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Novel Stimulants and Procedures in the Exploitation of Hevea: III. Comparison of Alternative Methods of Applying Stimulants

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The experiments described in this paper confirm and extend earlier work on the stimulant action of acetylene and 4-amino-3, 5, 6-trichloropicolinic acid (Picloram) on Hevea. Their main aim, however, was to develop practical procedures for yield stimulation by (2-chloroethyl)-phosphonic acid (ethephon, in the commercial formulation Ethrel).

Application of a sufficiently high concentration of ethephon in palm oil to scraped bark immediately below the cut gave excellent stimulation. This procedure appeared to be practical and suitable for large-scale testing. Stimulation was very effective with S/2.d/2 tapping but satisfactory yields were also obtained from trees tapped S/4.d/2 (2 × 2d/4). In the latter system the stimulant was applied to scraped bark below S/2 cuts which were then divided and their upper and lower halves tapped in alternation.

*Some procedures (*e.g., *spraying Ethrel on unscraped bark) were ineffective; others (*e.g., *its application in palm oil to unscraped bark below the cut) were unpromising. But, injection of Ethrel into the wood and its application in palm oil to scraped bark above the cut were found to be worthy of further study.*

With every method of application of the stimulant to bark, response declined on repeated reapplication unless the site was changed. The movement of the tapping cut provided the necessary change of site when Ethrel was applied immediately below it.

In an earlier experiment, LF. 1, (ABRAHAM *et al.*, 1971) applicators were used extensively to bring yield stimulants into contact with the bark of the Hevea trees. The applicators were expensive, rather troublesome to use and did not appear to be the best method of application for the stimulant Ethrel. Since Ethrel had earlier been shown (ABRAHAM, WYCHERLEY AND PAKIANATHAN, 1968) to be a yield stimulant for Hevea when applied in palm oil to scraped bark below the tapping cut, this was reinvestigated and new procedures explored in the experiments (LF. 2, LF. 3 and LF. 4) described in this paper.

These experiments were started after Experiment LF.1 but before all the results from the latter were available. The four experiments ran concurrently; in several instances the design of an experiment was modified while it was under way, in the light of results obtained from the others.

MATERIALS AND METHODS

Design

A randomised single-tree-plot design (BAPTIST AND DE JONGE, 1955) was used in the three experiments.

Stimulants

2,4,5-T (Flomore) and carbide were used as described previously (ABRAHAM *et al.*, *1971*).

Ethrel used throughout was the formulation Amchem 68–250 (AMCHEM PRODUCTS INCORPORATED, 1969), except during the first

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application in Experiment LF.2, when Amchem 68–64 was used (*cf*, ABRAHAM *et al.*, 1971)

4-amino-3,5,6-trichloropicolinic acid used was in the form of the iso-octyl ester (Picloram) obtained from Dow Chemical International.

Dibutyl phthalate was obtained from BDH Chemicals Ltd, Overseas Division, of Poole, England.

Applicators, rainguards, yield recording and analysis of data were all as described previously (ABRAHAM *et al.*, 1971), except where otherwise noted. A general exception was the use of only one applicator on each tree.

The individual experiments are now described in turn.

EXPERIMENT LF. 2

The trees were of four clones (Tjir 1, PB 49, RRIM 527 and PR 107) in Section D (ii) of the Smallholders' Nursery of the R.R.I.M. Experiment Station. They had been budded in 1951, opened for tapping in July 1957, then tapped regularly on S/2.d/2. Immediately before the experiment, they were being tapped on Panel C, *i.e.*, on the first panel of bark of first renewal which had been opened in October 1967.

Yields were pre-recorded for two months beginning December 1968 while S/2.d/2 tapping continued. Treatments were then distributed at random among trees of similar yield.

Eight trees were involved in each treatment, two of each clone. Yields from each treatment were recorded from two groups of four trees.

Treatments

General. Two tapping systems were used: S/2.d/2 and S/4.d/2. The S/2 cuts were those already in tapping. For the S/4 cuts, the lower halves of the original half spirals were used for the first eight months of the experiment, then a modification was introduced in two of the S/4 treatments, as described below.

The experiment included thirty-five treatments at the outset; two of them are no longer of interest; the rest are listed in *Table 1* with their original numbers. Where stimulants were used in palm oil, the concentration is given in percentage weight per weight (% w/w).

Initial application of stimulants. The first application of stimulants was made on 15 February 1969 by the following methods:

In treatments using applicators, only one applicator was placed on each tree, roughly 30 cm below the centre of the existing half-spiral cut. Unpublished small trials undertaken earlier had suggested that the use of two applicators per tree, as in Experiment LF.1, did not give significantly better results than one.

Where Ethrel was used in applicators (Treatments No. 2, 3, 24 and 25) the volume shown in *Table 1* refers to the formulation as supplied by the manufacturers. This volume was diluted to 30 ml with water, *not* propylene glycol, before injection into the applicator, a simplification of the technique used in Experiment LF.1 which was also suggested by (unpublished) preliminary trials.

In Treatments No. 4, 5, 26 and 27, Ethrel-in-palm oil was applied to a 4 cm band of scraped bark immediately below the tapping cut and of the same length as the cut. With S/4 cuts, the amount of Ethrel per tree was therefore approximately half of that applied under S/2 cuts (not exactly half, because of differences in the girths of individual trees).

In Treatments No. 6, 7, 30 and 31, Ethrel-in-palm oil was applied to a band of unscraped renewing bark immediately above the cut and about 4 cm wide. Again the length of the treated band was the same as that of the cut and trees with S/4 cuts received about half the dose of stimulant applied to trees tapped on S/2.

In Treatments No. 8, 9, 28 and 29, Ethrel-in-palm oil was applied to a 4 cm band of scraped bark on the lowest area of renewed bark above the graft union and vertically below the original S/2 cuts on the trees. In all these treatments, including those tapped on S/4, the band of stimulated bark was of S/2 length.

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The initial application of Ethrel by injection (Treatments No. *10*, *11*, 32 and 33) employed an experimental device to inject the stimulant through a hollow drill into the wood; this was not successful. The method used for subsequent injections is described below.

With carbide-in-applicator (Treatments No. 12 and 34), the technique was the same as in Experiment LF.1 except that only one applicator, charged with 30 g of calcium carbide, was used on each tree.

For Treatments No. 14 and 35 (carbide by injection), a bore hole was drilled in each tree just above the graft union at the right hand edge of the tapping panel. This was 5–6 cm deep, 13 mm in diameter and was inclined at about 45–50° to the vertical. Powdered calcium carbide (2 g) was placed in the hole — a larger dose being impractical — and the hole was closed with paper tissue and ammoniated latex.

Treatments with Picloram-in-palm oil (No. 15, 16, 17 and 18) and with 2, 4, 5-T (Flomore) (No. 21 and 22) were made only in combination with S/2 cuts, the procedures being the same as in the corresponding treatments with Ethrel-in-palm oil.

For Treatments No. 19 and 20 (Picloram formulation by injection), a bore hole was made in each tree as for 'carbide by injection' and Picloram (2 or 4 ml) as supplied by the manufacturers was measured into the hole with a graduated hypodermic syringe. The hole was then closed with paper tissue and ammoniated latex.

Where stimulants were applied in palm oil, the total amount of material actually used in each treatment was recorded; the average doses of active ingredient per tree were then calculated and are recorded in *Table 1*. The dose per tree depends on girth as well as on the concentration of the stimulant in the oil. The average girth of each group of eight trees was not the same; moreover, even with trees of uniform girth, the application of stimulants to bark using a brush is not an accurate quantitative procedure. There are thus some anomalies to be seen in *Table 1: e.g.*, although the concentration of Picloram in Treatment No. 15 was only half of that in Treatment No. *16*, the average absolute dose of Picloram per tree was more than half. Such anomalies are unavoidable especially in small-scale experiments but may need to be considered when interpreting results.

Control. Treatment No. 1 with trees scraped below the cut and treated with palm oil, then tapped on S/2.d/2, served as control throughout the experiment. When re-applications of stimulants were made in the other treatments the control trees were again scraped and treated with palm oil.

Reapplications of stimulants and changes of technique during the experiment. The second application of treatments was made two months after the initial application. Subsequent applications were made at two-monthly intervals.

Where applicators were used (Treatments No. 2, 3, 12, 24, 25 and 34), the second and third applications were made without change of site or technique. New applicators, placed immediately below the old, were used for the fourth application of Ethrel and of acetylene from carbide. No change was made in techniques or dose sizes. At the fifth and subsequent applications no further change of site was made.

Where stimulants were applied in palm oil immediately above or below tapping cuts (Treatments No. 4, 5, 6, 7, 15, 16, 17, 18, 21, 22, 26, 27, 30 and 31), reapplications naturally occurred on fresh bark because of the movement of the cut. In Treatments No. 26 and 27, Ethrel-in-palm oil was applied below S/4 cuts and the band of application was limited to the S/4 length. Consequently, both the absolute dose of Ethrel per tree and the area of bark treated were reduced as compared with the trees tapped on S/2. The effect of stimulation appeared to be limited by one or both of these factors, because the yields from these treatments during the first eight months were relatively poor compared with those obtained from S/4.d/2 with Ethrel-in-applicator and from S/2.d/2 with Ethrel below the cut. Therefore, at the fifth application, the tapping system in Treatments No. 26 and 27 was changed from S/4.d/2 to S/4.d/2 (2 × 2d/4) by reopening the upper half of the original S/2 cuts to make a second S/4 cut in each case. Ethrel-in-palm oil was then applied below both S/4 cuts, which were then tapped in alternation.

The dose of Ethrel in two other treatments tapped on S/4 (Treatments No. 30 and 31) was also only half of that applied to trees in the corresponding S/2 treatments, but with these the tapping systems and the length of the strip of bark receiving stimulant were *not* altered during the first year of the experiment.

Where Ethrel-in-palm oil was applied just above the graft union (Treatments No. 8, 9, 28 and 29), the first four applications were made to the same site. At the fifth application, a fresh band of scraped bark was used, immediately above the first; each subsequent application was made to a fresh band immediately above the preceding one.

In treatments with Ethrel-by-injection (Treatments No. 10, 11, 32 and 33), the first application failed as noted earlier. The second application was made by boring a hole in each tree, of the same size and at the same site as in other injection treatments. The volumes of Ethrel shown in *Table 1* were measured into the holes using the manufacturer's formulation without dilution. Holes were closed with paper tissue and ammoniated latex. Subsequent applications were made in the same way after opening the bore holes and cleaning them out with a drill. In other treatments involving injection (Treatments No. 14, 19, 20 and 35), reapplications were made without changes of method, after opening and cleaning the bore holes.

Results

Results from the first twelve months of this experiment are given in *Tables 1* and *2*. *Figures 1 – 7* show yield trends for the more interesting treatments.

Because the experiment employed a small number of trees of four different clones, the standard errors *(Table 1)* are large and most of the differences between individual treatments in respect of average yield over twelve months are statistically non-significant (exceptions are differences from control and between tapping systems). Some significant effects can be demonstrated by appropriate combinations of treatments, but these are not detailed here. The numerical data and the *Figures* allow tentative conclusions and permit a division of the treatments into promising or unpromising, thus achieving the purpose of the experiment.

The conventional stimulant 2, 4, 5-T in Treatments No. 21 and 22 produced typical responses for trees of this age, although applications below the cut were more frequent than usual *(Table 1)*. Responses in these treatments were somewhat depressed during the period of wintering and subsequent recovery of the trees after the first application *(Figure 1)*.

The attempt to 'inject' carbide into bore holes (Treatments No. 14 and 35) was made because the method seemed a possible simple alternative to plastic applicators, but it was not successful. The amount of carbide which can be 'injected' is severely limited by the size of the bore hole. It was found that the carbide reacts vigorously with moisture in the hole as soon as it is applied, so there is loss of acetylene. Yield stimulation was slight (see *Tables 1* and *2:* these treatments are omitted from the *Figures*).

With carbide-in-applicator (Treatments No. 12 and 34), yield stimulation was quite good: the response fell off with reapplications at the same site and reappeared when the applicator was shifted *(Figure 1)*. The yield from the S/4 treatment approached but did not equal that from the untreated S/2.d/2 control. These findings agree with the conclusions from Experiment LF.1.

In treatments with Picloram-in-palm oil applied below the cut (Treatments No. 15 and 16), the best result was obtained with the lower of the two concentrations [this concentration, 0.88% of a.e. (w/w) is the same as that designated 0.99% by ABRAHAM *et al.*, 1968]. In this case, the stimulation appeared to be rather greater than with 2, 4, 5-T although

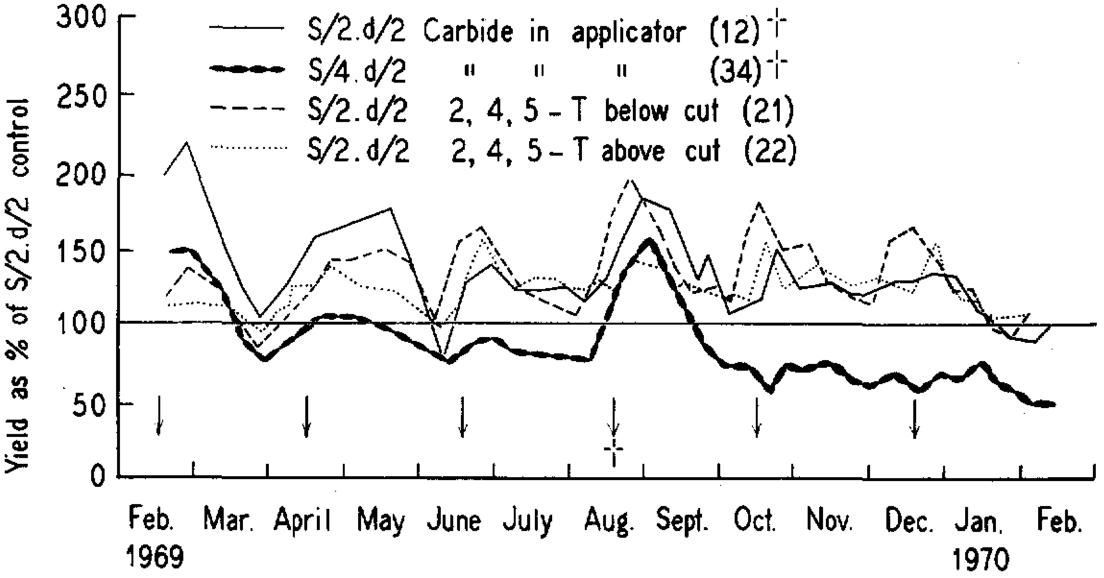

Figure 1. Experiment LF. 2: Treatments No. 12, 34, 21 and 22. [Dates of application are indicated by arrows; site of applicator changed at the point (†) indicated.]

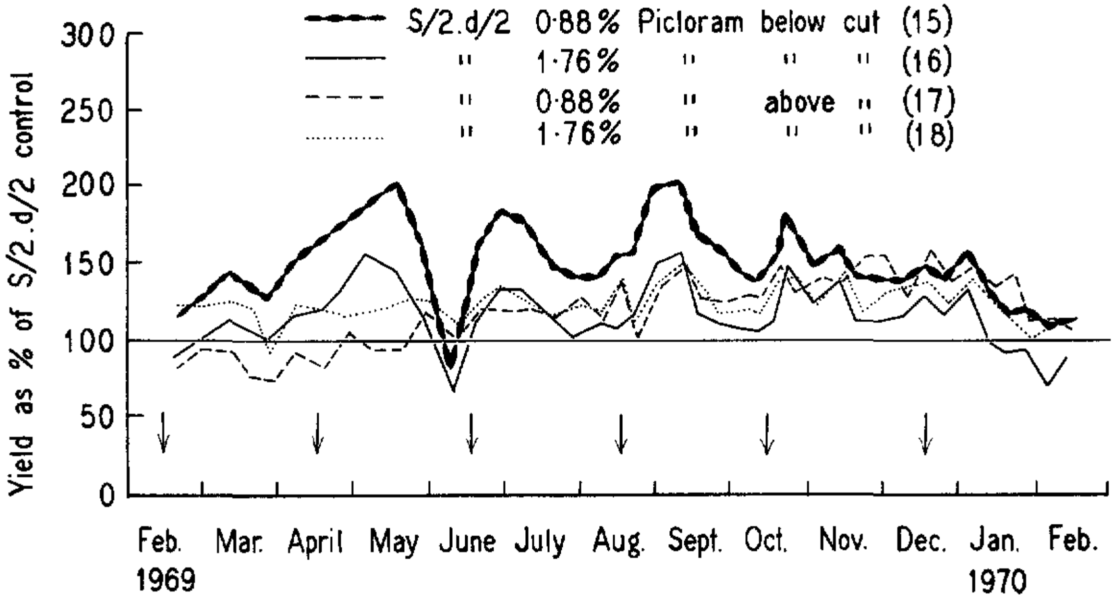

Figure 2. Experiment LF. 2: Treatments No. 15, 16, 17 and 18. (Dates of application are indicated by arrows.)

TABLE 1. EXPERIMENT LF. 2: ADJUSTED MEAN YIELD IN GRAMS PER TREE PER TAPPING

Treatment		No.	Yield (monthly)												Annual yield
			1	2	3	4	5	6	7	8	9	10	11	12	
S/2.d/2	Scraped + Palm oil	1	59.8	56.3	56.4	53.5	66.9	68.8	69.5	73.1	69.2	66.6	79.3	79.9	67.5
"	2 ml Ethrel formulation in applicator (0.96 g a.i. per tree)	2	121.4	102.9	116.6	94.1	115.9	93.9	174.4	135.3	124.9	109.7	149.0	101.7	119.7
"	4 ml Ethrel formulation in applicator (1.92 g a.i. per tree)	3	133.6	121.0	116.6	99.4	135.0	104.7	130.9	113.0	100.1	92.4	94.3	81.8	108.7
"	2.5% (a.i.) Ethrel-in-palm oil below the cut (0.05 g a.i. per tree)	4	84.0	65.6	88.4	63.4	111.1	72.7	109.8	72.3	113.6	65.4	68.0	42.1	77.8
"	6.7% (a.i.) Ethrel-in-palm oil below the cut (0.14 g a.i. per tree)	5	126.1	73.8	138.7	85.9	138.7	102.1	149.7	108.3	154.5	106.2	166.2	105.4	120.9
,,	2.5% (a.i.) Ethrel-in-palm oil above cut (0.04 g a.i. per tree)	6	73.0	65.7	102.9	61.7	101.0	90.9	102.9	93.5	112.5	95.7	140.5	100.0	96.1
"	6.7% (a.i.) Ethrel-in-palm oil above cut (0.09 g a.i. per tree)	7	90.3	60.6	96.9	59.3	110.3	84.1	111.9	95.4	139.5	98.6	148.4	101.6	100.5
"	2.5% (a.i.) Ethrel-in-palm oil above the graft union (0.05 g a.i. per tree)	8	75.5	62.3	72.6	58.8	69.3	70.1	75.1	73.7	119.0	92.1	135.7	95.6	84.5
"	6.7% (a.i.) Ethrel-in-palm oil above the graft union (0.16 g a.i. per tree)	9	92.5	67.8	71.2	69.3	78.3	77.6	80.7	76.1	139.8	103.3	151.1	108.4	94.3
"	1 ml Ethrel formulation by injection (0.48 g a.i. per tree)	10	—	—	157.1	88.8	156.5	85.2	122.0	80.9	146.7	88.9	137.8	80.7	113.0†
"	2 ml Ethrel formulation by injection (0.96 g a.i. per tree)	11	—	—	145.1	87.8	141.3	90.4	142.2	105.8	165.2	105.0	155.1	105.6	124.2†
"	30 g calcium carbide in applicator	12	114.8	66.4	91.2	67.2	87.5	85.1	117.2	90.7	90.4	82.4	100.5	77.3	89.0
"	2 g calcium carbide by injection	14	63.3	52.0	76.2	51.8	83.6	77.8	74.8	80.5	89.9	83.5	86.6	83.6	76.2
"	0.88% (a.e.) Picloram-in-palm oil below cut (0.018 g a.e. per tree)	15	78.8	77.3	99.4	76.5	117.0	101.9	127.9	111.8	111.8	96.6	115.1	94.5	101.1
"	1.76% (a.e.) Picloram-in-palm oil below cut (0.026 g a.e. per tree)	16	59.9	60.9	76.2	57.9	84.9	75.9	96.6	82.2	89.3	79.9	95.8	70.7	77.9
"	0.88% (a.e.) Picloram-in-palm oil above cut (0.009 g a.e. per tree)	17	53.2	45.4	52.5	55.2	81.2	85.6	86.6	93.6	98.0	97.1	116.2	96.6	82.3
"	1.76% (a.e.) Picloram-in-palm oil above cut (0.018 g a.e. per tree)	18	75.1	63.4	66.8	65.5	87.5	85.1	92.1	91.6	93.0	90.0	106.9	90.3	85.0
"	2 ml Picloram formulation by injection (0.48 g a.e. per tree)	19	57.7	53.0	64.6	70.2	71.6	79.0	84.0	94.7	92.0	81.3	93.3	89.9	78.8
"	4 ml Picloram formulation by injection (0.96 g a.e. per tree)	20	64.3	60.4	70.6	70.1	88.6	93.6	99.7	104.8	106.5	115.4	118.4	100.0	92.9
"	1% (a.e.) 2, 4, 5-T (Flomore) below cut (0.02 g a.e. per tree)	21	76.4	54.4	77.7	70.3	104.5	81.9	124.9	93.6	113.4	87.4	118.2	85.4	91.0
"	1% (a.e.) 2, 4, 5-T (Flomore) above cut (0.01 g a.e. per tree)	22	68.1	58.7	74.2	61.8	90.9	87.6	92.9	89.4	91.4	87.6	103.1	87.7	83.8
S/4.d/2	2 ml Ethrel formulation in applicator (0.96 g a.i. per tree)	24	84.5	73.0	86.6	68.7	100.2	89.4	170.3	120.0	79.8	67.0	75.3	60.7	88.8
"	4 ml Ethrel formulation in applicator (1.92 g a.i. per tree)	25	91.0	77.7	79.0	60.1	95.3	68.5	121.9	85.1	73.3	80.3	88.7	72.6	82.3
"	2.5% (a.i.) Ethrel-in-palm oil below cut (0.02 g a.i. per tree)	26*	52.8	39.3	50.1	39.9	67.0	48.9	71.4	55.2	86.6*	75.5	127.6	59.0	65.5
"	6.7% (a.i.) Ethrel-in-palm oil below cut (0.05 g a.i. per tree)	27*	72.2	46.3	60.4	41.5	76.6	51.4	85.6	71.4	136.5*	92.7	171.2	103.6	85.8
"	2.5% (a.i.) Ethrel-in-palm oil above graft union (0.06 g a.i. per tree)	28	83.2	56.2	58.8	55.0	54.3	56.0	58.8	57.7	78.4	65.6	111.7	81.2	68.9
"	6.7% (a.i.) Ethrel-in-palm oil above graft union (0.13 g a.i. per tree)	29	124 2	68.0	64.1	51.6	54.8	54.1	62.4	62.0	104.3	77.5	152.8	80.9	80.4
"	2.5% (a.i.) Ethrel-in-palm oil above cut (0.02 g a.i. per tree)	30	55.2	41.6	47.2	38.9	48.4	42.6	50.6	44.5	41.4	43.9	70.0	52.1	48.4
"	6.7% (a.i.) Ethrel-in-palm oil above cut (0.04 g a.i. per tree)	31	55.7	40.1	46.2	41.9	63.7	57.8	98.6	71.6	77.8	65.2	119.4	82.8	69.7
"	1 ml Ethrel formulation by injection (0.48 g a.i. per tree)	32	—	—	117.3	68.4	108.7	69.0	124.8	69.3	104.5	56.3	98.0	54.9	85.6†
"	2 ml Ethrel formulation by injection (0.96 g a.i. per tree)	33	—	—	125.6	68.3	145.7	89.4	159.1	90.7	141.1	85.2	107.9	63.5	106.3†
"	30 g calcium carbide in applicator	34	83.6	47.2	58.6	45.3	59.2	57.7	98.9	61.9	47.1	44.7	52.3	43.6	57.6
"	2 g calcium carbide by injection	35	60.7	40.2	55.7	45.1	66.3	56.9	57.4	56.2	41.0	35.6	37.3	46.2	49.5
S.E.			11.04	8.16	15.83	10.17	13.65	8.65	13.04	12.58	15.75	10.01	16.39	11.76	9.35
Min. sig. diff. ($P<0.05$)			31.8	23.5	45.6	29.3	39.3	24.9	37.5	36.2	45.3	28.8	47.2	33.9	28.4

* In Treatments No. 26 and 27 the tapping system changed to S/4.d/2. (2×2d/4) at the beginning of the ninth month.

† Converted to annual figures on a proportionate basis, *i.e.*, by multiplying the values over ten months by 1.2.

a.i. = Active ingredient a.e. = Acid equivalent

TABLE 2. EXPERIMENT LF. 2: ADJUSTED TREATMENT MEANS AS PERCENTAGE OF CONTROL

Treatment		No.	Yield (monthly)												Annual yield
			1	2	3	4	5	6	7	8	9	10	11	12	
S/2.d/2	Scraped + Palm oil	1	100	100	100	100	100	100	100	100	100	100	100	100	100
”	2 ml Ethrel formulation in applicator (0.96 g a.i. per tree)	2	203	183	207	176	173	136	251	185	181	165	188	127	177
”	4 ml Ethrel formulation in applicator (1.92 g a.i. per tree)	3	223	215	207	186	202	152	188	155	145	139	119	102	161
”	2.5% (a.i.) Ethrel-in-palm oil below the cut (0.05 g a.i. per tree)	4	140	116	157	118	166	106	158	99	164	98	86	53	115
”	6.7% (a.i.) Ethrel-in-palm oil below the cut (0.14 g a.i. per tree)	5	211	131	264	160	207	148	215	148	223	160	210	132	179
”	2.5% (a.i.) Ethrel-in-palm oil above cut (0.04 g a.i. per tree)	6	122	117	182	115	151	132	148	128	163	144	177	125	142
”	6.7% (a.i.) Ethrel-in-palm oil above cut (0.09 g a.i. per tree)	7	151	108	172	111	165	122	161	130	202	148	187	127	149
”	2.5% (a.i.) Ethrel-in-palm oil above the graft union (0.05 g a.i. per tree)	8	126	111	129	110	104	102	108	101	172	138	171	120	125
”	6.7% (a.i.) Ethrel-in-palm oil above the graft union (0.16 g a.i. per tree)	9	155	120	126	129	117	113	116	104	202	155	191	136	140
”	1 ml Ethrel formulation by injection (0.48 g a.i. per tree)	10	—	—	279	166	234	124	176	111	212	133	174	101	165†
”	2 ml Ethrel formulation by injection (0.96 g a.i. per tree)	11	—	—	257	164	211	131	204	145	239	158	196	132	181†
”	30 g calcium carbide in applicator	12	192	118	162	125	131	124	169	124	131	124	127	97	132
”	2 g calcium carbide by injection	14	106	92	135	97	125	113	108	110	130	125	109	105	113
”	0.88% (a.e.) Picloram-in-palm oil below cut (0.018 g a.e. per tree)	15	132	137	176	143	175	148	184	153	162	145	145	118	150
”	1.76% (a.e.) Picloram-in-palm oil below cut (0.026 g a.e. per tree)	16	100	108	135	108	127	110	139	112	129	120	121	89	116
”	0.88% (a.e.) Picloram-in-palm oil above cut (0.009 g a.e. per tree)	17	89	81	93	103	121	125	125	128	142	146	147	121	122
”	1.76% (a.e.) Picloram-in-palm oil above cut (0.018 g a.e. per tree)	18	125	113	118	122	131	124	132	125	134	135	135	113	126
”	2 ml Picloram formulation by injection (0.48 g a.e. per tree)	19	96	94	114	131	107	115	121	130	133	122	118	112	117
”	4 ml Picloram formulation by injection (0.96 g a.e. per tree)	20	107	107	125	131	132	136	143	143	154	173	149	125	138
”	1% (a.e.) 2, 4, 5-T (Flomore) below cut (0.02 g a.e. per tree)	21	128	97	138	131	156	119	180	128	164	131	149	107	135
”	1% (a.e.) 2, 4, 5-T (Flomore) above cut (0.01 g a.e. per tree)	22	114	104	131	115	136	127	134	122	132	132	130	110	124
S/4.d/2	2 ml Ethrel formulation in applicator (0.96 g a.i. per tree)	24	141	130	153	128	150	130	245	164	115	101	95	76	132
”	4 ml Ethrel formulation in applicator (1.92 g a.i. per tree)	25	152	138	140	112	142	100	175	116	106	121	112	91	122
”	2.5% (a.i.) Ethrel-in-palm oil below cut (0.02 g a.i. per tree)	26*	88	70	89	75	100	71	103	75	125*	113	161	74	97
”	6.7% (a.i.) Ethrel-in-palm oil below cut (0.05 g a.i. per tree)	27*	121	82	107	78	115	75	123	98	197*	139	216	130	127
”	2.5% (a.i.) Ethrel-in-palm oil above graft union (0.06 g a.i. per tree)	28	139	100	104	103	81	81	85	79	113	99	141	102	102
”	6.7% (a.i.) Ethrel-in-palm oil above graft union (0.13 g a.i. per tree)	29	208	121	114	96	82	79	90	85	151	116	193	101	119
”	2.5% (a.i.) Ethrel-in-palm oil above cut (0.02 g a.i. per tree)	30	92	74	84	73	72	62	73	61	60	66	88	65	72
”	6.7% (a.i.) Ethrel-in-palm oil above cut (0.04 g a.i. per tree)	31	93	71	82	78	95	84	142	98	113	98	151	104	103
”	1 ml Ethrel formulation by injection (0.48 g a.i. per tree)	32	—	—	208	128	163	100	180	95	151	85	124	69	125†
”	2 ml Ethrel formulation by injection (0.96 g a.i. per tree)	33	—	—	223	127	218	130	229	124	204	128	136	79	155†
”	30 g calcium carbide in applicator	34	140	84	104	85	89	84	142	85	68	67	66	55	85
”	2 g calcium carbide by injection	35	101	71	99	84	99	83	83	77	59	54	47	58	73

* In treatments No. 26 and 27 the tapping system was changed to S/4.d/2. (2×2d/4) at the beginning of the ninth month.

† Converted to annual figures on a proportionate basis, *i.e.*, by multiplying the values over ten months by 1.2.

a.i. = Active ingredient   a.e. = Acid equivalent

TABLE 3. EXPERIMENT LF. 3: ADJUSTED MEAN YIELD IN GRAMS PER TREE PER TAPPING

(Expressed within brackets as percentage of S/2.d/2 control)

Treatment		No.	Yield (monthly)												Annual yield
			1	2	3	4	5	6	7	8	9	10	11	12	
S/2.d/2	Scraped + Palm oil	1	65.9 (100)	65.2 (100)	84.4 (100)	87.2 (100)	75.0 (100)	81.0 (100)	77.8 (100)	92.5 (100)	101.0 (100)	120.7 (100)	106.1 (100)	51.6 (100)	83.2 (100)
"	1% (a.e.) 2, 4, 5-T (Flomore) below cut (0.03 g a.e. per tree) scraped	2	106.6 (162)	83.7 (128)	125.9 (149)	108.9 (125)	114.4 (153)	101.4 (125)	121.9 (157)	94.8 (103)	117.0 (116)	103.4 (86)	94.3 (89)	64.0 (124)	103.1 (124)
"	6.7% (a.i.) Ethrel-in-palm oil below cut (0.2 g a.i. per tree) scraped	3	84.0 (127)	58.9 (90)	126.7 (150)	71.7 (82)	100.9 (135)	71.0 (88)	112.8 (145)	72.6 (78)	110.7 (110)	84.4 (70)	110.8 (104)	36.5 (71)	86.6 (104)
"	10.0% (a.i.) Ethrel-in-palm oil below cut (0.32 g a.i. per tree) scraped	4	139.8 (212)	108.8 (167)	169.8 (201)	125.8 (144)	149.6 (199)	108.6 (134)	160.6 (206)	91.1 (98)	120.0 (119)	76.8 (64)	117.5 (111)	45.4 (88)	117.8 (142)
"	13.3% (a.i.) Ethrel-in-palm oil below cut (0.44 g a.i. per tree) scraped	5	147.8 (224)	94.1 (144)	195.5 (232)	109.1 (125)	174.0 (232)	115.7 (143)	200.6 (258)	108.2 (117)	194.9 (193)	139.6 (116)	191.7 (181)	68.9 (134)	144.8 (174)
"	13.3% (a.i.) Ethrel-in-palm oil below cut (0.44 g a.i. per tree) unscraped	6	80.3 (122)	65.7 (101)	125.4 (148)	104.2 (119)	124.5 (166)	101.4 (125)	157.4 (202)	105.9 (115)	153.6 (152)	118.0 (98)	107.5 (101)	67.8 (131)	109.2 (131)
"	13.3% (a.i.) Ethrel and 5% Dibutyl phthalate in palm oil below cut (0.52 g a.i. per tree) unscraped	7	99.7 (151)	76.3 (117)	151.1 (179)	112.0 (128)	140.7 (187)	122.0 (151)	160.1 (206)	97 0 (105)	148.6 (147)	122.9 (102)	108.4 (102)	55.1 (107)	116.2 (140)
"	0.82% (a.i.) Ethrel and 4% Dibutyl phthalate in water, sprayed below cut (5.07 g a.i. per tree)	8	75.8 (115)	47.4 (73)	67.3 (80)	59.5 (68)	80.9 (108)	69.8 (86)	95.2 (122)	67.5 (73)	85.3 (84)	89.3 (74)	86.6 (82)	63.4 (123)	73.8 (89)
"	1.6% (a.i.) Ethrel and 4% Dibutyl phthalate in water, sprayed below cut (10.80 g a.i. per tree)	9	92.4 (140)	69.3 (106)	84.6 (100)	74.6 (86)	113.7 (152)	82.1 (101)	132.0 (170)	89.5 (97)	108.9 (108)	92.0 (76)	76.5 (72)	52.3 (101)	89.0 (107)
S/4.d/2	6.7% (a.i.) Ethrel-in-palm oil below cut (0.09 g a.i. per tree) scraped	10	67.6 (103)	37.6 (58)	83.9 (99)	55.9 (64)	85.1 (113)	61.3 (76)	83.9 (103)	52.9 (57)	93.0 (92)	68.0 (56)	111.5 (105)	44.0 (85)	70.3 (84)
"	10.0% (a.i.) Ethrel-in-palm oil below cut (0.15 g a.i. per tree) scraped	11	54.8 (83)	35.3 (54)	78.4 (93)	48.9 (56)	92.9 (124)	59.7 (74)	108.4 (139)	62.0 (67)	129.8 (129)	95.4 (79)	165.4 (156)	57.6 (112)	81.4 (98)
"	13.3% (a.i.) Ethrel-in-palm oil below cut (0.22 g a.i. per tree) scraped	12	44.8 (68)	26.7 (41)	78.5 (93)	51.1 (59)	104.1 (139)	65.0 (80)	120.1 (154)	73.0 (79)	136.2 (135)	100.4 (83)	137.9 (130)	62.0 (120)	82.9 (100)
"	13.3% (a.i.) Ethrel-in-palm oil below cut (0.33 g a.i. per tree) unscraped	13	51.3 (78)	33.8 (52)	46.6 (55)	45.7 (52)	51.2 (68)	54.4 (67)	51.1 (66)	36.9 (40)	69.9 (69)	69.7 (58)	100.8 (95)	49.4 (96)	54.5 (66)
"	0.82% (a,i.) Ethrel and 4% Dibutyl phthalate in water, sprayed below cut (2.42 g a.i. per tree)	14	60.3 (91)	35.3 (54)	52.1 (62)	44.7 (51)	59.0 (79)	48.0 (59)	63.4 (81)	38.7 (42)	51.7 (51)	55.6 (46)	50.9 (48)	33.2 (64)	49.3 (59)
"	1.6% (a.i.) Ethrel and 4% Dibutyl phthalate in water, sprayed below cut (5.41 g a.i. per tree)	15	67.8 (103)	42.2 (65)	46.1 (55)	43.5 (50)	61.7 (82)	51.7 (64)	45.4 (58)	32.5 (35)	42.6 (42)	48.8 (40)	36.6 (34)	26.7 (52)	45.7 (55)
S.E.			11.83	11.48	18.81	15.23	15.00	14.32	19.54	11.57	22.62	20.73	18.29	11.34	14.15
Min. sig. diff. ($P < 0.05$)			36.1	35.0	57.4	46.5	45.9	43.7	59.7	35.3	69.1	63.3	55.9	34.6	43.2

TABLE 4. EXPERIMENT LF. 4: ADJUSTED MEAN YIELD IN GRAMS PER TREE PER TAPPING
(Expressed within brackets as percentage of S/2.d/2 control)

Treatment	No.	Yield (monthly) 1	2	3	4	5	6	7	8	9	10	11	12	Annual yield
S/2.d/2 Scraped + palm oil	1	37.0 (100)	54.4 (100)	51.4 (100)	38.0 (100)	76.9 (100)	104.6 (100)	71.0 (100)	60.5 (100)	45.6 (100)	29.2 (100)	18.3 (100)	23.5 (100)	51.6 (100)
” 1% (a.e.) 2, 4, 5-T (Flomore) below cut (0.02 g a.e. per tree) scraped	2	81.1 (219)	79.2 (146)	57.9 (113)	78.0 (205)	134.9 (175)	113.8 (109)	122.9 (173)	93.6 (155)	54.3 (119)	68.6 (235)	45.0 (246)	40.7 (173)	82.9 (161)
” 6.7% (a.i.) Ethrel-in-palm oil below cut (0.13 g a.i. per tree) scraped	3	87.9 (238)	63.8 (117)	52.8 (103)	114.7 (302)	104.6 (136)	99.9 (96)	115.5 (163)	103.4 (171)	61.1 (134)	113.5 (389)	37.2 (203)	37.0 (157)	84.3 (163)
” 10.0% (a.i.) Ethrel-in-palm oil below cut (0.20 g a.i. per tree) scraped	4	104.4 (282)	59.1 (109)	50.0 (97)	119.7 (315)	113.2 (147)	90.0 (86)	114.3 (161)	95.0 (157)	56.1 (123)	113.5 (389)	34.0 (186)	30.3 (129)	83.5 (162)
” 13.3% (a.i.) Ethrel-in-palm oil below cut (0.32 g a.i. per tree) scraped	5	115.3 (312)	86.3 (159)	77.2 (150)	166.3 (438)	160.9 (209)	137.4 (131)	138.3 (195)	127.2 (210)	80.6 (177)	148.9 (510)	47.6 (260)	44.7 (190)	113.2 (219)
” 6.7% (a.i.) Ethrel-in-palm oil above graft union (0.14 g a.i. per tree) scraped	6	100.3 (271)	60.9 (112)	48.7 (95)	39.2 (103)	67.8 (88)	114.0 (109)	142.3 (200)	98.6 (163)	71.9 (158)	132.5 (454)	42.6 (233)	57.6 (245)	83.3 (161)
” 10.0% (a.i.) Ethrel-in-palm oil above graft union (0.21 g a.i. per tree) scraped	7	81.7 (221)	60.0 (110)	48.9 (95)	40.3 (108)	73.1 (95)	128.0 (122)	146.3 (206)	106.4 (176)	75.7 (166)	146.9 (503)	56.2 (307)	65.5 (279)	87.8 (170)
” 13.3% (a.i.) Ethrel-in-palm oil above graft union (0.27 g a.i. per tree) scraped	8	60.9 (165)	45.9 (84)	38.0 (74)	36.6 (96)	55.0 (72)	75.1 (72)	112.1 (158)	63.1 (104)	42.5 (93)	98.8 (338)	25.7 (140)	32.5 (138)	59.3 (115)
S/4.d/2 (2×2d/4) 6.7% (a.i.) Ethrel-in-palm oil below cut (0.15 g a.i. per tree) scraped	9	45.6 (123)	40.4 (74)	38.6 (75)	96.2 (253)	68.0 (88)	80.3 (77)	90.7 (128)	63.6 (105)	43.1 (95)	81.7 (280)	21.0 (115)	17.6 (75)	58.5 (113)
” (2×2d/4) 10.0% (a.i.) Ethrel-in-palm oil below cut (0.20 g a.i. per tree) scraped	10	74.9 (202)	50.0 (92)	38.5 (75)	128.7 (339)	99.8 (130)	118.7 (113)	122.8 (173)	104.1 (172)	75.5 (166)	107.5 (368)	27.6 (151)	24.4 (104)	82.4 (160)
” (2×2d/4) 13.3% (a.i.) Ethrel-in-palm oil below cut (0.33 g a.i. per tree) scraped	11	94.6 (256)	54.2 (100)	38.8 (75)	141.0 (371)	99.4 (129)	111.3 (106)	123.6 (174)	80.8 (134)	56.6 (124)	108.8 (373)	25.0 (137)	24.3 (103)	81.5 (158)
” (2×2d/4) 6.7% (a.i.) Ethrel-in-palm oil above graft union (0.13 g a.i. per tree) scraped	12	39.1 (106)	34.5 (63)	23.9 (46)	27.8 (73)	47.9 (62)	72.1 (69)	91.3 (129)	61.3 (101)	38.4 (84)	80.8 (277)	22.1 (121)	31.1 (132)	49.1 (95)
” (2×2d/4) 10.0% (a.i.) Ethrel-in-palm oil above graft union (0.21 g a.i. per tree) scraped	13	53.9 (146)	31.7 (58)	26.8 (52)	21.3 (56)	38.1 (50)	62.7 (60)	90.9 (128)	54.8 (91)	33.9 (74)	99.0 (339)	19.6 (107)	26.7 (114)	48.4 (94)
” (2×2d/4) 13.3% (a.i.) Ethrel-in-palm oil above graft union (0.29 g a.i. per tree) scraped	14	45.6 (123)	33.4 (61)	27.3 (53)	25.9 (68)	55.9 (73)	110.3 (105)	131.1 (185)	92.3 (153)	61.2 (134)	118.9 (407)	26.4 (144)	35.7 (152)	65.8 (128)

the difference is not statistically significant. Application of Picloram above the cut (Treatments No. 17 and 18) appeared less effective (*Tables 1* and *2*, and *Figure 2*). This method had not been tested previously; the results with below-cut treatments are similar to those of ABRAHAM *et al.* (1968).

Injection of Picloram (Treatments No. 19 and 20), also a new procedure with this material, produced a definite yield response. The results (*Tables 1* and *2*) suggest, however, that a much larger dose in grams per tree is required than with Picloram-in-palm oil. Moreover, there was profuse bleeding of latex from the bore holes used for Picloram injections and the putrid smell developing at these sites suggested invasion by micro-organisms. Injection of Picloram is unpromising as a practical procedure and these treatments are omitted from the *Figures*.

Several of the Ethrel treatments gave outstanding results. With S/2 the best yields over the whole year, all approximately 180% of the control, were obtained with the applicator (0.96 g a.i. per tree — Treatment No. 2) with 6.7% Ethrel-in-palm oil below the cut (0.14 g a.i. per tree — Treatment No. 5) and by *injection* (0.96 g a.i. per tree — Treatment No. 11). The differences in yield between these treatments and the control are statistically significant (see *Tables 1* and *2*).

Although comparisons between individual treatments are mostly not statistically significant, they strongly suggest — and their combined effects show — that (1) the best treatments with Ethrel were superior to 2,4,5-T; (2) application in palm oil below the cut produced the same response with much less Ethrel than was required in the applicator or by injection; and (3) at the more effective

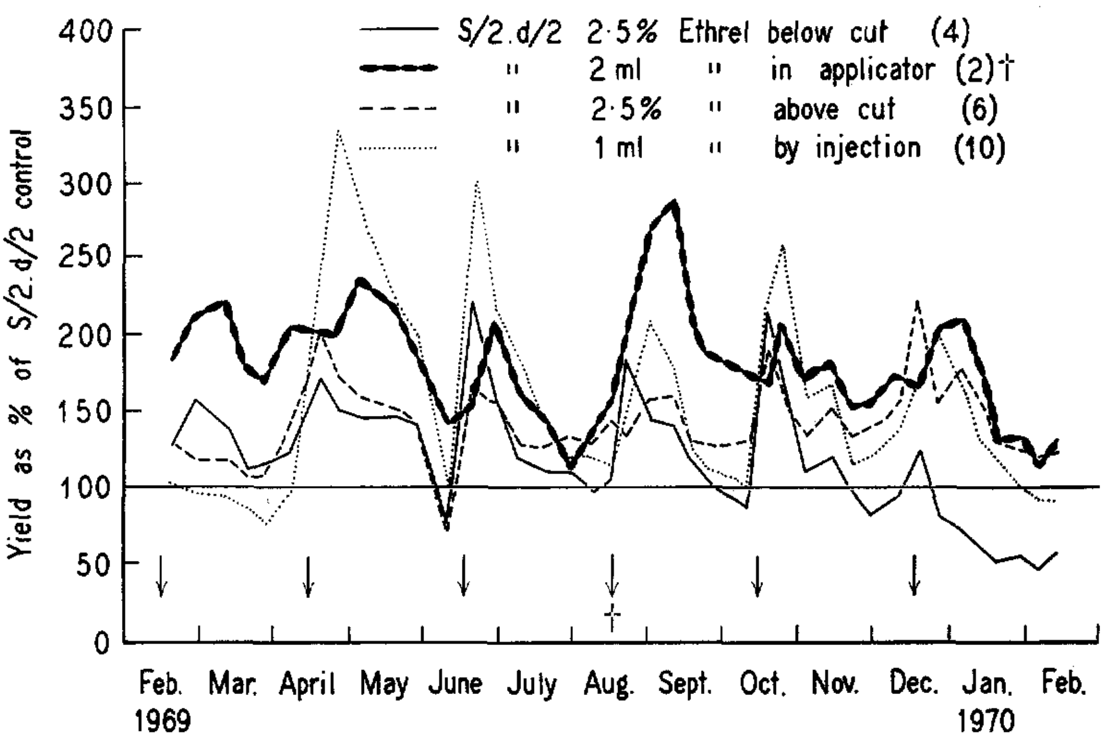

Figure 3. Experiment LF. 2: Treatments No. 4, 2, 6 and 10. [Dates of application are indicated by arrows; site of applicator changed at the point (†) indicated.]

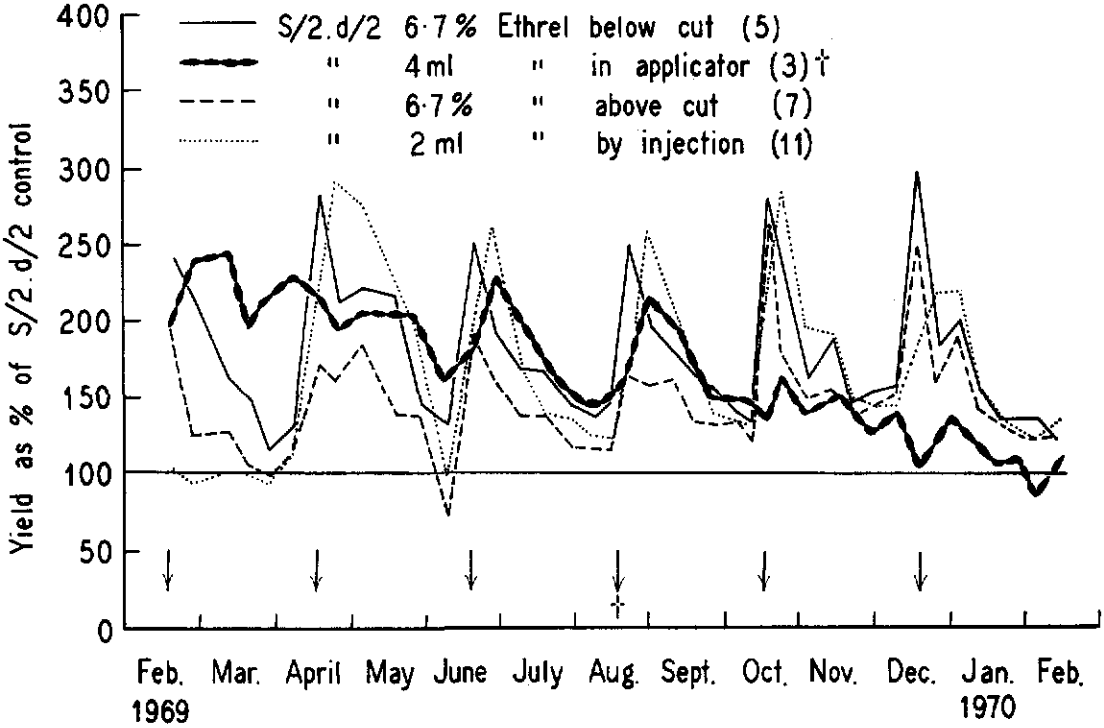

Figure 4. Experiment LF. 2: Treatments No. 5, 3, 7 and 11. [*Dates of application are indicated by arrows; site of applicator changed at the point (†) indicated.*]

of the two concentrations used in palm oil (6.7% a.i.), Ethrel gave a better result when applied below the cut than when applied above it or near the graft union. The case of application at the graft union is, however, complicated by the change of site which was made during the experiment; this is discussed further.

The yield trends with Ethrel treatments and S/2 tapping systems are shown in *Figures 3, 4* and *5*. The following features are of particular interest:

Successive reapplications of Ethrel-in-palm oil below the cut gave good responses. With the higher and more effective concentration no indication of a progressive decline was apparent. The response to successive re-applications above the cut seemed somewhat erratic, but there was again no progressive decline *(Figures 3* and *4)*.

At the lower dose of Ethrel-in-applicator, there appeared to be a slight decline in response by the third application at the same site. There was a clear increase in response at the fourth application, after shifting the applicator *(Figure 3)*. This effect was not seen with the higher and less effective dose of Ethrel-in-applicator and in this case there was a severe fall in response at the fifth and sixth applications *(Figure 4)*.

The failure of the first 'injection' of Ethrel is clearly apparent in *Figures 3* and *4*. Thereafter, each injection produced a good response especially with the higher of the two dose-levels used, although the site of injection was unchanged *(Tables 1* and *2)*.

The second, third and fourth applications of Ethrel-in-palm oil near the graft union were made to the same site as the original application. The fifth and sixth applications were each made to a fresh site. *Figure 5* clearly shows the improved responses resulting from this change. It seems plain that the performance of these systems over the year would have been better if the site had been changed for all the reapplications.

For the S/4 systems, the most important result was that the best Ethrel treatments gave yields exceeding that of the untreated S/2.d/2 control. Injection of Ethrel at the higher dose level (Treatment No. 33) yielded 155% of the control over the whole year. The yields obtained with Ethrel-in-applicator, 6.7% Ethrel-in-palm oil below the cut and several other treatments also exceeded the control.

Direct comparisons of the results for the whole year are complicated for many of the treatment by the changes made in application methods during the year. In such cases the yield trends shown in *Figures 5, 6* and *7* are more informative. It can be seen that many of the features noted with S/2 systems were reproduced.

The response to Ethrel-in-palm oil below the cut was not impaired at successive applications. However, limiting the application to an S/4 band of bark apparently restricted the response. A marked improvement was seen following the change of tapping system to S/4.d/2. (2 × 2d/4) *(Figures 6* and *7)*. This was made before the fifth application and effectively doubled the dose of stimulant per tree since the formulation was then applied to two S/4 bands. Had this system been used throughout the year, it appears likely that

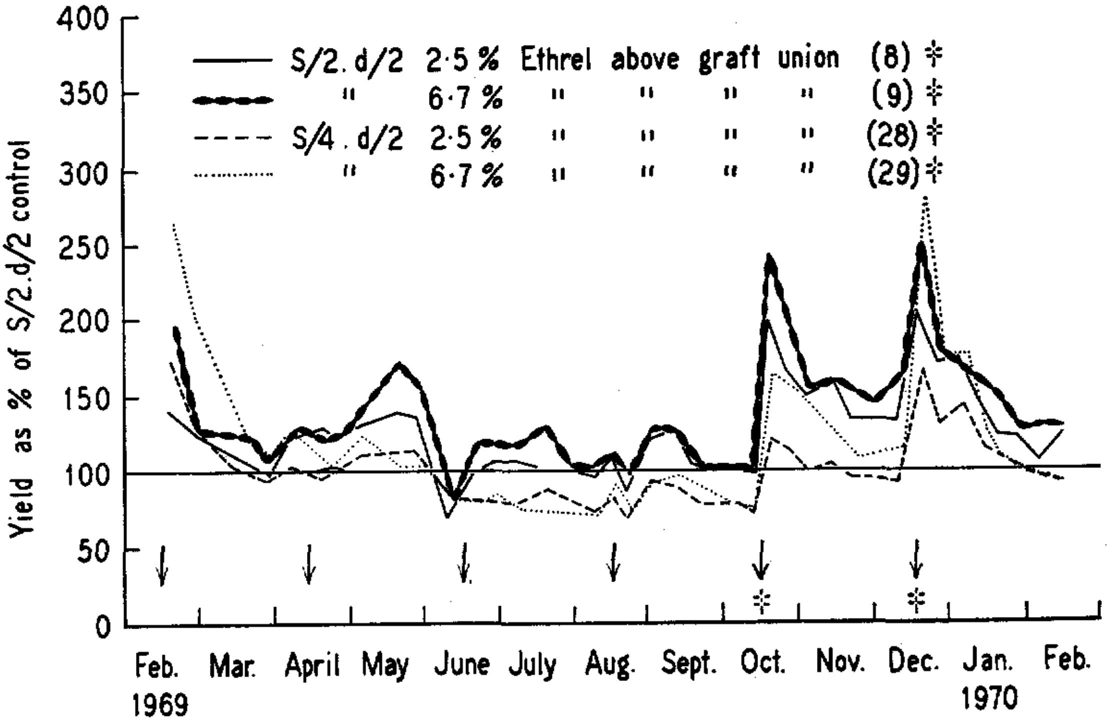

Figure 5. Experiment LF. 2: Treatments No. 8, 9, 28 and 29. [Dates of application are indicated by arrows; site of application changed at the points (‡) indicated.]

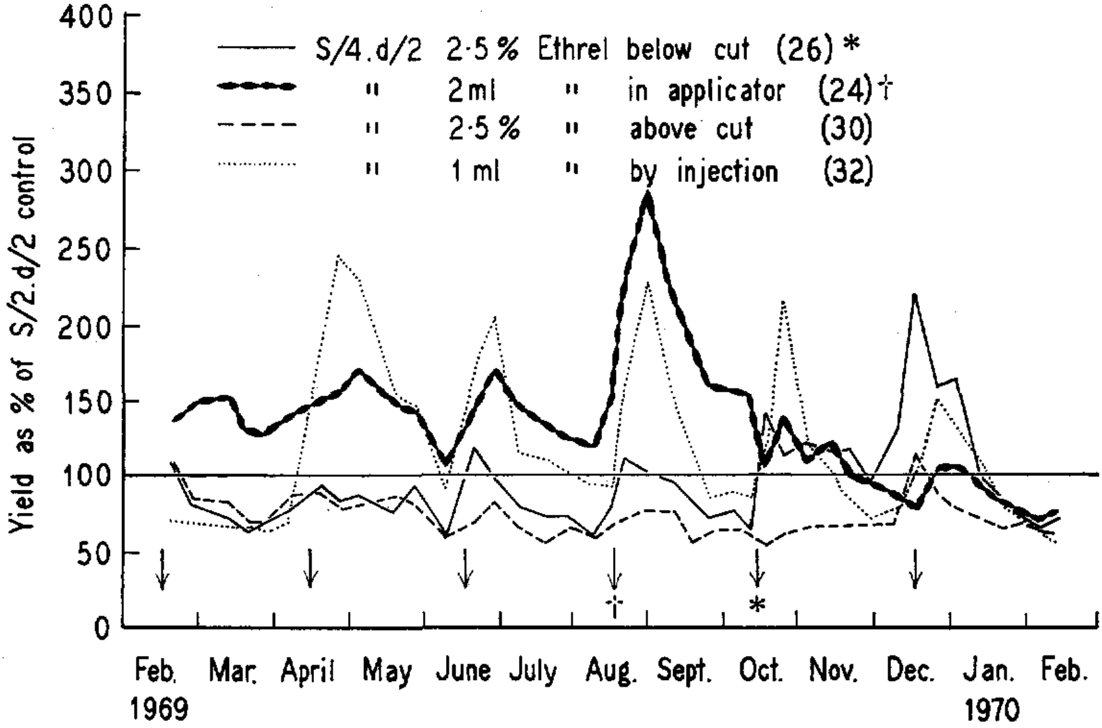

Figure 6. Experiment LF. 2: Treatments No. 26, 24, 30 and 32. [Dates of application are indicated by arrows. In Treatment No. 26, the tapping system was changed to S/4.d/2. (2 × 2d/4) at the point (*) indicated; site of applicator changed at the point (†) indicated.]

the overall yield would have been close to that obtained with a single S/4 cut and Ethrel injected at the higher, more effective dose. The system S/4.d/2 (2 × 2d/4) involves panel changing and this, as well as the increased dose of Ethrel, probably contributed to the good results obtained.

The expected improvement in response occurred when the Ethrel applicators were shifted at the fourth application (*Figures 6* and *7*). The lower of the two doses again appeared the better.

Repeated injections at the same site were effective (the reduced response at the last application shown in *Figures 6* and *7* was bettered at the next application, as in the case of the S/2 systems).

With Ethrel-in-palm oil applied near the graft union, the change of site at the fifth and sixth applications improved the response.

The effects of the various treatments on the conditions of the bark has so far been examined only macroscopically.

No effect was seen with applications of Ethrel, Picloram or 2, 4, 5-T below the cut. This is the expected result since the treated bark was tapped away.

In treatments with Ethrel or Picloram above the cut, the renewing bark developed a very thin and uniform corky layer without gross cracks or bleeding. The renewing bark beneath this appeared normal and yielded latex on pricking. By contrast, application of 2, 4, 5-T above the cut produced extremely corky and irregularly renewing bark.

Where Ethrel was applied near the graft union, the stimulated strip of bark developed a thick outer layer of brittle cork. This was especially marked at the original site which received four successive applications. As the treated bark aged, the corky tissue developed vertical cracks; it could be peeled off easily; no 'bleeding' was observed. Under the cork, latex-bearing tissue was detectable by pricking; however, there was some suggestion that this layer of tissue was thinner than normal.

The effects of acetylene and Ethrel in applicators were similar to those observed in Experiment LF. 1 and described in the previous paper (ABRAHAM *et al.,* 1971).

The severe 'bleeding' around bore holes used for Picloram injection has been mentioned. No such effect was seen with injected Ethrel.

Consideration of all the results of the experiment suggested that Ethrel-in-palm oil applied below the cut was the procedure most likely to find early practical application. Experiment LF.3 was designed to study this method in more detail but also included among the treatments some speculative methods of applying Ethrel.

EXPERIMENT LF. 3

The trees were of four clones (Tjir 1, PB 49, RRIM 501 and PR 107); these were also in Section D (ii) of the Smallholders' Nursery

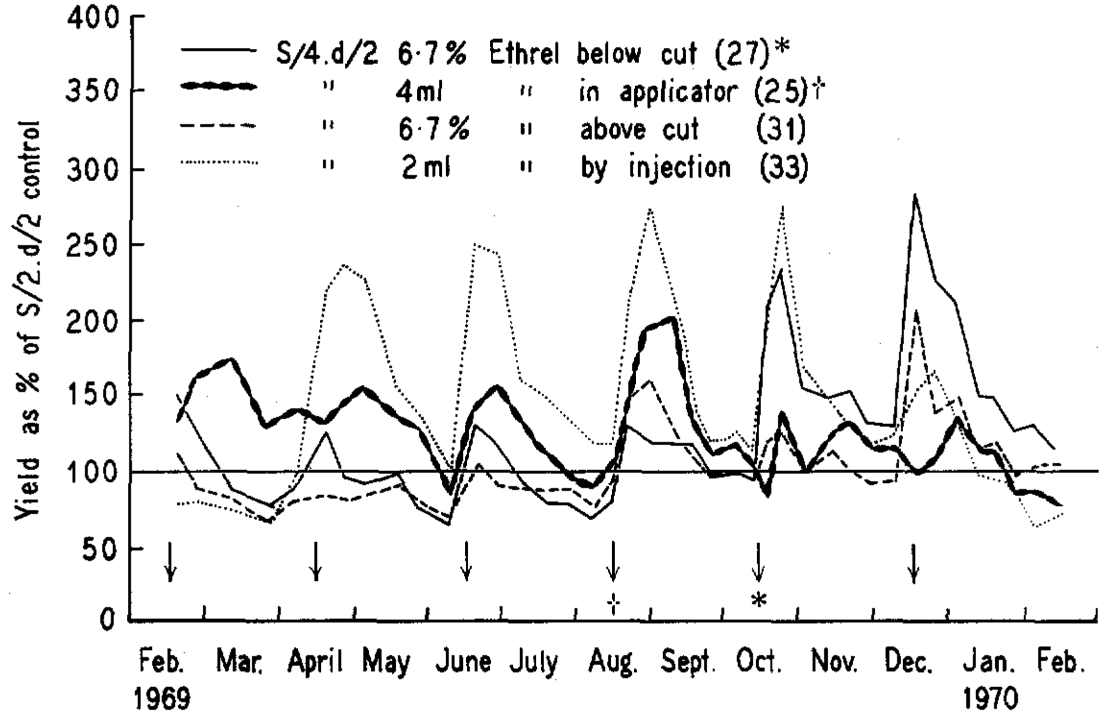

Figure 7. Experiment LF. 2: Treatments No. 27, 25, 31 and 33. [Dates of application are indicated by arrows. In Treatment No. 27, the tapping system was changed to S/4.d/2. (2 × 2d/4) at the point (*) indicated; site of applicator changed at the point (†) indicated.]

at the R.R.I.M. Experiment Station and the planting and tapping history were the same as for the trees of Experiment LF.2. Yields were pre-recorded at the same time and in the same way as in Experiment LF.2, and treatments were randomised similarly. Eight trees were taken for each treatment, two of each clone. Yields from each treatment were recorded from two groups of four trees.

Treatments and Methods of Application

General. Two tapping systems were used: S/2.d/2 and S/4.d/2. The S/4 cuts were the lower halves of the original half spirals (as at the beginning of Experiment LF.2). The fifteen treatments in Experiment LF.3 are listed in *Table 3.*

Initial application of stimulants. The first application of stimulants was made on 1 April 1969. Where 2,4,5-T (Flomore) or Ethrel-in-palm oil was applied to scraped bark below the cut (Treatments No. 2, 3, 4, 5, 10, 11 and 12), the technique was the same as in the preceding experiment except for the difference in concentration (% w/w) and dose-size (grams) shown in *Table 3.*

Applications of Ethrel-in-palm oil to unscraped bark (Treatments No. 6, 7 and 13) were also made to a band of standard width (4 cm) immediately below the cut. In Treatment No. 7, dibutyl phthalate was added to the Ethrel-in-palm oil mixture at a final concentration of 5% (w/w) in the hope that it might aid penetration of Ethrel into unscraped bark (dibutyl phthalate has been used for a similar purpose with 2, 4, 5-T; see RUBBER RESEARCH INSTITUTE OF MALAYA, 1960 and 1961).

In all applications to bark, whether scraped or not, trees with S/4 cuts received about half the absolute dose of stimulant applied to those tapped on S/2 and treated with the same stimulant mixture.

In Treatments No. 8, 9, 14 and 15, Ethrel as supplied by the manufacturers was diluted with water to the two different concentrations (% w/w) shown in *Table 3.* Dibutyl phthalate was added to each mixture to a final concentration of approximately 4% (w/w). The mixtures were then immediately sprayed on the tapping panels with a pneumatic hand sprayer. The panels were not scraped or otherwise pre-treated. The whole of each panel from the cut to the graft union was wetted with the spray: the dose of Ethrel per tree and the area treated varied with the cut length (S/2 or S/4) since the spray was applied only to the bark under the cut in tapping.

Control. Treatment No. 1 served as control throughout. The trees in this group were scraped below the cut and treated with palm oil, then tapped on S/2.d/2 exactly as in the control of Experiment LF.2.

Reapplications of stimulants and changes of technique during the experiment. The second application of treatments was done two months after the initial one and subsequent applications were at two-monthly intervals.

No change of technique was made with the treatments involving S/2 cuts and the movement of the cuts ensured that each reapplication in palm oil was made to a new site.

All reapplications by spraying were made without changing the technique used in the initial application. In these cases, the site was the same throughout, although the area of bark treated was reduced very slightly on successive applications because of the movement of the cut down the trees.

With trees tapped on S/4 and treated with Ethrel-in-palm oil (Treatments No. 10, 11, 12 and 13), the initial dose per tree and area of bark treated were roughly halved as compared with the case of trees tapped on S/2; the second and third applications were made immediately below the S/4 cuts and limited to the S/4 length as before. At the fourth application (on 4 October 1969), a new band of bark of S/2 length was scraped at a position about 75 cm below the S/4 cut and parallel with it on the trees of Treatments No. 10, 11 and 12. This band was of the standard width (4 cm). Ethrel-in-palm oil at the three concentrations used was applied to this band, thus approximately doubling the area of bark treated and the dose per tree. A similar modification was made to Treatment No. 13, but since the first three applications in this case had been made to unscraped bark, the fourth application was made to a new S/2 band of unscraped bark about 75 cm below the cut.

No change was made to the tapping cuts in these treatments. The fifth application of Ethrel-in-palm oil was made immediately *below* the band at 75 cm and each subsequent application below the preceding one.

Results

Results from the first twelve months of the experiment are given in *Table 3.* As with Experiment LF. 2, only the more interesting treatments are presented in *Figures 8* and *9.*

Standard errors are large for the same reasons as in Experiment LF. 2 and almost all the differences between individual treatments in respect of average yield over twelve months are statistically non-significant (exceptions are differences between effects of tapping systems). Nevertheless, the *Figures* reveal some unmistakable trends. The results are now considered in detail.

S/2 systems. With Ethrel-in-palm oil applied to scraped bark below the cut (Treatments No. 3, 4 and 5), response increased with increasing concentration of Ethrel. This relationship was maintained quite consistently at every reapplication. The initial response, *i.e.,* the peak yield after stimulation, was always greater with Ethrel, at all dose-levels, than with 2,4,5-T. With Ethrel, yields fell away rather steeply from the initial peak, while the effect of 2,4,5-T was a little more persistent *(Figure 8).* Over twelve months, the lowest concentration of Ethrel (6.7% w/w) gave less total yield than 2,4,5-T but

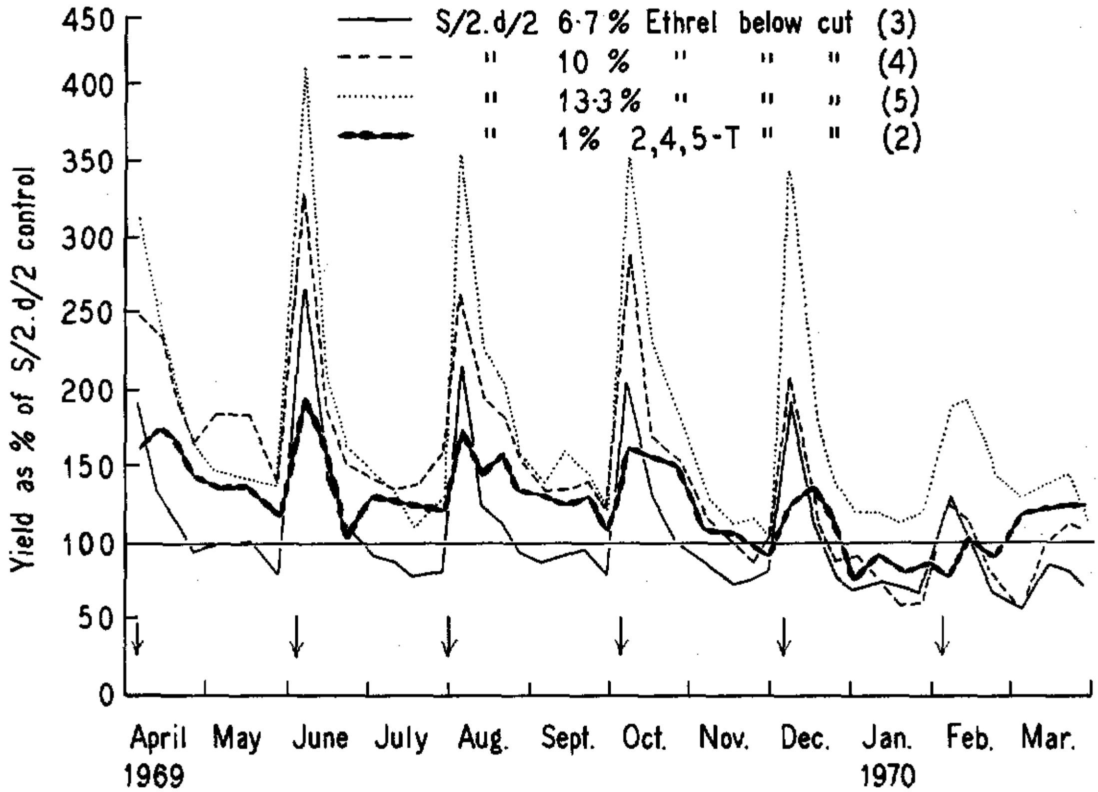

Figure 8. Experiment LF. 3: Treatments No. 3, 4, 5 and 2. (Dates of application are indicated by arrows.)

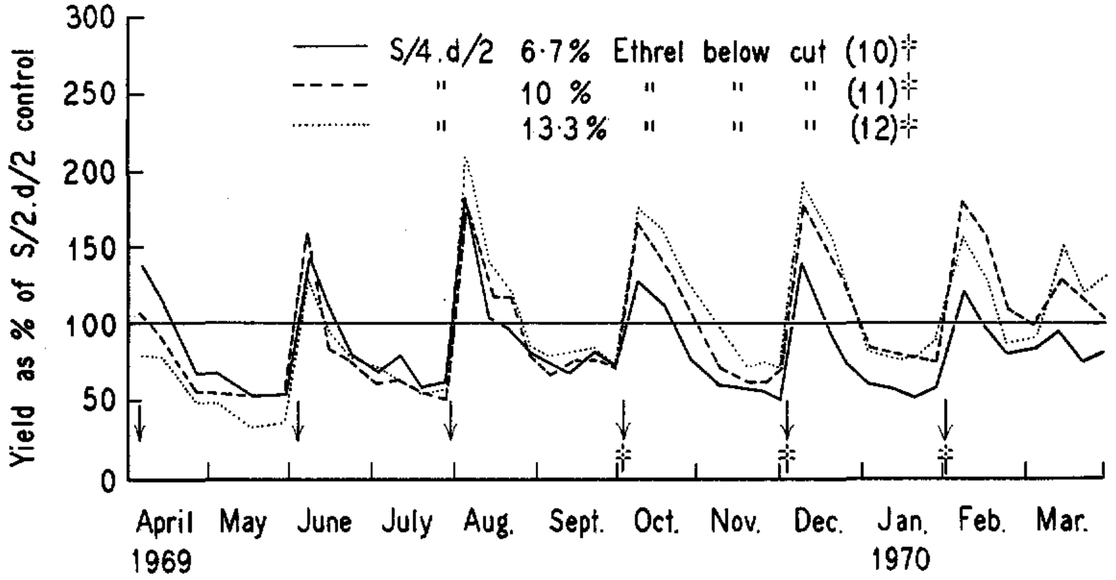

Figure 9. Experiment LF. 3: Treatments No. 10, 11 and 12. [Dates of application are indicated by arrows; site of application changed at the points (‡) indicated].

the medium concentration (10.0% w/w) and the highest (13.3% w/w) out-yielded 2,4,5-T. The yield with the highest concentration, 174% of the control, was very satisfactory *(Table 3)* and was significantly better than either control or application of Ethrel at the lowest concentration.

Results with Ethrel-in-palm oil applied to unscraped bark (Treatments No. 6 and 7) were inferior to those with the same concentration of Ethrel on scraped bark, whether or not the penetrant, dibutyl phthalate, was used. Spraying aqueous Ethrel on unscraped bark (Treatments No. 8 and 9) appeared quite ineffective *(Table 3;* none of these treatments is shown in the *Figures)*. It will be noted that very high doses of Ethrel were used in the spray treatments. Possibly, smaller doses would have given better results but this method is unpromising: it is wasteful of material and the results with Ethrel-in-palm oil on unscraped bark suggest that scraping is necessary.

S/4 systems. Results with the S/4 system showed some puzzling features. As already noted, the dose of Ethrel per tree was approximately doubled at the fourth application by changing the length of the band of application from S/4 to S/2; at the same time it was moved 75 cm below the cut. Possibly the movement of the site cancelled any effect of increased dosage because there was no improvement in response *(Figure 9)*.

Over twelve months, the best yield from the S/4 system was obtained with the highest concentration of Ethrel and the yields from the two lower concentrations were in the expected order *(Table 3)*. But, this was not true at every application (as it was in the S/2 treatments): for example, at the second and sixth applications, the highest response was produced by the medium (10%) concentration *(Figure 9)*. The authors cannot offer any explanation for this. Applications of Ethrel to unscraped bark, whether in palm oil (Treatment No. 13) or by spraying (Treatments

No. 14 and 15) were as unpromising with the S/4 as with the S/2 cuts *(Table 3)*.

The most notable positive result with the S/4 system is that, in combination with the highest concentration of Ethrel-in-palm oil applied to scraped bark, it yielded as well over twelve months as the untreated S/2.d/2 control *(Table 3)*.

As with Experiment LF.2, the results of the present experiment, shown in *Table 3* and *Figures 8* and *9*, refer to four clones taken together. Since there were only two trees of each clone in each treatment, separate presentation of the results from each clone was not justifiable. However, examination of the experimental records on a clonal basis suggested that Tjir 1 had given a much larger response to Ethrel than the other three clones and that the intermediate, rather than the highest, concentration of Ethrel might be optimal for Tjir 1. Other (unpublished) small trials had also suggested a very pronounced response to Ethrel from Tjir 1, which responds well to other stimulants.

For these reasons, Experiment LF.4 concentrated on Tjir 1.

EXPERIMENT LF. 4

The trees were all of clone Tjir 1 in Field 47 of the R.R.I.M. Experiment Station. These had been budded in 1951-2, opened for tapping in April 1959 and then tapped regularly on S/2.d/2. Immediately before this experiment they were being tapped on Panel C which had been opened in December 1968.

Yields were pre-recorded for two months from January 1969 and treatments were distributed at random among trees of similar yield.

Ten trees were taken for each treatment. Yields were recorded from all ten trees in each treatment taken together.

Treatments and Methods of Application

General. There were two tapping systems: S/2.d/2 and S/4.d/2 (2 × 2d/4). The S/2 cuts were those already in tapping. For the S/4 system, the existing S/2 cuts were divided into two halves (upper and lower) and these were tapped alternately. The experiment included fourteen treatments listed in *Table 4*.

Initial application of stimulants. The first application of stimulants was made on 3 May 1969. As *Table 4* shows, there was one treatment (No. 2) with 2,4,5-T (Flomore) and the rest were with three different concentrations of Ethrel-in-palm oil to two different sites: immediately below the cut and on the lowest area of renewing bark immediately above the graft union. With trees tapped on S/2 the application of stimulant was made at either site to an S/2 band of scraped bark of standard width (4 cm).

With the S/4 system, Ethrel-in-palm oil was also applied from the outset to bands of half-spiral length and standard (4 cm) width. Where application was below the cut, the band extended along the whole length of the original half-spiral although this was divided into two for tapping. Thus, by contrast with the initial application and the earlier reapplications in Experiments LF. 2 and LF. 3, the dose of stimulant per tree was not halved for the S/4 systems.

The trees in Experiment LF.4 were moreover of rather uniform girth. The percentage concentration of stimulant and average absolute dose per tree in this experiment (see *Table 4*) therefore show a more proportionate relationship than those of Experiment LF. 2 (see *Table 1*).

Control. Treatment No. 1 served as control throughout and corresponded exactly with the controls of Experiment LF. 2 and LF. 3.

Reapplications of stimulants and changes of technique during the experiment. The second application of stimulants was made three months after the initial application and subsequent applications at three-monthly intervals. Where the initial application was immediately below the cut, no change in technique was made on reapplication and the movement of the cuts provided a new site for each application. Where the initial application was just above the graft union, the second application was made without change of site. For the third application, a fresh band of scraped bark immediately above the first was used and each subsequent application was made to a fresh band immediately above the preceding one.

Results

Results from the first twelve months of the experiment are given in *Table 4* and *Figures 10 – 13*.

At the period of maximum yield after the third application, one week's crop was lost due to a freak storm; no attempt was made to correct the yield data for this loss. Accordingly, the third set of peaks in *Figures 10 – 13* gives an underestimate of the true extent of stimulation. The results for the full year are similarly, though only slightly, affected.

With the S/2 systems the outstanding result was the yield obtained by application of the highest concentration (13.3% w/w) of Ethrel-in-palm oil to scraped bark below the cut (219% of control over the year — Treatment No. 5.) The overall yields from the corresponding treatments with the two lower concentrations of Ethrel were unexpectedly equal. In this respect the results differ from those of Experiment LF. 3. The finding that Ethrel gave the best response at 13.3% and not 10% was also contrary to the indications from Experiment LF. 3 in respect of Tjir 1.

The responses to Ethrel immediately after the fourth application are noteworthy *(Table 4)*. Trees in several of the treatments yielded four or five times as much rubber as the controls during the month following stimulation. This remarkable response occurred during January and February 1969, the wintering period which is not considered favourable for conventional stimulation. The fourth set of peaks in *Figure 10* also illustrates

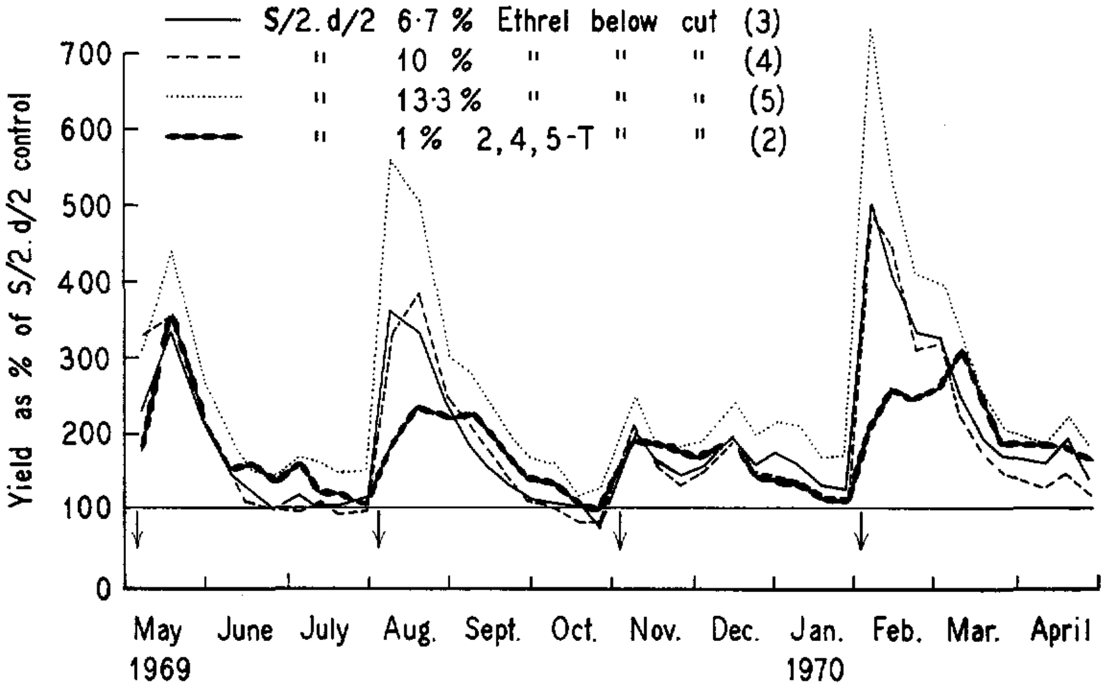

Figure 10. Experiment LF. 4: Treatments No. 3, 4, 5 and 2. (Dates of application are indicated by arrows.)

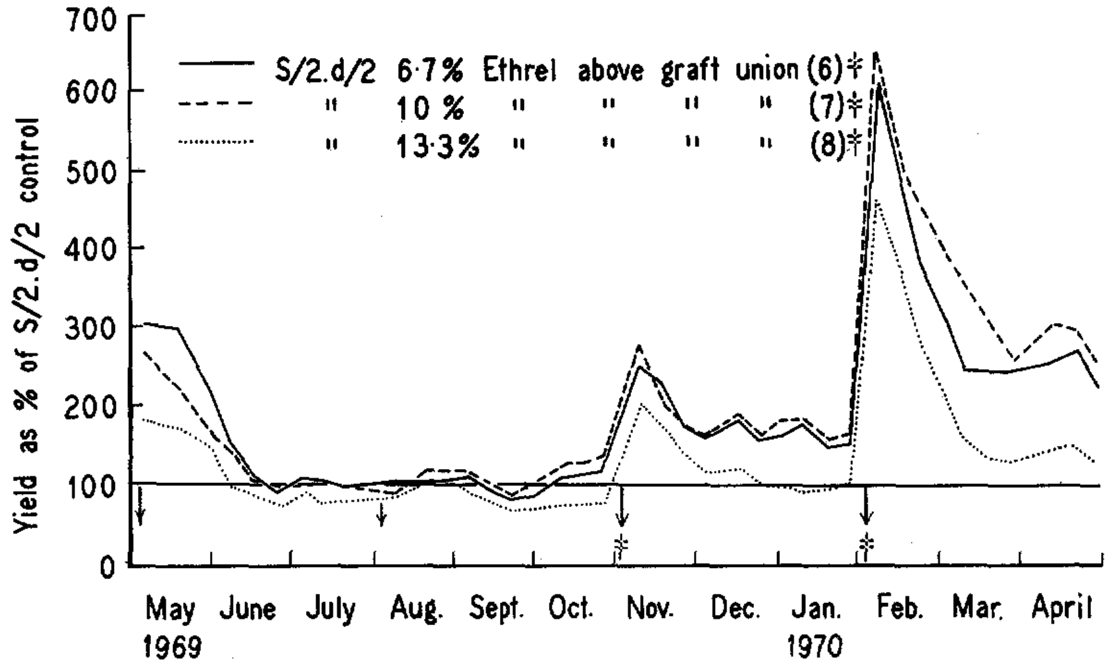

Figure 11. Experiment LF. 4: Treatments No. 6, 7 and 8. [Dates of application are indicated by arrows; site of application changed at the points (‡) indicated.]

the superiority of Ethrel to 2,4,5-T during this period.

It may also be noted that, at the R.R.I.M. Experiment Station where the trial was conducted, wintering was unusually severe on this occasion: there was rapid, fairly uniform defoliation followed by extreme depression of the yield of untreated trees during refoliation. The period of low rainfall, usual at this time in the area, was more marked and prolonged than the average.

The yield trends illustrated in *Figure 10* confirmed that repeated applications of Ethrel below the cut gave undiminished responses. The decline from the peak yield after each application was rather steep, as in earlier experiments.

Response to 2,4,5-T (Treatment No. 2) in the present experiment was good and somewhat more persistent than with Ethrel. The overall yield for the year was substantially less than that with the highest concentration of Ethrel but about equal to that with the two lower concentrations.

Figure 11 shows that the second application of Ethrel to an unchanged site near the graft union was ineffective. Although, from the results of Experiment LF. 2 this was expected, the effect was even more pronounced in this case (compare *Figure 11* with *Figure 5*). Possibly this was due to the longer interval between applications in LF. 4 (three months instead of two). This would tend to permit greater proliferation of cork, and therefore lessen perhaps the penetration of the stimulant to the phloem beneath. The use of fresh sites at the fourth and fifth applications near the graft union produced a greatly improved response.

It is difficult to compare the whole year's results from applications below the cut with those from applications near the graft union because of the negative result with the second application in the latter case. Even allowing for this, there are some odd features. At the initial application near the graft union, the response was related inversely to the concentration of Ethrel applied. At the fourth application, the highest concentration again produced the lowest response, but the medium (not the lowest) concentration gave the best stimulation.

The best results with the S/4 systems were obtained with the two higher concentrations of Ethrel-in-palm oil applied to scraped bark below the cuts. The overall yield for the year from these treatments (No. 10 and 11) was about 160% of the S/2.d/2 control and the response during wintering was excellent, as with the S/2 treatment. Thus the use of two adjacent S/4 cuts with Ethrel applied below each proved an effective system, as the results from the latter part of Experiment LF. 2 had suggested. However, the production of equal stimulation by two different concentrations of Ethrel is difficult to explain.

With the S/4 system, as with the S/2, the results from application of Ethrel-in-palm oil near the graft union were complex. One point was obvious: a reapplication on the site of the initial application was quite ineffective and a change of site at each subsequent application corrected this. But, it is difficult to interpret the effects of different concentrations of Ethrel, *e.g.*, at the first application the medium concentration gave the best response, while at the fourth application the highest concentration was the best.

The condition of the bark after applications of Ethrel-in-palm oil near the graft union was similar to those described in the results of Experiment LF. 2.

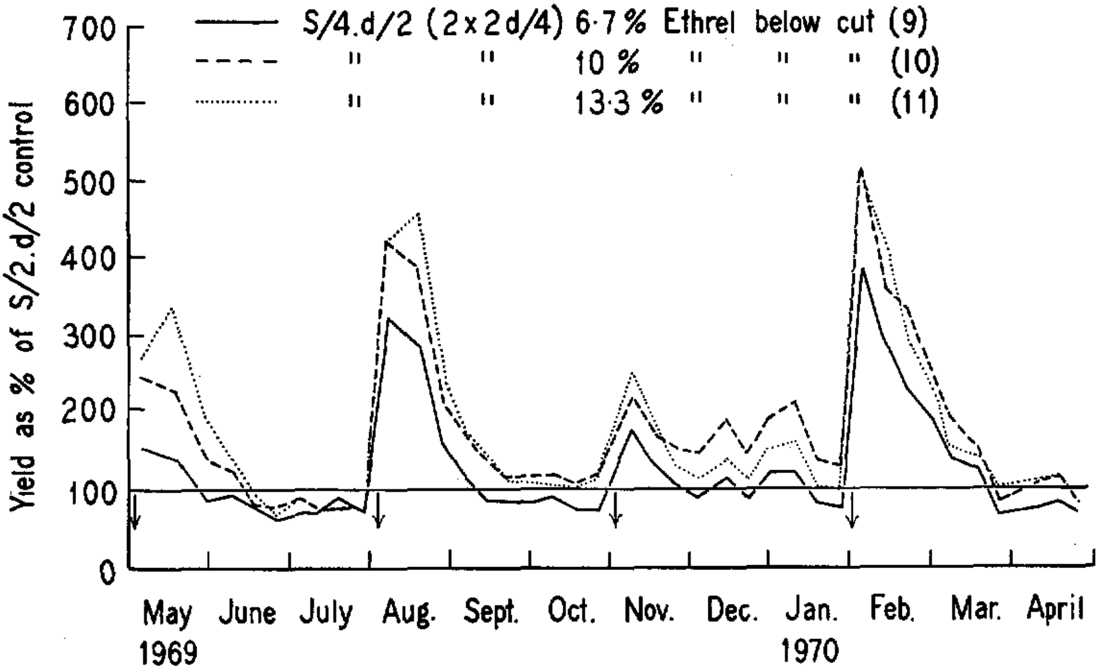

Figure 12. Experiment LF. 4: Treatments No. 9, 10 and 11. (Dates of application are indicated by arrows.)

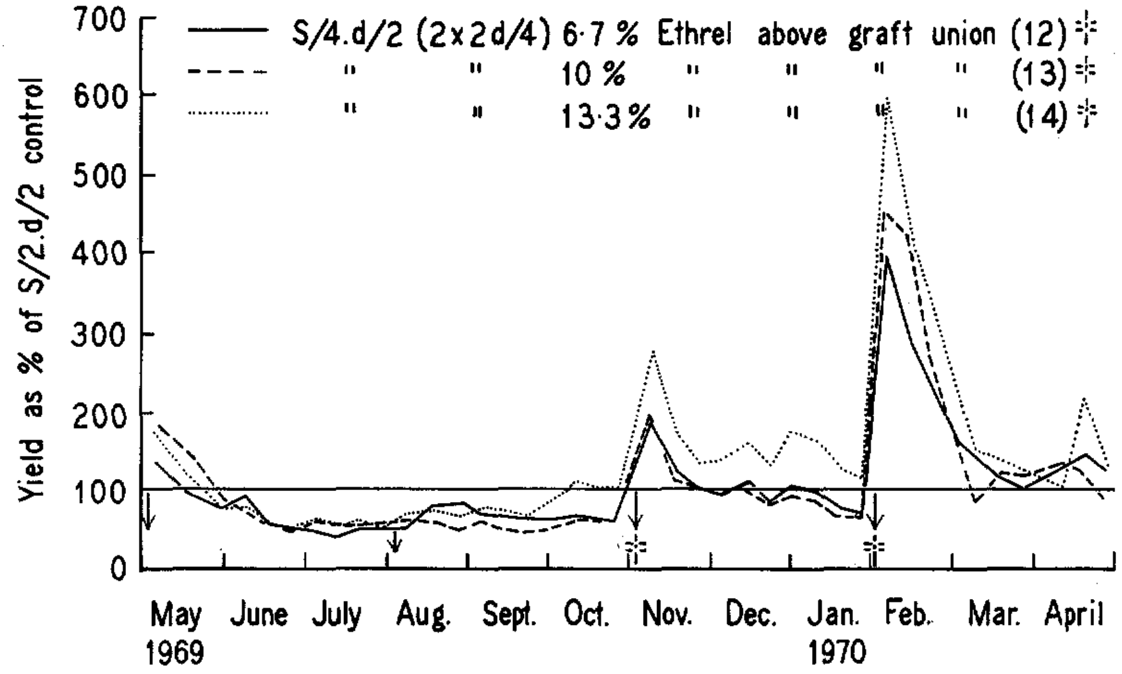

Figure 13. Experiment LF. 4: Treatments No. 12, 13 and 14. [Dates of application are indicated by arrows; site of application changed at the points (‡) indicated.]

DISCUSSION AND CONCLUSION

Several of the treatments included in Experiments LF. 2, LF. 3 and LF. 4, such as 'injection' of calcium carbide and spraying of Ethrel, which gave unpromising results, require no further comment.

The findings with Picloram (Experiment LF. 2) confirm those of ABRAHAM *et al.* (1968) and indicate that the compound might possibly be used by application in palm oil to renewing bark above the cut. Although yields were less than those obtained by application below the cut, the procedure has the advantage of avoiding the considerable expense of scraping bark below the cut. More extensive trials would be needed with Picloram applied to renewing bark to decide whether it had any practical value and to define optimum dose levels etc.

In the case of carbide-in-applicators (Experiment LF. 2), the use of a single applicator is an advance of technique over Experiment LF.1, since it is easier and cheaper than using two. The results confirm the main conclusions from the first year of Experiment LF.1 (ABRAHAM *et al.*, 1971): acetylene from carbide is a stimulant; it is effective with S/4 cuts, but less so than Ethrel by the techniques so far tested. Response to repeated applications at one site declines; shifting the applicator restores the response.

The use of Ethrel-in-applicators no longer appears attractive. To obtain good responses, it is apparently necessary to use larger doses than are required in palm oil and also to move the applicators periodically, which is costly and troublesome.

Injection of Ethrel into the wood has been shown to give excellent stimulation with five successive applications at the same site. This is of some theoretical interest, since the three experiments are consistent in showing that when Ethrel is applied to bark the site must be changed frequently. However, results from the second year of Experiment LF. 2 (which are not presented in this paper) have shown that there is a severe decline in response to Ethrel at the eighth and subsequent applications by injection to the original site. Moreover, even the first year's results imply that it is necessary to use larger doses of Ethrel when it is injected than when it is applied in palm oil.

For these reasons, injection of Ethrel does not appear suitable for early practical application. The method deserves further study and it has use as an experimental procedure, *e.g.*, it enabled the authors (in unpublished experiments) to study the effect on trees of excessive systemic doses of Ethrel which caused temporary defoliation but no other ill-effects.

Application of Ethrel-in-palm oil to renewing bark above the cut did not, in Experiment LF. 2, give results as good as those with applications below the cut. But the authors do not think this conclusive for several reasons. The concentration of Ethrel-in-palm oil in this experiment may not have been optimum: at the same concentration of Ethrel-in-palm oil, application above the cut appears to result in a smaller absolute dose per tree than application below the cut (see *Table 1*); the yields from the two procedures need to be compared over a long period; application above the cut is attractive for economic reasons; Ethrel appears not to damage renewing bark as does 2,4,5-T but it is important to confirm this also over a long period.

It is doubtful whether application of Ethrel-in-palm oil near the graft union offers any advantage but the experiments are conclusive on one point: it is essential to change the site for each application. Further experiments in which this is done from the outset are indicated.

The method of choice for large-scale testing is clearly Ethrel-in-palm oil applied to scraped bark below the cut. The yields obtained with this procedure and S/2.d/2 tappings were excellent; there was no failure of response on repeated reapplication and no indication of ill-effects on the trees. As ABRAHAM *et al.* (1968) remarked, yield stimulation by Ethrel is somewhat transient but this is compensated in part by the very large initial response, when a sufficient dose is used, and can be further counteracted by application at higher frequency than has been used in the past with 2,4-D and 2,4,5-T. Two-monthly applications were used in Experiment LF.4. Comparison of yield trends in the *Figures* suggests that higher yields are obtainable by two-monthly than by three-monthly applications, but this is not conclusive with S/2.d/2 tapping at the highest concentration of Ethrel tested.

The optimum dose of Ethrel has not proved easy to determine. With S/2.d/2 tapping and comparing three concentrations of Ethrel-in-palm oil (6.7, 10.0 and 13.3% w/w), the highest concentration gave the best response on a mixture of four clones considered together, but there were indications that Tjir 1 favoured the medium concentration (Experiment LF. 3). However, when the same three concentrations were tested with Tjir 1 alone, the highest concentration was the best (Experiment LF. 4). The second result may appear the more reliable since a larger number of trees was used but differences in girth complicate the issue. The trees of Experiment LF. 3 were larger than those of LF. 4. Hence, at any one concentration of Ethrel, they received a larger absolute dose in grams per tree, as is evident when *Tables 3* and *4* are compared. Little consideration has been given to this factor in past studies of yield stimulation. It is possible that no single concentration of Ethrel is exactly optimum for trees of different girth even if they are all of the same clone.

The authors concluded that larger trials with several clones would be needed to study the question of optimum concentration further. However, the experiments reported here show that good results are obtained with 6.7, 10.0 and 13.3%; lower concentrations are unlikely to be useful.

Experiments LF. 2 and LF. 4, especially the latter, establish the practicability of the tapping system S/4.d/2. (2 × 2d/4) in combination with Ethrel, *i.e.,* the system in which the stimulant is applied below the whole length of an S/2 cut which is then tapped alternately on its upper and lower halves. This system employs a relatively short tapping cut but also involves a form of panel changing. The design of the experiments reported here does not permit a decision on the relative contributions to yield of combining a short cut with an effective stimulant and panel-changing *per se.*

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