FIELD EXPERIMENTS ON THE CHEMICAL CONTROL OF SHOT-HOLE BORER (*XYLEBORUS FORNICATUS* EICHH.) ON TEA SOON AFTER PRUNING

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These experiments were planned to investigate the influence of dieldrin spraying soon after pruning on:

1. Shot-hole Borer population,
2. the numbers of galleries made by Shot-hole Borer,
3. the production of new wood by tea bushes,
4. the yield of tea,
5. possible taint and the liquoring properties of manufactured tea,
6. dieldrin residues in made tea, and
7. the side-effect of Tea Tortrix (*Homona coffearia* Nietn.) caterpillars resulting from the destruction of the parasite *Macrocentrus homonae* Nixon.

Some of the experiments were also intended to investigate (8) the re-infestation by Shot-hole Borer of tea fields sprayed by dieldrin, and (9) the value of DDT sprays for controlling Tea Tortrix.

The field work was carried out by Judenko and Shanmugam, and the statistical interpretations by Hasselo. Experiments were begun in 1960 and carried out by Judenko and Shanmugam till August-September 1961. Some of the results have been described previously (Judenko 1961, and 1961a). They were six experiments which are described in Table 1. The first three of these experiments were well-replicated randomized block trials with plots of 200–500 bushes. The other three experiments were of the type described by Cranham, Danthanarayana and Ranaweera (1962) and the plots were quarter fields of about 9 acres.

TABLE 1.—*Index of Experiments*

Expt. No. and Estate	Extent acres	Dieldrin dosage lb/acre(1)	Water gal/ acre	Date of pruning 1960	Date sprayed 1960	Age of tea, years
1/60 Hantane ...	4.8	5.1	97	22–29.2	29. 2– 4.3	35
7/60 Kirimetiya ...	1.3	2.3	108	9–10.3	15.3	ca. 20
13/60 Bandarapola ...	1.3	2.8	139	18–19.4	22.4	40
16/60 Rye ...	35.4	1.6	71	31. 8– 5.9	10. 9–16.9	11
17/60 Queenstown ...	37.9	1.7	93	25. 8–12.9	22. 9– 4.10	38
18/60 Demodera ...	36.7 (2)	1.6	103	28–30.9	12.10–17.10	51

NOTES.—(1) *On the basis of 2,500 bushes per acre, except in experiment No. 16/60 where the number was 3,400 per acre.*

(2) *In Judenko (1960) an incorrect figure of 27.15 acres was quoted for the extent of the Demodera experimental area (18/60).*

In all six experiments, the tea was sprayed with 'Dieldrex Extra' (Shell Company of Ceylon Ltd.) to a height of 12 in. above ground level when the bark of the tea bushes was dry (Judenko 1958a and 1960). Birchmeier 'Automat' self-acting knapsack sprayers and 'Mars' pressure-retaining knapsack sprayers were used, fitted with single 'Horto-Sapphire' fog nozzles with an orifice of 0.55 mm, except in experiment 13/60 where 'Duro' nozzles of 1.65 mm orifice were used instead. To charge the sprayers, a Birchmeier 'Ideal' charge pump was used at Hantane, Kirimetiya and Bandarapola and the Favori-Colibri 'Vitiver' charge pump in the remaining three experiments.

The weights of green leaf of alternate pluckings were recorded at Hantane, Kirimetiya and Bandarapola under the supervision of the staff of the Institute. In the three remaining experiments, the weights of all the pluckings were recorded under the supervision of the staff of the estates.

RANDOMIZED BLOCK TRIALS

In experiments carried out at Hantane, Kirimetiya and Bandarapola, the dosages of dieldrin used were high (Table 1) in order to find out the maximum effect on yield of tea.

EXPERIMENT No. 1/60, HANTANE ESTATE

There were six randomized blocks, each containing four plots of 500 bushes. The total number of plots was thus 24, namely 12 dieldrin-sprayed and 12 untreated. The individual blocks were scattered in a tea field which was not sprayed with dieldrin except on the treated plots. The type of pruning was 'cut-across' at 18 inches.

The experimental area was pruned from 22nd to 29th February 1960, and sprayed from 29th February to 4th March. Some rain fell (0.21 in.) on February 29th after the day's spraying had been completed.

Influence of dieldrin spraying on the number of live adults

There was no significant difference between the numbers of live adults on treated and on control plots in the pre-treatment examination. Table 2 shows that there were very large differences between the number of live adults on treated and control plots in all four post-treatment examinations, *i.e.* at 9, 12, 15 and 18 months after spraying; all these differences are statistically significant. Examinations Nos. 4 and 5 show that in June and August 1961, *i.e.* 15–18 months after spraying, a few adults were found on the sprayed plots.

Influence of dieldrin spraying on the total number of galleries

The differences in the total number of galleries between treated and control plots before spraying was insignificant (Table 2). The differences in all four post-treatment examinations were statistically significant in the 2nd and 3rd examinations at $P=0.05$, and in the 4th and 5th examinations at $P=0.001$.

Influence of dieldrin spraying on the percentage of standard units with young bark

The differences between the percentages of standard units with young bark on treated and on control plots before spraying, as well as in examinations Nos. 2, 3

and 4 are not statistically significant. In examination No. 5, *i.e.* 18 months after spraying, the difference became significant (P=0.001) (Table 2).

The non-significance of the large increase of the number of units with young bark obtained in examination No. 4 was due to a very large variation between the plots, and it is thought that the sampling error on a sample size of 25 standard units per plot was very high. It may be concluded from these results that the formation of new wood after pruning is considerably retarded in the bushes infested by Shot-hole Borer, but that in order to detect this at an early date, a sample larger than 25 standard units per plot should be taken.

Influence of dieldrin spraying on the yield of tea

Tables 3 and 4 show that the effect of dieldrin spraying on the yield of tea does not become apparent until 12 months after spraying. From this time onwards, there is a progressive yield increase which is significant and which has probably not reached its peak by the end of August 1961, *i.e.* 18 months after spraying.

Correlations

Table 5 shows that there exists a positive correlation between the number of live adults and the total number of galleries, whereas the number of live adults is inversely correlated with the percentage of standard units with young bark and with the yield of tea.

Table 6 shows that in the period of 12–18 months after spraying there was an inverse correlation between the total number of galleries and the yield of tea, and that in the period of 15–18 months after spraying the correlation coefficient was high.

Comparison of the data given in Tables 5 and 6 shows that the relationship between the total number of galleries and yield (r=–0.75 to–0.78) is closer than that between the number of live adults and yield (r=–0.58 to –0.73). The number of galleries therefore seems to give a better picture of the effect of Shot-hole Borer on yield than the number of live adults. This is not surprising since the number of galleries represents the accumulated shot-hole-borer attack over the period, whereas the number of live adults represents only the attack going on at one time.

It appears from Table 2 that the total numbers of galleries per 50 standard units in the control 15 and 18 months after spraying were 67 and 79 respectively and in the treated plots were 22 and 13 respectively, the differences being 45 and 68 galleries per 50 standard units respectively. Because these differences correspond with yield increases of 31% and 53% respectively on the sprayed plots, one may conclude that an attack of about 40 galleries per 50 standard units corresponds with a loss of yield of about 25%.

It was shown previously (Judenko 1958, Table 5) that 40 galleries per 50 standard units is the lowest level of shot-hole-borer infestation, at which, in the opinion of some of the planters, the yield of tea is visibly decreased.

Table 7 shows that the correlation coefficient of the relationship between the percentage of standard units with young bark and the yield of tea in the period 12–18 months after spraying is significant although not high. It indicates that there exists a direct relationship between yield of tea and the production of young wood, whose development after pruning was increased indirectly by dieldrin spraying.

TABLE 2.—*The effects of dieldrin spraying of recently pruned tea on infestation with Shot-hole Borer up to 18th months later.*

Expt. No.	Date of spray in 1960	Exam. No.	Months after spray	Date of examination	Occurrence per 50 Standard Units					
					Live adults		galleries		Standard units with young bark	
					Avg. no. in control	% less in expt. plots	Avg. no. in control	% less in expt. plots	Avg. no. in control	% increase in expt. plots
1/60	4.3	1	Before	22–29.2.60	14	29	91	9	11	18
		2	9	24–25.11.60	4	100	66	17	1	300
		3	12	22–23.2.61	15	100	64	36	8	2
		4	15	8–9.6.61	33	94	67	67	19	37
		5	18	25–29.8.61	61	90	79	78	16	81
7/60	15.3	1	Before	11–14.3.60	16	0	78	0	9	0
		2	8	21–22.11.60	43	98	73	12	2	100
		3	11	27.2.61	15	87	81	18	1	430
		4	15	12–13.6.61	10	90	68	47	10	40
		5	18	5–6.9.61	10	70	61	46	5	220
13/60	22.4	1	Before	19–20.4.60	20	25	70	0	1	100
		2	7	23.11.60	1	100	57	0	1	33
		3	12	17–18.4.61	9	100	47	0	7	0
		4	15	17–18.7.61	4	75	43	17	17	6

TABLE 3.—*The effects of dieldrin spraying of pruned tea on yields of green leaf. The yields are given as the totals from the beginning of the pruning cycle from alternate pluckings, calculated in lb per acre of 2,500 bushes. In the cases starred* the yields are adjusted to 200 bushes per plot.*

Expt. No.	Date of spray in 1960	Period of time when yield was examined	Months after spray	Yield of untreated plots	% increase over control not sprayed	Significance
1/60	29.2–4.3	7.7–8.12.60	9	499	3	Not sign.
		7.7.60–2.3.61	12	820	5	Not sign.
		7.7.60–8.6.61	15	1241	14	sign. (P=0.05)
		7.7.60–31.8.61	18	1494	21	Highly sign. (P=0.01)
7/60	15.3	10.8–23.11.60	8	524*	12	sign. (P=0.05)
		10.8.60–15.2.61	11	831*	15	sign. (P=0.05)
		10.8.60–21.6.61	15	1523*	16	sign. (P=0.05)
		10.8.60–31.8.61	18	1810*	16	sign. (P=0.05)
13/60	22.4	12.8–25.11.60	7	685*	6	Not sign.
		12.8.60–21.4.61	12	1401*	4	Not sign.
		12.8.60–21.7.61	15	1908*	6	Not sign.

TABLE 4.—*Influence of dieldrin spraying on yield of tea*

Expt. No.	Estate	Date of spraying in 1960	Period when yield was examined	Months after spraying	Yield of green leaf of alternate pluckings in lbs/acre (2,500 bushes per acre) in control	% increase in yield	Significance of increase
1/60	Hantane	29.2–4.3	7.7–8.12.60	0—9	499	3	Not sign.
			8.12.60–2.3.61	9—12	344	7.5	Not sign.
			2.3.61–8.6.61	12—15	474	31	Very highly sign. (P=0.001)
			8.6–31.8.61	15—18	296	53	Very highly sign. (P=0.001)
7/60	Kirimetiya	15.3	10.8–23.11.60	0—8	524*	12	sign. (P=0.05)
			9.11.60–15.2.61	8—11	307*	18	sign. (P=0.05)
			15.2–21.6.61	11—15	692*	18	sign. (P=0.05)
			21.6–31.8.61	15—18	287*	7	Not sign.
13/60	Bandarapola	22.4	24.3–23.6.61	11—14	613*	6	Not sign.
			21.4–23.6.61	12—14	330*	8.5	sign. (P=0.05)
			21.4–1.9.61	12—16	744*	8.5	sign. (P=0.05)

**Yield adjusted to 200 plants per plot.*

TABLE 5.—*Expt.1/60. Hantane: Relationship between the number of live adults and (a) total number of galleries, (b) percentage of standard units with young bark, and (c) yield of green leaf*

Correlation with:	Total no. of galleries Mean of June and August 1961 Exams.	% of standard units with young bark. Mean of June and August 1961 Exams.	Yield of green leaf 2.3–31.8.61
LIVE ADULTS			
June 1961 examination	r= +0.789**	—	r= — 0.579*
August 1961 examination	r= +0.919***	—	r= — 0.686*
Mean of June and August 1961 examinations	r= +0.921***	r= — 0.598*	r= — 0.731**

*significant at P=0.05
**significant at P=0.01
***significant at P=0.001

TABLE 6.—*Expt. 1/60, Hantane: Relationship between the total number of galleries and weight of the yield of tea*

Examination of total number of galleries		Total number of galleries	Yield of green leaf in the Period 12–18 months after spraying, from 2-3-61 to 31-8-61
Date	Month after spraying		
22–23.2.61	12	G 1	r = – 0.488 (P = 0.05)
8–9.6.61	15	G 2	r = – 0.760 (P = 0.001)
25–29.8.61	18	G 3 G 4 (mean of G2 & G3)	r = – 0.748 (P = 0.001) r = – 0.788 (P = 0.001)

TABLE 7.—*Expt. 1/60, Hantane: Relationship between yield of tea and production of young bark*

Examinations of total number of galleries		B=% of standard units with young bark	Yield of green leaf in lb/acre	
Date	Months after spraying		From 2.3—8-6-61, *i.e.* 12–15 months after spraying	From 2.3—31-8-61, *i.e.* 12–18 months after spraying
8–9.6.61	15	B 1	r=0.458*	r=0.454*
25–29.8.61	18	B 2	r=0.414*	r=0.469*
		B 3 (mean of B1 + B2)	—	r=0.572**

**significant at P=0.05*

***significant at P=0.01*

The correlation coefficients obtained (Table 7) are too low to be of any practical use in predicting yield increases caused by dieldrin spraying from increases in the percentage of standard units with young bark. The low correlation coefficients are at least partly due to the small sample size (25 standard units) per plot.

Influence of dieldrin spraying on Tea Tortrix population

Examinations were carried out monthly from March 1960 till May 1961, except in September. The highest population was found in August, *i.e.* 6 months after dieldrin spraying, when 64 caterpillars were recorded per 100 treated bushes and 15 caterpillars per 100 control bushes. Thus, there was no outbreak of Tortrix on plots of 500 bushes scattered in an unsprayed field.

Influence of dieldrin spraying on taint and on the liquoring properties of manufactured tea

These points were investigated for the first and second tippings, in May and June 1960 respectively, and also for pluckings carried out in August and September 1961 over 18 months after spraying. The first tipping was done on 25th May 1960, *i.e.* 82 days after spraying; rainfall between spraying and tipping amounted to 20.17 in. The second tipping was done 103 days after spraying during which period rainfall amounted to 25.3 in. All tipped leaf from the treated and control plots of these two tippings was manufactured by the Technologist of the Tea Reseach Institute of Ceylon, who reported that the made tea was free from taint and showed no difference from the control as regards liquoring properties. The taint and liquoring properties of made tea were also the same in pluckings carried out on the 31st of August, and 7th and 14th September 1961, *i.e.* about 18 months after spraying, when the treated plots yielded 52%, 75% and 60% more green leaf respectively than the control plots. The above-mentioned investigations show that dieldrin spraying does not in any way affect the quality of the made tea.

Influence of dieldrin spraying on dieldrin residues in made tea

Samples of treated and manufactured teas obtained from the first tipping, which were taken 82 days after spraying, were sent to the Shell International Company in England for examination of dieldrin residues. A residue of 0.08 p.p.m. of dieldrin residue was found. It should be noted that 5.1 lb. dieldrin per acre was used in this experiment. The residue was less than the tolerance of 0.1 p.p.m. or 0.25 p.p.m. set for dieldrin on several food crops in the U.S.A. (U.S.D.A., 1961).

Conclusions

The following results of dieldrin sprayings, applied at Hantane to tea bushes soon after pruning at the rate of 5.1 lb per acre, were obtained during the first 18 months after treatment: dieldrin-spraying decreased significantly the number of live adults and the total number of galleries in 9–18 months after treatment, and increased significantly the number of standard units with young bark in the first 18 months after spraying and the yield of tea in the period 12–18 months after pruning, but it did not alter the quality of manufactured tea.

During the first 18 months of observations a positive correlation was found between the number of live adults and the total number of galleries made by Shot-hole Borer and also between the number of standard units with young bark and the yield of tea.

Inverse relationships were found between the total number of galleries and the yield of tea, and between the number of live adults and the percentage of standard units with young bark.

Dieldrin spraying did not significantly increase the Tea Tortrix population and did not affect the taint and liquoring properties of made tea, but very small dieldrin residues were present in the tea made from leaf obtained from the first tipping.

EXPERIMENT No. 7/60, KIRIMETIYA ESTATE

There were four randomized blocks, each block containing four plots of about 200 bushes. The total number of plots was thus 16, namely 8 treated and 8 untreated. As at Hantane, the blocks were surrounded by unsprayed tea in an unsprayed field, but were not so scattered as at Hantane. It was assumed, during the marking out of the experimental area, that the number of bushes per plot was 200 whereas in fact it varied somewhat owing to vacancies. In the computations shown in Tables 3 and 4 in respect of the yields of tea, corrections have been made for the actual numbers of bushes.

The figures for yield of green leaf obtained in Block 4 of the trial are rather inconsistent and are therefore ignored. The figures shown in Tables 3 and 4 refer to the results obtained in Blocks 1, 2 and 3 only.

The experimental area was pruned on 9th and 10th March, 1960; the type of pruning was light at 18 inches. The area was sprayed on 15th March during dry weather.

Table 2 shows the differences between the numbers of live adults on treated and control plots, which were significant in examinations made at 8, 11 and 15 months after spraying (Table 8). This difference was not significant in the pre-treatment examination, nor in the examination made 18 months after spraying.

Table 2 shows also the differences between the total numbers of galleries on treated and control plots, which were significant in examinations carried out at 11, 15 and 18 months after spraying, but not significant in the first two examinations (Table 8).

If the differences in numbers of galleries between all the sprayed and all the unsprayed plots are averaged, they amount to an average for the last three examinations of 20 galleries per 50 standard units, the sample size being 200 standard units. On the basis of the results obtained at Hantane, such a difference would correspond with an increase in yield on the treated plots of approximately 15%, which is of the same order of magnitude as that actually recorded, *i.e.* 16%. It may be concluded, therefore, that a sample size of 25 standard units will show up yield differences of not less than 50% (Hantane), and a sample size of 200 units will show up yield differences of 15% (Kirimetiya).

The differences between the percentages of standard units with young bark on treated and control plots were significant only in the examinations carried out at 11 and 18 months after spraying (Table 8).

TABLE 8.—*Expt. 7/60, Kirimetiya: effect of dieldrin spray on live adults, galleries and production of young wood.*

Exam. No.	Months after spraying	No. of live adults	Total no. of galleries	Percent. of standard units with young bark
1	Pre-treatment examination	—	—	—
2	8	+	—	—
3	11	+	+	+
4	15	+	+	—
5	18	—	+	+

+ significant effect of dieldrin spray at P=0.05
— non-significant effect of dieldrin spray at P=0.05

Table 3 shows that the differences between the total yields of tea on treated and control plots were significant at P=0.05 in the examinations carried out at 8, 11, 15 and 18 months after spraying. Table 4 shows that these differences were significant within the periods of 0–8 months and 11–15 months after spraying, but that this difference was not significant in the period 15–18 months after spraying.

Significant correlations have not yet been found between the yield of tea and such factors as number of live adults, total numbers of galleries, and percentage of standard units with young bark in the Kirimetiya experiment. The total number of galleries was negatively correlated with percentages of standard units with young bark (r=–0.66, significant at P=0.05) for September 1961.

Table 9 shows that there exists a significant positive relationship between the number of live adults and the total number of galleries in June 1961 only.

TABLE 9.—*Expt. 7/60, Kirimetiya: relationship between numbers of live adults and total numbers of galleries*

No. of live adults	Total number of galleries	
	Exam. carried out in June, 1961	Exam. carried out in September, 1961
June 1961	r = + 0.78**	r = + 0.44
September 1961	—	r = + 0.36

(**significant at P=0.01)

The correlations are not nearly so good in this experiment as in the Hantane trial. This is probably due to the small sample size of 25 standard units per plot and to the low level of infestation in this experiment in June and especially in September 1961 (Table 2).

Influence of dieldrin spraying on Tea Tortrix

Examinations were carried out monthly from May 1960 till May 1961, except in September. The highest population was found in July, *i.e.* 21 caterpillars per 100 treated bushes and 6 caterpillars per 100 control bushes. There was no outbreak.

Conclusions

In the Kirimetiya experiment, the numbers of live adults and the total numbers of galleries were less as a result of dieldrin spraying, although the percentage control was not as good as in the Hantane experiment. Significant yield increases were also obtained at Kirimetiya, but again they were smaller than at Hantane. An increase in the percentage of standard units with young bark also occurred at Kirimetiya.

Evidence was obtained to show that the effect of shot-hole-borer infestation on yield is closely related to the total number of galleries. The extent to which this effect can be demonstrated is dependent upon sample size. For a sample size of 200 standard units, yield increases of 15% could be demonstrated and were found to correspond with a difference in accumulated borer attack of 20 galleries per 50 standard units.

EXPERIMENT No. 13/60, BANDARAPOLA GROUP

There were four randomized blocks, each containing 4 plots of about 200 bushes. The total number of plots was thus 16, namely 8 treated and 8 untreated. Each block was surrounded by unsprayed tea. Although variation in the numbers of bushes per plot was small, these numbers were adjusted to 200 bushes per plot in respect of the yield figures shown in Tables 3 and 4.

The experimental area was pruned on 18th and 19th April, 1960. The method of pruning was light, at 18 inches. Spraying was carried out on 22nd April in dry weather, which was followed by rainfall (0.85″).

Influence of dieldrin spraying on the number of live adults, the total number of galleries and the yield of tea

Tables 2 and 3 show that significant increases in the yield of tea on the treated plots were found only in the period from 12–14 and 12–16 months after spraying. Because the number of live adults and the total number of galleries in the control and sprayed plots were very low in this trial (Table 2), tests of statistical significance were not applied to these observations *per se* nor in relation to the obtained significant increase in yield of tea in the last few months.

Had the sample size of the number of standard units per plot been larger, some relationship might have become evident. To overcome these difficulties, it was shown previously that a rough approach may be adopted, *i.e.* by relating the differences in number of galleries (on the basis of 50 standard units) between all the sprayed and unsprayed plots with the yield difference obtained.

In examination No. 4 (Table 2), which was carried out in July 1961, the difference amounted to 7 galleries per 50 standard units (sample size: 200 standard units), which on the basis of the yield responses obtained at Hantane, would correspond with a percentage yield increase of $\frac{7}{40} \times 30\% = 5.25\%$. This is of the same order of magnitude as the yield increase actually obtained, approximately 8% in July and August 1961 (Table 3).

Influence of dieldrin spraying on Tea Tortrix

Examinations were carried out monthly from May 1960 till May 1961, except in September. The highest population was found in July, *i.e.* 26 caterpillars per 100 treated bushes and 14 caterpillars per 100 control bushes. There was no outbreak.

Summary and conclusions regarding the randomized-block field experiments

1. A single application of dieldrin had the following effects in the first 15–18 months after pruning:

(*a*) it decreased the number of live adults of Shot-hole Borer and the number of galleries made by this pest in the tea branches;

(*b*) it did not increase appreciably the infestation with Tea Tortrix, on plots of the size used in these trials;

(*c*) it increased significantly the number of standard units with young bark, and the weight of the green leaf harvested;

(*d*) it had no effect whatsoever on the taint and liquoring properties of the manufactured tea;

(*e*) it caused a very slight dieldrin residue in the manufactured tea made from the leaf, that was obtained from the first tipping.

2. A sample size of 25 standard units is too small to predict reliably, from the number of galleries, increases in yield of less than 50% in the tea bushes 18 months after pruning. Differences in the number of galleries in samples of 200 standard units on the other hand appeared to give a good indication of yield increases as small as 10%.

3. For practical purposes, it would be useful to be able to estimate from the borer attack on a given field whether spraying would be economically worth while. In these experiments, there was an increase in yield of the order of 30% on the sprayed plots at the time, (*i.e. not* over the whole pruning cycle) that the accumulated attack on the untreated plots was heavier by 40 galleries per 50 standard units. Within the range of yield increases encountered (between 0% and 60%) and the numbers of galleries observed (up to 80 galleries per 50 standard units) in the first 18 months after spraying, the relationship between yield differences and differences in attack (galleries) was probably linear. This point needs further investigation. All three experiments have been continued.

LARGE-SCALE EXPERIMENTS

Three large-scale experiments were laid out at Rye, Queenstown and Demodera (Table 1). These experiments were designed by the Shot-hole Borer Sub-committee of the Tea Reseach Institute of Ceylon.

Each of these experiments occupied either the whole or the greater part of a field and the experimental area was divided approximately into four parts. The yields from 7–8 plucking rounds before pruning were weighed separately for the four different parts.

After pruning, two opposite quarters were left as controls, and the other two were sprayed with dieldrin. Each dieldrin block was roughly divided into two halves, one of which was to be sprayed with DDT on the foliage to suppress caterpillars of Tea Tortrix.

The following types of pruning were used in the individual experimental areas: at Rye, cut across, with lungs 18 in. above ground level; at Queenstown, medium hard; and at Demodera hard cut-across.

Dieldrin sprayings were carried out only when the lowest 12 in. of the tea bushes were dry. If it began to rain during spraying, the work was stopped. If the lower parts of the bushes did not dry before midday, no sprayings were carried out on that day.

It is obvious that the best time to spray dieldrin against Shot-hole Borer is during dry periods.

At Rye estate, dieldrin sprayings were completed within six days, in four of which it rained (0.87 in.) after the day's work was over. At Queenstown, dieldrin sprayings were completed within 10 days, with rainfall occurring during two days (total amount 0.43 in.). Because of rainy weather the area at Demodera could not all be sprayed with dieldrin in time, so that only 15 acres were sprayed out of the 18 acres intended. On this estate, spraying was completed within 8 days. It rained on all 8 days (total amount 4.27 in.). The number of man days per acre varied considerably and depended on the number of bushes per acre, the size of the bushes, the configuration of the land and the distance between the places where the sprayers were filled and the sprayed area. On an average the figures for Rye, Demodera and Queenstown were 6, 7 and 10 man-days per acre respectively. It should be mentioned that some parts of the sprayed area at Queenstown were very steep, so that the spraying operators were able to spray these areas only when going up the slope.

Influence of dieldrin sprayings on the number of live inmates and the number of galleries

Table 10 shows that within 10–11 months after dieldrin spraying there was a considerable reduction in the number of live inmates, some reduction in the number of obviously open galleries and a very small or no reduction in the total number of galleries.

TABLE 10.—*Influence of dieldrin spraying on the numbers of live inmates and of galleries.*

	Expt. 16/60 Rye		Expt. 17/60 Queenstown		Expt. 18/60 Demodera	
Period of examinations (months after spraying)	2—11		1—11		1—10	
No. of examinations ...	10		11		12	
	Treated	Control	Treated	Control	Treated	Control
No. of galleries :—						
Obviously open ...	33	88	92	131	113	230
Total ...	1,847	1,922	1,779	1,647	2,257	2,386
No. of live inmates :—						
Eggs ...	0	9	0	39	0	32
Larvae & pupae ...	0	29	7	107	2	85
Adults ...	1	40	2	63	4	63
Total ...	1	78	9	209	6	180

(*N.B.—25 standard units with old bark only were examined monthly in each section*)

Influence of dieldrin and DDT sprayings on the number of Tortrix larvae and on the yield of tea

"Sillortox" an emulsion containing 25% DDT (Fison's (Ceylon) Ltd.) was used in all the DDT sprayings.

At Rye Estate, DDT spraying was carried out on 9th and 10th November 1960 at the rate of 1.9 lb of actual DDT to 50 gal per acre. Spraying was carried out only when the foliage of the tea bushes was dry (rain on the days of spraying amounted to 0.02 in. and 0.07 in.). In general, the caterpillar population was

very low. The highest population was found in February 1961, *i.e.* about 5 months after the application of dieldrin. The number of caterpillars found in this month per 100 tea bushes amounted to: Control—1; tea sprayed with dieldrin only—18; tea sprayed with dieldrin and DDT—38.

The dates of pruning and of sprayings on the experimental area at Rye were as follows: pruning of Block 1—August 31st to September 2nd 1960; dieldrin spraying of Block 1—September 10th—13th, (*i.e.* 8–13 days after pruning); DDT spraying of Block 1A—November 9th—10th, (*i.e.* in two months after dieldrin spraying).

At Queenstown DDT was sprayed on 5th, 6th and 7th of January 1961 at the rate of 1.8 lb of actual DDT to 52 gal of water per acre.

Just prior to the spraying of Block 4A (see Table 11) the leaves were slightly wet, but they soon dried. 0.08 in. of rain fell on the 7th of January after the spraying was completed.

It would appear from this experiment (Table 11) done 4–5 weeks after pruning, that the dieldrin spraying caused a severe outbreak of Tortrix caterpillars on the blocks sprayed with dieldrin only, and that the number of caterpillars on the control blocks was lower than on the blocks sprayed with dieldrin. This outbreak appeared 5 months after the dieldrin spraying and in about a further 4 or 5 months the attack almost faded out. Table 11 also shows that DDT spraying applied 3–3½ months after dieldrin spraying can reduce the outbreak of caterpillars caused by a dieldrin spray at pruning.

TABLE 11.—*Expt. 17/60, Queenstown Group: Influence of dieldrin and DDT sprayings on Tortrix population. Pruning of Block 4: 25th August—2nd September 1960. Dieldrin spraying of Block 4: 22nd–28th September, i.e. 4–5 weeks after pruning. DDT spraying of Block 4A: 6–7th January 1961, i.e. 3–3½ months after dieldrin spraying.*

No. in order	Calendar month	Months after		No. of Tortrix caterpillars per 100 bushes			Months after DDT spraying
		Pruning	Dieldrin spraying	Block 1 control	Block 4B Dieldrin only	Block 4A Dieldrin +DDT	
1	Nov. 60	2	1	0	1	6	—
2	Dec. 60	3	2	6	148	18	—
3	Jan. 61	4	3	14	24	3	—
4	Feb. 61	5	4	204	5,076	46	1
5	March 61	6	5	167	1,691	28	2
6	April 61	7	6	249	800	441	3
7	May 61	8	7	129	519	508	4
8	June 61	9	8	46	114	165	5
9	May—June 61	8–9	7–8	175	633	673	4–5
10	July 61	10	9	11	49	45	6
11	August 61	11	10	1	3	4	7

The yield data of Table 12 would indicate that the outbreak of caterpillars did not appreciably decrease the yield of tea.

TABLE 12.—*Expt. 17/60, Queenstown: Influence of dieldrin and DDT sprayings on yield of tea.*

Period of plucking	Months after dieldrin spraying	Weight of green leaf (lb. per acre)		
		Block 1 Control	Block 4B Dieldrin only	Block 4A Dieldrin + DDT
November 1960 to August 1961 (28–29 rounds)	0–10	2,203	2,340	2,353

At Demodera, spraying took place on the 14th February and on 2nd and 3rd March 1961, at the rate of 1.8 lb of actual DDT to 55 gal of water per acre. Just before the DDT spraying of Block 4A (see Table 13) the foliage was wet and after the work was completed, it rained (0.15 in.).

Comparison of the data given in Tables 11 and 13 suggests that the population of caterpillars at the Demodera experiment was lower than at Queenstown, and that even on the blocks sprayed with dieldrin, it did not reach epidemic levels. As in Queenstown, the outbreak of caterpillars at Demodera appeared about 5 months after dieldrin spraying and almost disappeared about 4 or 5 months later.

Of the caterpillars found at Rye, Queenstown and Demodera, about 90% were Tea Tortrix (*Homona coffearia* Nietner) and the rest Tea Leaf Roller (*Gracillaria theivora* Wlsm., Gracillariidae).

TABLE 13.—*Expt. 18/60, Demodera Group: Influence of dieldrin and DDT sprayings on Tortrix caterpillars. Pruning of Block No. 4: 28th—30th September '60. Dieldrin spraying of Block 4B: 12th—15th October, i.e. about 2 weeks after pruning. DDT spraying of Block 4A: 14th February '61, i.e. about 4 months after dieldrin spraying*

No. in order	Calendar month	Months after		No. of Tortrix caterpillars per 100 bushes			Months after DDT spraying
		Pruning	Dieldrin spraying	Block 1 Control	Block 4B Dieldrin only	Block 4A Dieldrin + DDT	
1	November 60	1	1	0	3	2	—
2	December 60	2	2	3	3	2	—
3	January 61	3	3	0	1	3	—
4	February 61	4	4	25	105	68	—
5	March 61	5	5	18	557	2	1
6	April 61	6	6	63	453	49	2
7	May 61	7	7	22	290	292	3
8	June 61	8	8	60	254	297	4
9	July 61	9	9	8	29	39	5
10	August 61	10	10	5	5	8	6

It would appear from the comparison of data given in Tables 10 and 13 that the reduction in the number of caterpillars on the blocks sprayed with DDT was poorer at Demodera than at Queenstown. One of the reasons might well be the adverse weather conditions during DDT spraying at Demodera. To summarise, the influence of dieldrin and DDT spraying on the numbers of Tortrix caterpillars and the influence of these caterpillars on the yield of tea needs further detailed investigation. The results obtained so far do not contradict the suggestion of Baptist (1956) that the period during which insecticides can safely be applied for the control of Shot-hole Borer is limited to the first 3 weeks after pruning and that insecticidal applications then are reasonably safe and are unlikely to initiate an outbreak of Tortrix. The effect obtained with DDT sprayings against Tea Tortrix caterpillars would confirm in general the results of similar investigations carried out by Baptist (1956) and Cranham (1961), and Cranham, Danthanarayana and Ranaweera (1962).

Influence of dieldrin and DDT sprayings on the yield of tea

Tables 14, 15 and 16 show that in the first 10–11 months after spraying the yield of tea in the treated blocks in all three field experiments increased somewhat. The statistical validity of these results could not be tested owing to the design of the trials.

TABLE 14.—*Expt. 16/60. Rye Estate. Influence of dieldrin and DDT sprayings on yield of tea.*

Time of pluckings	Months after spraying	No. of rounds examined	Weight of green leaf (lbs/acre)			
			Blocks 2 & 4 (Control)		Blocks 1 & 3 (Treated)	
			Weight	%	Weight	%
Before pruning and spraying. July–August 1960	—	7	593	100	616	104
Ater pruning and spraying. Nov. 1960–24-8-61	11	32	4,823	100	5,267	109

TABLE 15.—*Expt. 17/60, Queenstown Group: Influence of dieldrin and DDT sprayings on yield of tea*

Time of Pluckings	Months after spraying	No. of rounds examined	Weight of green leaf (lbs/acre)			
			Blocks 1 & 3 (Control)		Blocks 2 & 4 (Treated)	
			Weight	%	Weight	%
Before pruning and spraying. June–August 1960	—	8	337	100	275	82
After pruning and spraying. February–August 1961 ...	11	27	1,915	100	2,174	114

TABLE 16.—*Expt. 18/60, Demodera Group: Influence of dieldrin and DDT sprayings on yield of tea.*

Time of pluckings	Months after spraying	No. of rounds examined	Weight of green leaf (lbs/acre)			
			Blocks 1 & 3 (Control)		Blocks 2 & 4 (Treated)	
			Weight	%	Weight	%
Before pruning and spraying, July–Sept. 1960 ...	—	7	571	100	588	103
After pruning and spraying, January-August 1961	10	26–29	3,160	100	3,387	107
		Average per one round	225	100	254	113

Conclusions

The following conclusions can be drawn for the period covering the first 10–11 months after spraying with 1.6—1.7 lb of active ingredient of dieldrin per acre.

1. The results strongly indicate that spraying with dieldrin caused a very large reduction in the number of live inmates inside the branches.

2. Dieldrin spraying, carried out in about 4–5 weeks after pruning, caused a severe outbreak of Tea Tortrix caterpillars, whereas application of this spray at about 2 weeks after pruning, caused only a small or no outbreak. This may not be a general conclusion.

3. Finally, DDT spraying at the rate of 1.8 lb of active ingredient per acre at 3–4 months after dieldrin spraying reduced the number of Tortrix caterpillars. All three experiments have been continued.

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References

BAPTIST, B. A. (1956). The tea-leaf-eating Tortrix caterpillar (*Homona coffearia* Nietn.) as a limiting factor in insecticidal application on tea. *Tea Quart.* **27**: 28–35.

CRANHAM, J. E. (1961). The natural balance of pests and parasites on Ceylon tea, especially Tea Tortrix and *Macrocentrus*. *Tea Quart.* **32**: 26–36.

CRANHAM, J. E., DANTHANARAYANA, W. & RANAWEERA, D. J. W. (1962). The chemical control of Shot-hole Borer with dieldrin. Interim report on estate trials 1960–1961. *Tea Quart.* **33**: 5–33.

JUDENKO, E. (1958). Trials with a method of assessment of infestation caused by Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on old tea. *Tea Quart.* **29**: 51–59.

JUDENKO, E. (1958a). Preliminary small-scale field experiments on a chemical method for the prevention of Shot-hole Borer (*Xyleborus fornicatus* Eichh.) attack on tea in plucking. *Tea Quart.* **29**: 115–124.

JUDENKO, E. (1960). Further small-scale field experiments on the chemical control of attack by Shot-hole Borer (*Xyleborus fornicatus* Eichh.) on tea in plucking. *Tea Quart.* **31**: 19–25.

JUDENKO, E. (1961). Report of the Entomologist (Special Research on Shot-hole Borer) for 1960. *Rep. Tea Res. Inst. Ceylon:* 66–69.

JUDENKO, E. (1961a). Control of Shot-hole Borer (*Xyleborus fornicatus* Eichh.): experiments in progress. *Tea Quart.* **32**: 23–25.

U.S. DEPARTMENT OF AGRICULTURE (1961). Insecticide recommendations of the Entomology Research Division for the control of insects attacking crops and livestock for 1961. *Agriculture Handbook*, no. 120, 138 pp.