J. nat. Rubb. Res., **11**(3), 200–214

Effects of Tapping and Intensive Stimulation on Yield, Dryness Incidence and Some Physiological Latex Parameters of Clone RRIM 600

DO KIM THANH*, S. SIVAKUMARAN**# AND WONG KAI CHOO***

A four-year experiment studied the yield responses, dryness incidence and some physiological latex parameters of clone RRIM 600 on two tapping frequencies (alternate daily d/2; fourth daily d/4) of half-spiral tapping system combined with four stimulation frequencies [unstimulated control (0/y); 4 applications/year (4/y); 30 applications/year (30/y); 60 applications/year (60/y)] of 2.5% ethephon applied by groove method. Low tapping frequency of d/4 gave significantly higher g/t/t but lower kg/ha/year and cumulative kg/ha when compared to d/2 frequency. When very high stimulation frequency of 30/y or 60/y were applied, the bulk of the yield increase in response to stimulation was only recorded in the first year of tapping, with increase thereafter being marginal when compared to the unstimulated control. No significant differences in yield were obtained between stimulations 30/y and 60/y. Incidence of dryness was not affected by stimulation frequency upto 30/y, but was significantly increased when at stimulation frequency of 60/y.

Trees tapped on d/2 frequency in contrast to d/4 recorded consistently lower readings of physiological latex parameters such as plugging index (PI), initial flow rate (IFR), total solid content (TSC) and dry rubber content (DRC) but higher bottom fraction (BF), thiol content (R-SH) and inorganic phosphorus content (Pi). Similarly, intensive frequencies of stimulation (30/y and 60/y) produced lower values of PI, IFR, TSC and DRC but higher values of BF and Pi when compared to low stimulation frequency 4/y or unstimulated control. Under our experimental conditions sucrose and pH of latex were not affected by both tapping and stimulation treatment and this finding is at variance with other published reports. The significance of changes in these various physiological latex parameters are discussed in relation to yields obtained with the different combinations of tapping and stimulation frequencies.

The yield productivity of *Hevea* trees can be increased beyond its genetic potentials by appropriate manipulation of tapping and stimulation methods. However, very intensive tapping could lead to physiological stress in the tapping panel resulting in development of

*Rubber Research Institute of Vietnam, 177 Hai Ba Trung St., Ward 6, Dist. 3, HCM City, Vietnam
**Rubber Research Institute of Malaysia, P.O. Box 10150, Kuala Lumpur, Malaysia
***Universiti Pertanian Malaysia, 43400 Serdang, Selangor, Malaysia
#Corresponding author

tapping panel dryness[1,2]. Similarly heavy stimulation over the long term on successive tapping panels could also result in deleterious effects on the physiology and anatomy of the bark[3].

It is imperative for sustained yield productivity of *Hevea* trees that the exploitation intensity adopted does not lead to irreversible physiological stress in the tapping panel. It has been shown that the physiological status of the tapping panel can be monitored by routine analysis of selected physiological latex parameters[4]. It was therefore considered beneficial to study changes in physiological latex parameters in trees subjected to various intensities of exploitation. Thus in this study changes in some physiological latex parameters in trees of clone RRIM 600 subjected to two tapping systems in combination with intensive stimulation have been investigated. The relationship between changes in these parameters and yield and associated parameters are discussed.

MATERIALS AND METHODS

The experiment was conducted at *Field 53C*, Rubber Research Institute Experiment Station, Selangor, Malaysia, on clone RRIM 600. The trees were tapped on half-spiral system with two tapping frequencies, *viz.* alternate daily tapping (d/2) and fourth daily tapping (d/4). These tapping systems were combined with stimulation frequencies of 0, 4, 30 and 60 applications per year, *viz.*:

- ½S d/2 6d/7 unstimulated (control);
- ½S d/2 6d/7+ET 2.5% Ga(1) 4/y (4 applications a year)
- ½S d/2 6d/7+ET 2.5% Ga(1) 30/y (30 applications a year)
- ½S d/2 6d/7+ET 2.5% Ga(1) 60/y (60 applications a year)
- ½S d/4 6d/7 unstimulated
- ½S d/4 6d/7+ET 2.5% Ga(1) 4/y (4 applications a year)
- ½S d/4 6d/7+ET 2.5% Ga(1) 30/y (30 applications a year)
- ½S d/4 6d/7+ET 2.5% Ga(1) 60/y (60 applications a year).

Stimulation was by means of ethephon at 2.5% concentration applied by the groove method. Yield recordings were carried out on second virgin panel (*BO-2*). The duration of recording was for a period of four years. Physiological latex parameters were determined from March to October 1994, this duration being towards the final year of the four-year period of yield recording. Each treatment was replicated three times with nine trees per replication. The treatments were laid in a randomised complete block design (RCBD).

For yield recording, latex from all trees per treatment per replication were bulked together and weighed as bulked wet weight of latex. Late drips were similarly recorded as bulked wet weight of cuplump. Dry rubber content (DRC) of latex was determined twice a month for each treatment while that of cuplump was calculated on the assumption of 40%–50% water content.

Dryness incidences were recorded in November of each tapping year. The percentage of dryness was derived by expressing the total length of dry cut of each treatment as a percentage of the total length of cut of that treatment.

For determination of physiological latex parameters, the following methods were followed:

- *Initial flow rate and plugging index.* Initial flow rate (IFR) (ml/minute) and plugging index (PI) were determined following the method described by Milford *et al.*[5] IFR defined as the rate of latex flow in millilitres per minute was recorded by measuring the volume of latex at the end of five minutes flow. PI was derived by dividing the IFR by total volume of latex recorded on the day of measurement. This was multiplied by a common factor of 100 for convenient expression.

- *Determination of bottom fraction.* Bottom fraction (BF) (%) was determined by the haematocrit method. Latex was pipetted into a haematocrit tube which had one end sealed. The sample was kept in ice (0°–5°C). It was centrifuged at 15 000 r.p.m. for 15 min using a micro haematocrit centrifuge (MHC-Hawksley). As soon as the sample was taken out of the centrifuge, the length of bottom fraction as distinguished from the top rubber fraction by a layer of clear serum was measured.

BF was calculated as:

$$BF\ \% = \frac{\text{Length of BF}}{\text{Total length of latex column}} \times 100$$

- *pH measurement.* pH of latex was measured by a pH-meter (Hanna Instrument 8417) with combined electrode WTM E-50. Prior to measurement, the pH-meter was calibrated with buffer solution of pH = 7.01 at ambient temperature. The electrode was dipped in the latex and after a stabilisation period of 2–5 min per reading was recorded.

- *Other parameters.* Determination of total solid content (TSC), DRC in %, sucrose, inorganic phosphorus (Pi), thiols in mM (R-SH) were carried out following the methods described by I.R.C.A.[6], Jacob *et al.*[7,8], and Do and Nguyen[9].

The sampling procedures for analysis of physiological latex parameters were as follows: 20 drops of latex from each tree in the same replication were pooled into a small vial which was kept in ice. The pooled latex was then pipetted in 1 ml fraction for TSC determination and 1 ml for extraction by 2.5% trichloroacetic acid. The extracted aliquots from trichloroacetic acid was always kept in cooled condition (0°–5°C) for the determination of sucrose, inorganic phosphorus and thiols content.

RESULTS

Mean Dry Rubber Yield per Tree per Tapping

Analysis of variance showed that there were significant treatment but no interaction effects on mean dry rubber yield per tree per tapping (g/t/t) over 4 years. High tapping frequency of d/2 gave significantly lower yield (g/t/t) when compared to d/4 frequency (*Table 1*). All stimulated treatments produced significantly higher g/t/t than the unstimulated control. Among the stimulated treatments, intensive stimulations of 30/y and 60/y produced significantly higher yield than stimulation of 4/y. However, there was no significant difference between 30/y and 60/y.

TABLE 1. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER TREE PER TAPPING (G/T/T) OVER 4 YEARS OF TAPPING

Tapping frequency	Stimulation frequency				Mean
	Control	4/y	30/y	60/y	
½S d/2	57.9	64.7	79.9	77.6	70.0
½S d/4	57.1	70.3	92.5	100.4	80.1
Mean	57.5	67.5	86.1	89.0	75.1

$LSD_{0.05}$ (tapping frequency) = 6.1
$LSD_{0.05}$ (stimulation frequency) = 8.7

The trend of mean g/t/t over four years of tapping is shown in *Figure 1*. There appeared to be differences between the two tapping frequencies in response to stimulation. Under high tapping frequency of d/2, stimulations 30/y and 60/y produced higher yield when compared to stimulation 4/y or the unstimulated control in the first year of tapping. However, their yield differences declined with subsequent years of tapping such that at the fourth year of tapping, no differences in yield were detected among stimulated and unstimulated trees. With low tapping frequency of d/4, the higher yields produced by stimulations 30/y and 60/y over those of stimulation 4/y or unstimulated control were sustained throughout the four years of tapping though their yield differences were less in later tapping years.

Mean Dry Rubber Yield per Hectare per Year

There were significant treatment but no interaction effects on mean dry rubber yield per hectare per year (kg/ha/year) over four years of tapping. High tapping frequency of d/2 produced significantly higher kg/ha/year than the lower tapping frequency of d/4 (*Table 2*). This result was the reverse of that of g/t/t.

All stimulated treatments produced significantly higher kg/ha/year than the unstimulated control. Among the stimulated treatments, stimulations of 30/y and 60/y gave significantly higher yield than stimulation 4/y.

Cumulative Dry Rubber Yield per Hectare

Analysis of variance on cumulative dry rubber yield per hectare (kg/ha) showed significant treatment but no interaction effects. Results on kg/ha cumulated over four years of tapping were similar to those of kg/ha/year (*Table 3*).

Dryness Incidence

The data on frequency of dryness incidence at the end of fourth year of tapping are presented in *Table 4*. Values in percentages were transformed using square root transformation and analysis of variance performed on the transformed values. Significant effect due to stimulation treatment was obtained while there were no significant effects due to tapping frequency or interaction. High stimulation frequency of 60/y resulted in significantly higher dryness incidence than the other stimulation treatments as well as the unstimulated control. No

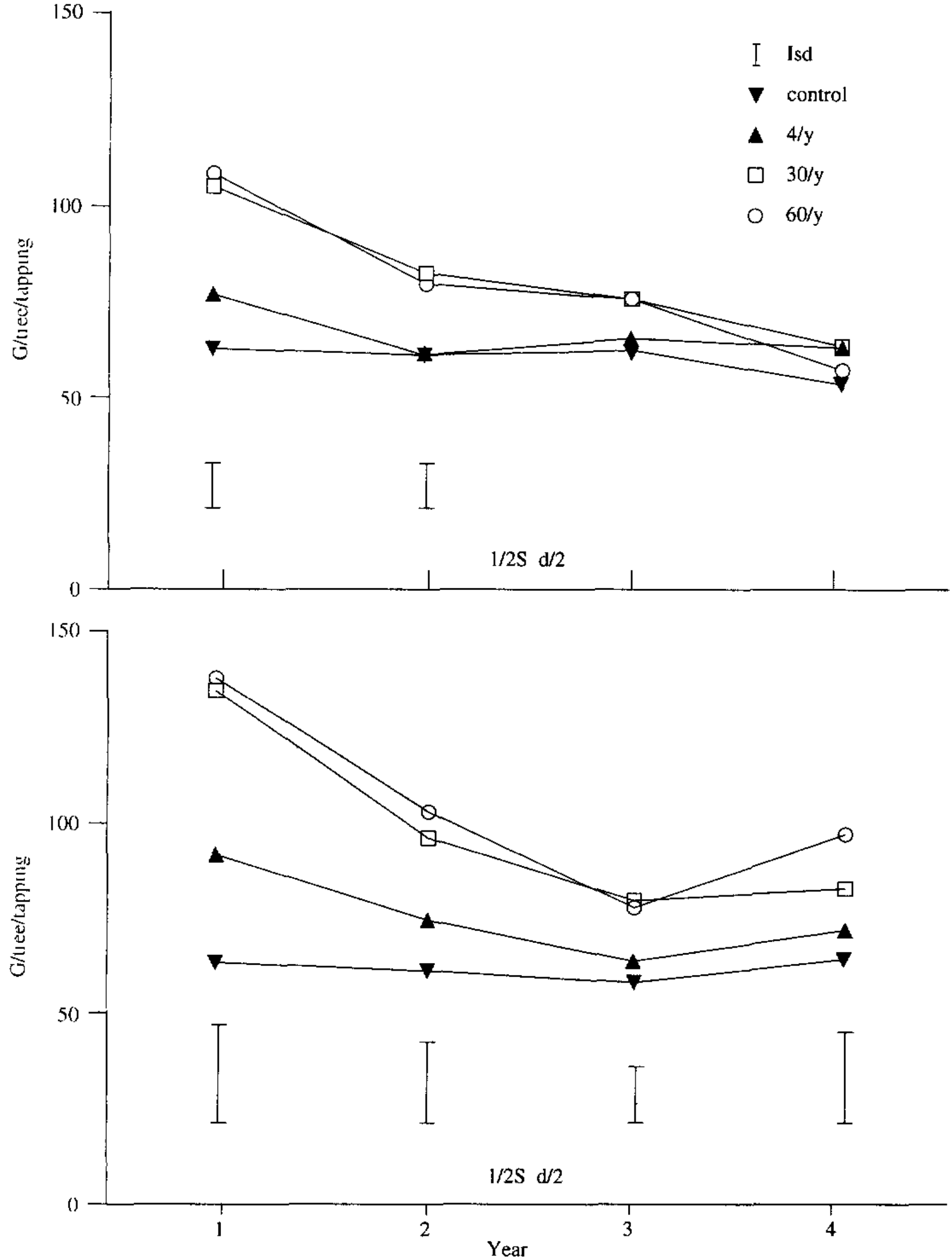

Figure 1 Mean g/t/t as influenced by stimulation treatments under two tapping frequencies

TABLE 2 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER HECTARE PER YEAR (KG/HA/YEAR) OVER 4 YEARS OF TAPPING

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	2 056	2 298	2 829	2 754	2 484
½S d/4	1 103	1 358	1 786	1 939	1 547
Mean	1 580	1 828	2 308	2 347	2 015

$LSD_{0.05}$ (tapping frequency) =160

$LSD_{0.05}$ (stimulation frequency) = 227

TABLE 3 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON CUMULATIVE DRY RUBBER YIELD PER HECTARE (KG/HA) OVER 4 YEARS OF TAPPING

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	8 223	9 193	11 317	11 016	9 937
½S d/4	4 410	5 429	7 142	7 754	6 184
Mean	6 317	7 311	9 230	9 385	8 061

$LSD_{0.05}$ (tapping frequency) =642

$LSD_{0.05}$ (stimulation frequency) = 907

TABLE 4 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON DRYNESS INCIDENCE

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	8.0 (2.2)	3.8 (2.1)	7.3 (2.6)	22.3 (4.7)	10.4 (2.9)
½S d/4	0.0 (1.0)	3.6 (1.8)	6.4 (2.5)	16.9 (4.1)	6.7 (2.4)
Mean	4.0 (1.6)	3.7 (2.0)	6.9 (2.6)	19.6 (4.4)	8.6 (2.7)

Figures in brackets denote the transformed data

$LSD_{0.05}$ on transformed values (tapping frequency) = 0.8

$LSD_{0.05}$ on transformed values (stimulation frequency) = 1.1

significant differences in dryness incidence were obtained between the lower stimulation frequencies (4/y and 30/y) and the control

Physiological Latex Parameters

Physiological latex parameters associated with latex flow Analyses of variance on physiological latex parameters associated with latex flow function such as PI, IFR, DRC, BF and TSC revealed significant effect due to tapping and stimulation treatments but no significant effect due to interaction

Plugging index High tapping frequency of d/2 resulted in significantly lower PI than the lower tapping frequency of d/4 (*Table 5*). All stimulated treatments produced significantly lower PI than the unstimulated control There was a progressive reduction in PI with increase in stimulation frequency from 4/y to 60/y.

Initial flow rate High tapping frequency of d/2 produced significantly lower IFR than low tapping frequency of d/4 (*Table 6*) Significantly lower IFR were produced by stimulation frequencies of 30/y and 60/y when compared to those of stimulation 4/y or unstimulated control

Bottom fraction. High tapping frequency of d/2 produced significantly higher BF than low tapping frequency of d/4 (*Table 7*) Stimulation 30/y produced significantly higher BF than the unstimulated control No significant differences were detected between stimulations 30/y and 60/y and also between stimulation 4/y and the control

Total solid content and dry rubber content High tapping frequency of d/2 produced significantly lower TSC than low tapping frequency of d/4 (*Table 8*) Stimulations 30/y and 60/y led to significantly lower TSC when compared to stimulation 4/y or unstimulated control. Tapping and stimulation treatments affected DRC in a similar manner as TSC

Physiological latex parameters associated with latex metabolism. Analyses of variance on physiological latex parameters associated with latex metabolism such as thiols content (R-SH) and Pi showed significant treatment effects while with sucrose and pH there was no significant treatment effects No significant interaction effect was obtained for all the above parameters

TABLE 5 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON PLUGGING INDEX

Tapping frequency	Stimulation frequency				Mean
	Control	4/y	30/y	60/y	
½S d/2	3 93	2 47	2 14	1 55	2 52
½S d/4	4 55	4 09	2 37	1 86	3 22
Mean	4 24	3 28	2 26	1 71	2 87

$LSD_{0 05}$ (tapping frequency) = 0 38

$LSD_{0 05}$ (stimulation frequency) = 0 54

TABLE 6 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON INITIAL FLOW RATE (ML/MINUTE)

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	4.4	3.2	2.1	1.7	2.9
½S d/4	5.2	5.6	3.5	4.0	4.6
Mean	4.8	4.4	2.8	2.9	3.7

$LSD_{0.05}$ (tapping frequency) = 0.6
$LSD_{0.05}$ (stimulation frequency) = 0 8

TABLE 7 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON BOTTOM FRACTION (%)

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	21.9	21.1	25.6	25.1	23.4
½S d/4	14.5	17.1	20.6	18.7	17.7
Mean	18.2	19.1	23.1	21.9	20.6

$LSD_{0.05}$ (tapping frequency) = 2.5
$LSD_{0.05}$ (stimulation frequency) = 3.5

TABLE 8 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON TOTAL SOLID AND DRY RUBBER CONTENTS (%)

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	40.5 (35 1)	39.6 (35 0)	35.3 (31.2)	35.7 (32.0)	37.8 (33.3)
½S d/4	47.8 (41.6)	47.0 (40.2)	45.4 (40.1)	43.2 (38.5)	45 9 (40.1)
Mean	44.2 (38 4)	43.3 (37.6)	40.4 (35.7)	39.5 (35.3)	41.8 (36.7)

Figures in brackets are values for dry rubber contents
$LSD_{0.05}$ (tapping frequency) = 1.9 (1.5)
$LSD_{0.05}$ (stimulation frequency) = 2.7 (2.2)

Thiols content. High tapping frequency of d/2 produced significantly higher R-SH than low tapping frequency of d/4 (*Table 9*). No significant differences in R-SH were obtained between stimulated treatments and the unstimulated control.

Inorganic phosphorus. High tapping frequency of d/2 produced significantly higher Pi than lower tapping frequency d/4 (*Table 10*). Stimulation 60/y produced significantly higher Pi than stimulation 4/y or unstimulated control.

Sucrose. Tapping and stimulation treatments have no significant effect on the sucrose content of latex (*Table 11*).

pH. This parameter was also not affected by both tapping and stimulation treatments (*Table 12*).

DISCUSSION

There were no interaction effects between tapping and stimulation frequencies on mean dry rubber yield (g/t/t) during the first three years of tapping. Irrespective of tapping frequency, high stimulations (30/y and 60/y) tended to produce higher yield than low stimulation (4/y) or unstimulated control, though the magnitude of their yield differences declined with progressive years of tapping. The bulk of the increase in response to application of high dosages was only recorded in the first year of tapping, with increase thereafter being of a lower magnitude. During the fourth tapping year, no significant differences in yield were obtained among stimulated and unstimulated treatments under high tapping frequency of d/2 while under low tapping frequency d/4 the higher yields produced by high stimulations 30/y and 60/y were still above those of low stimulation 4/y or unstimulated control. However, yield responses did not increase proportionately with level of stimulation applied. The results suggest that high stimulations even though combined with low tapping frequency may result in low yield responses in later tapping years. In earlier trials it was shown that for sustained and positive response to be obtained over the long term, it would be preferable to apply low dosages of stimulant over a longer duration rather than high dosages over shorter duration[10].

The latex physiological parameters could be classified into two groups, namely a group which has a bearing on latex flow and another

TABLE 9. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON THIOLS CONTENT (mM)

Tapping frequency	Stimulation frequency Control	4/y	30/y	60/y	Mean
½S d/2	0.41	0.38	0.35	0.39	0.38
½S d/4	0.34	0.31	0.33	0.34	0.33
Mean	0.38	0.35	0.34	0.37	0.36

$LSD_{0.05}$ (tapping frequency) = 0.03

TABLE 10. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON INORGANIC PHOSPHORUS (mM)

Tapping frequency	Stimulation frequency				Mean
	Control	4/y	30/y	60/y	
½S d/2	14.09	13.33	14.20	15.80	14.36
½S d/4	10.29	9.58	13.33	14.45	11.91
Mean	12.19	11.46	13.77	15.13	13.13

$LSD_{0.05}$ (tapping frequency) = 1.89
$LSD_{0.05}$ (stimulation frequency) = 2.68

TABLE 11. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON SUCROSE CONTENT (mM)

Tapping frequency	Stimulation frequency				Mean
	Control	4/y	30/y	60/y	
½S d/2	5 96	5.47	3.44	4.69	4.89
½S d/4	5.71	5.32	4.41	5.19	5.16
Mean	5.84	5.40	3.93	4.94	5.02

TABLE 12. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON LATEX pH

Tapping frequency	Stimulation frequency				Mean
	Control	4/y	30/y	60/y	
½S d/2	6.80	6.75	6.78	6.80	6.78
½S d/4	6.75	6.73	6.81	6.80	6.77
Mean	6.78	6.74	6.80	6.80	6.78

group on latex metabolism. The parameters in the former group include PI, IFR, DRC, TSC and BF. The latter group includes sugar, Pi, pH of latex and thiols (R-SH). It has been reported that some of these parameters such as TSC, DRC and thiols may have dual functions *i.e.* roles in both latex flow and metabolism[4,8]. The biological roles and significance of these parameters have been reported in various publications[4,5,8,11].

The values recorded for the various parameters would seem to indicate that the effects of intensive stimulation and higher tapping frequency on these parameters were similar. All parameters were significantly affected by both tapping and stimulation treatments except for sucrose and pH, while thiol content was only influenced by tapping treatment.

Trees tapped on d/4 frequency in contrast to d/2 frequency recorded consistently higher readings for the various latex physiological parameters associated with latex flow namely PI, IFR, TSC and DRC This is likely to indicate that trees tapped on low frequency have longer time to regenerate the cell contents which results in higher values of TSC and DRC. Higher values of TSC and DRC, in turn, have an effect on latex viscosity[12] which could limit the latex flow[4,13]. This limitation on latex flow is also reflected by the high PI values recorded in these studies The PI values for d/2-tapped trees being lower than d/4-tapped trees, would therefore be expected to give higher yields per tapping. However, this was not so in the present experiment. In relating the values of physiological latex parameters to yield performance, it must be pointed out that in the present experiment, yields were based on the means of four years of tapping whereas the physiological latex parameters were based on the means of eight months of recordings, towards the final stage of the yield recording period. Notwithstanding this disparity in periods of recording for yield and physiological latex parameters, the absence of a higher yield per tapping of d/2 tapped trees may be explained as such that, though a lower PI would have contributed to a higher volume of latex, nevertheless the dry rubber yields would be lower because of lower DRC values recorded with the higher frequency of tapping. Furthermore, the low initial flow rate for d/2 tapped trees could have resulted in the lower PI and yield per tapping. It is apparent from this study that different factors were limiting latex flow in d/2 and d/4 frequencies Hence, in d/2 the limitation is the short intervals between tappings with inadequate replenishment, while in d/4 frequency it could be the high DRC and PI. Therefore, the application of stimulation to low frequency tapping is necessary to enhance latex flow and overcome flow limiting factors. Earlier works stressed that stimulation played a key role in achieving the desired productivity from low frequency tapping systems[14,15]. This was true in this study, since stimulation was effective in lowering the PI and DRC values with consequently better yields. This can be explained by the fact that stimulation delays plugging in stimulated trees and consequently increases the flow time resulting in yield increases[11,16].

Several researchers[17–20] have emphasised the role of lutoids in latex coagulation. It has been reported that the presence of high percentage of undamaged lutoids in the latex is a reflection of greater latex stability. The results obtained in this study on percentage of bottom fraction using the haematocrit technique showed significant differences among treatments. Trees tapped on d/2 frequency had higher volumes for bottom fraction than that of d/4 tapped trees This could be explained by the fact that with low tapping frequency, there is higher turgor pressures within the vessels due to adequate regeneration of latex contents between tappings and loadings of sucrose in the vessels. Thus, when a tapping cut is opened in a low frequency tapped tree it can be expected that there will be a marked collapse in turgor pressure immediately under the cut with consequently far greater dilution effects[21]. The dilution effects could be attributed to movement of latex from the surrounding areas to the drainage area below the cut[22–25] and also movement of water and other minerals to this area, hence the far greater dilution effect on latex The marked dilution effect can result in greater bottom fraction damage and consequently increased formation of plugs at points of destabilisation in the latex vessel This could account for the reduced amount of bottom fraction recorded in low frequency tapped trees in this study

Ethephon stimulated treatments, in this study, had more bottom fraction thus indicating greater stability of latex in stimulated trees. It is known that stimulation effect on latex flow is mediated through delayed plugging in the latex vessels[26] The delayed plugging would mean less damaged lutoids with fewer plug formation Thus, stimulation is most likely to confer greater stability on the lutoid particles with slower plugging and enhanced flow Ethylene was reported to have a direct effect *in vitro* on the swelling of lutoid thus contributing to lesser number of damaged lutoids[27] Therefore, the findings established in this study conform to expected trends previously reported. The reduced extent of damaged bottom fraction as reflected in higher values, as expected, resulted in better yield performance from stimulated treatments

In relation to latex metabolism parameters, d/2 tapping and intensive stimulation (30/y and 60/y) resulted in higher value for Pi when compared to low frequency tapping (d/4) and unstimulated control or trees treated with mild stimulation (4/y) Inorganic phosphorus reflects the energy metabolism in laticiferous system[4] It is formed *in situ* from the hydrolysis of phosphorylated molecules and that of inorganic pyrophosphate produced by the rubber transferase responsible for the lengthening of the polyisoprenic chain[28]. It influences to a considerable extent the various processes in the glucidic metabolism by providing necessary energy[29] Therefore, the high content of free inorganic phosphorus recorded in d/2-tapped and intensively stimulated trees reflects the active metabolism in laticiferous cells of these trees. The higher metabolism observed in these trees is related to the higher yield produced by these trees and the consequent processes related to replenishment and regeneration in latex vessel of these trees.

Thiols are the main reducing molecules in latex which play an important role in protection of latex organelle membranes by neutralising the metabolic by-products of metabolic processes such as hydrogen peroxide (H_2O_2) and superoxide ions (O_2^-)[30]. The removal of free toxic oxygen radicals from the laticiferous system will contribute to latex stability and consequently increased duration of latex flow Thiols have a role as potential activators of certain key enzymes in latex such as invertase and pyruvate kinase[31]. In this study, latex stimulation did not significantly affect thiol content but tapping frequency influenced the levels of thiol compounds in the latex. The higher values recorded in d/2 tapped trees may plausibly be explained by its dual functions in both latex metabolism and latex flow

It has also been reported that stimulations resulted in lower sucrose content in latex vessel over the long-term[32–34]. It has been reported that there is an increasing sucrose content immediately at the first tapping after stimulation largely due to the 'sink effect' where sucrose was transported from the other parts of the rubber tree to the laticifers and from hydrolysis of starch reserves present in the bark[35]. In the present experiment, there were no significant differences in the sucrose contents among the various treatments. The lack of changes in the sucrose contents may be attributed to the decline in yield increases noted after the first tapping year, despite the intensity of stimulation.

The changes in latex physiological parameters obtained with intensive stimulation would indicate modifications in the laticiferous system. However, these changes have not resulted in development of physiological stress in the panel because there were no significant differences recorded in terms of dryness incidence among stimulation treatments, with the exception of trees stimulated with 60/y The significant incidence of dryness in the latter treatment, however, was not accompanied with marked increase in yields because it was only marginally higher than that obtained with 30/y. The exhaustion theory with excessive drainage of assimilates resulting in dryness would not be applicable to these trees[36]. The other plausible explanation for higher incidence could be due to organelle damage from build up of toxic oxygen radicals in the laticiferous system with a reduction in thiol compounds. However, this was not noted in results obtained in this study. It is therefore unlikely that the higher incidence of dryness in the treatment with 60/y is a result of physiological stress in the panel. It could be due to other factors which are outside the scope of this study

Date of receipt. August 1996
Date of acceptance· November 1996

REFERENCES

1 PARANJOTHY, K , GOMEZ, J B AND YEANG, H Y (1976) Physiological Aspects of Brown Bast Development *Proc Int Rubb Conf 1975, Kuala Lumpur,* **2**, 181.

2 CHRESTIN, H , JACOB, J L AND D'AUZAC, J (1985) Biochemical Basis for Cessation of Latex Flow and Occurrence of Physiological Bark Dryness *Proc Int Rubb Conf 1985, Kuala Lumpur,* **3**, 20

3. PAKIANATHAN, S W , SAMSIDAR HAMZAH, SIVAKUMARAN, S AND GOMEZ, J B (1982) Physiological and Anatomical Investigations on Long-term Ethephon Stimulated Trees *J Rubb Res Inst Malaysia,* **30**, 63

4 JACOB, J L , ESCHBACH, J M PREVÔT, J C , ROUSELL, D , LACROTTE, R , CRESTIN, H AND D'AUZAC, J (1986) Physiological Basis for Latex Diagnosis of the Functioning of the Laticiferous System in Rubber Trees *Proc Int Rubb Conf 1985, Kuala Lumpur,* **3**, 43

5. 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**, 274

6 I R C A (1986) Fiche d'expérimentation Côte d'Ivoire I R C A -Côte d'Ivoire pp E1-E6

7 JACOB, J L , LACROTTE, R , SERRES, E AND ROUSSEL, D (1987) Le Diagnostic Latex Ses Bases, Sa Mise au Point Ekona IRCA-Côte d'Ivoire

8 JACOB, J L , SERRES, E , PRÉVÔT, J C , LACROTTE, R , VIDAL, A , ESCHBACH, J M AND D'AUZAC, J (1988) Development of the *Hevea* Latex Diagnosis *Agritrop* , **12**, 97

9 DO KIM THANH AND NGUYEN THUY HAI (1990) Phuong phap chan doan cac thong so sinh ly mu *Hevea brasiliensis* Ly thuyet can ban va phuong phap phan tich. Vien KTKT Cao Su (in Vietnamese)

10 DO KIM THANH, SIVAKUMARAN, S AND WONG KAI CHOO (1966) Long-term Effect of Tapping and Stimulation Frequency on Yield Performance of Rubber Clone GT1 *J nat Rubb Res* **11(2)**, 96

11 GOMEZ, J B (1983) *Physiology of Latex (Rubber) Production* Monograph No 8 Malaysian Rubber Research and Development Board

12 VAN GILS G E (1951) Studies of the Viscosity of Latex I Influence of the Dry Rubber Content *Archf Rubbercult Ned-Indie,* **28**, 61

13 D'AUZAC, J AND JACOB, J L (1984) Physiology of the Laticiferous System in *Hevea* Basis and Application to Productivity *Compte-Rendu du Colloque Exploitation-Physiologie et Amelioration de l'Hevea, July 1984,* p 63 Paris I R C A - GERDAT

14 SIVAKUMARAN, S AND ISMAIL HASHIM (1986) Low Frequency Tapping System Approaches Towards Improved Performance *Proc Int Rubb Conf 1985, Kuala Lumpur* **3**, 317

15 SIVAKUMARAN, S (1994) Labour Saving Technologies Factors Impeding Adoption *Workshop on Exploitation Technologies to Address Current Labour Problems in the Rubber Industry, Dec 1994, Kuala Lumpur* Paper No 13

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

17 PAKIANATHAN, S W , BOATMAN, S G AND TAYSUM, D H (1966) Particle Aggregation Following Dilution of *Hevea* Latex A Possible Mechanism for the Closure of Latex Vessels after Tapping *J Rubb Res Inst Malaya,* **19**, 259

18 PUJANISCLE, S (1968) Caractere Lysosomal des Lutoides du Latex l'*Hevea brasiliensis Physiol Veg ,* **6**, 27

19 SOUTHORN, W A AND EDWIN, E E (1968) Latex Flow Studies II Influence of Lutoids on the Stability and Flow of *Hevea* Latex *J Rubb Res Inst Malaya,* **20**, 187

20 CHRESTIN, H (1984) Biochemical Basis of Bark Dryness *Compte-Rendu du Colloque Exploitation- Physiologie et Amelioration de l'*Hevea *1984,* p 273 Paris I R C A - GERDAT

21 BUTTERY, B R AND BOATMAN, S G (1967) Effects of Tapping, Wounding and Growth Regulators on Turgor Pressure in *Hevea brasiliensis J Exptl Bot* **18**, 644

22 FREY-WYSSLING, A (1932) Investigation on the Dilution Reaction and the Movement of the Latex of *Hevea brasiliensis* During Tapping *Arch Rubbercult,* **16**, 285

23. DE JONGE, P (1955) Stimulation of Yield in *Hevea brasiliensis* III Further Observations on the Effects of Yield Stimulants *J Rubb Res Inst Malaya,* **14**, 383

24 LUSTINEC, J , CHAI, K C AND RESING, W L (1966) L'aire drainée chez les jeunes arbes de l'*Hevea brasiliensis Rev Gen Caoutch Plast ,* **43**, 1343

25 PAKIANATHAN, S W , WAIN R L AND NG E K (1976) Studies on Displacement Area on Tapping in Mature *Hevea* Trees *Proc Inter Rubb Conf 1975, Kuala Lumpur,* **2**, 225

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

27 RIBBAILLER, D (1972) Quelques aspects du rôle des lutoides dans la physiologie et lécoulement du latex d'*Hevea brasiliensis*. Action de produits liberant de l'éthylène Thèse Doct Etat. Sci Nat Université Abijan Côte d'Ivoire.

28. LYNEN, F (1969) Biochemical Problems of Rubber Synthesis. *J Rubb Res Inst Malaya*, **21**, 389.

29. JACOB, J L AND PREVÔT, J C (1992) Metabolism of the Laticiferous System and its Biochemical Regulation *Natural Rubber Biology, Cultivation and Technology (Sethuraj, M R and Mathews, N M eds)*, p. 116 New York. Elsevier Science Publishers

30. ELSTNER, E F (1982) Oxygen Activation and Oxygen Toxicity *Ann Rev Pl Physiol*, **33**, 73.

31. JACOB, J L, PRÉVÔT, J C AND PRIMOT, L (1981) La Pyruvate Kinase du Latex d'*Hevea brasiliensis*. *Rev Gen Caoutch Plast*, **612**, 89

32. BEALING, F J AND CHUA, S E (1972) Output, Composition and Metabolic Action Activity of *Hevea* Latex in Relation to Tapping Intensity on the Onset of Brown Bast. *J Rubb Res Inst Malaysia*, **23**, 204.

33. LOW, F C AND GOMEZ, J B (1982) Carbohydrates Status of Exploited *Hevea* I. The Effect of Different Exploitation Systems on the Concentration of Major Soluble Carbohydrates in Latex *J Rubb Res Inst Malaya*, **30**, 1.

34. GOHET, E, PRÉVÔT, J C, ESCHBACH, J M, CLÉMENT, A AND JACOB, J L (1996) Clone, Growth and Stimulation Latex Production Factors. *Plantations Recherche, Developpement* **3(1)**, 36.

35 TUPY, J (1973) The Level and Distribution Pattern of Latex Sucrose Along the Trunk of *Hevea brasiliensis* as Affected by the Sink Region Induced by Latex Tapping *Physiol Veg*, **11**, 1

36 SIVAKUMARAN, S, PAKIANATHAN, S W AND ABRAHAM, P.D (1984) Continuous Yield Stimulation – Plausible Cause for Yield Decline. *J Rubb Res Inst Malaysia*, **32**, 119.