J. Rubb. Res. Inst. Malaysia, **26(3)**, 112–122

Variations in Stimulation Response in Yield of a Hevea *Clone I. Component Variance Model*

C.S. CHOW and H. TAN

The component variances and their proportions were estimated based on a fixed-effects model in the analysis of variance for the short- and long-term variations in yield response of clone RRIM 605 to stimulation with ethephon and 2,4,5-T. Increased fluctuations corresponding to the trend and environmental factors are highlighted. Wide variations within stimulation periods constitute the major variation in stimulated yield. A reduction in variation in tapping cut and an increase in variation in tapping frequency under stimulation were shown. Tapping systems superior to those investigated in the experiment may be expected in future.

Stimulation of latex yield in *Hevea brasiliensis* is an important aspect of research in the rubber industry. Apart from physiological and biochemical studies[1–9] on yield stimulation, one aspect of practical importance is the optimum use of stimulants in conjunction with tapping systems. As yield stimulants may cause undesirable side effects on trees over a long period, knowledge on such effects is therefore very important to maintain the future active life and to obtain maximum profit from the trees.

In early experiments of the Rubber Research Institute of Malaysia (RRIM) emphases were made on the search for possible yield stimulants, their effectiveness and suitable application methods for *Hevea* clones[10,11]. Wycherley[12] described the results of experiments over four to five years of stimulation on a few clones using 2,4-D (2, 4 dichlorophenoxy acetic acid) and 2,4,5-T (2,4,5 trichlorophenoxy acetic acid). He reported clonal differences for yield response, percentage late drip, dry rubber content and girth increment in different tapping systems.

Later, ethephon (2 chloroethyl-phosphonic acid) was found to be more effective than conventional stimulants[13–16]. A series of experimental trials was then initiated to compare the long-term effects of ethephon and 2,4,5-T with various tapping systems[13,14,16].

Several statistical techniques are available to summarise the results of these long-term stimulation trials. However, an extensive study of the data collected over years has not been attempted so far. This paper therefore aims at using variance component analysis to investigate the systematic short- and long-term variations and their interactions with the tapping systems in terms of yield responses to ethephon and 2,4,5-T from one of the recent stimulation experiments.

Experimental Data

Data were derived from the experiment carried out in the Pinang Tunggal Estate, Sungei Patani, Kedah. Details of the experiment and part of the yield results (up to thirty-eight months' yield) have already been described[17,18]. Briefly, the experiment involved the clone RRIM 605 tapped on *Panel C*. Two stimulants, ethephon (10% i.e.) and 2,4,5-T (1% i.e.) have been used in conjunction with fifteen tapping systems including unstimulated controls for every

COMMUNICATION 640

tapping system. This forms a factorial set of forty-five treatments. The fifteen tapping systems consisted of three cut systems (S/2, S/R and S/1) and three tapping frequencies (d/2, d/3 and d/4) combined factorially; and, two panel cut systems (S/2 and 2S/8) and the same three tapping frequencies combined factorially with panel-changing (*Panels C* and *D*). Stimulations were done bi-monthly and four sets of average yields were recorded at equal intervals (normally twelve days, called a cycle) within one stimulation period. Treatments were applied to groups of twenty-four trees arranged in two replicates. The following yield attributes were studied:

- Total yield (gramme per tree per tapping) was measured for every cycle (about two weeks) within each stimulation period of two months for four years.
- Total yield response to stimulation was estimated as the difference between total yield (normal yield plus late drip) from the stimulated and unstimulated (control) trees.

Pre-treatment data were available but they were not used for covariance adjustment due to lack of correlation of yield over the long period with pre-treatment effects over time.

Statistical Analysis

The analysis of variance for a fixed-effect model[19] was used to analyse the data. From the mean squares of the analysis of variance, the component variance and their proportions with respect to the total variance component for the various factors, namely, the stimulants, periods, tapping cuts, tapping frequencies, cycles and their interactions were estimated. In each analysis of variance, consideration was given for the different order of errors associated with different factors. The total variance component was used because it could reinforce the implication of a significant result shown in the mean squares by indicating its contribution to the total variation by the particular factors[21].

In the traditional analysis of variance, however, mean squares are sufficient to show significant differences among factors. They do not necessarily indicate the magnitude of variation and the relative contribution of each factor. Therefore, the present method adopted is considered more appropriate in the analysis and interpretation of the data.

RESULTS AND DISCUSSION

Total Yield

The separate analysis of variance of total yield with and without stimulation showed significant differences in the variation of almost all the factors studied *(Table 1)*. From the estimated component variances and total variance component, the item periods representing trend and environmental factors, were found to account for a large proportion of variation in the total yield obtained by stimulation compared with the control. The component variance of the ethephon stimulated yield was more than twice that of the 2,4,5-T stimulated yield. The high component variance of the Error (a) also indicated that fluctuation of yield under control conditions was greatly reflected in the stimulated yield *(Figure 1)*. The fluctuation in terms of sum of squares of deviations from trend (assuming quadratic) was found to be 25% more in the 2,4,5-T stimulated yield than in the control but 105% more in the ethephon stimulated yield. The magnitude of the cyclical (short-term) variation for ethephon stimulated yield (36% of total variance) was very large compared with that for 2,4,5-T stimulated yield (5% of total variance).

TABLE 1. ANALYSES OF VARIANCE (IN COMPONENT VARIANCES) FOR TOTAL YIELDS

Source of variations	d.f.	Control: Component variance	Control: Proportion total variance (%)	Ethephon: Component variance	Ethephon: Proportion total variance (%)	2,4,5-T: Component variance	2,4,5-T: Proportion total variance (%)
Replicates	21	9.17	0.87	0.00	0.00	0.00	0.00
Periods (P)	23	167.17***	15.86	652.49***	18.97	298.00***	22.11
Error (a)	23	173.14	16.43	210.50	6.12	231.83	17.20
Tapping systems (T)			27.38		13.7		18.18
Cuts (S)	4	116.30***	11.03	34.14***	0.99	42.73***	3.17
Frequencies (D)	2	66.17***	6.28	427.26***	12.42	161.17***	11.96
S × D	8	106.12***	10.07	720.44***	2.11	41.13***	3.05
T × P			10.26		2.74		15.78
S × P	92	104.94***	9.96	23.91**	0.69	150.43***	11.16
D × P	46	3.12NS	0.30	68.24***	1.98	43.80***	3.25
S × D × P	184	0.00NS	0.00	0.00NS	0.00	18.40***	1.37
Error (b)	336	178.48	16.93	292.70	8.51	122.25	9.07
Cycles (C)	3	1.37***	0.13	1 236.52***	35.94	51.16***	3.80
C × P	69	57.48***	5.45	132.58***	3.85	78.72***	5.84
C × T			0.31		2.30		0.89
C × S	12	2.21***	0.21	21.71***	0.63	7.21***	0.53
C × D	6	0.84***	0.08	49.25***	1.43	4.88***	0.36
C × S × D	24	0.19NS	0.02	6.64***	0.19	0.00NS	0.00
C × T × P			1.75		1.41		2.09
C × S × P	276	11.53***	1.09	11.35***	0.33	9.10***	0.68
C × D × P	138	5.75***	0.55	36.16***	1.05	16.94***	1.26
C × S × D × P	552	1.15***	0.11	0.00NS	0.00	2.00***	0.15
Error (c)	1 080	48.80	4.63	164.60	4.78	68.20	5.06

Figures underlined are the sums of individual proportions of related components.
Significance was indicated by mean squares with respect to appropriate error.
NS = Not significant at $P < 0.05$
** $P < 0.01$
*** $P < 0.001$

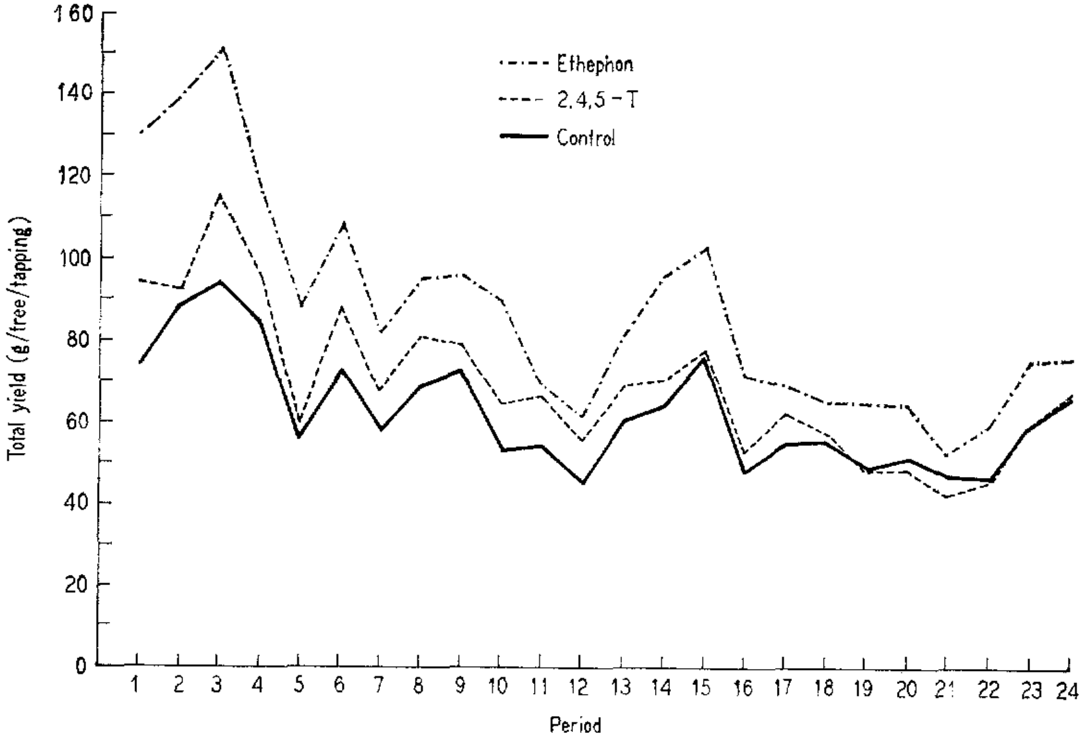

Figure 1. Total yield obtained with ethephon and 2,4,5-T stimulation and control over twenty-four periods.

Ethephon-stimulated yield declined much more rapidly from the first cycle to the subsequent cycles than the 2,4,5-T stimulated yield. The decline in yield was 30%–40% from the first to the second cycle for ethephon stimulated yield but less than 10% for 2,4,5-T stimulated yield *(Figure 2)*. On the average, yield of the third cycle was about 45%–60% of the first cycle for ethephon stimulated yield but 75%–95% for 2,4,5-T stimulated yield. For the fourth cycle, ethephon stimulated yield was about 40%–50% of that of the first cycle but was 65%–95% in the case of 2,4,5-T stimulated yield.

The rather mild interactions between cycle and tapping systems in both stimulants *(Table 1)* suggested that the inherent cyclical effects of the stimulants on *Hevea* were probably relatively independent of tapping effects. However, the great difference in cyclical effects between the two stimulants reflected that the method of stimulation including concentration of stimulant frequency and timing of application could be very important.

Considering the variation of tapping systems, the main effect of tapping cuts was reduced substantially from 11% in the control yield to only 1%–3% in the stimulated yield. In terms of component variance, the ethephon stimulated yield was more than six times of the control yield and 2.6 times that of the 2,4,5-T stimulated yield, though the proportion contributed to total variance was about the same (about 12% total variance component). On the other hand, the total variance component of tapping

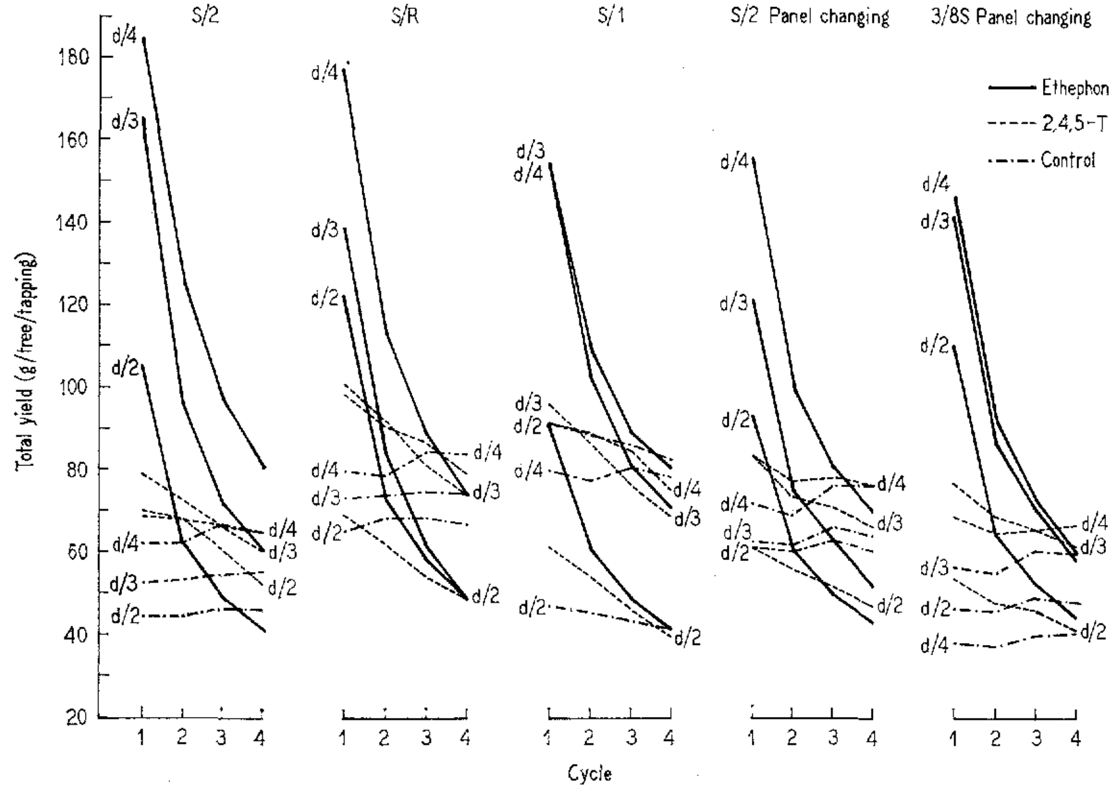

Figure 2. Total yield for different tapping systems.

frequencies in the stimulated yields was about double that of the control. In the case of 2,4,5-T stimulated yield, however, the cut effect varied with time and environmental fluctuations as indicated by the 11% total variance component of the S × P interaction (as similar to that of control) compared with the negligible 1% for ethephon stimulated yield. The reduction in variation for tapping cut and the increase in variation for tapping frequency under stimulation, especially with ethephon, suggest that tapping frequency accounted for more variation than tapping cut while the reverse was true for tapping without stimulation. This may imply a favourable choice of shorter tapping cuts and, more important, an appropriate tapping frequency. This suggestion is in line with that of Abraham *et al.*[18]

Total Yield Response

A similar analysis on total yield response to the two stimulants *(Table 2)* showed a rather different pattern of variations in the factors considered. Cyclical variations of 46% in the ethephon stimulated yield response and 9% in the 2,4,5-T stimulated yield response were even higher than those observed in the total yield *(Table 1)*.

Table 3 illustrates the frequent negative response particularly in the third and fourth cycles and in the later years of stimulation with both the stimulants. Of the fifteen tapping systems considered, positive response to ethephon for the four cycles throughout the four-year stimulation period was observed only in the S/2.d/4 and 3/8S.d/4 (2×4d/8) systems. In the case of 2,4,5-T stimulation, however, only the latter tapping system gave

TABLE 2. ANALYSES OF VARIANCE (IN COMPONENT VARIANCES) FOR TOTAL YIELD RESPONSE TO STIMULATION

Source of variations	d.f.	Ethephon Component variance	Ethephon Proportion total variance (%)	2,4,5-T Component variance	2,4,5-T Proportion total variance (%)
Replicates	1	1.90	0.07	14.96	2.14
Periods (P)	23	175.91***	6.38	34.22***	4.90
Error (a)	23	88.57	3.21	0.00	0.00
Tapping systems (T)			13.03		19.40
Cuts (S)	4	142.65***	5.17	21.80***	3.12
Frequencies (D)	2	183.57***	6.66	19.31***	2.76
S × D	8	33.22***	1.20	94.43***	13.52
T × P			4.02		0.41
S × P	92	70.03***	2.54	2.88NS	0.41
D × P	46	40.82***	1.48	0.00NS	0.00
S × D × P	184	0.00NS	0.00	0.00NS	0.00
Error (b)	336	308.45	11.19	325.00	46.52
Cycles (C)	3	1 279.52***	46.41	61.69***	8.83
C × P	69	106.49***	3.86	16.60***	2.38
C × T			3.41		1.07
C × S	12	30.76***	1.12	4.01***	0.57
C × D	6	57.53***	2.09	2.12***	0.30
C × S × D	24	5.47***	*0.20	1.41**	0.20
C × T × P			1.96		3.06
C × S × P	276	33.33***	1.21	5.62***	0.80
C × D × P	138	20.80***	0.75	3.02***	0.43
C × S × D × P	552	0.00NS	0.00	12.80***	1.83
Error (c)	1 080	178.20	6.46	78.7	11.27

Figures underlined are the sums of individual proportions of related components.
Significance was indicated by testing mean squares with respect to appropriate error terms.
NS = Not significant at $P<0.05$
** $P<0.01$
*** $P<0.001$

all positive responses. It follows therefore that while the total (or mean) response for a stimulation period or over any arbitrary period may be positive, negative responses were likely later in the stimulation period for many tapping systems. It implies that short-term profit in terms of additional yield due to stimulation especially with ethephon was highly variable in particular when short-term prices were fluctuating. In cases where sale of products was made immediately or a few days after tapping, a depressed revenue was possible at a later part (cycles) of the stimulation period more so when prices of rubber were low. While the difference between component variances (or total variance component) of tapping cut and tapping frequency in both of the stimulated total yield were significant *(Table 1)*, the difference was negligible in the case of yield response *(Table 2)*. This suggests that a negative correlation may exist between the effects of tapping cut of the control and the stimulated yield (since the yield response is defined as the difference of the latter and the former). The tapping cut that gives lower yield under control conditions would tend to give relatively higher yield under stimulation and *vice versa*. In fact, the same argument may be given to the higher variation in cycle effects in the case of yield response than in total yield. A much greater cut × frequency interaction in yield response to 2,4,5-T stimulation but negligible in ethephon stimulation was also observed. A relatively large fluctuation was associated

TABLE 3. MEAN YIELD RESPONSE TO ETHEPHON AND 2,4,5-T BY TAPPING SYSTEM, YEAR AND CYCLE WITH CONTROL YEARLY MEAN

Tapping cut	Year	Cycle	Mean yield response (%) d/2 Ethephon	d/2 2,4,5-T	d/3 Ethephon	d/3 2,4,5-T	d/4 Ethephon	d/4 2,4,5-T
S/2	1	1	93.36	38.26	145.21	22.78	165.45	11.36
		2	26.70	36.84	71.06	21.56	115.62	12.33
		3	8.14	22.23	35.31	13.28	66.73	4.03
		4	− 0.66	10.42	19.55	3.03	43.40	0.02
		Mean	31.89	26.94	67.78	15.16	97.80	6.93
		Control	49.79 g/tree/tapping		60.26 g/tree/tapping		64.57 g/tree/tapping	
	2	1	77.72	34.61	130.24	34.88	130.13	17.13
		2	24.38	30.73	42.01	22.80	53.72	11.13
		3	8.16	19.91	14.27	14.20	11.93	0.43
		4	− 1.51	10.03	1.28	8.68	2.33	− 3.98
		Mean	27.19	23.82	46.95	20.14	49.53	6.18
		Control	41.58 g/tree/tapping		49.50 g/tree/tapping		64.31 g/tree/tapping	
	3	1	50.06	21.01	101.24	34.31	126.25	1.04
		2	16.15	21.58	33.97	23.80	60.72	3.37
		3	5.72	13.69	13.20	12.48	30.43	0.41
		4	− 3.30	5.14	3.27	8.72	11.40	− 7.72
		Mean	17.16	15.35	37.92	19.83	57.20	− 0.73
		Control	42.82 g/tree/tapping		53.68 g/tree/tapping		65.65 g/tree/tapping	
	4	1	24.83	7.85	68.13	16.08	73.46	− 0.32
		2	− 0.48	5.98	29.90	10.28	30.55	− 1.87
		3	−11.48	1.15	8.82	8.29	12.30	− 7.44
		4	−14.74	− 1.27	− 0.68	0.58	6.58	− 5.80
		Mean	− 0.47	3.43	26.54	8.81	30.72	− 3.86
		Control	46.78 g/tree/tapping		51.14 g/tree/tapping		59.83 g/tree/tapping	
S/1	1	1	36.82	12.01	76.52	5.37	76.61	33.95
		2	3.16	2.57	9.69	− 9.03	42.96	29.79
		3	− 9.44	− 7.97	−10.97	−24.33	11.59	19.36
		4	−11.12	− 9.39	−19.55	−25.98	11.78	11.46
		Mean	4.85	− 0.70	13.92	−13.49	35.73	23.64
		Control	80.84 g/tree/tapping		138.55 g/tree/tapping		118.81 g/tree/tapping	
	2	1	48.94	20.12	52.19	− 0.97	77.96	12.64
		2	17.39	11.68	4.02	− 7.39	28.12	4.63
		3	9.53	3.54	−12.08	−12.49	7.18	0.07
		4	5.93	− 0.96	−18.82	−17.24	2.62	− 5.78
		Mean	20.45	8.60	6.33	− 9.52	28.97	2.89
		Control	33.90 g/tree/tapping		73.40 g/tree/tapping		66.48 g/tree/tapping	
S/1	3	1	53.78	12.89	66.45	5.17	80.68	8.80
		2	22.84	9.78	15.16	4.02	30.71	7.46
		3	12.87	4.48	− 1.58	− 6.05	11.32	0.63
		4	7.73	0.33	−11.61	−11.18	− 3.70	−14.08
		Mean	24.30	6.87	17.11	− 2.01	29.75	0.70
		Control	34.05 g/tree/tapping		74.90 g/tree/tapping		71.23 g/tree/tapping	
	4	1	36.84	12.98	58.81	10.56	59.69	9.46
		2	16.58	12.88	27.53	4.82	26.34	5.88
		3	7.27	8.21	3.26	1.93	6.78	− 0.43
		4	3.23	4.73	− 0.97	0.35	− 1.61	− 5.08
		Mean	15.98	9.70	22.16	4.41	22.80	2.46
		Control	28.44 g/tree/tapping		61.59 g/tree/tapping		59.02 g/tree/tapping	
S/R	1	1	85.24	29.18	110.21	57.70	153.03	32.62
		2	10.01	10.12	37.38	48.43	83.53	22.40
		3	− 8.78	− 4.76	1.08	33.75	39.33	11.98
		4	−15.75	− 7.28	−13.89	20.03	18.18	1.93
		Mean	17.68	6.82	33.69	39.98	73.52	17.23
		Control	81.69 g/tree/tapping		78.31 g/tree/tapping		96.97 g/tree/tapping	

TABLE 3. MEAN YIELD RESPONSE TO ETHEPHON AND 2,4,5-T BY TAPPING SYSTEM, YEAR AND CYCLE WITH CONTROL YEARLY MEAN (CONTD.)

Tapping cut	Year	Cycle	Mean yield response (%)					
			2 × 2d/4		2 × 3d/6		2 × 4d/8	
			Ethephon	2,4,5-T	Ethephon	2,4,5-T	Ethephon	2,4,5-T
	2	1	55.02	0.78	63.38	33.64	87.47	29.73
		2	5.15	− 8.38	5.33	22.86	23.66	19.68
		3	−10.96	−15.08	−19.85	6.13	−10.81	3.23
		4	−19.91	−24.10	−31.10	− 0.65	−22.06	− 1.22
		Mean	7.33	−11.70	4.44	15.50	19.56	12.86
		Control	64.48 g/tree/tapping		73.30 g/tree/tapping		80.81 g/tree/tapping	
	3	1	53.88	− 2.55	57.10	24.23	85.98	15.50
		2	5.61	− 6.77	3.09	14.81	21.78	8.69
		3	− 7.23	−14.96	−13.58	5.26	− 2.74	− 0.22
		4	−16.88	−22.26	−29.91	− 5.58	−21.63	−11.38
		Mean	8.85	−11.63	4.18	9.68	20.85	3.15
		Control	63.15 g/tree/tapping		71.12 g/tree/tapping		80.29 g/tree/tapping	
	4	1	33.50	− 9.93	35.48	− 5.57	55.51	− 0.27
		2	1.08	−15.34	− 3.10	− 9.22	10.47	− 2.03
		3	−14.50	−20.94	−22.32	−15.58	−10.04	− 8.68
		4	−19.32	−20.26	−28.52	−16.45	−15.35	− 7.02
		Mean	0.19	−16.62	− 4.61	−11.70	10.15	− 4.50
		Control	58.49 g/tree/tapping		71.67 g/tree/tapping		67.45 g/tree/tapping	
S/2	1	1	47.45	7.13	95.23	41.87	133.57	10.93
		2	1.23	− 2.96	38.77	33.18	63.70	2.15
		3	−15.14	−15.60	9.00	21.64	26.78	− 3.87
		4	−17.46	−16.19	3.78	16.35	17.14	− 6.64
		Mean	4.02	− 6.90	36.71	28.26	60.29	0.64
		Control	87.25 g/tree/tapping		73.84 g/tree/tapping		92.24 g/tree/tapping	
	2	1	25.76	− 0.39	48.58	25.12	86.33	22.96
		2	− 2.78	− 3.62	3.13	13.21	28.43	17.26
		3	−13.28	− 8.13	−10.92	4.55	2.64	10.99
		4	−19.42	−11.69	−22.36	2.64	−10.65	9.28
		Mean	− 2.43	− 5.96	4.61	11.38	26.69	15.12
		Control	51.42 g/tree/tapping		64.20 g/tree/tapping		76.09 g/tree/tapping	
	3	1	33.71	− 2.98	52.89	12.58	65.08	18.89
		2	0.24	− 5.91	8.01	7.59	20.60	17.64
		3	−12.05	−11.46	− 4.96	− 0.35	− 6.28	7.97
		4	−18.82	−15.43	−16.73	− 3.93	−17.44	4.86
		Mean	0.77	− 8.95	9.80	3.97	15.49	12.34
		Control	57.54 g/tree/tapping		61.23 g/tree/tapping		65.75 g/tree/tapping	
	4	1	20.68	− 5.44	42.61	2.41	37.95	− 4.33
		2	3.66	− 5.05	7.43	− 7.74	8.71	− 1.78
		3	−13.15	−10.10	− 9.12	− 8.45	− 9.22	− 5.68
		4	−19.02	−11.65	−18.02	−10.39	−17.37	− 7.37
		Mean	− 1.96	− 8.06	5.73	− 6.04	5.02	− 4.79
		Control	49.18 g/tree/tapping		55.51 g/tree/tapping		58.74 g/tree/tapping	
3/8S	1	1	101.88	13.51	125.39	31.51	141.26	20.35
		2	41.50	7.80	56.08	21.86	84.46	23.80
		3	17.04	− 2.23	27.79	9.99	60.54	21.78
		4	8.61	− 5.04	16.63	6.40	39.88	14.66
		Mean	42.26	3.51	56.47	17.44	81.53	20.15
		Control	52.60 g/tree/tapping		65.16 g/tree/tapping		38.53 g/tree/tapping	
	2	1	66.11	10.38	102.01	34.32	115.31	51.22
		2	12.10	1.69	37.02	20.99	56.05	38.60
		3	− 1.56	− 1.71	13.33	13.92	30.55	35.58
		4	−10.58	− 8.09	− 0.83	6.62	19.36	46.07
		Mean	16.52	0.57	37.88	18.96	55.32	42.87
		Control	47.59 g/tree/tapping		55.45 g/tree/tapping		40.78 g/tree/tapping	

TABLE 3. MEAN YIELD RESPONSE TO ETHEPHON AND 2,4,5-T BY TAPPING SYSTEM, YEAR AND CYCLE WITH CONTROL YEARLY MEAN (CONTD.)

Tapping cut	Year	Cycle	Mean yield response (%)					
			d/2		d/3		d/4	
			Ethephon	2,4,5-T	Ethephon	2,4,5-T	Ethephon	2,4,5-T
	3	1	51.85	6.63	74.18	11.50	105.23	30.61
		2	11.01	2.61	17.37	8.19	48.13	31.08
		3	− 1.99	− 3.42	0.22	0.91	24.98	28.95
		4	−10.13	− 6.80	−14.11	− 4.09	9.54	24.52
		Mean	12.68	− 0.25	19.42	4.13	46.97	28.79
		Control	47.81 g/tree/tapping		61.73 g/tree/tapping		42.32 g/tree/tapping	
	4	1	38.21	− 0.52	51.50	5.43	68.98	19.78
		2	13.03	− 4.74	16.01	4.34	29.89	13.34
		3	− 1.10	− 5.76	− 3.10	− 5.79	10.27	14.76
		4	− 7.88	− 7.99	− 8.03	− 2.90	5.57	16.11
		Mean	10.57	− 4.75	14.09	0.27	28.68	16.00
		Control	42.54 g/tree/tapping		49.25 g/tree/tapping		37.13 g/tree/tapping	

		Ethephon	2,4,5-T	Control
Means of cycles for given year and tapping system	S.E.	−3.845	2.561	−
	L.S.D.	10.68	7.10	−
Mean of tapping frequencies for given year and tapping cut or *vice versa*	S.E.	5.424	5.359	3.986
	L.S.D.	15.03	14.86	11.05

with tapping systems in yield response in the case of 2,4,5-T where nearly half (47%) of the total variance was due to error b, in contrast to the negligible fluctuation in period (error a) as shown in *Table 2.* These may indicate the non-additive and less consistent tapping effects in 2,4,5-T stimulation than in ethephon stimulation.

Comparison of variation due to different factors may indicate their relative weights in certain practical considerations. The analysis of variance for total yield response (meaned over cycles) *(Table 4)* shows that while an 18% variation due to the difference in stimulants was sufficiently large to express the superiority of one stimulant (ethephon) to the other (2,4,5-T), the total variation of about 15% due to tapping systems was also indicative of the possible variation of the same order. In addition, the total interaction between stimulants and tapping systems amounted to about 11%. It implies that although the tapping systems included in this experiment were fixed or selected (based on the factorial basis), it does not however preclude the high possibility, that better (or inferior) tapping systems than those considered in the experiment may be found.

CONCLUSION

The fluctuation of yields under unstimulated conditions was increased to a greater extent by ethephon stimulation than by 2,4,5-T stimulation. The short-term variation in stimulated yield and yield response accounted for the major variation under ethephon stimulation but was only moderate with 2,4,5-T stimulation. The possibility for negative responses towards the end of the second year or so implied a loss of profit especially towards the end of a stimulation period or in the long-term of continuous stimulation. A reduction in variation of tapping cut and an increase of tapping frequency under stimulation especially with ethephon implied the advantage of the choice of shorter tapping cut and the importance of an appropriate tapping frequency.

TABLE 4. ANALYSIS OF VARIANCE FOR TOTAL YIELD RESPONSE

Source of variation	d.f.	Component variance	Proportion total variance (%)
Replicates	1	129.3	0.85
Stimulants (T)	1	2 737.6***	17.95
Periods (P)	23	1 313.7***a	8.61
T × P	23	636.6***a	4.17
Error (a)	47	156.4	1.03
Tapping cuts (S)	4	1 110.5***	7.28
Tapping frequencies (D)	2	828.6***a	5.43
S × D	8	293.7***a	1.93
T × S	4	410.3***	2.69
T × D	2	514.5***a	3.37
P × S	92	637.6***a	4.18
P × D	46	112.4***a	0.74
T × S × D	8	714.3***a	4.68
P × S × D	184	0.0NS	0.00
T × P × S	92	0.0NS	0.00
T × P × D	46	78.0NS	0.51
T × P × S × D	184	0.0NS	0.00
Error (b)	672	5 581.3	36.59

Significance was indicated by testing mean squares with respect to appropriate error terms.
[a]Sum of the regression components (up to or less than the cubic) and the remainder
NS = Not significant at $P<0.05$
*** $P<0.001$

The evidence suggests that some other tapping systems which are likely to be superior to those used in the experiment may be worthwhile considering to reduce fluctuation in variations over a long period of time.

ACKNOWLEDGEMENT

The authors wish to thank Mr T.C. P'ng, Mr G.C. Iyer and Dr P.K. Yoon of the Rubber Research Institute of Malaysia and Dr P.R. Wycherley, Director of Kings' Park and Botanic Garden, Western Australia for helpful comments on this paper. They are also grateful to the Exploitation Section in providing the data and Miss Peggy Lee in data analyses.

Rubber Research Institute of Malaysia
Kuala Lumpur *January 1979*

REFERENCES

1. BOATMAN, S.G. (1966) Preliminary Physiological Studies on the Promotion of Latex Flow by Plant Growth Regulations. *J. Rubb. Res. Inst. Malaya*, **19(5)**, 243.

2. BUTTERY, B.R. AND BOATMAN, S.G. (1967) Effects of Tapping, Wounding and Growth Regulators on Turgor Pressure in *Hevea brasiliensis* Muell. Arg. *J. exp. Bot.*, **18(57)**, 644.

3. MILFORD, G.F.J., PAARDEKOOPER, E.C. AND HO, C.Y. (1969) Latex Vessel Plugging, Its Importance to Yield and Clonal Behaviour. *J. Rubb. Res. Inst. Malaya*, **21(1)**, 274.

4. SOUTHORN, W.A. (1969) Physiology of *Hevea* (Latex Flow). *J. Rubb. Res. Inst. Malaya*, **21**, 494.

5. OSBORNE, D.J. AND SARGENT, J.A. (1974) A Model for the Mechanism of Stimulation of Latex Flow in *Hevea brasiliensis* by ethylene. *Ann. appl. Biol.*, **78**, 83.

6. YIP, ESAH, SOUTHORN, W.A. AND GOMEZ, J.B. (1974) Latex Flow Studies. IX. Effect of Application of Yield Stimulants on Rheology of *Hevea* Latex and on Concentrations of Charged Components in Its Sera. *J. Rubb. Res. Inst. Malaysia*, **24(2)**, 103.

7. SETHURAJ, M.R., GEORGE, M.J. AND SULOCHANAMMA, S. (1975) Physiological Studies on Yield Stimulation of *Hevea brasiliensis*. *Proc. Int. Rubb. Conf. Kuala Lumpur 1975*, **2**, 280.

8. TUPY, J. AND PRIMOT, L. (1976) Control of Carbohydrate Metabolism by Ethylene in Latex Vessels of *Hevea brasiliensis* Muel. Arg. in Relation to Rubber Production. *Biologia Pl.*, **18**, 373.

9. PAKIANATHAN, S.W. (1977) Some Factors Affecting Yield Response to Stimulation with 2-chloroethylphosphonic Acid. *J. Rubb. Res. Inst. Malaya,* **25,** 50.

10. BAPTIST, E.D.C. AND DE JONGE, P. (1955) Stimulation of Yield in *Hevea brasiliensis*. II. Effect of Synthetic Growth Substances on Yield and on Bark Renewal. *J. Rubb. Res. Inst. Malaya,* **14,** 362.

11. DE JONGE, P. (1961) Tapping of Young Rubber. *Plrs' Bull. Rubb. Res. Inst. Malaya No. 56,* 149.

12. WYCHERLEY, P.R. (1974) Tapping Intensity and Response to Yield Stimulation. *J. Rubb. Res. Inst. Malaya,* **24(2),** 75.

13. ABRAHAM, P.D. (1970) Field Trials with Ethrel. *Plrs' Bull. Rubb. Res. Inst. Malaya No. 111,* 366.

14. ABRAHAM, P.D., P'NG, T.C. AND NG, F.K. (1971) RRIM Ethrel Trials: Progress Report. *Proc. Rubb. Res. Inst. Malaya Plrs' Conf. Kuala Lumpur 1971,* 1.

15. ABRAHAM, P.D., BLENCOWE, J.W., CHUA, S.E., GOMEZ, J.B., MOIR, S.W., PAKIANATHAN, S.W., SEKHAR, B.C., SOUTHORN, W.A. AND WYCHERLEY, P.R. (1971) Novel Stimulants and Procedures in the Exploitation of *Hevea.* I. Introductory Review. *J. Rubb. Res. Inst. Malaya,* **23(2),** 85.

16. ABRAHAM, P.D., BLENCOWE, J.W., CHUA, S.E., GOMEZ, J.B., MOIR, S.W., PAKIANATHAN, S.W., SEKHAR, B.C., SOUTHORN, W.A. AND WYCHERLEY, P.R. (1971) Novel Stimulants and Procedures in the Exploitation of *Hevea.* II. Pilot Trial Using (2-chloroethyl)-phosphonic Acid (Ethephon) and Acetylene with Various Tapping Systems. *J. Rubb. Res. Inst. Malaya,* **23(2),** 90.

17. ABRAHAM, P.D., P'NG, T.C., LEE, C.K., SIVAKUMARAN, S. AND LEONG WING (1973) RRIM Ethrel Trials on Estate: Further Results. *Proc. Rubb. Res. Inst. Malaya Plrs' Conf. Kuala Lumpur 1973,* 74.

18. ABRAHAM, P.D., P'NG, T.C., LEE, C.K., SIVAKUMARAN, S., MANIKAM, B. AND YEOH, C.P. (1976) Ethrel Stimulation of *Hevea. Proc. Int. Rubb. Conf. Kuala Lumpur 1975,* **2,** 347.

19. OSTLE, B. (1966) *Statistics in Research (2nd ed).* The Iowa State University Press, Oxford & IBH Publishing Co.

20. FEDERER, W.T. (1955) *Experimental Design,* Chapter 10, Oxford & IBH Publishing Co.

21. HAY, W.L. (1963) *Statistics,* Chapters 10 & 12. New York: Holt, Rinehart and Winston, Inc.