done in June and July 1960 in fine weather and on dry bark.

The results are given in Table 1 and Figures 3-6. The first sample recorded was taken just before treatment. Both treated plots have shown an excellent control up to 16 months from spraying. The untreated plots show a steady rise in the number of galleries and in infestation up to 10-12 months after spraying, then a sharp drop occurred in infestation. A severe drought was experienced by this estate during this period which must account for the drop in infestation, since it has been shown that adequate moisture in the wood is vital for the development and existence of Shot-hole Borer (Gadd, 1947; Judenko, 1956).

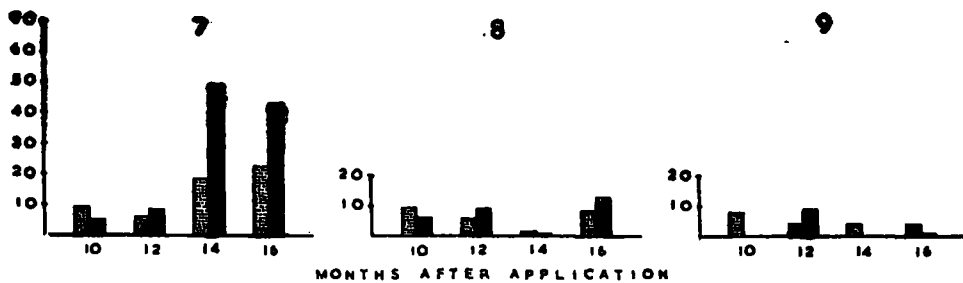
The rainfall data show that the drought began in May 1961 and lasted until September. June, July and August had very low monthly rainfalls of 1.00, 1.68 and 2.31 inches respectively. The sharp drop in infestation shows up clearly in the September samples when the estate had suffered three months of severe drought (Figs. 5 and 6). A high percentage of the bushes wilted in the drought and markedly more bushes wilted on the untreated plots. A count on August 30th showed 3,175 bushes wilted on the control plots and 1,616 bushes wilted on the sprayed plots.

TABLE 1.—*Trial No. 1. Uva Ketawella 1956 new clearing. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION									
			0	1	3	7	10	12	14	16		
1	Untreated	Galleries Infestation	18 —	22 20	28 54	54 104	125 215	112 104	102 23	95 8		
2	'Dieldrex 20', 0.9 lb dieldrin per acre	Galleries Infestation	16 —	18 2	10 0	7 25	6 15	2 0	3 0	3 0		
3	Untreated	Galleries Infestation	44 —	40 6	56 102	88 182	104 122	129 148	138 11	91 21		
4	'Dieldrex—20', 1.8 lb dieldrin per acre	Galleries Infestation	22 —	2 4	8 0	1 0	7 6	1 0	17 1	3 0		



Figures 3-6. Trial No. 1, Uva Ketawella 1956 new clearing. The fully shaded histograms represent infestation and the stippled histograms represent the number of galleries per 100 sample units from dieldrin-treated plots No. 2 and No. 4 (Figures 3 and 4) and untreated plots No. 1 and No. 3 (Figures 5 and 6).



Figures 7-9. Trial No. 2, Rothschild Group. The fully shaded histograms represent infestation and the stippled histograms represent the number of galleries per 100 sample units. Figure 7—unsprayed plots (avg.). Figure 8—1.5 lb. dieldrin. Figure 9—3 lb. dieldrin.

TRIAL No. 2. (Rothschild Group, Field No. 17 T.V.Y; 7.2 acres). This relatively small area was also divided as four plots with similar treatments to Trial No. 1. In this case Plot No. 2 was given two spray rounds of 3 pints 'Dieldrex 20' in 70 gallons of water per acre, and Plot No. 4 two rounds of 6 pints in 70 gallons of water per acre. Spraying was done during the first half of July 1960. The results are shown in Table 2 and Figures 7, 8 and 9. The infestation was low up to 12 months after treatment. In the 14-month and 16-month samples there are appreciable differences in favour of the treated plots but the infestation is not yet high. It is premature to assume that there is a significant difference between the 1.5 lb-dieldrin plot (No. 2) and 3 lb-dieldrin plot (No. 4).

TABLE 2.—*Trial No. 2. Rothschild Group. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION			
			10	12	14	16
1	Untreated	Galleries	13	9	27	33
		Infestation	9	14	60	74
2	'Dieldrex—20', 3 pints twice	Galleries	9	6	2	8
		Infestation	6	9	1	17
3	Untreated	Galleries	5	3	9	11
		Infestation	1	2	37	11
4	'Dieldrex—20', 6 pints twice	Galleries	8	4	4	4
		Infestation	0	9	0	1

TRIAL No. 3. (Delta Group, South Field No. 10: 13 acres). This field was divided into four plots but the untreated plots were a continuous block and have been sampled as one plot. Plot 1 was given 2 rounds of 3 pints 'Dieldrex Extra' in 70 gallons of water per acre. Plot 2 received 2 rounds of 6 pints of 'Dieldrex Extra' in 70 gallons of water per acre. Spraying was done in September and October 1960. The results are given in Table 3.

TABLE 3.—*Trial No. 3. Delta Group. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION			
			8	10	12	14
1	'Dieldrex—Extra' 3 pints twice	Galleries	5	9	3	9
		Infestation	40	54	14	30
2	'Dieldrex—Extra' 6 pints twice	Galleries	10	9	5	11
		Infestation	26	2	5	16
3	Untreated	Galleries	1	2	5	14
		Infestation	0	0	25	56

In this trial the first counts showed a low level of infestation on the treated plots and none was detected on the untreated plot. The samples taken at 12 and 14 months after spraying show relatively small differences in favour of the treated plots but the infestation is still rather low on all plots. Conclusions would be premature.

TRIAL No. 4. (Balangoda Group, Field Pinnawella No. 5: 26 acres). The applications in this larger area of mature tea were as for the Delta and Rothschild Trials, *i.e.* Plot No. 1—two rounds of 3 pints of 'Dieldrex 20' in 100 gallons of water per acre; Plot No. 3—two rounds of 6 pints of 'Dieldrex 20' in 100 gallons of water per acre. Plots 1 and 3 were subdivided for DDT spraying on half of each plot and in this trial the sub-plots 1A and 1B, 3A and 3B were sampled separately for Shot-hole Borer.

TABLE 4.—*Trial No. 4. Balangoda Group. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION		
			10	12	14
1A	'Dieldrex—20', 3 pints twice	Galleries Infestation	2 2	9 12	12 64
1B	'Dieldrex—20', 3 pints twice	Galleries Infestation	1 10	3 9	3 27
2	Untreated 6 pints twice	Galleries Infestation	24 73	44 106	40 90
3A	'Dieldrex—20', 6 pints twice	Galleries Infestation	0 0	2 12	1 1
3B	'Dieldrex—20', 6 pints twice	Galleries Infestation	0 0	2 0	3 24
4	Untreated	Galleries Infestation	13 70	15 56	20 47

The results are given in Table 4. There were marked differences in favour of the treated plots at 10 months; and in the untreated plots the infestation of the new wood, as soon as it was thick enough to sustain borer galleries, was quite heavy for this stage from pruning. The differences have decreased as shown by the later samples at 12 and 14 months, and at 14 months the 3 lb plots show somewhat less infestation than the 1.5 lb plots. Future developments remain to be seen.

TRIAL No. 5. (Uva Ketawella Estate, Field No. 14a: 35 acres). In this trial, with the keen co-operation of the Superintendent, the opportunity was taken to compare the effect of (a) two spraying rounds of 3 pints of 'Dieldrex 20' in 80 gallons of water per acre with (b) one round of 6 pints of 'Dieldrex 20' in 80 gallons of water per acre. In addition, comparison was made with (c) two rounds of 3 pints applied by the method of spraying used by Dr Judenko (Judenko 1958), spraying only the basal parts of the frame to a height of 12" from the ground. Pre-pruning was carried out in this field at a height of 22 in., and the spraying was done after the pre-prune in August and September 1960, to the height of the prune in treatments (a) and (b). This trial, and part of Trial No. 10 (also at Uva Ketawella) were the only trials in which pre-pruning was practised.

The results are given in Table 5 and Figs. 10-12. All treated plots with the exception of Plot 5 have shown low levels of infestation up to 12 months from spraying. The high count in Plot No. 5 cannot be accounted for and, rather curiously, it appears to be getting less (Table 5). The untreated plots were rather heavily infested after one year.

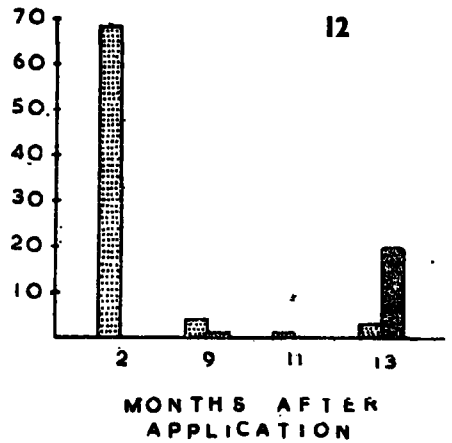
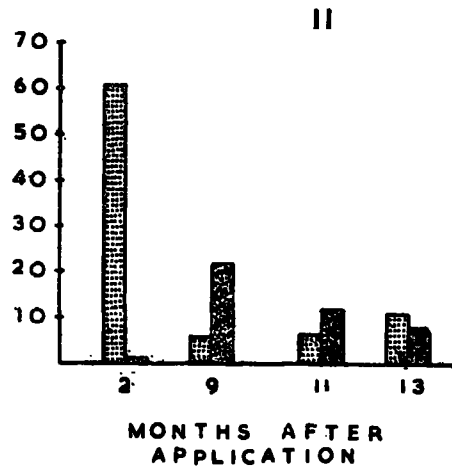
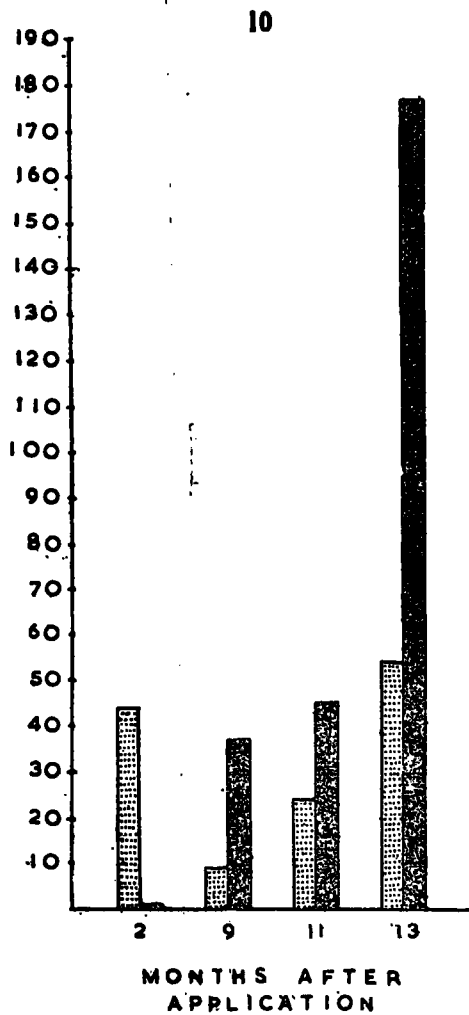
TABLE 5.—*Trial No. 5. Uva Ketawella No. 14A Field. Number of galleries and infestation for 100 sample units.*

No.	TREATMENT		MONTHS AFTER APPLICATION			
			3*	8	10	12
1	Untreated	Galleries	50	7	28	49
		Infestation	2	50	61	123
2	'Dieldrex—20', 3 pints twice.	Galleries	56	3	4	4
		Infestation	0	8	4	1
3	'Dieldrex—20', 6 pints once.	Galleries	56	3	1	4
		Infestation	0	2	0	16
4	'Dieldrex—20', 3 pints twice, to 12" only.	Galleries	60	3	0	1
		Infestation	6	0	0	1
5	'Dieldrex—20', 3 pints twice, to 12" only.	Galleries	59	18	19	38
		Infestation	0	81	30	31
6	'Dieldrex—20', 3 pints twice.	Galleries	68	0	5	2
		Infestation	0	0	13	0
7	'Dieldrex—20', 6 pints once.	Galleries	80	0	0	2
		Infestation	0	0	0	25
8	Untreated	Galleries	73	11	19	58
		Infestation	0	23	29	230

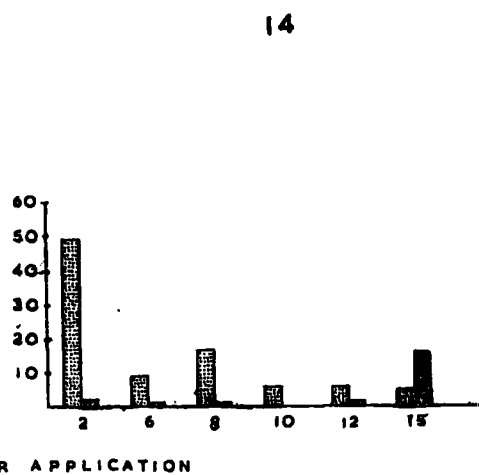
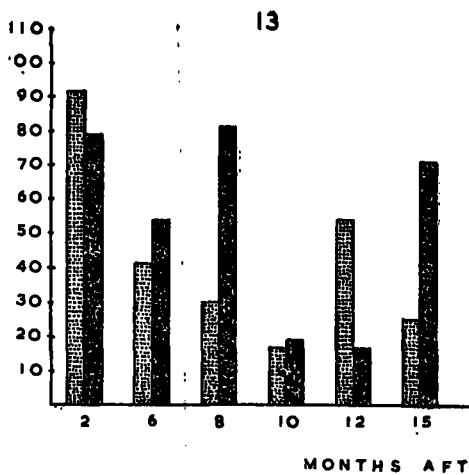
*Sampling from wood of previous pruning cycle.

TRIAL No. 6. (Imboolpittia Estate, 1957 and 1958 new clearings: 15 acres). In this trial a comparison was made between 'Dieldrex 20' and 'Gammalin 20' (20% gamma BHC) at equivalent rates of 1.5 lb. of the insecticide per acre. These two treatments were repeated, beside untreated control plots, on the 10-acre 1957 clearing and the 5-acre 1958 clearing. Spraying was done in July and August 1960.

The results in the two clearings are quite different. The results for the 1957 clearing are given in Table 6, and Figs. 13 and 14. The dieldrin-treated plot shows a steady control up to 12 months after spraying with the appearance of slightly more infestation at 15 months. The 'Gammalin' treated plot showed an infestation as heavy as the control six months after spraying, since when the numbers have declined. This clearing was pruned in May 1961 eight months after spraying which presumably accounts for the fall in infestation in the ten and twelve month samples.



Figures 10-12. Trial No. 5, Uva Ketawella Field No. 14A. The fully shaded histograms represent infestation and the stippled histograms represent the number of galleries per 100 sample units. Figure 10—untreated plots No. 1 and No. 8 (averages). Figure 11—Plots Nos. 2, 4, 5 and 6 (averages) treated with two rounds of 3 pints of Dieldrex. Figure 12—Plots Nos. 3 and 7 (averages) treated with one round of 6 pints of Dieldrex.



Figures 13-14. Trial No. 6, Imboolpittia 1957 new clearing. The fully shaded histograms represent infestation and the stippled histograms the number of galleries per 100 sample units. Figure 13—untreated control plot No. 3. Figure 14—1.5 lb dieldrin per acre.

TABLE 6.—*Trial No. 6. Imboolpittia 1957 new clearing—Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION					
			2	6	8	10	12	15
1	'Dieldrex—20', 3 pints twice.	Galleries Infestation	49 2	9 1	27 1	6 0	6 2	5 16
2	'Gammalin—20', 3 pints twice.	Galleries Infestation	67 10	27 38	26 115	16 8	22 17	8 4
3	Untreated	Galleries Infestation	92 79	41 54	30 82	17 19	54 17	25 71

The 1958 new clearing was pruned by the Superintendent quite soon after spraying (September 1960) and this showed a relatively poor effect of the dieldrin (Table 6A). It is thought that the pruning to 12" removed most of the sprayed bark so that the applications have had little effect.

TABLE 6A.—*Trial No. 6. Imboolpittia 1958 new clearing. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION					
			2	6	8	10	12	15
1	'Dieldrex—20', 3 pints twice.	Galleries Infestation	69 5	17 0	38 37	9 35	26 58	12 25
2	'Gammalin—20', 3 pints twice.	Galleries Infestation	33 14	22 9	9 33	4 5	11 12	6 18
3	Untreated	Galleries Infestation	59 16	63 24	26 84	6 41	10 7	10 4

TRIAL No. 7. (Choisy Estate, Field Chetty B, 20 acres). Both treated plots, Nos. 1 and 4, were given two applications of three pints of 'Dieldrex Extra' in 100 gallons of water per acre. The first round of spraying was done during a spell of very wet weather from the 5th to the 21st September 1960. The second spraying round was done on the 4th and 5th October in better weather. It is likely that a good deal of the spraying was not done on dry bush frames. The results are shown in Table 7, and for the eight and ten-month samples are rather confusing. On the twelve-month sample, Plot No. 1 compares favourable with the untreated plots but No. 4 does not show up well.

TABLE 7.—*Trial No. 7. Choisy Estate. Number of galleries and infestation per 100 sample units.*

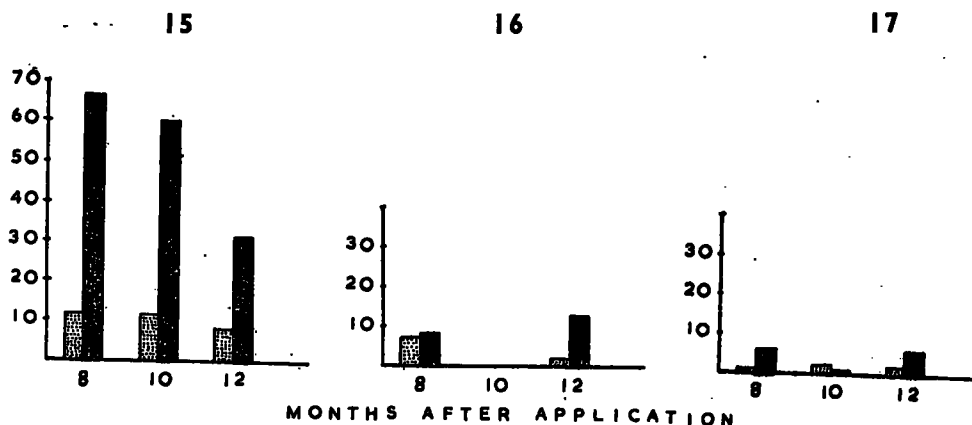
PLOT No.	TREATMENT		MONTHS AFTER APPLICATION		
			8	10	12
1	'Dieldrex-Extra', 3 pints twice.	Galleries	10	10	1
		Infestation	17	22	0
2	Untreated	Galleries	7	11	19
		Infestation	16	48	51
3	Untreated	Galleries	10	13	31
		Infestation	16	13	68
4	'Dieldrex-Extra', 3 pints twice.	Galleries	28	18	14
		Infestation	105	16	46

TRIAL No. 8. (Meddetenne Estate, Field Balapokuna No. 2A: 27 acres). The treatment proposed for plots No. 1 and No. 4 was two rounds of three pints Dieldrex 20 in 100 gallons of water per acre but the amounts actually applied were three pints in 129 gallons per acre on Plot No. 1 and 2.14 pints in about eighty gallons on Plot No. 4. The opportunity was also taken, due to the interest of the Superintendent, to try out low-volume mist-blowing on Plot No. 3. The treatment attempted was six pints of Dieldrex in six gallons of water per acre applied by knapsack mist-blower ('Motoblo' 1959 model). Due to a lack of control of the speed of the operator the treatment actually averaged about 4 pints of 'Dieldrex' in 4 gallons of water per acre; there was one application. The different plots in this field were pruned over a period of nearly two months and spraying was done from August to October 1960.

TABLE 8.—*Trial No. 8. Meddetenne Estate. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION		
			8	10	12
1	'Dieldrex—20', 3 pints twice.	Galleries	1	3	4
		Infestation	6	1	13
2	Untreated	Galleries	12	12	8
		Infestation	66	60	31
3	'Dieldrex—20', 4 pints once, low- volume.	Galleries	7	0	2
		Infestation	8	0	13
4	'Dieldrex—20', 2.1 pints twice.	Galleries	2	0	0
		Infestation	7	0	0

The results are given in Table 8 and in Figures 15, 16 and 17. Up to one year from spraying the infestation of all plots is rather low and the differences in favour of the treated plots are not large.



Figures 15-17. Trial No. 8, Meddetenne Estate. The fully shaded histograms represent infestation and the stippled histograms represent the number of galleries per 100 sample units. Figure 15—untreated plot No. 2. Figure 16—Plot No. 3, low-volume application, 1 lb. dieldrin per acre. Figure 17—Plots 1 and 4 (average); high-volume application.

TRIAL No. 9. (Meddecombra Group, Field Accramally No. 43A: 28 acres) Plots Nos. 1 and 3 were given two rounds of 3 pints of 'Dieldrex 20' in 70 gallons of water per acre in November and December 1960. The results are given in Table 9. The infestation has remained low on all plots up to 10½ months after spraying.

TABLE 9.—*Trial No. 9. Meddecombra Group. Number of Galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION		
			6	8	10½
A	'Dieldrex—20', 3 ints twice.	Galleries	1	0	0
		Infestation	21	0	0
B	Untreated	Galleries	1	4	1
		Infestation	0	14	1
C	Untreated	Galleries	1	6	6
		Infestation	1	24	6
D	'Dieldrex—20', 3 pints twice.	Galleries	0	0	0
		Infestation	0	0	0

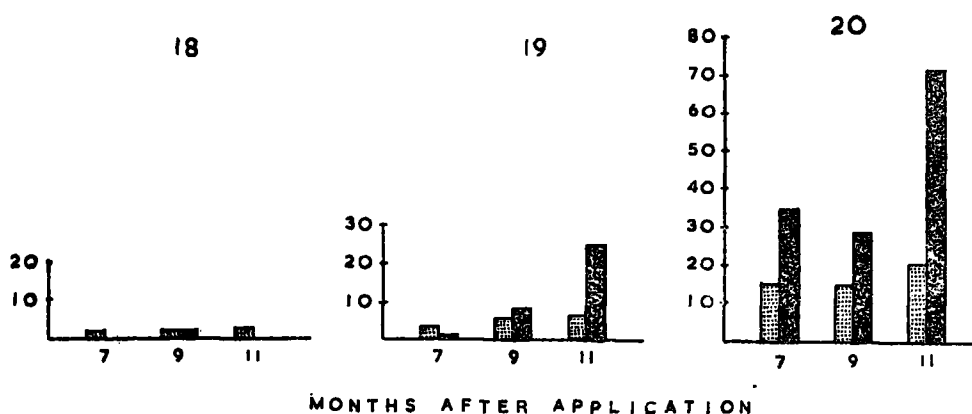
TRIAL No. 10. (Uva Ketawella Estate, Field No. 8: 20 acres). As with the Meddetenne trial the opportunity occurred in this trial to try low-volume applications. Since pre-pruning is usually carried out on this estate, the Superintendent wished to see whether this method of pruning or a high cut-across prune seemed better suited to mist-blower applications. Plots A (pre-pruned) and D (cut-across) were sub-divided and the sub-plots A1 and D1 were sprayed by knapsack mist-blower ('Motoblo' 1960 model) using six pints of 'Dieldrex Extra' in eight gallons of water per acre. Sub-plots A2 and D2 were unsprayed. Plot B was given two rounds of three pints 'Dieldrex Extra' in 90 gallons of water per acre. Plot C, as an experimental treatment which the Superintendent wished to try, was treated with 100 lb of 'Gammexane' dust (0.65% gamma B.H.C.) per acre applied to the soil.

The low-volume treatments were sprayed on dry bush frames but with 1.53 inches of rainfall following treatment the same day (November 11th). The high-volume treatment was done in drier weather.

TABLE 10.—*Trial No. 10. Uva Ketawella Estate, No. 8 Field. Number of galleries and infestation per 100 sample units.*

PLOT No.	TREATMENT		MONTHS AFTER APPLICATION		
			7	9	11
A1	'Dieldrex-Extra', 6 pints once, low-volume.	Galleries Infestation	2 0	10 9	6 20
A2	Untreated	Galleries Infestation	7 26	4 7	18 65
B	'Dieldrex-Extra', 3 pints twice, high-volume.	Galleries Infestation	2 0	2 2	3 0
C	Gammexane Dust, 100 lb per acre	Galleries Infestation	26 83	22 40	39 127
D1	'Dieldrex-Extra', 6 pints once, low-volume.	Galleries Infestation	3 2	2 7	8 31
D2	Untreated	Galleries Infestation	22 44	26 50	24 79

The results are given in Table 10. All treatments except C show a marked reduction in infestation compared with the untreated plots. The 11-month counts for the low-volume plots A1 and D1 are higher than the count for the high-volume plot B. The Gammexane plot C shows no control.



Figures 18-20. Trial No. 10, Uva Ketawella Field No. 8. The fully shaded histograms represent infestation and the stippled histograms represent the number of galleries per 100 sample units. Figure 18—High-volume application of 1.5 lb. dieldrin per acre. Figure 19—Low-volume application of 1.5 lb. dieldrin per acre. Figure 20—Untreated plots.

Discussion

There is marked evidence of control of Shot-hole Borer by dieldrin in most of the trials, notably in all three trials at Uva Ketawella, at Balangoda Group, Imboolpittia and Rothschild Estates. The only plots which show poor or no control are Plot No. 4 in the Choisy trial which is thought to be due to spraying on wet bark, and the 1958 new clearing at Imboolpittia, where pruning to twelve inches was done very soon after spraying. In the three remaining trials, at Delta Group, Meddecombra Group and Meddetenne Estate, the differences between treated and untreated plots are still quite small.

Table 11 and 12 summarise the data for infestation and galleries in the ten trials after about one year. The counts given here are for 12 months after spraying in all trials except No. 9 (10½ months) and No. 10 (11 months); they are the average figures for treated and untreated plots. Testing the null hypothesis that there is no difference between treated and untreated on the transformed (square root) data, we obtain values of 't' which indicate a very highly significant overall difference between treated and untreated plots for infestation and a highly significant difference for number of galleries.

Row 5 in both Tables 11 and 12 gives the percentage reduction in infestation and in number of galleries on the treated plots as compared with the untreated control plots (=100%) for each trial. This averages 74% for infestation and 67% for galleries but it will be seen that the percentage control is much better for those trials that have more infestation and galleries on the untreated plots, notably Trials Nos. 1, 4, 5 and 10. Three of these trials were at Uva Ketawella Estate, indicating an unusually rapid build-up of infestation of this estate. Trials Nos. 6 and 7 contained one plot each which shows poor control. In the remaining four trials, the infestation and attack after one year are still quite light and the facts would suggest that the percentage control should improve as the infestation of the untreated plots becomes heavier.

Statistical analysis of these data shows a highly significant difference in favour of dieldrin. This result is encouraging but not very meaningful. Of greater practical importance is the length of time for which dieldrin will maintain control of the borer by comparison with the untreated plots in each trial. This we cannot yet judge, and we also have to determine a criterion of control. We might reasonably consider that this consists in keeping the pest below a level which causes a loss of crop. An important step forward has been made by Judenko, Shanmugam and Hasselo (1962) in finding that, on the Hantane trial, there is a correlation between number of galleries (accumulated attack) and loss of crop. If further work confirms this relationship, we should be able to define control as keeping the number of galleries below a level, to be determined, which would be expected to cause an appreciable loss of crop.

We can then see, in each trial, for how long treatment is effective in keeping attack below this level. For this assessment, the number of galleries in new wood is the yardstick.

The trends in infestation are, however, also of vital importance. It is likely that we shall reach a stage when in the untreated plots the live infestation is declining after a peak in numbers, and on the treated plots it will have risen to a level to equal it. From this time on, the infestation of the untreated plots should continue to decline, and that of the treated plots *may* continue to rise. This again, it is too early to judge, but it is clear that the trials will provide invaluable data as a study in the population dynamics of Shot-hole Borer which will be more extensive than any attempted previously (cf. Gadd, 1949).

Although yield is not being assessed in these trials, differences in wood growth and the fullness of the plucking table can be assessed visually. Very marked differences have been apparent in the new clearings sprayed at Uva Ketawella and Imboolpittia. It is likely that the weight of prunings at the next pruning time will provide a useful measure of the growth of wood during the cycle. Yield and wood growth are positively correlated.

TABLE 11.—*Summary of infestation data for ten trials, one year after spraying.*

	AVERAGE INFESTATION PER 100 SAMPLE UNITS IN TRIAL NO.										Average all Trials
	1	2	3	4	5	6	7	8	9	10	
1. Untreated plots ...	126	8.0	25.0	81.0	176.5	37.5	59.5	31.0	3.5	72.0	62.00
2. Treated plots ...	0	4.5	9.5	8.3	12.3	20.5	23.0	8.7	0	17.0	10.38
3. Difference, d. ...	126	3.5	15.5	72.7	164.2	17.0	36.5	22.3	3.5	55.0	51.62
4. \sqrt{d}	11.22	1.87	3.94	8.53	12.82	4.12	6.04	4.72	1.87	7.42	6.26
5. Percent Control ...	100	44	62	90	93	45	61	72	100	76	74

Standard error (\sqrt{d})=0.9033. H_0 ; $t=6.93$ ($<P=0.001$)

TABLE 12.—*Summary of data on galleries for ten trials, one year after spraying.*

	AVERAGE NUMBER OF GALLERIES PER 100 SAMPLE UNITS IN TRIAL NO.										Average all Trials
	1	2	3	4	5	6	7	8	9	10	
1. Untreated plots ...	120.5	6.0	5.0	29.5	53.5	17.5	25.0	8.0	3.5	21.5	29.00
2. Treated plots ...	1.5	5.0	4.0	4.0	8.2	8.5	7.5	2.0	0	5.7	4.64
3. Difference, d. ...	119.0	1.0	1.0	25.5	45.3	9.0	17.5	6.0	3.5	15.8	24.36
4. \sqrt{d}	10.91	1.00	1.00	5.05	6.73	3.00	4.18	2.45	1.87	3.98	4.02
5. Percent control ...	99	17	20	76	75	51	70	75	100	73	67

Standard error (\sqrt{d})=0.9561. H_0 ; $t=4.201$ ($<P=0.01$)

The Tortrix Side-effect

ASSESSMENT

The assessment of the numbers of Tortrix larvae and pupae, and of the cocoons of *Macrocentrus*, involved the collection in cloth bags of all the Tortrix 'nests' on each bush of a sample of bushes in the plot. Generally, this sample comprised at least 100 bushes per plot taken in groups of 5-10 bushes (each collected separately) to give a systematic coverage of the plot, including the boundaries and the centre. The collected material was then examined in the laboratory and the numbers of (1) Tortrix larvae, (2) Tortrix pupae and (3) *Macrocentrus* cocoons were recorded. The percentage of the Tortrix larvae parasitized by *Macrocentrus* was estimated by dissecting only the larger larvae, of the fourth and fifth instar.

Assessment of the numbers of Tortrix larvae could not be carried out on all trials; a collecting team of several people was required. The numbers present cannot be estimated visually, since the number of nests present is not a good indication of the number of larvae present; there are many empty nests at later stages of the attack. A graded estimate of damage to the tea bushes can, however, be made visually and for this purpose we worked with three common categories of damage—light, moderate and heavy—and reserved two extra categories for the extreme conditions, namely very light and very heavy. The meanings of these categories are given below.

1. Very light damage—a few Tortrix nests to be seen on a small percentage of the bushes after some searching.
2. Light damage—Tortrix nests easily spotted without searching, few per bush and not on most bushes.
3. Moderate damage—Tortrix nests several per bush, on most bushes, but damage not severe enough seriously to hinder recovery from pruning or seriously to affect crop.
4. Heavy damage—damage on virtually all the bushes, and on some bushes severe enough seriously to hinder recovery from pruning or seriously to affect crop.
5. Very heavy damage—severe defoliation widespread; recovery from pruning stopped or the field out of production.

In addition the words 'patchy' or 'local' may be used to describe attacks that are not fairly general in a whole field or plot.

Observations suggest that there is no close relationship between the seriousness of Tortrix damage and the numbers occurring. The stage or recovery from pruning at which the attack occurs, and the duration of the attack, are factors which greatly influence the effect of the damage done by a given number of larvae. Thus, ten larvae per bush occurring on bushes within a month after bud-break can seriously inhibit recovery, whereas the same number on bushes in plucking, or even after tipping, will not greatly affect the formation of the plucking table or the crop. An important practical criterion in the practical assessment of damage during recovery from pruning is whether or not the bushes are 'filling out' despite the attack; this distinction separates the categories of moderate and heavy damage.

RESULTS OF TRIALS

1. Fourteen trials contained plots treated at 1.5 lb dieldrin per acre applied either as one spray round of six pints 'Dieldrex' per acre or two spray rounds of three pints of 'Dieldrex'. For the purpose of judging the Tortrix side-effect, no distinction is drawn here between one or two rounds.

On the plots of these trials treated with 1.5 lb dieldrin (no DDT), there were cases of moderate damage in seven of the trials, light damage in three trials and very light damage in four trials. There were no cases of heavy damage except on very local areas of the plots. Observations and counts on some of these trials will be described below.

2. In four of these trials there were also plots treated with 3 lb dieldrin at two spray rounds of six pints Dieldrex with and without DDT. Of the plots without DDT, one experienced a heavy attack, two had moderate damage and the remaining one a very light attack. On two of the trials there was an appreciably worse attack on the 3 lb dieldrin plots than on the 1.5 lb. dieldrin plots.

3. It is not felt that the trials gave a fair comparison between the plots sprayed with dieldrin only and the plots sprayed with dieldrin and DDT. It is known from observations and reports on the estate use of DDT on whole fields that the results in control of Tortrix are in fact generally good. However, on plots of the size used in these trials, adjacent to infested plots, the dispersal of Tortrix was sufficiently rapid to reduce quickly or obliterate differences in infestation which were initially in favour of the DDT-sprayed plots.

Further work on the rate and range of dispersal of Tortrix is desirable, but there is strong evidence already that this insect disperses rapidly over considerable distances (Cranham 1962). Hence, the results obtained in these trials are not a fair indication of the value of DDT when used on whole fields. Once this point was realised, two later trials were modified so that the plots with and without DDT were half fields, but there was no more than a very light attack in these trials.

4. We wished also to study the effect of different times of application for the DDT spray, *i.e.* whether it can be effectively applied mixed with the dieldrin spray (on clean and cut-across pruning) or separately soon afterwards, or whether it was better applied later (just after tipping), when a build-up of Tortrix usually occurs. Again, the results obtained with the earlier timings of DDT are not considered a fair picture of what would happen on whole fields, because of the rapid dispersal of Tortrix from plot to plot. The very fact that this occurred, however, points to the later application of DDT as being preferable.

We give below results and observations from the individual trials. Only four trials with moderate attacks were sampled in detail on repeated occasions, and these all happen to have been trials in which the DDT was applied with, or about two weeks after, the dieldrin spray.

TRIAL No. 4. (Balangoda Group, Pinnawella Field No. 5). The dieldrin-sprayed plots were of eight acres each and the two untreated control plots were of five acres. Dieldrin spraying was done between July 11th and August 5th 1960 and the DDT spraying on sub-plots 1B and 3B ten days later on August 15th-16th (six pints of 'Didimac 25'* in 100 gallons of water per acre).

*ex Imperial Chemical Industries (Export) Ltd.

Tortrix attack was first noted by the estate in late November nearly four months after dieldrin spraying, and the first sampling was carried out on December 5th. The results of this and later samplings are given in Table 13.

TABLE 13.—*Balangoda Group (Pinnawella No. 5) trial. Number of Tortrix larvae and pupae per 100 bushes (percentage parasitism by Macrocentrus in brackets*)*.

Plot No.	Acreage	Treatment	NUMBER OF TORTRIX (% Parasitism) SAMPLED ON			
			Dec. 5	Jan. 10	Feb. 18	March 21
1A	4	Dieldrin 3 lb	1009(0.8%)	1339(6%)	623(29%)	169(41%)
1B	4	Dieldrin 3 lb + DDT	125(0%)	633(6%)	340(20%)	68(47%)
2	5	Untreated	23(42%)	47(64%)	53(53%)	22(70%)
3A	4	Dieldrin 1.5 lb	280(6%)	257(6%)	90(50%)	27(80%)
3B	4	Dieldrin 1.5 lb + DDT	88(30%)	186(10%)	50(60%)	16(3/6)
4	5	Untreated	13(4/7)	9(2/3)	14(2/3)	5(1/2)

*Where only 10 larvae or fewer were obtainable for dissection the actual numbers are entered e.g. (3/7) means three larvae out of seven were parasitized.

Plots 1A and 1B, sprayed with two rounds of six pints of Dieldrex (3 lb per acre) suffered worse attack than Plot 3A and 3B which received two rounds of three pints of Dieldrex (1.5 lb per acre). On December 5th, damage was heavy on Plot 1A and, as shown in Table 13, there were about eight times as many Tortrix on this plot (no DDT) as on Plot 1B (DDT). A less marked difference occurred between Plots 3A and 3B. Plots 1A and 1B were sampled at sixteen points and on the first sampling there proved to be more Tortrix on the side of 1B adjacent to 1A, suggesting that Tortrix was migrating across. The gradient of infestation across Plot 1B and the difference in count between Plots 1A and 1B were greatly reduced on the next sampling in January.

The untreated plots were never more than lightly infested; here the activities of *Macrocentrus* were sufficient to prevent more than a light infestation developing. This was true, with minor or local exceptions, of all the trials. In some cases there did in fact appear to be an 'overflow' of Tortrix resulting in a more marked infestation just on the edge of an untreated plot where it adjoined a dieldrin-sprayed and infested area. This resulted in a local increase in Tortrix and consequently of *Macrocentrus*, thus providing greater numbers of the parasite available at the boundaries of the sprayed areas, which could in due course migrate into the sprayed area.

On the first sampling (Dec. 5th), no *Macrocentrus* were found in Plot 1B; three cocoons and one parasitized larva were found in Plot 1A near the edges of the plot bordering tea or jungle. On the second sampling (Jan. 10th) sixteen cocoons and seventeen parasitized Tortrix larvae were found in both plots, fairly widely scattered in the plots. This would suggest that as soon as *Macrocentrus* is able to survive on a sprayed area, it is quickly dispersed over it.

Table 13 shows the decline in numbers of Tortrix following the peak numbers of early January and the rise in percentage parasitism on the sprayed plots. By early April there were few Tortrix and fresh damage was negligible on all plots; there was no resurgence of Tortrix after that time. Moderately bad attack had persisted for about two months longer on the 3 lb dieldrin plots than on the 1.5 lb dieldrin plots, and even on March 21st the percentage parasitism on these plots was still rather low, about 50%. From this level it appeared to achieve complete control in a month or less.

TRIAL No. 6. (Imboolpittia Estate, new clearings).

The plots of this trial were smaller than at Balangoda. Plots 1A and 1B of the 1957 new clearing were 1.75 acres each in size and were surrounded by unsprayed tea. The incidence of Tortrix on these plots was heavier than on the dieldrin plots of the 1958 new clearing, and the latter were not sampled in detail.

On plots 1A and 1B, Tortrix became apparent less than two months after dieldrin spraying and even on the first sampling *Macrocentrus* was abundant all over the plots. There was again, like the Balangoda trial, an indication that Tortrix was migrating from the dieldrin-only Plot 1A to the dieldrin-DDT Plot 1B, obscuring initial differences. Table 14 records the counts made.

TABLE 14.—*Imboolpittia* 1957 New Clearing Trial: number of Tortrix larvae and pupae per 100 bushes. (Percentage parasitism by *Macrocentrus* in brackets).

Plot No.	Acreage	Treatment	NUMBER OF TORTRIX (% Parasitism) SAMPLED ON		
			Nov. 3	Nov. 22	Jan. 1
1A	1.75	Dieldrin 1.5 lb	190(84%)	140(87%)	33(7/10)
1B	1.75	Dieldrin 1.5 lb + DDT	56(6/6)	130(73%)	26(4/9)
2	5.	Untreated	3(—*)	3(1/1)	3(2/2)

*No mature larvae for dissection.

As would be expected from the quick re-establishment of *Macrocentrus*, the attack quickly petered out and the appearance of the bushes was much improved even by the second sampling date, November 22nd. It is probable that the peak in Tortrix numbers occurred before the first sampling.

TRIAL No. 14. (Attempettia Estate trial).

This trial was arranged purely to compare the effect on Tortrix of dieldrin alone (Plots 2 and 4) against dieldrin and DDT applied together (Plots 1 and 3), and no untreated plots were left. Tortrix attack was somewhat worse on the paired Plots 1 and 2 and was sampled on these plots only in detail. Table 15 records the counts made on this trial.

TABLE 15.—*Attempettia Estate trial: number of Tortrix larvae and pupae per 100 bushes (percentage parasitism by Macrocentrus in brackets).*

Plot No.	Acreage	Treatment	NUMBER OF TORTRIX (% Parasitism) SAMPLED ON				
			May 19	June 19	July 17	Aug. 11	Sept. 21
1.	6	Dieldrin 1.5 lb + DDT	96(23%)	107(29%)	296(53%)	100(63%)	11(5/9)
2.	6	Dieldrin 1.5 lb	146(11%)	288(16%)	323(50%)	92(71%)	9(5/9)

The attack developed by May, three months after the first dieldrin spray (two rounds of 3 pints per acre) and just prior to tipping. Even at this stage, the parasitized Tortrix larvae found were scattered over the plots and not confined to the edges. Initially, the visible damage was somewhat worse in the dieldrin-only plot than in the dieldrin-DDT plot but both plots reached similar peak numbers of Tortrix by July.

Visible damage in July was moderately bad, except for about one acre of Plot 2 which was suffering heavy damage and was resprayed with DDT by the estate. At this stage, parasitism had reached about 50% and numbers of Tortrix then declined, until by September they were negligible.

TRIAL No. 11. (Kataboola Group, Middle Division No. 4. Field)

This trial was arranged for the same reason as the Attempettia trial and there was no untreated plot. In order to make the plots as large as possible, the available area of 14½ acres was divided into two plots only: Plot 1, dieldrin 1.5 lb only (7 acres), and Plot 2, dieldrin 1.5 lb with DDT (7½ acres). Spraying was done in two rounds which were both completed in December, 1960. The counts are recorded in Table 16.

TABLE 16.—*Kataboola Field No. 4 trial: number of Tortrix larvae and pupae per 100 bushes (percentage parasitism by Macrocentrus in brackets).*

Plot No.	Acreage	Treatment	NUMBER OF TORTRIX (percent parasitism) SAMPLED ON		
			March 16	May 5	June 6
1	7	Dieldrin 1.5 lb	367(53%)	187(57%)	11(77%)
2	7.5	Dieldrin 1.5 lb + DDT	102(48%)	92(62%)	8(7/8)

Tortrix attack developed in early March, two and a half months after the first spraying round. The plots were sampled intensively at 47 sub-plots on nine lines of survey. The attack was initially heavier on Plot 1 and at the edge of Plot 2 adjacent to Plot 1. Afterwards the attack was fairly general on Plot 2 although it remained lighter than on Plot 1.

In the first sampling three months after spraying, *Macrocentrus* was already plentiful, about 50%, and distributed more or less evenly all over both plots. From mid-March the numbers of Tortrix declined and the attack faded out in late May.

The Re-establishment of *Macrocentrus*

Dieldrin spraying has the effect of greatly reducing or even eliminating *Macrocentrus* temporarily in areas sprayed with it. The evidence points to elimination in some cases. In any event, the number of Tortrix on most unsprayed tea is extremely low and consequently the number of *Macrocentrus* must be very small. Nevertheless, wherever Tortrix develops on sprayed areas, *Macrocentrus* appears. This has proved to be the case in fifteen trials of the present series 1960/1961 and on all other dieldrin-sprayed fields which have been examined. Hence it would appear that *Macrocentrus* is always available, although the rate at which it resumes control varies greatly from place to place. Observations on the present trials give some idea of the chronology of re-establishment of *Macrocentrus*.

TABLE 17.—*Re-establishment of Macrocentrus on seven trials which experienced moderate Tortrix damage on the 1.5 lb-dieldrin plots.*

Trial (Number)	Month sprayed (mean date)	Tortrix outbreaks started (month); percent parasitism found in first sample.	Outbreak lasted until (month); duration of outbreak; percent parasitism in last sample, if known.
No. 4, Balangoda Group	Late July 1960	Late November (after 4 months). Dec. 5th—6%	Mid-February 1961 (2½ months) Feb. 18th—60%
No. 6, Imboolpittia Estate	August 1960	November (after 3 months) Nov. 3rd—84%	December (1 month) Nov. 22nd—87%
No. 2, Rothschild Group	July 1960	November (after 4 months) Dec. 23rd—14%	February 1961 (3 months) % parasitism high.
No. 5, Uva Ketawella Estate	August 1960	Late November (after 3 months) Dec. 12th—5%.	February 1961 (3 months, then resprayed with DDT.)
No. 10, Uva Ketawella Estate	November 1960	Late February 1961 (after 3 months). Feb. 28th—0%	May 1961 (3 months) parasitism still rather low, Tortrix reduced by birds as well.
No. 11, Kataboola Group	December 1960	Mid-March (after 2½ months). March 16th—53%	May (2 months) June 6th—77%.
No. 14, Attampettia Estate	February 1961	Mid-May (after 2½ months) May 19th—11%	August (3 months) August 11th—63%

Table 17 summarises the observations of how soon *Macrocentrus* was found on the sprayed plots of these trials and how long it took to build up to numbers which exerted control of the Tortrix. There are considerable differences. In the Kataboola trial, 53% parasitism was found after only two and a half months, and in the smaller plots at Imboolpittia there was 84% parasitism only three months after spraying. In contrast, the level at Balangoda, four months after spraying, was only 6%, at Attampittia two and a half months after spraying it was 11%, and at Uva Ketawella No. 8 no parasitism was found three months after spraying. The time taken for the parasite to build up in numbers and resume control also varies, but less than might be expected from the variation in the initial occurrence of the parasite. None of the attacks on the plots of trials reported here lasted for more than three months although the attack on No. 5 trial might have gone on longer if it had not been resprayed with DDT. The re-establishment of the parasite on Uva Ketawella was much less satisfactory than elsewhere.

The rate of dispersal of *Macrocentrus* must be high (Cranham 1961a). In the plots of these trials there was no appreciable delay detected between the appearance of the parasite near the edges of a plot and its appearance at the centre. The parasite was very quickly distributed widely over the plots even when the percentage of Tortrix parasitized was still quite low, say 10%. On sprayed fields of 30 or 40 acres (not in these trials), initial differences have been found between the edges and middle of the field (notably at Kataboola Group, Uva Ketawella Estate and Goorokoya Estate) and it is to be expected that the larger the area sprayed at one time the longer the delay will be in re-establishment of the parasite. If a large part of an estate is to be sprayed within a few months, the factors influencing the parasite are likely to be more complex. Only observations on practical usage can determine the position. So far it is apparent that there are a few estates in which the immigration and build-up of the parasite on sprayed fields has been much slower than on estates in general, thus creating a more difficult problem in Tortrix control, but there is no reason to think that these estates are permanently in this position. At present the factors which may operate in this can only be guessed at, e.g. isolation of the sprayed area from other tea by grassland; a very low initial availability of the parasite, or a heavy mortality of the parasite caused by extensive spraying of dieldrin; natural enemies or climatic factors which may reduce the normal rate of increase.

It is clear that at worst, Tortrix attack, if allowed to go unchecked by DDT spraying, can be so bad as to result in very bad defoliation and a loss of crop large enough to counter-balance the possible yield increases to be obtained from shot-hole-borer control. This is known to have occurred on three estates out of about a hundred who have experimented with dieldrin spraying in 1960 and 1961. All three estates have sprayed other fields with dieldrin with negligible damage by Tortrix.

It is clear also, from work on natural outbreaks, that the situation can arise where despite a high level of parasitism Tortrix can continue for some weeks to do appreciable damage (Cranham 1962); this has never been noted so far on dieldrin-sprayed areas. By and large, the efficiency of *Macrocentrus* is very remarkable and re-establishment is delayed on only a small percentage of fields sprayed.

The use of DDT

As a study of the value of DDT in controlling Tortrix until the *Macrocentrus* resumes control, these trials must be considered unsatisfactory. They have however, confirmed the results of other work (Cranham 1962) that the rate of dispersal of Tortrix is high. Since this is so, it is likely that the value of using DDT on whole fields can only be judged on whole fields.

Seven out of fourteen of the trials reported here had Tortrix outbreaks causing moderate damage on plots sprayed with 1.5 lb dieldrin per acre. This is very much in line with the results of a survey in 1960 of fourteen experimental sprayings by estates (1959-1960); in these, too, seven out of fourteen trials suffered appreciable attacks. A check on the efficiency of DDT when sprayed on whole fields can therefore be made by determining the frequency of outbreaks following DDT spraying on a large number of fields; this should be very much less than the frequency of 50% found on unsprayed fields. A survey of estate results will be required to evaluate this. So far, few fields seem to have suffered a resurgence of Tortrix after the recommended DDT spray at tipping (Cranham 1961).

It is very notable that the application of DDT has never appeared to hinder the re-establishment of the parasite. If DDT is used on a Tortrix outbreak where *Macrocentrus* is already fairly plentiful (but not in control) the effect is to leave a few Tortrix larvae of which a high percentage are parasitized, thus altering the ratio of Tortrix to parasite in favour of the parasite (Cranham 1962). We might expect that in resorting to chemical control with DDT, we would be again (*i.e.* after dieldrin) temporarily sacrificing the parasite, but this is not so. This is of course very fortunate and means that there is no reason to hesitate to use DDT, wherever Tortrix is a problem, on this account.

On another account, however, there is a reason to hesitate, at least in some districts—namely, a possible increase in Red Spider Mite following DDT (Cranham 1962). This has been reported and seen on certain fields on estates in the districts of Pussellawa, Kandy, Rakwana and Morawak Korale. It has not occurred generally and it did not occur in any of the seventeen trials of the present series where DDT was used. On those estates where experience shows that this is liable to occur, there is clearly a need for a suitable alternative control for Tortrix which does not have this side-effect.

Other possible side-effects from dieldrin

A significant feature of Tortrix outbreaks following dieldrin is that usually the bad attack is virtually confined to the sprayed area, unless *Macrocentrus* is also in very short supply in the unsprayed tea nearby. It will be seen from Tables 13 and 14 how small the numbers of Tortrix were on the unsprayed plots. This is another feature which shows the extraordinarily high efficiency of the parasite.

With other pests whose numbers may be increased as a result of using dieldrin, we could be badly misled if we assumed that the increased occurrence would be largely confined to the sprayed area. We would expect to find a gradient in numbers of the pest from the sprayed area into the surrounding unsprayed tea but this gradient might be so extended, and so complicated by other factors, as to be hard to determine. On cocoa in Ghana, Entwistle, Johnson and Dunn (1959) have demonstrated such a gradient in infestation of the moth *Eulophonotus myrmeleon* Feld. (Lepidoptera, Cossidae) and of an unidentified bark-eating caterpillar (Metarbelidae), as pests whose incidence has been increased by the use of dieldrin.

There are on Ceylon tea and shade trees a number of pests whose incidence we are watching closely, to see if it is associated with the use of dieldrin. It is interesting that two of them are similar species to those noted by Entwistle *et al.*, namely Red Borer, *Zeuzera coffeae*, Nietn. (Cossidae) on tea, and Albizzia Bark-eating Borer, *Indarbela quadrinotata* Walk. (Metarbelidae) on *Albizzia falcata* (L.)

Back (= *moluccana* Miq.). There is absolutely no proof as yet that the numbers of these species have been increased where dieldrin has been used. They have been a nuisance on some estates which have used dieldrin. They have been equally numerous on some other estates well away from dieldrin spraying.

It will be noted that one of them is a pest of a shade tree, and it is our impression that apart from Tortrix on the tea itself, the occurrence of other pests as side-effects of dieldrin is at least as likely on the shade trees as on tea itself. Tortrix itself has been known to defoliate *Albizzia falcata* on sprayed areas, and there was fairly clear evidence on the Imboolpittia trial of an unidentified lepidopterous caterpillar defoliating *Albizzia falcata* more seriously on the dieldrin plot than on the unsprayed and 'Gammalin' plots. There are also other lepidopterous caterpillars, which have not yet been identified, attacking *Albizzia*.

The Tea Leaf Roller, *Gracillaria theivora* Wlsm. was common on tea in some sprayed fields at Uva Ketawella Estate, although Tortrix was far more numerous. Judenko (1962) has also reported the occurrence of this species on a dieldrin trial at a neighbouring estate in the Hali-Ela district.

It is reasonably certain that dieldrin itself is not likely to increase the numbers of mites, of any of the four species occurring on tea. The effect of DDT on the numbers of Red Spider has been noted above.

Summarising, we can say that other than Tea Tortrix, outbreaks of pests which could conceivably be side-effects of dieldrin spraying have been few and very localised so far. It would be relevant to stress again that if they do occur they are as likely to occur in the shade trees, particularly *Albizzia falcata*, as in the tea.

Summary

This paper is an interim report on the progress (up to late 1961) of several large-scale field trials started in 1960 and 1961 on the control of Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on Ceylon tea, by spraying the insecticide dieldrin on the dry bark of the bush frames soon after pruning. Dieldrin at 1.5 lb per acre has given good results, either as one spraying of six pints of 'Dioldrex' (20% dieldrin) in 70-100 gallons water per acre, or as two sprayings, at an interval of three weeks, of three pints of 'Dioldrex' in 70-100 gallons water.

In ten trials, approximately twelve months after spraying, there was an over-all significant reduction in numbers of the borer on the plots sprayed with dieldrin compared with the unsprayed plots. The trials must run for at least a full pruning cycle of 2 or 3 years in order to assess the length of time for which dieldrin will give control. It is concluded that their particular value will be as a study of the population dynamics of Shot-hole Borer on dieldrin-sprayed and unsprayed plots under diverse conditions.

The results obtained by applying similar doses of dieldrin in 4 and 8 gallons of water per acre by knapsack mist-blowers are also encouraging.

Lindane at 1.5 lb per acre ('Gammalin 20') was included in one trial and gave poor results.

Tea Tortrix (*Homona coffearia* Nietn.), arising as a side-effect from the use of dieldrin due to temporary reduction in the numbers of the parasite *Macrocentrus homonae* Nixon, caused moderately bad damage on seven out of fourteen trials on plots sprayed with 1.5 lb dieldrin per acre. The attacks were largely confined

to the dieldrin-sprayed areas. One spray of DDT emulsion (2 lb DDT per acre) to half of each dieldrin-sprayed plot failed to maintain good control of Tortrix in these trials because of rapid dispersal of Tortrix. When sprayed on the whole of a dieldrin-sprayed field or plot, DDT has given good control. The DDT did not appear to interfere with the re-establishment of *M. homonae*. Where Tortrix outbreaks occurred, the time taken for the parasite to re-establish control of the Tortrix varied between three and six months after spraying in the different trials.

No other side-effects of dieldrin that are comparable to that of Tea Tortrix occurred in these trials. Tortrix larvae and the larvae of some unidentified Lepidoptera have been noted also defoliating *Albizzia falcata* used as a shade tree above the tea. The incidence of a few other pests requires investigation.

DDT did not cause outbreaks of Red Spider Mite in any of the seventeen trials reported here, although a few cases of such outbreaks have been noted elsewhere.

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