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Tapping Intensity and Response to Yield Stimulation

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The relationship between response to stimulation and tapping system is examined. The response is much reduced in long-cut systems compared with half-spirals; the modification of response by frequency is less consistent. The effects of tapping system on response seem to operate through their effect on late drip and d.r.c., which are investigated by correlation analyses and analyses of variance of response, girth increment, late drip and d.r.c. according to tapping system, experiment (clone), year and frequency of stimulation.

Stimulation of *Hevea* to obtain greater yields of rubber by application of chemicals to the latex-bearing tissues of the tree is now well established in commercial practice. In this paper the discussion is confined to stimulants containing 2,4-D (2,4 dichlorophenoxyacetic acid), 2,4,5-T (2,4,5 trichlorophenoxyacetic acid), their salts and esters, which are applied in greases or pastes to the bark of the tree. The carriers in these greasy mixtures are vegetable and/or mineral oils, *e.g.* palm oil and petrolatum respectively. The bark is lightly scraped to remove the outer cork when application is made below the tapping cut. 2,4-D is usually employed at 1.5% acid equivalent and 2,4,5-T at 1.0%.

In this paper, response is defined as the ratio of the yield of dry rubber from stimulated to that from unstimulated control trees. The stimulated and control trees are of the same cultivar, age, location and history, and are tapped on the same tapping system in all comparisons of response to stimulation. Although the absolute difference in yield between stimulated and control trees is of economic importance, the ratio is used here as a measure of the physiological response. The ratio or relative response is expressed as percentage of control.

The percentage responses to stimulation found by DE JONGE (1955) of clonal seedlings tapped on the second panel of bark of first renewal over one year, during which three applications of stimulant were made at four-monthly intervals, were:

Tapping system	Response
2C/1.d/3.267% 9 months 2C/1.d/2.400% 3 months	87
2C/1.d/3.267%	102
2C/1.d/4.200%	140

The RUBBER RESEARCH INSTITUTE OF MALAYA (1960) reported an experiment on mixed buddings in which low cuts were in the first panel of bark of first renewal and high cuts were in virgin bark. The factorial experiment compared all combinations of (a) alternate versus third-daily tapping, (b) low S/2 cuts alone, high V/2 cuts alone or double 2C/2 cuts, and (c) unstimulated versus stimulated at six-monthly intervals. The percentage responses to stimulation were:

Frequency	Low S/2	High V/2	Double 2C/2
d/2	136	163	129
d/3	148	265	130

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In both the foregoing examples the response to stimulation increased as the intensity of tapping decreased. DE JONGE (1961) generalised to this effect. Further support came from ANLIKER AND SCANLON (1965) who experimented with buddings (twenty-five to twenty-nine years old) of five clones. They compared two methods of applying 2,4-D stimulant, namely above and below the cut, with untreated controls combined factorially with three tapping systems for thirty months. The percentage responses were as in *Table 1*. Although the S/2.d/1.23d/46.100% system was of the same percentage intensity as the S/2.d/2.100%, the responses to stimulation were poorer on daily periodic than continuous alternate-daily tapping with one exception (War 4 below the cut).

The orthogonally designed experiments on trees tapped on the first panel of bark of first renewal by DE JONGE AND TAN (1969) gave a less consistent relationship between response and intensity of tapping. Their results for three years with clones PB 86 and PR 107 and for two years with Ch E Garden Seedlings are summarised in *Table 2*. Only in PR 107 is there a significant negative correlation between percentage response and percentage intensity of tapping. In both clones PB 86 and PR 107 response declines in general as the cut length increases, but in Ch E seedlings the three-quarter spiral cuts give a better response to stimulation than either half- or full-spiral cuts. The relationship between response and frequency of tapping is not consistent for either any cultivar or length of cut.

The purpose of this paper is to examine the response to stimulation in relation to tapping system using the data from the series of tapping experiments reported by NG *et al.* (1965), NG *et al.* (1969) and NG *et al,* (1970). The designs and details of the experiments have been given by NG *et al.* (1965 and 1969).

EXPERIMENTAL

The tapping experiments are designated Panel A and Panel B according to whether the first or the second panel of virgin bark is tapped. The locations of those considered here are indicated as Estate I, Port Dickson, (Panel A and B experiments), Estate II, Rengam, (Panel A experiments) and Estate IV, Klang, (Panel B experiments). Eleven Panel A experiments, three at Estate I

TABLE 1. PERCENTAGE RESPONSE TO STIMULATION
(Data from ANLIKER AND SCANLON, 1965)

Stimulant application	Tapping system	Clone				
		War 4	AVROS 49	BD 5	Tjir 1	AVROS 50
Above-cut	S/2.d/1.23d/46.100%	151	124	115	116	120
	S/2.d/2.100%	174	147	136	124	127
	S/2.d/3. 67%	219	180	164	151	144
Below-cut	S/2.d/1.23d/46.100%	127	96	104	112	100
	S/2.d/2.100%	115	127	108	116	114
	S/2.d/3. 67%	144	130	122	120	122

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TABLE 2. PERCENTAGE RESPONSE TO STIMULATION
(*Data from* DE JONGE AND TAN, 1969)

Clone	Tapping frequency	Length of cut		
		S/2	S/R	S/1
PB 86	d/2	118	108	109
	d/3	132	112	99
	d/4	104	109	107
PR 107	d/2	135	124	99
	d/3	142	121	92
	d/4	137	139	126
Ch E	d/2	102	–	–
	d/3	116	124	112
	d/4	114	124	104
	d/6	115	134	108

S/R = three-quarters spiral

on GT 1, RRIM 605 and RRIM 623, and eight at Estate II on GT 1, PB 5/51, PB 5/63, RRIM 513, RRIM 600, RRIM 605, RRIM 607 and RRIM 623, consist (for the purposes of this paper) of ten tapping systems combined factorially without and with stimulation twice per year. Two Panel A experiments at Estate II on PR 107 and RRIM 612 consist of six tapping systems combined factorially with three stimulation treatments: nil, twice per year and six times per year. All six Panel B experiments on PB 86, PR 107 and RRIM 501 at Estate I and on PB 5/51, PR 107 and RRIM 513 at Estate IV consist of five tapping systems combined factorially with three stimulation treatments: nil, twice per year and six times per year.

All experiments were recorded for five years, except for the Panel A experiments on RRIM 605 and RRIM 623 at Estate I and on PR 107 and RRIM 612 at Estate II (which were recorded for four years) and the Panel B experiment on RRIM 501 at Estate I (which was terminated after two years). Girths were measured at the beginning of each year of tapping and at the end of the last year of tapping in every trial, and the increments in girth during each year of tapping have been calculated, although only the total increment over the whole period is considered here. Yields were recorded for each year of tapping. The crop harvested after the usual hour for latex collection was recorded separately and designated 'late drip', which has been expressed as the percentage of the total crop for each year of tapping. The d.r.c. of the harvested latex was determined periodically on samples in the Panel A experiments. The d.r.c. was not determined during the first year of any Panel A experiment and it was not determined during the second year of those on RRIM 605 and RRIM 623 at Estate I; it was determined during the remaining years. In the Panel B experiments the d.r.c. was determined from the bulked latex of each treatment throughout all years. The d.r.c. was expressed as a percentage.

ANALYSES

The method has been to seek correlations between the response to stimulation and such variates as the proportion of late drip and the d.r.c. in the corresponding unstimulated control treatments. Then the influence of tapping system on these variates, with which the response to stimulation was associated, was investigated. This was complicated because the tapping systems did not form a fully factorial or orthogonal arrangement of lengths of cuts and frequencies of tapping, for example the frequency d/2 was confounded with S/2 cuts, whereas d/6 was confounded with S/1. Therefore comparisons between frequencies have been made within one length of cut at a time, and between length of cuts have been made within one frequency, adequate replication

was obtained by combining the data for the same year of different experiments or of different years for each experiment.

Simple linear regression analyses have been used throughout. The percentage values for response, percentage late drip and d.r.c. have been used without any transformations, because over their respective ranges no significant departures from the normal distribution are likely. Comparisons are much easier with untransformed values and may be interpreted directly.

Analyses of Variance

In the analyses of variance *(Table 3)* as all the treatments considered are pre-determined, all the effects and interactions are tested against the interaction of highest order as an estimate of the error. In all cases there are significant differences in response between tapping systems. There are significant differences between experiments (*i.e.* clones for the greater part) and between years in all sets of data, except for RRIM 605 and RRIM 623 at Estate I. Many interactions are significant but for simplicity only main effects and the interactions of tapping systems × experiments and of years × frequencies of application are given in *Tables 4, 5* and *6*.

The correlation of response with relative intensity of tapping is in general negative, but significant in only a few cases. Responses are usually better in half-spiral than in full-spiral systems of the same percentage intensity; *Table 4* provides five exceptions to this in PB 5/63, RRIM 513 and RRIM 623 (thrice) out of twenty-seven comparisons; *Tables 5* and *6* provide seven more exceptions out of twenty comparisons. The relationship between response and frequency of tapping shows many interactions.

The overall mean response in the Panel A and Panel B experiments is about the same, but this is confounded with the sites, clones, tapping systems, frequency of stimulation and number of years recorded in the different experiments. However, if the comparison is limited to the clones PB 5/51, PR 107 and RRIM 513 common to both the Panel A and Panel B experiments, and to the respective tapping systems, frequencies of stimulation and years of recording common to the corresponding experiments, the mean response in both Panel A and Panel B experiments is the same, *i.e.* 107.6%.

In the Panel A experiments reported in *Table 4*, the mean responses do not differ significantly over the first three years, but are significantly lower in the latter two years, especially the last. There is no clear relationship between response and the succession of years for RRIM 605 and RRIM 623 in *Table 5a*, but in PR 107 and RRIM 612 *(Table 5b)* the response rises from an approximately average figure in the first year to a maximum in the third and then falls very markedly in the fourth. In the five Panel B experiments which ran for five years there is a marked, progressive decline in response with the succeeding years *(Table 6a)*. There is also a large fall from the first to the second year in RRIM 501 *(Table 6b)*.

The interaction 'years × frequencies of application' is significant in all Panel B experiments, the response falling away more in the six applications per year treatments, which initially gave the greater response. There was a tendency towards this in the Panel A experiments on PR 107 and RRIM 612, but it was not significant.

Girth Increments

The rate of girthing is influenced by treatment, including tapping system and stimulation. The girth of the trees is one of the factors determining yield, both directly through the length of cut and indirectly as indicative of the size of the tree and its competitive position in the stand. Therefore girth increments are examined here, partly

TABLE 3. ANALYSES OF VARIANCE OF RESPONSE TO STIMULATION

Source	(1) Nine Panel A Expts (over five years)		(2) Two Panel A Expts (over four years)		(3) Two Panel A Expts (over four years)		(4) Five Panel B Expts (over five years)		(5) RRIM 501 (Panel B)	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
Between experiments or clones (E)	8	286.7789***	1	31.2500	1	499.5938***	4	189.4240***	–	–
Between tapping systems (T)	9	935.1249***	9	203.8333***	5	668.8354***	4	1 512.9940***	4	631.1750***
Between years (Y)	4	118.0311**	3	39.4333	3	260.5382***	4	3 034.5740***	1	1 280.0000***
Between frequencies of stimulation (F)	–	–	–	–	1	906.5104***	1	36.8640*	1	192.2000***
E × T	72	162.8394***	9	171.2500***	5	449.1187***	16	534.5815***	–	–
E × Y	32	143.1886***	3	99.7056*	3	51.5382*	16	166.6490***	–	–
E × F	–	–	–	–	1	178.7604**	4	102.1440***	–	–
T × Y	36	43.5941**	27	52.0444	15	87.1465***	16	187.7565***	4	64.3750**
T × F	–	–	–	–	5	50.9354*	4	166.1540***	4	1.0750
Y × F	–	–	–	–	3	27.5660	4	263.4540***	1	115.2000**
E × T × Y	288	29.6002	27	27.7549	15	42.1965**	64	51.1440***	–	–
E × T × F	–	–	–	–	5	50.2354**	16	88.9715***	–	–
E × Y × F	–	–	–	–	3	3.9827	16	15.5840	–	–
T × Y × F	–	–	–	–	15	7.0576	16	12.0065	4	2.0750
E × T × Y × F	–	–	–	–	15	11.2576	64	9.1740	–	–

(1) = Experiments on GT 1 at Estate I and on GT 1, PB 5/51 and 5/63 and RRIM 513, 600, 605, 607 and 623 at Estate II
(2) = Experiments on RRIM 605 and 623 at Estate I
(3) = Experiments on PR 107 and RRIM 612 at Estate II (two frequencies of stimulation)
(4) = Experiments on PB 86 and PR 107 at Estate I and on PB 5/51, PR 107 and RRIM 513 at Estate IV (two frequencies of stimulation)
(5) = Experiment on RRIM 501 at Estate I (two frequencies of stimulation)
d.f. = degree of freedom
m.s. = mean square.

TABLE 4. AVERAGE RESPONSE TO STIMULATION IN NINE PANEL A EXPERIMENTS

Tapping system	Average response to stimulation (%) [±2.43 (6.7)]									Mean [±0.81 (2.2)]
	RRIM 607	RRIM 605	RRIM 513	GT 1 (I)	RRIM 600	GT 1 (II)	RRIM 623	PB 5/51	PB 5/63	
S/2.d/2.9m/12	118.2	126.6	108.8	119.6	115.4	113.8	104.8	101.6	102.0	112.3
S/2.d/3.9m/12	112.2	108.8	119.2	115.1	113.0	104.6	100.0	109.6	106.4	109.9
S/2.d/2.100%	116.0	112.4	98.4	112.6	115.4	113.6	96.6	105.2	102.6	108.1
S/2.d/4.50%	117.2	109.8	106.0	110.0	103.6	100.8	106.0	112.6	103.8	107.8
S/2.d/3.67%	103.4	110.8	104.2	116.0	101.6	105.4	101.4	102.8	97.8	104.8
S/R.d/4.70%	100.6	106.6	104.8	106.4	103.0	106.6	105.8	106.0	96.4	104.0
S/1.d/6.67%	95.6	108.4	105.6	97.8	99.0	102.4	103.6	104.2	96.4	101.4
S/1.d/4.9m/12	101.8	97.0	101.0	91.0	104.4	101.6	106.6	95.8	103.2	100.3
S/1.d/3.9m/12	107.8	95.2	106.6	92.6	102.2	100.2	102.0	92.2	101.6	100.0
S/1.d/4.100%	109.0	98.0	107.4	95.2	94.4	98.8	97.4	88.8	104.8	99.3
Mean [±0.77 (2.1)]	108.2	107.4	106.2	105.6	105.2	104.8	102.4	101.9	101.5	104.8
Mean [±0.57 (1.6)]	Year									
	–	–	1	2	3	4	5	–	–	–
	–	–	105.1	105.2	106.3	104.2	103.2	–	–	–

as the results of stimulation and partly as causes of variation in the response to stimulation with time.

The girth increments for the whole period of each experiment, two years in RRIM 501 on Panel B, four years in four Panel A experiments and five years in nine Panel A and five Panel B experiments, are analysed in *Tables 7, 8, 9* and *10*. The analyses of variance *(Table 7)* show that there are significant differences in girth increment between experiments, except between the two Panel A experiments on RRIM 605 and RRIM 623 at Estate I. There are significant differences between tapping systems in all cases. Girth increments are better with half spiral than full spiral tapping. The periodic systems give better girthing than continuous systems.

With the marginal exception of PB 5/63, stimulation has reduced the girth increment

TABLE 5A. AVERAGE RESPONSE TO STIMULATION IN TWO PANEL A EXPERIMENTS

Tapping system	Average response (%) [±2.63 (7.6)]		Mean [±1.86 (5.4)]
	RRIM 605	RRIM 623	
S/2.d/3.9m/12	122.5	108.3	115.4
S/2.d/2.100%	117.8	111.8	114.8
S/2.d/4.50%	116.3	108.8	112.5
S/2.d/2.9m/12	114.0	110.0	112.0
S/1.d/6.67%	108.3	112.0	110.1
S/R.d/4.70%	104.3	110.8	107.5
S/2.d/3.67%	104.5	109.0	106.8
S/1.d/3.9m/12	98.8	111.3	105.0
S/1.d/4.100%	100.3	106.5	103.4
S/1.d/4.9m/12	107.3	93.0	100.1
Mean [±0.83 (2.4)]	109.4	108.1	108.8
Mean [±1.18 (3.4)]	Year		
	1	2	3	4
	109.6	106.7	109.4	109.4

TABLE 5B. AVERAGE RESPONSE TO STIMULATION IN TWO PANEL A EXPERIMENTS

Tapping system	*Average response* (%) [±1.19 (3.6)]		Mean [±0.84 (1.5)]
	PR 107	RRIM 612	
S/2.d/4.50%	120.3	120.0	120.0
S/2.d/3.67%	126.9	103.9	115.4
S/1.d/6.67%	113.3	110.5	111.9
S/2.d/2.100%	112.0	104.4	108.2
S/1.d/4.100%	107.9	105.0	106.4
S/1.d/3.133%	97.6	106.8	102.2
Mean [±0.48 (1.5)]	113.0	108.4	110.7

Frequency of stimulation	Year				Mean [±0.48 (1.5)]
	1	2	3	4	
×2 per year	107.7	107.3	110.6	104.9	107.6
×6 per year	113.2	114.8	118.8	108.3	113.8
Mean [±0.68 (2.1)]	110.4	111.1	114.7	106.7	110.7

significantly in all Panel A experiments, *(Tables 8* and *9)*. This could account for the apparent falling response to stimulation (ratio of yield stimulated to yield unstimulated as percentage) in the later years in the majority of the Panel A experiments. Although there was no significant trend with time in the response of RRIM 605 and RRIM 623 over four years at Estate I, the girth increments were depressed by stimulation there also.

The difference of about 1 cm in 15 in the average girth increment between stimulated and unstimulated trees may seem small. The average girth of the trees in all Panel A experiments was about 54 cm at the commencement; the tapping cuts would have been about 1.5% longer in the unstimulated than the stimulated trees at the end. Using the formula of SHORROCKS *et al.* (1965), it is estimated that the unstimulated trees had dry weights of their shoots about 4% greater than those of the stimulated trees, which is a little more than the average decline in response of 2%. Since these were 'single tree plot' experiments in which trees receiving different treatments are adjacent to each other, there may have been a progressive tendency for the unstimulated trees to overgrow and shade the stimulated trees.

Although slight, this difference in growth may be enough to account for the apparent decline in response to stimulation. This argument applies with even greater force to the falling response to full spiral tapping.

It remains an open question whether the declining responses would be observed in experiments, where the plots allocated to each treatment were large enough to eliminate competition between trees of different treatments.

TABLE 6A. AVERAGE RESPONSE TO STIMULATION IN FIVE PANEL B EXPERIMENTS

Tapping system	Average response (%) [±0.96(2.7)]					Mean [±0.43(1.2)]
	PR 107(I)	PB 5/51	PB 86	PR 107(IV)	RRIM 513	
S/2.d/4.50%	119.6	122.7	103.0	109.9	100.2	111.1
S/2.d/3.67%	117.1	110.4	102.5	112.4	108.2	110.1
S/1.d/6.67%	109.3	107.5	107.1	105.6	104.1	106.7
S/2.d/2.100%	108.5	96.5	108.7	110.0	102.2	105.2
S/1.d/4.100%	89.2	95.8	109.0	90.2	101.9	97.2
Mean [±0.43(1.2)]	108.7	106.6	106.1	105.6	103.3	106.1
Frequency of stimulation	**Year [±0.6(1.7)]**					**Mean [±0.27(0.8)]**
	1	2	3	4	5	
× 2 per year	113.2	108.3	105.5	103.0	98.5	105.7
× 6 per year	121.0	110.1	105.4	101.8	93.9	106.4
Mean [±0.43(1.2)]	117.1	109.2	105.4	102.4	96.2	106.1

TABLE 6B. AVERAGE RESPONSE TO STIMULATION IN ONE PANEL B EXPERIMENT (RRIM 501)

Tapping system	Average response (%) [±0.72(2.8)]	Frequency of stimulation	Year [±0.64(2.5)]		Mean [±0.46(1.8)]
			1	2	
S/2.d/4.50%	128.8	× 2 per year	114.8	103.6	109.2
S/2.d/3.67%	121.5				
S/1.d/6.67%	109.5	× 6 per year	125.8	105.0	115.4
S/2.d/2.100%	102.8				
S/1.d/4.100%	99.0				
Mean	112.3	Mean [±0.46 (1.8)]	120.3	104.3	112.3

TABLE 7. ANALYSES OF VARIANCE OF GIRTH INCREMENTS

Source	(1) Nine Panel A Expts (five years)		(2) Two Panel A Expts (four years)		(3) Two Panel A Expts (four years)		(4) Five Panel B Expts (five years)		(5) RRIM 501 (Panel B)	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
Between experiments or clones (E)	8	206.8269***	1	0.4840	1	122.8403***	4	80.2549***	–	–
Between tapping systems (T)	9	116.3176***	9	27.7271***	5	36.7825***	4	27.2796***	4	0.4123*
Between frequencies of stimulation (F)	1	47.3294***	1	8.4640**	2	4.6759**	2	1.7810**	2	0.4187
E × T	72	2.6287***	9	1.1312	5	4.2043**	16	0.9570***	–	–
E × F	8	1.3231**	1	0.0490	2	0.0719	8	0.0653	–	–
T × F	9	0.4236	9	0.2979	10	0.3628	8	0.4364	8	0.1053
E × T × F	72	0.4047	9	0.5373	10	0.4810	32	0.2243	–	–

The girth increments are for the whole duration of the experiment.
(1), (2), (3), (4) and **(5)**: Experimental details as in *Table 3*.
(1) and **(2)**: The frequencies of stimulation were nil and twice per year.
(3), **(4)** and **(5)**: The frequencies of stimulation were nil, twice and six times per year.
d.f. = degree of freedom
m.s. = mean square

TABLE 8. GIRTH INCREMENTS DURING FIVE YEARS IN NINE PANEL A EXPERIMENTS

Tapping system	Girth increment (cm) [±0.45(1.3)]									Mean [±0.15(0.4)]
	RRIM 600	GT L (I)	GT 1 (II)	RRIM 607	RRIM 623	RRIM 605	RRIM 513	PB 5/63	PB 5/51	
S/2.d/3.9m/12	24.3	22.5	22.4	18.6	17.1	16.9	14.4	13.6	14.7	18.3
S/2.d/4.50%	23.8	21.1	21.6	18.1	17.1	15.8	13.4	11.5	14.3	17.4
S/2.d/2.9m/12	22.3	21.3	19.8	17.3	16.4	15.8	13.8	13.1	13.2	17.0
S/2.d/3.67%	22.9	19.4	20.2	17.2	15.9	14.1	11.8	11.6	13.2	16.2
S/2.d/2.100%	23.0	19.2	19.2	16.2	15.1	15.3	12.1	13.1	11.6	16.0
S/1.d/4.9m/12	19.6	16.2	13.7	13.7	13.6	13.5	11.8	11.8	10.5	13.8
S/1.d/3.9m/12	18.8	16.2	13.3	13.7	12.5	13.6	11.0	13.0	9.9	13.5
S/1.d/6.67%	19.2	14.6	12.3	10.4	12.0	10.0	9.6	9.8	9.4	12.9
S/R.d/4.70%	19.4	15.0	13.6	12.5	12.5	10.9	10.6	9.8	10.3	12.7
S/1.d/4.100%	16.9	12.7	10.2	9.9	11.2	10.6	8.4	9.4	8.2	10.8
Frequency of stimulation	Girth increment (cm) [±0.20(0.6)]									Mean [±0.07(0.2)]
Unstimulated	21.9	18.7	17.0	15.2	14.6	13.9	12.0	11.9	12.2	15.3
Stimulated (× 2 per year)	20.1	16.9	16.2	14.2	14.0	13.3	11.3	11.4	10.8	14.3
Mean [±0.14(0.4)]	21.0	17.8	16.6	14.7	14.3	13.6	11.7	11.6	11.5	14.8

In the Panel B experiments *(Table 10)* the differences in girth increments are mainly between the trees stimulated six times per year and those stimulated twice, rather than between the latter and the unstimulated trees. This is in agreement with the greater initial responses to more frequent stimulation and the more marked decline in these treatments.

The initial mean girth in the five Panel B experiments which ran for five years was about 72.5 centimetres. The tapping cuts in the unstimulated trees were little longer than those stimulated twice per year and only 0.6% longer than those stimulated six times per year. The estimated shoot dry weights of the unstimulated trees were only 0.3% and 1.7% greater than those of trees stimulated twice and six times per year respectively. Thus, reduced girth increment is a less convincing explanation of declining responses in Panel B experiments, although the declines were more marked and rapid in the Panel B than the Panel A experiments.

PUSHPARAJAH *et al.* (1971) showed that stimulated trees lost more nutrients than control trees and that the loss was proportionately heavier than the increase in yield. Higher rates of fertilisation were needed

TABLE 9A. GIRTH INCREMENTS DURING FOUR YEARS IN TWO PANEL A EXPERIMENTS (RRIM 605 AND 623)

Tapping system	Girth increment (cm) [±0.52(1.7)]		Mean [±0.37(1.2)]
	Unstimulated	Stimulated (× 2 per year)	
S/2.d/3.9m/12	17.8	16.6	17.2
S/2.d/2.9m/12	17.6	15.9	16.7
S/2.d/3.67%	16.2	15.5	15.9
S/2.d/2.100%	16.8	15.0	15.9
S/2.d/4.50%	15.7	15.2	15.4
S/1.d/3.9m/12	13.5	13.4	13.4
S/1.d/4.9m/12	13.9	12.8	13.3
S/R.d/4.70%	11.4	10.7	11.0
S/1.d/6.67%	10.8	10.5	10.7
S/1.d/4.100%	10.6	9.7	10.1
Clone	Girth increment (cm) [±0.23(0.7)]		Mean [±0.16(0.5)]
RRIM 623	14.5	13.6	14.1
RRIM 605	14.3	13.4	13.8
Mean [±0.16(0.5)]	14.4	13.5	14.0

TABLE 9B. GIRTH INCREMENTS DURING FOUR YEARS IN TWO PANEL A EXPERIMENTS (RRIM 612 AND PR 107)

Tapping system	Girth increment (cm) [±0.40(1.3)]		Mean [±0.28(0.9)]
	RRIM 612	PR 107	
S/2.d/2.100%	20.3	15.3	17.8
S/2.d./450%	20.4	15.0	17.7
S/3.d/3.67%	19.6	14.6	17.1
S/1.d/3.133%	14.4	13.0	13.7
S/1.d/6.67%	13.5	11.3	13.1
S/1.d/4.100%	14.9	11.5	12.5
Frequency of stimulation	Girth increment (cm) [±0.28(0.9)]		Mean [±0.20(0.6)]
Unstimulated	17.8	14.3	16.0
Stimulated (× 2 per year)	16.9	13.1	15.0
Stimulated (× 6 per year)	16.8	13.0	14.9
Mean [±0.16(0.5)]	17.2	13.5	15.3

TABLE 10. GIRTH INCREMENTS DURING FIVE YEARS IN FIVE PANEL B EXPERIMENTS AND DURING TWO YEARS IN ONE PANEL B EXPERIMENT

Tapping system	Girth increment (cm) [±0.27(0.8)]					Mean [±0.12(0.4)]	Girth increment (cm) RRIM 501 [±0.19(0.6)]
	PR 107 (I)	PR 107 (IV)	PB 86	PB 5/51	RRIM 513		
S/2.d/4.50%	12.3	10.0	8.6	7.0	6.4	8.9	2.2
S/2.d/2.100%	12.0	10.5	7.2	5.3	6.6	8.3	2.6
S/2.d/3.67%	11.4	9.1	7.9	6.0	6.0	8.1	2.5
S/1.d/6.67%	9.5	6.4	6.2	4.7	4.3	6.2	1.9
S/1.d/4.100%	9.6	6.3	5.0	4.4	4.0	5.8	1.8
Frequency of stimulation	**Girth increment (cm) [±0.21(0.6)]**					**Mean [±0.09(0.3)]**	**Girth increment (cm) [±0.15(0.5)]**
Unstimulated	11.0	8.6	7.3	5.7	5.7	7.7	2.4
Stimulated (× 2 per year)	11.1	8.7	6.9	5.5	5.5	7.6	2.3
Stimulated (× 6 per year)	10.7	8.1	6.7	5.2	5.1	7.2	1.9
Mean [±0.12(0.4)]	11.0	8.4	7.0	5.5	5.4	7.5	2.2

by stimulated trees to sustain responses. There was no differential manuring of stimulated and control trees in these experiments. This offers another possible explanation of the declining responses.

Correlations

Correlations within experiments between tapping systems are given in *Table 11*. The response to stimulation is not significantly correlated with the year in the Panel A experiments except for PB 5/51, as has already been noted. In most of the Panel B experiments there is a significant negative correlation between response and year, that is response declines in the later years. Therefore in the Panel B experiments the response is correlated with all variates such as girth which are also correlated with age, when the combined data for all years are considered.

In about half the Panel A experiments there is a significant negative correlation between response and percentage late drip in the unstimulated control for the combined data. The significance of this is improved when the common regression of the regressions for the individual years is considered. A large percentage late drip indicates a long flow. Stimulation prolongs flow. Stimulation is less effective where the flow is already long in the control.

In more than half of the Panel B experiments the marked decline in percentage late drip with age (see *Table 16*) results in a positive correlation between response and percentage late drip for the combined data for all years. However, extracting the common regression gives a negative correlation in most cases, significant in both experiments on PR 107. The case of PB 86 is exceptional.

TABLE 11. CORRELATION COEFFICIENTS WITHIN EXPERIMENTS BETWEEN TAPPING SYSTEMS FOR ALL YEARS D.R.C. WAS RECORDED

Panel	Clone	Estate	Frequency of stimulation	Degree of freedom		Year	Response to stimulation (%)				Late drip and d.r.c. in unstimulated treatment (%)
							Late drip in unstimulated treatment (%)		d.r.c. in unstimulated treatment (%)		
				A	B		A	B	A	B	
A	GT 1	I	× 2	38	28	−0.229	−0.761***	−0.794***	0.448**	0.326*	−0.564***
A	RRIM 605	I	× 2	18	14	−0.132	−0.655**	−0.682**	0.305	0.395	−0.444*
A	RRIM 623	I	× 2	18	14	−0.417	0.215	−0.476*	0.064	0.310	−0.798***
A	GT 1	II	× 2	38	28	−0.193	−0.403**	−0.444**	0.318	0.303	−0.789***
A	PB 5/51	II	× 2	38	28	−0.386*	−0.384*	−0.587***	0.493**	0.633***	−0.538***
A	PB 5/63	II	× 2	38	28	−0.019	−0.174	−0.143	−0.115	−0.141	0.222
A	RRIM 513	II	× 2	38	28	−0.297	0.017	−0.097	0.245	0.259	−0.562***
A	RRIM 600	II	× 2	38	28	−0.045	−0.470**	−0.672***	−0.038	0.031	−0.417**
A	RRIM 605	II	× 2	38	28	0.065	−0.734***	−0.784***	0.368*	0.380*	−0.492**
A	RRIM 607	II	× 2	38	28	0.040	−0.470**	−0.469**	0.032	0.033	−0.617***
A	RRIM 623	II	× 2	38	28	0.314	−0.005	−0.118	0.114	0.106	−0.585***
A	PR 107	II	× 2	16	9	−0.133	−0.412	−0.487	0.807***	0.806***	−0.595**
A	PR 107	II	× 6	16	9	−0.258	−0.538*	−0.700**	0.816***	0.807***	–
A	RRIM 612	II	× 2	16	9	−0.076	−0.110	−0.117	0.547*	0.547*	−0.564*
A	RRIM 612	II	× 6	16	9	−0.182	−0.165	−0.207	0.474*	0.474	–
B	PB 86	I	× 2	23	10	−0.426*	0.649***	0.664***	−0.385	−0.330	−0.401*
B	PB 86	I	× 6	23	10	−0.651***	0.412*	0.270	−0.582**	−0.431*	–
B	PR 107	I	× 2	23	10	−0.574**	−0.241	−0.514*	−0.183	0.641**	−0.534**
B	PR 107	I	× 6	23	10	−0.592**	−0.291	−0.591**	−0.198	−0.609**	–
B	RRIM 501	I	× 2	8	4	−0.422	−0.492	−0.440	0.648*	0.829**	−0.206
B	RRIM 501	I	× 6	8	4	−0.668*	−0.483	−0.437	0.478	0.846**	–
B	PB 5/51	IV	× 2	23	10	−0.628***	0.519**	−0.060	0.418*	0.792***	−0.325
B	PB 5/51	IV	× 6	23	10	−0.610**	0.593**	0.240	0.345	0.690***	–
B	PR 107	IV	× 2	23	10	−0.647***	0.432*	−0.435*	0.088	0.628**	−0.572**
B	PR 107	IV	× 6	23	10	−0.693***	0.495*	−0.493*	0.140	0.810***	–
B	RRIM 513	IV	× 2	23	10	−0.114	0.305	0.220	−0.210	−0.149	−0.710***
B	RRIM 513	IV	× 6	23	10	−0.657***	0.610**	−0.082	−0.293	0.117	–

A = Combined data for all years
B = Common regression of the individual years

It responded to stimulation of full spiral comparatively well *(Table 6)*.

The correlations between response and percentage d.r.c. are positive in most cases; however, they are significant in only a third of the Panel A experiments. The common regression gives a significant correlation in most Panel B experiments, although negative in two of the nine significant cases.

There is a negative correlation, significant in most experiments, between percentage late drip and percentage d.r.c. As will be seen from *Tables 21* and *22*, this derives mainly from the small percentage late drip and high percentage d.r.c. in half-spiral systems and the converse with long cuts.

The correlations within tapping systems between experiments are given in *Table 12*. The significant correlations in Panel A are negative between response and percentage late drip and positive between response and percentage d.r.c. The position is reversed for all years combined in Panel B. Extracting the common regression from those of the individual years gives no significant correlation between response and percentage late drip, but a negative, significant correlation between response and d.r.c. in S/2.d/2.100% stimulated six times per year and positive, significant correlations between response and d.r.c. in S/2.d/3.67% stimulated twice per year and S/2.d/4.50% stimulated six times per year. In general, there is a marked negative correlation between percentage late drip and d.r.c. Presumably in those clones with a long flow period the dilution reaction (FREY-WYSSLING, 1932) operates longer and the d.r.c. of the later-flow fractions before collection is lowered.

Despite exceptions, response to stimulation is generally correlated within years negatively with the percentage late drip and positively with the d.r.c. in the control system. Only before the first application of stimulants may the percentage late drip and d.r.c. be expected to be the same in both control and stimulated treatments. Although tapping system accounts for a greater proportion of the variation in percentage late drip and d.r.c. than does stimulation *(Tables 13* and *17)* stimulation increases the former and reduces the latter. Unless the trees have returned to the control condition before each successive stimulation, there would be a likelihood that the percentage late drip and d.r.c. had been modified unfavourably by previous stimulations before the later applications. This may also contribute to the decline with age in response to repeated stimulation in the Panel B experiments, despite the progressively more favourable conditions of percentage late drip and d.r.c. in the controls.

The d.r.c. as observed in these experiments may be confounded to some extent with percentage late drip. The d.r.c. was determined on that part of the crop harvested as latex at the normal hour of collection Variation in the percentage late drip results in the d.r.c. being determined on different fractions of the total crop.

Variation in Percentage Late Drip

The analyses of variance are in *Tables 13* *15* and *16*. Although the main effects of experiments, tapping systems, years (especially in Panel B) and frequency of stimulation are marked, there are also many significant interactions. If the late drip is 2%, nearly fifty times more crop is harvested at the usual hour than afterwards, whereas if the late drip is 33% the ratio is only twice. Generally, the effects of tapping system, clone and year are much greater than those of stimulation. The differences in late drip between half spiral and long cuts are in most cases greater than those due to frequency.

On the average, stimulation increases the late drip by 2.5% in half-spiral systems which have a control late drip of about 5.0%.

TABLE 12. CORRELATION COEFFICIENTS WITHIN TAPPING SYSTEMS BETWEEN EXPERIMENTS FOR ALL YEARS D.R.C. WAS RECORDED

Panel	Tapping system	Frequency of stimulation	Degree of freedom		Response to stimulation (%)				Late drip and d.r.c. in unstimulated treatment (%)
					Late drip in unstimulated treatment (%)		d,r.c. unstimulated treatment (%)		
			A	B	A	B	A	B	
A	S/2.d/2.100%	× 2	44	34	0.155	0.114	0.102	0.129	−0.656***
A	S/2.d/3.67%	× 2	44	34	−0.151	−0.307*	0.325*	0.405**	−0.661***
A	S/2.d/4.50%	× 2	44	34	−0.325*	−0.274	0.408**	0.397**	−0.753***
A	S/R.d/4.70%	× 2	38	28	−0.408**	−0.373*	0.437**	0.446**	−0.519***
A	S/1.d/4.100%	× 2	44	34	−0.081	0.036	−0.013	−0.057	−0.415**
A	S/1.d/6.67%	× 2	44	34	−0.448**	−0.354*	0.322*	0.259	−0.588***
A	S/2.d/2.9m/12	× 2	38	28	−0.131	−0.163	0.101	0.114	−0.715***
A	S/2.d/3.9m/12	× 2	38	28	0.019	−0.011	0.174	0.276	−0.763***
A	S/1.d/3.9m/12	× 2	38	28	−0.033	0.113	−0.057	−0.029	−0.150
A	S/1.d/4.9m/12	× 2	38	28	−0.265	−0.088	−0.049	−0.033	−0.430**
B	S/2.d/2.100%	× 2	25	10	0.199	−0.221	−0.566**	−0.317	−0.495**
B	S/2.d/2.100%	× 6	25	10	0.282	−0.210	−0.779***	−0.613**	–
B	S/2.d/3.67%	× 2	25	10	0.443*	0.228	−0.117	0.479*	−0.471*
B	S/2.d/3.67%	× 6	25	10	0.386*	0.026	−0.421*	0.003	–
B	S/2.d/4.50%	× 2	25	10	0.365	0.043	−0.252	0.238	−0.406*
B	S/2.d/4.50%	× 6	25	10	0.457**	0.098	−0.215	0.504*	–
B	S/1.d/4.100%	× 2	25	10	0.207	−0.214	−0.450*	−0.388	0.059
B	S/1.d/4.100%	× 6	25	10	0.422*	0.051	−0.401*	−0.320	–
B	S/1.d/6.67%	× 2	25	10	0.412*	−0.110	−0.431*	−0.242	−0.336
B	S/1.d/6.67%	× 6	25	10	0.551**	−0.084	−0.195	+0.369	–

A = Combined data for all years
B = Common regression of the individual years

TABLE 13. ANALYSES OF VARIANCE OF PERCENTAGE LATE DRIP

Source	(1) Nine Panel A Expts (over five years)		(2) Two Panel A Expts (over four years)		(3) Two Panel A Expts (over four years)		(4) Five Panel B Expts (over five years)		(5) RRIM 501 Panel B (over two years)	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
Between experiments or clones (E)	8	2 379.6545***	1	933.1560***	1	14.7584***	4	173.1729***	–	–
Between tapping systems (T)	9	3 486.8985***	9	1 790.8623***	5	919.3580***	4	1 071.1878***	4	331.3189***
Between years (Y)	4	953.1965***	3	266.1881***	3	125.8208***	4	1 625.7040***	1	20.6670*
Between frequencies of stimulation (F)	1	2 287.3900***	1	574.5640***	2	158.8319***	2	113.6321***	2	208.7244***
E × T	72	80.0890***	9	7.2909***	5	9.2217***	16	55.3496***	–	–
E × Y	32	249.5556***	3	62.1362***	3	46.5856***	16	119.6625***	–	–
E × F	8	31.9301***	1	36.2902***	2	29.7138***	8	13.5332***	–	–
T × Y	36	26.9704***	27	37.5992***	15	16.5666***	16	18.4184***	4	24.0495**
T × F	9	14.1806***	9	9.3664***	10	11.7420***	8	11.0269***	8	8.5831*
Y × F	4	4.1538**	3	0.1175	6	2.0762*	8	5.2736***	2	15.5610*
E × T × Y	288	5.3463***	27	4.3527***	15	3.3887***	64	7.2536***	–	–
E × T × F	72	3.3461***	9	4.8782***	10	2.5569**	32	1.7229***	–	–
E × Y × F	32	4.1044***	3	8.0041***	6	4.0697***	32	1.5917***	–	–
T × Y × F	36	2.7734***	27	1.4693	30	0.5754	32	1.0517**	8	2.0773
E × T × Y × F	288	1.0224	27	0.8507	30	0.6412	128	0.5301	–	–

(1), (2), (3), (4) and **(5)**: Experimental details as in *Table 3*. Percentage late drip was recorded in all years.
(1) and **(2)**: The frequencies of stimulation were nil and twice per year.
(2), (4) and **(5)**: The frequencies of stimulation were nil, twice and six times per year.
d.f. = degree of freedom
m.s. = mean square

TABLE. 14. MEAN LATE DRIP AS PERCENTAGE OF TOTAL CROP IN NINE PANEL A EXPERIMENTS

Tapping system	Percentage late drip [±0.32(0.9)]									Mean [±0.11(0.3)]
	GT 1 (I)	PB 5/63	RRIM 600	RRIM 605	RRIM 607	RRIM 523	GT 1 (II)	PB 5/51	RRIM 513	
S/1.d/4.100%	32.1	26.7	19.0	20.3	20.8	15.9	17.5	13.0	10.9	19.6
S/1.d/4.9m/12	32.2	24.3	19.8	20.5	20.7	15.6	14.5	12.1	9.0	18.7
S/1.d/6.67%	33.6	25.7	14.9	16.4	18.9	16.3	15.1	12.2	8.4	17.9
S/1.d/3.9m/12	26.9	21.1	16.8	19.1	20.3	13.8	12.3	9.8	8.9	16.5
S/R.d/4.70%	26.7	23.5	13.2	12.8	12.7	8.2	11.1	6.5	6.3	13.4
S/2.d/4.50%	12.5	19.0	10.5	8.5	6.3	3.9	3.5	3.8	4.4	8.0
S/2.d/3.9m/12	10.7	13.4	9.5	7.5	5.5	2.9	1.8	3.1	4.6	6.6
S/2.d/3.67%	9.8	15.6	9.3	7.5	5.2	2.8	2.0	2.9	3.8	6.5
S/2.d/2.9m/12	5.7	9.6	7.0	5.9	5.6	1.5	2.2	1.8	4.2	4.8
S/2.d/2.100%	5.1	8.6	5.9	5.3	3.9	1.6	1.8	1.6	3.4	4.1
Mean [±0.10(0.3)]	19.5	18.7	12.6	12.4	12.0	8.2	8.2	6.7	6.4	11.6

Frequency of stimulation	Year [±0.11(0.3)]					Mean [±0.05(0.1)]
	1	2	3	4	5	
Unstimulated	12.4	11.9	10.1	8.3	7.3	10.0
Stimulated (× 2 per year)	15.5	15.2	13.8	11.3	10.2	13.2
Mean [±0.08(0.2)]	14.0	13.6	12.0	9.8	8.7	11.6

The ratio of late drip stimulated to control is about 1.5 for half spiral and the ratio of yield at normal collection to that obtained afterwards is 19 to 1 in control, but is about 12 to 1 in stimulated, whereas on the average stimulation increases the late drip by 3.4% in long-cut systems, which have a control late drip of about 17.5%. The ratio of late drip stimulated to control is about 1.2 for long cuts and the ratio of yield at normal collection to that obtained afterwards is nearly 5 to 1 in control, but is nearly 4 to 1 in stimulated. The change in flow pattern due to stimulation is evidently much greater in half-spiral (low percentage late drip in control) than in long-cut systems.

Variation in D.R.C.

The analyses of variance are given in *Tables 17, 18, 19* and *20*. The main effects of clones, tapping systems and years (except in RRIM 501) are highly significant. Stimulation or the frequency of stimulation is

TABLE 15A. MEAN PERCENTAGE LATE DRIP IN TWO PANEL A EXPERIMENTS (RRIM 605 AND 623)

Tapping system	Mean late drip (%) [±0.33(0.9)]		Mean [±0.23(0.7)]
	RRIM 605	RRIM 623	
S/1.d/6.67%	32.7	31.1	31.9
S/1.d/4.9m/12	32.9	29.0	30.9
S/1.d/4.100%	31.9	26.6	29.2
S/1.d/3.9m/12	29.0	23.2	26.1
S/R.d/4.70%	25.3	19.0	22.1
S/2.d/4.50%	13.9	9.2	11.5
S/2.d/3.9m/12	14.0	8.0	11.0
S/2.d/3.67%	11.4	6.9	9.1
S/2.d/2.9m/12	10.0	4.4	7.2
S/2.d/2.100%	7.8	3.4	5.6
Mean [±0.010(0.3)]	20.9	16.1	18.5

Frequency of stimulation	Year [±0.21(0.6)]				Mean [±0.10(0.3)]
	1	2	3	4	
Unstimulated	19.9	17.0	15.4	13.9	16.6
Stimulated (× 2 per year)	23.8	20.8	19.1	17.8	20.4
Mean [±0.15(0.4)]	21.9	18.9	17.3	15.9	18.5

TABLE 15B. MEAN PERCENTAGE LATE DRIP IN TWO PANEL A EXPERIMENTS (RRIM 612 AND PR 107)

Tapping system	Mean late drip (%) [±0.23(0.7)]		Mean [±0.16(0.5)]
	RRIM 612	PR 107	
S/1.d/4.100%	14.5	13.0	13.8
S/1.d/3.133%	13.4	11.3	12.4
S/1.d/6.67%	12.5	11.2	11.9
S/2.d/4.50%	1.5	2.7	2.1
S/2.d/3.67%	1.5	1.5	1.5
S/2.d/2.100%	0.8	0.8	0.8
Mean [±0.09(0.3)]	7.4	6.7	7.1

Frequency of stimulation	Year [±0.28(0.8)]				Mean [±0.12(0.3)]
	1	2	3	4	
Unstimulated	6.1	6.9	3.9	3.1	5.0
Stimulated (× 2 per year)	8.5	9.6	7.5	4.8	7.6
Stimulated (× 6 per year)	9.5	10.6	7.6	6.4	8.5
Mean [±0.13(0.4)]	8.0	9.0	6.4	4.8	7.1

significant also in most cases. Many interactions are significant, but this in part derives from the many degrees of freedom rather than accounting for a large part of the variation.

In the nine Panel A experiments there are big differences in mean d.r.c. between clones (experiments) and to a lesser extent in the five Panel B experiments. In all

TABLE 16A. MEAN PERCENTAGE LATE DRIP IN FIVE PANEL B EXPERIMENTS

Tapping system	Mean late drip (%) [±0.19 (0.5)]					Mean [±0.08(0.2)]
	RRIM 513	PR 107 (I)	PB 5/51	PR 107 (IV)	PB 86	
S/1.d/4.100%	12.4	14.7	8.4	8.4	11.3	11.0
S/1.d/6.67%	13.8	13.7	8.0	8.0	9.6	10.6
S/2.d/4.50%	6.8	4.0	6.6	4.5	2.1	4.8
S/2.d/3.67%	5.9	3.3	5.6	3.8	1.4	4.0
S/2.d/2.100%	5.2	2.1	4.5	3.4	0.8	3.2
Mean [±0.08(0.2)]	8.8	7.6	6.6	5.6	5.0	6.7

Frequency of stimulation	Mean late drip (%) by year [±0.15(0.4)]					Mean [±0.07(0.2)]
	1	2	3	4	5	
Unstimulated	12.0	8.0	3.7	2.4	2.3	5.7
Stimulated (× 2 per year)	14.0	9.5	5.1	3.4	3.1	7.0
Stimulated (× 6 per year)	15.1	10.2	5.6	3.9	2.9	7.5
Mean [±0.08(0.2)]	13.7	9.2	4.8	3.2	2.8	6.7

TABLE 16B. MEAN PERCENTAGE LATE DRIP IN ONE PANEL B EXPERIMENT (RRIM 501)

Tapping system	Mean late drip (%) [±0.59(1.9)]	Frequency of stimulation	Mean late drip (%) by year [±0.64(2.1)]		Mean [±0.46(1.5)]
			1	2	
S/1.d/4.100%	33.0	Unstimulated	17.4	22.0	19.7
S/1.d/6.67%	31.9				
S/2.d/4.50%	21.8	Stimulated (× 2 per year)	22.5	25.7	25.6
S/2.d/3.67%	20.5				
S/2.d/2.100%	16.1	Stimulated (× 6 per year)	28.5	28.8	28.7
Mean	24.7	Mean [±0.37(1.2)]	23.8	25.5	24.7

TABLE 17. ANALYSES OF VARIANCE OF D.R.C.

Source	(1) Nine Panel A Expts (over four years)		(2) Two Panel A Expts (over two years)		(3) Two Panel A Expts (over three years)		(4) Five Panel B Expts (over five years)		(5) RRIM 501 Panel B (over two years)	
	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.	d.f.	m.s.
Between experiments or clones (E)	8	434.8117***	1	16.6532***	1	260.7115***	4	157.5273***	–	–
Between tapping systems (T)	9	461.9293***	9	22.8643***	5	383.8107***	4	629.5395***	4	5.4378***
Between years (Y)	3	39.4833***	1	43.6602***	2	51.6937***	4	318.9971***	1	0.2253
Between frequencies of stimulation (F)	1	88.5504***	1	12.2462**	2	29.8609**	2	56.9140***	2	4.9054***
E × T	72	9.1714***	9	5.7045**	5	4.5215	16	14.8742***	–	–
E × Y	24	9.2931***	1	8.5150**	2	0.5351	16	14.5313***	–	–
E × F	8	4.2677***	1	0.0660	2	1.5090	8	3.4114***	–	–
T × Y	27	1.9181***	9	4.7371**	10	3.5443	16	15.5893***	4	1.2679**
T × F	9	1.0247	9	1.2842	10	0.6462	8	1.2358**	8	0.2853
Y × F	3	2.5689*	1	1.3260	4	0.4053	8	2.9109***	2	1.4493**
E × T × Y	216	3.0281***	9	2.3204*	10	1.4004	64	2.6598***	–	–
E × T × F	72	1.7260**	9	0.5959	10	0.6983	32	1.4113***	–	–
E × Y × F	24	0.5903	1	0.4063	4	0.5443	32	1.0014*	–	–
T × Y × F	27	0.7237	9	0.4748	20	0.7035	32	0.4306	8	0.1218
E × T × Y × F	266	0.7384	9	0.6876	20	3.0544	128	0.5457	–	–

(1), (2), (3), (4) and **(5)**: Experimental details as in *Table 3*.
D.R.C. was recorded in columns
(1): second, third, fourth and fifth years.
(2): third and fourth years.
(3): second, third and fourth years.
(4): all five years.
(5): both years.
(1) and **(2)**: The frequencies of stimulation were nil and twice per year.
(2), (4) and **(5)**: The frequencies of stimulation were nil, twice and six times per year.
d.f. = degree of freedom
m.s. = mean square.

TABLE 18. MEAN D.R.C. IN NINE PANEL A EXPERIMENTS

Tapping system	Mean d.r.c. (%) [±0.30(0.9)]									Mean [±0.10(0.3)]
	PB 5/51	RRIM 513	RRIM 623	RRIM 607	RRIM 605	GT 1 (II)	RRIM 600	GT 1 (I)	PB 5/63	
S/2.d/4.50%	43.4	42.0	40.0	40.9	40.4	40.2	38.4	36.6	33.2	39.5
S/2.d/3.9m/12	41.2	39.5	38.3	38.7	38.5	38.7	36.2	34.4	30.6	37.3
S/2.d/3.67%	41.5	37.2	38.2	38.5	38.4	38.0	36.7	35.5	31.9	37.3
S/R.d/4.70%	39.9	37.1	38.2	37.2	37.1	34.6	35.9	33.8	31.1	36.1
S/1.d/6.67%	40.0	36.4	35.1	36.6	35.9	34.1	37.0	32.6	31.5	35.5
S/2.d/2.100%	38.8	36.0	36.4	36.0	36.4	35.5	34.6	35.2	29.6	35.4
S/2.d/2.9m/12	38.6	37.7	35.8	35.2	34.5	37.0	33.0	34.3	29.1	35.0
S/1.d/4.9m/12	36.7	35.7	33.3	33.4	32.8	32.6	33.4	31.4	29.8	33.2
S/1.d/4.100%	34.8	34.2	34.4	33.0	32.8	30.1	33.0	29.1	30.1	32.4
S/1.d/3.9m/12	33.1	32.5	30.6	30.9	30.9	31.1	31.4	31.0	27.3	31.0
Mean [±0.10(0.3)]	38.8	36.8	36.0	36.0	35.8	35.2	35.0	33.4	30.4	35.3

Frequency of stimulation	Year [±0.09(0.3)]				Mean [±0.05(0.1)]
	2	3	4	5	
Unstimulated	36.0	35.2	35.4	35.8	35.6
Stimulated (× 2 per year)	35.7	34.5	34.5	35.0	34.9
Mean [±0.07(0.2)]	35.9	34.8	35.0	35.4	35.3

experiments there are differences between tapping systems, large in the nine Panel A experiments and those on PR 107 and RRIM 612, but somewhat smaller in the others. Although differences in mean d.r.c. between years are significant in all except RRIM 501, the trends are not consistent. There is no clear trend with age in the nine Panel A experiments. There is an increase from the third to fourth year (the only years d.r.c. was recorded) in RRIM 605 and 623 at Estate I but a decline for the other Panel A experiments on PR 107 and RRIM 612 at Estate II. Only in the Panel B experiments was there a clear trend of rising d.r.c. with age, although even that faltered at the fourth year. The differences in d.r.c. between years and due to stimulation are small compared with those due to clones and tapping systems.

Over all the experiments, the effect of stimulation is to multiply the control d.r.c. by a factor of approximately 0.98, that is to reduce the control d.r.c. by about one unit (1%). The effect of tapping system on d.r.c., in particular the contrast between

TABLE 19A. MEAN D.R.C. IN TWO PANEL A EXPERIMENTS (RRIM 623 AND 605)

Tapping system	Mean d.r.c. % [±0.41(1.3)]		Mean [±0.29(0.9)]
	RRIM 623	RRIM 605	
S/2.d/3.67%	39.6	39.3	39.5
S/2.d/4.50%	39.8	39.1	39.4
S/2.d/3.9m/12	39.3	38.1	38.7
S/R.d/4.70%	37.6	37.5	37.5
S/2.d/2.100%	39.3	35.7	37.5
S/2.d/2.9m/12	38.5	35.5	37.0
S/1.d/6.67%	35.3	37.3	36.3
S/1.d/4.100%	36.8	34.8	35.8
S/1.d/4.9m/12	34.8	35.7	35.2
S/1.d/3.9m/12	35.2	34.2	34.7
Mean [±0.13(0.42)]	37.6	36.7	37.2
Frequency of stimulation	Year [±0.19(0.6)]		Mean [±0.13(0.42)]
	3	4	
Unstimulated	36.7	38.4	37.6
Stimulated (× 2 per year)	36.2	37.4	36.8
Mean [±0.13(0.42)]	36.4	37.9	37.2

TABLE 19B. MEAN D.R.C. IN TWO PANEL A EXPERIMENTS (PR 107 AND RRIM 612)

Tapping system	Mean (d.r.c.) % [±0.58(1.7)]		Mean [±0.41(1.2)]
	PR 107	RRIM 261	
S/2.d/4.50%	44.8	41.8	43.3
S/2.d/3.67%	42.6	38.7	40.6
S/1.d/6.67%	40.0	38.0	39.0
S/2.d/2.100%	39.9	35.3	37.6
S/1.d/4.100%	34.5	32.3	33.4
S/1.d/3.133%	32.4	29.4	30.9
Mean [±0.24(0.7)]	39.0	35.9	37.5
Frequency of stimulation	Year [±0.50(1.5)]			Mean [±0.29(0.9)]
	2	3	4	
Unstimulated	39.3	39.0	37.2	38.5
Stimulated (× 2 per year)	38.2	37.7	35.8	37.2
Stimulated (× 6 per year)	37.8	36.9	35.4	36.7
Mean [±0.29(0.9)]	38.4	37.9	36.1	37.5

TABLE 20A. MEAN D.R.C. IN FIVE PANEL B EXPERIMENTS

Tapping system	Mean d.r.c. (%) [±0.19(0.5)]					Mean [0.09(0.2)]
	PB 5/51	RRIM 513	PR 107(I)	PR 107(IV)	PB 86	
S/2.d/4.50%	45.7	43.0	40.6	42.0	40.3	42.3
S/2.d/3.67%	43.2	41.4	39.0	40.1	39.0	40.5
S/1.d/6.67%	42.3	37.5	38.2	38.1	36.7	38.5
S/2.d/2.100%	38.9	38.3	38.9	37.7	36.6	38.1
S/1.d/4.100%	35.6	34.8	35.3	33.8	33.5	34.6
Mean [±0.09(0.2)]	41.1	39.0	38.4	38.3	37.2	38.8

Frequency of stimulation	Mean d.r.c. by year [±0.15(0.4)]					Mean [±0.07(0.2)]
	1	2	3	4	5	
Unstimulated	36.4	38.8	40.5	40.0	41.2	39.4
Stimulated (× 2 per year)	35.9	37.7	40.1	39.6	41.5	39.0
Stimulated (× 6 per year)	35.1	37.0	39.1	38.3	40.8	38.1
Mean [±0.09(0.2)]	35.8	37.8	39.9	39.3	41.2	38.8

TABLE 20B. MEAN D.R.C. IN ONE PANEL B EXPERIMENT (RRIM 501)

Tapping system	Mean d.r.c. (%) [±0.14(0.5)]	Frequency of stimulation	Mean d.r.c. (%) by year [±0.16(0.5)]		Mean [±0.11(0.4)]
			1	2	
S/2.d/4.50%	38.2	Unstimulated	37.4	38.4	37.9
S/2.d/3.67%	37.4	Stimulated (× 2 per year)	37.5	37.0	37.2
S/1.d/6. 67%	38.0	Stimulated (× 6 per year)	36.4	36.6	36.5
S/2.d/2.100%	36.2				
S/1.d/4.100%	36.3				
Mean	37.2	Mean [±0.09(0.3)]	37.1	37.3	37.2

half spirals and long cuts, is far less consistent than the effect of cut length on percentage late drip. In the case of late drip there is a clear separation between half spirals and long cuts irrespective of the overall intensity, The d.r.c. is usually lower in long-cut than for half-spiral systems of the same intensity, but, although there is this trend in ranking, the two classes overlap.

The interaction of stimulation with length of cut is also less pronounced for d.r.c. than for percentage late drip. In several experiments the average factor of 0.98 applies to both long cuts and half spirals; in other experiments a slightly lower factor operates for the long cuts and in yet others a slightly larger factor.

Although there is a tendency for stimulation to depress the d.r.c. progressively more with age in the Panel A experiments, this is not so in the Panel B experiments. If this was so in Panel B experiments, it might provide a further explanation for the declining responses to stimulation with age. The failure to find this may be associated with the much more dramatic decline in the percentage late drip with age in the Panel B experiments than in the Panel A experiments. This has a confounding effect on d.r.c., because d.r.c. is determined only in the crop harvested as latex at the usual hour of collection, and the proportion of this to the total crop varies with percentage late drip. However, without details of the variation in d.r.c. during flow in control and stimulated trees, it is not possible to predict these confounded effects.

Tapping System and Late Drip

Late drip is more in long cuts than half spirals *(Tables 14, 15* and *16)* and among half-spiral systems it is less the more frequent the tappings. The effect of frequency within full spirals is not consistent. In *Table 21* the effects of length of cut and frequency on percentage late drip is shown for the unstimulated controls only. The data for continuous and periodic systems have been combined for the Panel A experiments, because preliminary analyses of the separate data led to the same conclusions.

TABLE 21. COMPARISON OF MEAN PERCENTAGE LATE DRIP BY LENGTH OF CUT AND FREQUENCY OF TAPPING IN ALL UNSTIMULATED TREATMENTS, CONTINUOUS AND PERIODIC TAPPING COMBINED

Length of cut	Panel A Experiment				Length of cut	Panel B Experiment			
	Tapping frequency					Tapping frequency			
	d/2	d/3[c]	d/4[d]	d/6		d/2	d/3	d/4[g]	d/6
S/2[a]	2.47 ±0.301 (86)	4.28 ±0.499 (86)	5.20 ±0.967 (46)	–	S/2[e]	3.11	4.27	5.02	–
S/R	–	–	11.36 ±1.402 (40)	–	S/1[f]	–	–	10.34	10.88
S/1[b]	–	14.56 ±1.109 (46)	17.18 ±0.911 (86)	15.84 +1.395 (46)					

Number of observations is given within brackets.

[a]Means in this row differ significantly ($P < 0.01$).

[b]Means in this row do not differ significantly.

[c],[d]Means in each of these columns differ significantly ($P < 0.001$).

Each mean is of twenty-seven observations; the pooled s.e. of any mean ±1.242.

Minimum significant ($P < 0.05$) difference between any pair of means is 3.48.

[e],[f]Means in each of these rows do not differ significantly.

[g]Means in this column differ significantly ($P < 0.001$).

In both Panel A and Panel B experiments there is a significant increase in percentage late drip as the length of cut increases. In the Panel A experiments the percentage late drip increases significantly with decreasing frequency of tapping of half spirals. Other differences due to frequency are not significant. The percentage late drip is at a maximum for d/4 tapping among S/1 cuts (or among all cuts for that matter) in the Panel A experiments.

Tapping System and D.R.C.

The d.r.c. is lower in long-cut than in half-spiral systems of the same intensity, and within any length of cut the d.r.c. declines in general with more frequent tapping *(Tables 18, 19* and *20)*. This is demonstrated for the unstimulated, control treatments in *Table 22*. The d.r.c. is lower in long cuts than in half spirals at the same frequency, and is higher the less the frequency of tapping for any cut-length. These effects are quite consistent for d.r.c., whereas the corresponding effects are not so for percentage late drip. Moreoever the differences for d.r.c. attain a higher level of significance than for percentage late drip; in this d.r.c. may be judged to be more sensitive to changes in frequency of tapping than is percentage late drip.

DISCUSSION

The response to stimulation is negatively correlated with percentage late drip and positively correlated with d.r.c. as a general rule, although there are exceptions to this. The negative correlations with percentage late drip are higher in Panel A and the positive correlations with percentage d.r.c. are higher in Panel B (after extraction of the common regression from the regressions for the individual years in both cases). Late drip and d.r.c. are not independent of each other, but negatively correlated for the greater part; however, they are positively correlated within half-spiral systems between frequencies, other factors constant.

Since for a given frequency of tapping (as far as these incompletely orthogonal comparisons allow) the percentage late drip

TABLE 22. COMPARISON OF MEAN PERCENTAGE D.R.C. BY LENGTH OF CUT AND FREQUENCY OF TAPPING IN ALL UNSTIMULATED TREATMENTS, CONTINUOUS AND PERIODIC TAPPING COMBINED

Length of cut	Panel A Experiments				Length of cut	Panel B Experiments			
	Tapping frequency					Tapping frequency			
	d/2	d/3[c]	d/4[d]	d/6		d/2	d/3	d/4[g]	d/6
S/2[a]	35.80 ±0.334 (86)	37.90 ±0.359 (86)	40.01 ±0.498 (46)	–	S/2[e]	38.47	41.03	42.09	–
S/R	–	–	36.27 ±0.412 (40)	–	S/1[f]	–	–	35.43	39.03
S/1[b]	–	31.96 ±0.372 (46)	33.37 ±0.284 (86)	36.53 ±0.475 (46)					

Number of observations is given within brackets.

[a],[b]Means in each of these rows differ significantly ($P < 0.001$).

[c],[d]Means in each of these columns differ significantly ($P < 0.001$).

Each mean is of twenty-seven observations; the pooled s.e. of any mean is ±0.552.

The minimum significant ($P < 0.05$) difference between any pair of means is 1.55.

[e],[f]Means in either row differ significantly ($P < 0.001$).

[g] Means in this column differ significantly ($P < 0.001$).

is greater and the d.r.c. is lower in long-cut systems than in half-spirals the poorer response to stimulation in the former than in the latter is entirely consistent.

Increasing the frequency of tapping in half-spiral systems reduces the percentage late drip and the d.r.c. The reduction in late drip should increase the response to stimulation, whereas the reduction in d.r.c. should decrease the response to stimulation. These opposing tendencies result in the variable responses in relation to frequency among half-spiral systems.

In full-spiral systems the effect of frequency on late drip is inconsistent and the influence on response through late drip may be expected to be inconsistent also. However, there is a significant increase in d.r.c. with reduced frequency of tapping full spiral and this may give rise to a fair response to stimulation, as is seen in several instances for S/1.d/6.67%.

Therefore, the responses to stimulation in relation to tapping system may be explained largely in terms of the effects of the latter on the percentage late drip and the d.r.c. The percentage late drip in particular is a measure of flow characteristics, even if a less precise measure than the plugging index of MILFORD *et al.* (1969). They showed a positive correlation between response to stimulation and plugging index (in which a high plugging index is approximately equivalent to short flow and less late drip), and a positive correlation between the plugging index and the percentage d.r.c. of the latex between clones.

The effect of stimulation is to reduce plugging and to prolong flow. The opportunity for stimulation to be effective is greater in a situation of high plugging, short flow and low late drip. If flow is prolonged, dilution of the latex will also be prolonged and the mean d.r.c. reduced. Increased flow will increase total yield, but reduced d.r.c. will reduce total yield. The response to stimulation will be the product of these opposing effects. Negative responses in yield to stimulation (that is responses of less than 100% as defined here) will arise when the prolongation in flow is inadequate in relation to the fall in d.r.c. Thus, a negative response arises in part from the same physiological processes as a positive response in yield. For the rest, whether the response is positive or negative will depend on the ability of the tree to regenerate rubber in the latex to restore the d.r.c. This ability may be associated partly with the initial d.r.c., so that the final response is not only correlated negatively with the initial or control percentage late drip, but positively with the initial or control d.r.c. The ability to regenerate rubber may be better in periodic systems than in the equivalent systems tapped continuously and so account for the often better responses to stimulation in the periodic systems.

If these conclusions are correct, it should be possible to use them to predict or explain responses to stimulation in new situations. ABRAHAM *et al.* (1971 a and b) inferred positive interactions in yield between the more effective novel stimulants, decreasing intensity and the introduction of panel changing. Among the new series of experiments reported by NG *et al.* (1970) were some comparing single half-spiral and panel-changing systems. The mean percentage late drip and d.r.c. are compared for these in *Table 23.*

Panel changing has increased the percentage late drip significantly and reduced the d.r.c. in the comparison available for S/2.d/2.100% and the corresponding system. These effects would be expected to reduce the response to stimulation with panel changing at alternate d/2 tappings. Panel changing has increased percentage late drip and reduced d.r.c. in the comparison of S/2.d/3.67% and the corresponding system, but proportionately less than in the former example. Little effect on response to stimulation due to panel changing might be ex-

TABLE 23. COMPARISON OF PERCENTAGE LATE DRIP AND D.R.C. IN SINGLE HALF- SPIRAL AND PANEL CHANGING SYSTEMS

Tapping system	Late drip (%)			d.r.c. (%)		
	Single S/2		Panel changing	Single S/2		Panel changing
S2.d/2.100% *versus* S/2.d/2(2 × 2d/4)100%[a]	9.6	±3.32* (9.4)	19.4	31.1	±1.78 (5.1)	28.8
S/2.d/3.67% *versus* S/2.d/3(2 × 3d/6)67%[b]	15.5	±1.26 (3.6)	17.0	36.0	±0.67* (1.9)	34.0
S/2.d/4.50% *versus* S/2.d/4(2 × 4d/8)50%[c]	17.2	±1.36** (3.9)	11.3	38.6	±0.73 (2.1)	38.0

*$P < 0.05$ **$P < 0.01$

[a]One experiment on RRIM 701, two years.

[b]One experiment on RRIM 701, two years, and two experiments each on PB 28/59 and RRIM 628, three years.

[c]Two experiments each on PB 28/59 and RRIM 628, three years.

pected. Panel changing has significantly decreased percentage late drip and only slightly reduced d.r.c. in the S/2.d/4.50% comparison. Panel changing might be expected to enhance the response to stimulation in this case.

The novel and more effective stimulants may introduce further interactions, but his example offers an explanation why the response to stimulation improves with panel changing and reduced frequency of tapping.

CONCLUSIONS

The generalisation that response to stimulation is negatively correlated with relative tapping intensity (both expressed as percentages) is not established with confidence in most of the Panel A experiments, but it is in most of the Panel B experiments. Responses are better in half-spiral than in long-cut systems of the same frequency of tapping or of the same relative intensity.

Among half-spiral systems response does not show a clear pattern in relation to frefrequency in Panel A experiments, but, in general, response increases with declining frequency in Panel B experiments. Among full-spiral systems response is generally better on d/6 than on d/4 in both Panel A and Panel B experiments. The comparison between d/3 and d/4 full-spiral systems is available only in Panel A and partly confounded with periodic *versus* continuous tapping; the pattern is not consistent although responses are better in d/4 than d/3 in more cases than the converse. Responses are often better in periodic than in continuous tapping of the same system.

There is some decline in response with age, successive years, in Panel A experiments and more markedly in Panel B experiments. Depressed girth increments in the stimulated trees, lack of compensatory fertiliser and depressed d.r.c. in the stimulated trees compared with controls are possible but not fully satisfactory explanations of the declines in response.

When the effects of years are eliminated by extracting the common regressions, there are in many, but not all, cases significant correlations between response and (a) percentage late drip (negative) and (b) percentage d.r.c. (positive). Although there is a general negative correlation between percentage late drip and d.r.c., this does not account for all their mutual variation and they are posi-

tively correlated between frequencies within half-spiral systems (clones and years).

The effects of cut-length and frequency of tapping on the percentage late drip and the d.r.c. are discussed in detail and shown to account for much of the variation in response to stimulation with tapping system. Late drip is related negatively with plugging index and hence with established flow phenomena. The d.r.c. is partly correlated with late drip as a result of the dilution reaction, but d.r.c. may be an indicator of the tree's ability to regenerate rubber also and so have a direct influence on the response to stimulation.

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