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Long-term Effect of Tapping and Stimulation Frequency on Yield Performance of Rubber Clone GT 1

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A fourteen-year experiment was conducted to study the yield responses and dryness incidence of rubber clone GT 1 to half- spiral tapping at frequencies d/2 (alternate daily), d/3 (third daily) and d/4 (fourth daily) in combination with stimulation frequencies of 0/y (unstimulated control), 2/y (two rounds/year), 3/y (three rounds/year), 4/y (four rounds/year) and 6/y (six rounds/year) of ethephon at 2.5% concentration applied by groove method. Mean dry rubber yield/tree/tapping (g/t/t) and mean dry rubber yield/hectare/year (kg/ha/year) over 14 years' of tapping were affected by interaction between tapping and stimulation frequencies. Under high stimulation frequencies of 4/y and 6/y there was a progressive increase in g/t/t with reduction in tapping frequencies from d/2 to d/4. This has led to comparable kg/ha/year among the three tapping frequencies. In spite of lesser number of tappings, d/3 tapping frequency produced cumulative yield (kg/ha) comparable to that of d/2 tapping frequency. Positive responses of g/t/t, kg/ha/year and cumulative kg/ha to stimulations 4/y and 6/y were obtained only under low tapping frequencies of d/3 and d/4. Virgin and renewed tapping panels responded in a similar manner to the tapping and stimulation treatments. Dryness incidence was not significantly affected by any of the treatment combinations.

Early works show that yield responses of d/2-tapped trees to stimulation decline after a few years of application of high concentrations of ethephon[1,2]. This has led to consideration of less intensive exploitation systems such as lower tapping frequency in combination with lower ethephon stimulation. It has also been reported that interaction between tapping and stimulation frequencies is of importance in long-term productivity of *Hevea* trees[3]. Interest is also focussed on the yield responses to stimulation of tapping panels which have previously been stimulated. With the above in view the present study analysed data from a fourteen-year experiment to determine the long-term effect of various combinations of tapping and stimulation frequencies on yield performance of clone GT 1.

MATERIALS AND METHODS

The experiment was conducted in a commercial estate located in Selangor, Malaysia. The trees were tapped half spiral cut on three frequencies, *viz.* alternate daily (d/2), third daily (d/3), and fourth daily (d/4) tapping. These tapping

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frequencies were factorially combined with stimulation frequencies of 0/y (unstimulated control), 2/y (two rounds/year), 4/y (four rounds/year) and 6/y (six rounds/year) of ethephon at 2.5 % concentration applied by groove method. Thus, the experiment consisted of 12 treatment combinations replicated three times in a randomised complete block design and with 20 trees per treatment combination per replication. Trees were tapped throughout the year, including the defoliation season.

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 of latex was determined twice a month for each treatment while that of cuplump was calculated on the assumption of 40% – 50% water content. Yield recordings were carried out throughout the first virgin panel (*BO-1*), the second virgin panel (*BO-2*), and the first renewed panel (*BI-1*). The duration of recording was over 14 years. Due to the high tapping intensity of ½S d/2 system, yield recording for this treatment included the yield from part of the second renewed panel (*BI-2*).

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.

RESULTS

Effects of Tapping and Stimulation Frequencies on Mean Dry Rubber Yield Per Tree Per Tapping

Mean yield over 14 years of tapping. Statistical analysis on mean dry rubber yield per tree per tapping (g/t/t) over 14 years of tapping showed significant effects due to tapping and stimulation frequencies as well as their interaction. Under higher stimulation of four rounds/year (4/y) and six rounds/year (6/y), there was a progressive increase in mean dry rubber yield/tree per tapping (g/t/t) when tapping frequency was reduced from alternate daily tapping (d/2) to fourth daily tapping (d/4) (*Table 1*). With low stimulation of two rounds/year (2/y), no significant differences were obtained between tapping frequencies of d/3 and d/4, although their yields were significantly higher than that of d/2 tapping frequency. When no stimulation was applied, only d/4 was significantly higher than d/2.

Under high tapping frequency of d/2, stimulation with ethephon did not lead to increase in mean dry rubber yield/tree/tapping when compared to the unstimulated control. However, under lower tapping frequencies of d/3 and d/4, stimulations 4/y and 6/y led to significant increase in mean dry rubber yield when compared to the unstimulated control. The increase in yield ranged from 7% to 22%. No significant differences were obtained between stimulations 4/y an 6/y. Under similar condition, lower stimulation 2/y did not differ significantly from the unstimulated control in mean dry rubber yield.

Mean yield of treatments under tapping panel BO-1. The performance of mean dry rubber yield/tree/tapping (g/t/t) of panel *BO-1* in response to treatments is presented in *Table 2*. There were significant effects due to tapping and stimulation treatments but with no significant interaction effect. Tapping frequency d/4 significantly out-yielded tapping frequency d/3 which in turn out-yielded tapping frequency d/2. Yields due to stimulation of 4/y and 6/y were significantly higher than unstimulated control.

TABLE 1 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER TREE PER TAPPING (G/T/T) OF GT 1 OVER 14 YEARS OF TAPPING

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	50.4	49.9	49.9	46.5	49.2
½S d/3	50.7	60.5	64.8	65.6	60.4
½S d/4	62.7	65.1	84.9	81.4	73.5
Mean	54.6	58.5	66.5	64.5	61.0

$LSD_{0.05}$ (tapping frequency) = 6.6
$LSD_{0.05}$ (stimulation frequency) = 7.6
$LSD_{0.05}$ (tapping × stimulation interaction) = 11.2

TABLE 2 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER TREE PER TAPPING (G/T/T) OF GT 1 AT TAPPING PANEL *BO-1*

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	35.6	38.4	36.5	39.2	37.4
½S d/3	38.0	41.4	48.5	50.2	44.5
½S d/4	47.4	46.7	49.6	55.4	49.8
Mean	40.3	42.2	44.9	48.3	43.9

$LSD_{0.05}$ (tapping frequency) = 3.4
$LSD_{0.05}$ (stimulation frequency) = 3.9

Mean yield of treatments under tapping panel BO-2. There were significant effects due to tapping and stimulation treatments as well as their interaction on g/t/t at tapping panel *BO-2*. Under stimulations 4/y and 6/y, there was a progressive increase in g/t/t when tapping frequency was reduced from d/2 to d/4 (*Table 3*). With low stimulation (2/y) or no stimulation (0/y) only d/4 was significantly higher than d/2.

Under tapping frequency d/2, there was no response to stimulation, while under lower frequencies of d/3 and d/4 positive responses to stimulations 4/y and 6/y were obtained.

Mean yield of treatments under tapping panel BI-1. Statistical analysis revealed significant effects due to tapping and stimulation treatments as well as their interaction on g/t/t at tapping panel *BI-1*. Under

TABLE 3 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER TREE PER TAPPING (G/T/T) OF GT 1 AT TAPPING PANEL *BO-2*

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	53.8	53.4	53.0	52.4	53.2
½S d/3	55.4	65.9	71.9	73.9	66.8
½S d/4	67.3	68.2	93.7	91.9	80.3
Mean	58.8	62.5	72.9	72.7	66.7

$LSD_{0.05}$ (tapping frequency) = 6.6
$LSD_{0.05}$ (stimulation frequency) = 7.6
$LSD_{0.05}$ (tapping × stimulation interaction) = 13.2

TABLE 4. EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER TREE PER TAPPING (G/T/T) OF GT 1 AT TAPPING PANEL *BI-1*.

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	51.7	48.1	48.9	42.1	47.7
½S d/3	56.2	71.6	70.4	68.4	66.7
½S d/4	72.3	85.5	120.6	99.1	94.4
Mean	60.1	68.4	80.0	69.9	69.6

$LSD_{0.05}$ (tapping frequency) = 10.3
$LSD_{0.05}$ (stimulation frequency) = 11.9
$LSD_{0.05}$ (tapping × stimulation interaction) = 20.5

stimulations 4/y and 6/y, there was a progressive increase in g/t/t when tapping frequency was reduced from d/2 to d/4 (*Table 4*). With low stimulation 2/y, no significant differences were obtained between tapping frequencies of d/3 and d/4, although their yields were significantly higher than that of d/2 tapping frequency. When no stimulation was applied, only d/4 was significantly higher than d/2.

Under tapping frequencies of d/2 and d/3 no response to stimulation was obtained while under tapping frequency of d/4 there were positive responses to stimulations 4/y and 6/y. Tapping frequency d/4 with stimulation 4/y produced the highest yield among all treatment combinations.

Yield trends in response to exploitation systems. The year effect was not examined statistically as the error mean square values for each of the 14 years were not homogenous. However, attempts were made to present the yield trends in response to the various exploitation systems (*Figure 1*). Under tapping frequency d/2, there were no significant differences among the stimulation treatments in most of the 14 years of tapping except year 4, 9 and 14. Stimulation 6/y increased yield when compared to unstimulated control in years 4 and 9. These two periods also coincided with the changing of new tapping panel from *BO-1* to *BO-2* and from *BO-2* to *BI-1*, respectively. Under tapping frequency d/3 stimulations 4/y and 6/y consistently produced higher yield than the unstimulated control throughout the 14 years' of tapping. Similar trend was also obtained under tapping frequency d/4.

In general, yields on panel *BO-1* were lower than those of later tapping panels. This though true of most clones, was however more marked for clone GT I, because it is known to be a slow starter clone[3].

Effects of Tapping and Stimulation Frequencies on Mean Dry Rubber Yield Per Hectare Per Year

Analysis of variance on mean dry rubber yield per hectare per year (kg/ha/year) over 14 years of tapping showed significant effects due to main treatments as well as their interaction. With high stimulations of 4/y and 6/y, no significant differences in mean yield per hectare per annum were obtained among tapping frequencies of d/2, d/3 and d/4 (*Table 5*). However, under low stimulation of 2/y, there was an increase in mean yield per hectare per annum with increased frequency of tapping although no significant differences were detected between tapping frequencies d/2 and d/3. Unstimulated control showed similar trend as low stimulation 2/y except that no significant differences were detected between tapping frequencies d/3 and d/4.

Under high tapping frequency of d/2, no significant differences in mean dry rubber yield per hectare per annum (kg/ha/year) were obtained betwen stimulated treatments and unstimulated control. However, under lower tapping frequencies of d/3 and d/4, stimulations 4/y and 6/y significantly increased yield when compared to the unstimulated control.

The trend of kg/ha/year in response to treatments during each of the 14 years of tapping was similar to that of g/t/t yield performance (*Figure 2*).

Effects of Tapping and Stimulation Frequencies on Cumulative Dry Rubber Yield Per Hectare (Kg/Ha)

There were signifinant effects due to tapping and stimulation treatments but with no significant interaction effect on cumulative (14 years) dry rubber yield per hectare (kg/ha). Inspire of lesser number of tappings, d/3 tapping frequency produced cumulative yield comparable to that of d/2 frequency (*Table 6*). However, tapping frequency d/4 produced cumulative yield which was significantly less than that of d/2 frequency. Stimulations 4/y and 6/y significantly increased cumulative yield when compared to the unstimulated control.

Effects of Tapping and Stimulation Frequencies on Dryness Incidence

Though dryness incidences were recorded yearly, analyses were caried out only for values occuring at the final year of each tapping panel. Statistical analysis of square-root transformed data revealed that there were no significant effect due to treatment or interaction for all tapping panels (*Table 7*).

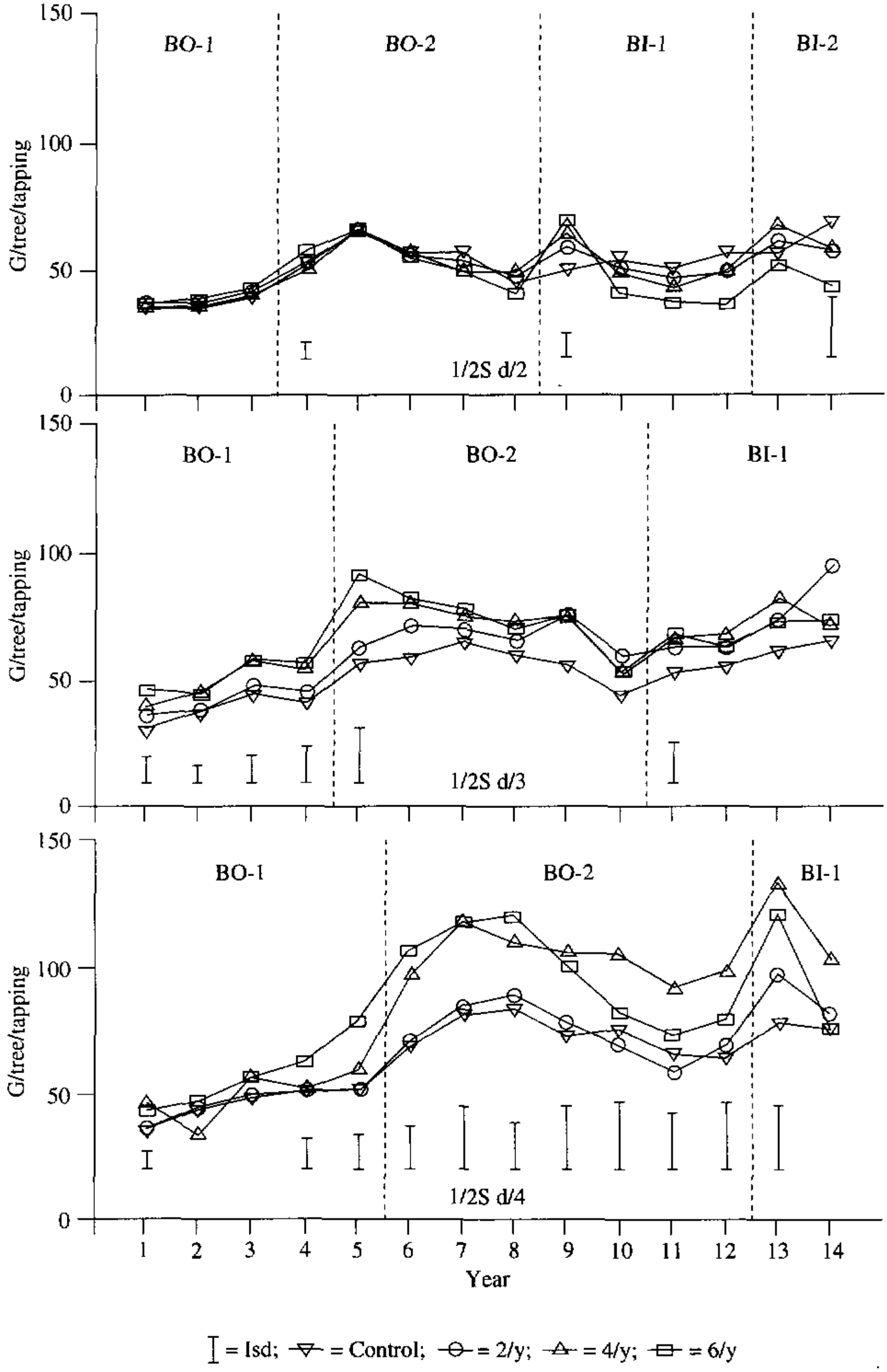

Figure 1. Yield performance (g/t/t) of GT 1 tapped half-spiral cut with different tapping and stimulation frequencies over 14 years' of tapping.

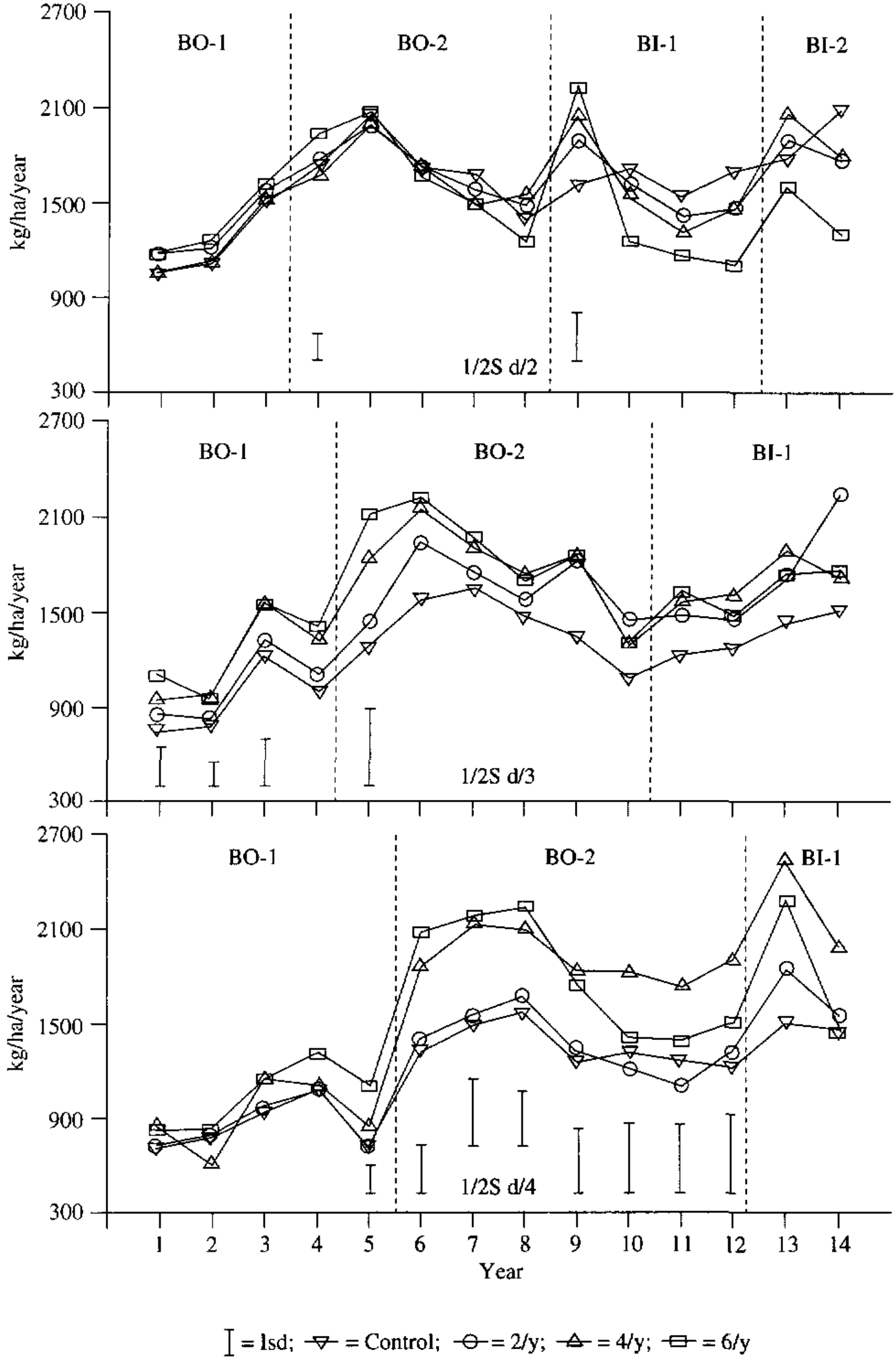

Figure 2. Yield performance (kg/ha) of GT 1 tapped half-spiral cut with different tapping and stimulation frequencies over fourteen years of tapping.

TABLE 5 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON MEAN DRY RUBBER YIELD PER HECTARE PER ANNUM (KG/HA/YEAR) OF GT 1 OVER 14 YEARS OF TAPPING

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	1617	1603	1603	1500	1581
½S d/3	1235	1475	1580	1599	1472
½S d/4	1156	1203	1568	1498	1356
Mean	1336	1427	1584	1532	1470

$LSD_{0.05}$ (tapping frequency) = 148
$LSD_{0.05}$ (stimulation frequency) = 171
$LSD_{0.05}$ (tapping × stimulation interaction) = 266

TABLE 6 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON CUMULATIVE DRY RUBBER YIELD PER HECTARE (KG/HA) OF GT 1 FOR 14 YEARS OF TAPPING

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	22642	22443	22437	20992	22129
½S d/3	17295	20650	22123	22382	20613
½S d/4	16189	16848	21957	20977	18933
Mean	18709	19980	22172	21450	20578

$LSD_{0.05}$ (tapping frequency) = 1860
$LSD_{0.05}$ (stimulation frequency) = 2148

DISCUSSION

The long term data revealed that the yield performance (g/t/t) of clone GT 1 was influenced by the interaction between tapping and stimulation frequency. Under ethephon stimulation (2.5%) of four rounds (4/y) and six rounds per year (6/y), there was a progressive increase in mean dry rubber yield per tree per tapping (g/t/t) over 14 years with reduction in tapping frequency from d/2 to d/4. For the unstimulated controls, only d/4 frequency was significantly higher in mean dry rubber yield per tree per tapping than d/3 or d/2 tapping. The increase in yield (g/t/t) with decrease in tapping frequency can be attributed to the fact that trees tapped on low frequencies had longer intervals between tappings to allow for regeneration in the latex vessels thus replenishing laticiferous content removed during the previous tapping[6,12].

TABLE 7 EFFECTS OF TAPPING AND STIMULATION FREQUENCY ON DRYNESS (%) INCIDENCE OF GT 1

Tapping frequency	Stimulation frequency				
	0/y (Control)	2/y	4/y	6/y	Mean
½S d/2	1.5 (1.4)	14.2 (3 2)	2 1 (1.6)	19.2 (3.9)	9.3 (2.5)
½S d/3	6.0 (2 6)	1.7 (1.5)	6.1 (2.7)	5.5 (2.3)	4.8 (2.3)
½S d/4	1.2 (1 4)	19.4 (4.3)	6.8 (2.2)	17.0 (4.1)	11.1 (3.0)
Mean	2 9 (1 8)	11.8 (3.0)	5.0 (2.2)	13.9 (3.4)	8.4 (2.6)

Figures in bracket denote the transformed data

There was an inverse relationship between degree of response to stimulation and frequency of tapping in terms of yield per tree per tapping. There was an increasing trend in response with progresive reduction in frequency of tapping. Thus, with d/2 tapping, the responses were generally poor or even negative on later tapping panels irrespective of frequency of stimulant application. In contrast, trees tapped on d/3 and d/4 recorded positive responses above respective unstimulated trees for higher frequencies of stimulant application. In particular this relationship was very marked for d/4-tapped trees, with significantly higher response for 4 and 6 rounds of application. The above relationship tends to conform to previously reported studies[1].

The reduced number of tappings obtained with low frequency tapping systems (d/3 and d/4) would result in lower yields per hectare per year (kg/ha/year) and this was apparent in data obtained in this study. This was true for both the unstimulated trees and trees with only two rounds of stimulation per year. However, when stimulation was increased to four rounds (4/y) and six rounds per year (6/y), yield per hectare per annum of d/3 and d/4 tapping frequencies were comparable to that of d/2 tapping frequency. Thus, it is necessary to couple low frequency tapping systems with adequate stimulation to enhance both yield per tapping and yield per hectare obtained with these systems to ensure economic viability.

The influence of position of tapping cut on yield performance has been examined. It is evident that there was a resurgence in yield response during the first year of tapping on panel *BO-2* after the cut was changed over from panel *BO-1*. The yield responses during the last year of tapping on panel *BO-2* recorded a decline as the cut approached the stock/scion union. The above phenomena can be attributed to the availability of drainage areas on the panel[13]. Thus, the high yield response during the first year is due to the availability of a larger drainage area on the panel, while the poor responses during the last year is due to the limitation in drainage area as circumscribed by the stock/scion union. These trends observed conform to findings elsewhere, which show that available drainage area can influence yield responses because the increase in duration of latex flow time in stimulated trees is due largely to an extension of drainage area on the panel[8]. It is also evident from the present study over the long term that renewed panel formed over previously stimulated virgin panel will only respond positively to stimulation if trees had been tapped continuously on low frequency (d/4) from commencement of tapping on panel *BO-1*, in contrast to trees tapped on higher frequencies of d/2 and d/3.

It is projected that due to increasing shortage of skilled tappers and rising costs of production, low frequency systems will be increasingly used to overcome these severe constraints. However, adoption of these systems has not been very encouraging because of concerns on the long term yield viability of these systems and possible consequences of high levels of stimulation from commencement of tapping on the first virgin panel. The findings established in this paper particularly over the long term would be very beneficial in promoting the wider scale adoption of these labour saving systems to overcome current limitations. The cumulative dry rubber yields per hectare obtained with low tapping frequencies of d/3 and d/4 were only 93% and 86%, respectively of that obtained from d/2-tapped trees. It has been established that low tapping frequency would be profitable if break-even yields of 90% of that of d/2-tapped trees are achieved with these systems[7,10]. This would imply that yield obtained on d/3 frequency in this study are economically viable. Studies reported elsewhere[4] on other clones indicated that yield/ha/year and consequently cumulative yield/ha could be enhanced with increased intensity of stimulation above that reported in this study. It will be useful to establish if additional stimulation than that used in this study on d/4-tapped trees will further enhance cumulative yields.

The long term consequences of repeated stimulation over successive years are best reflected in levels of dryness incidence recorded. The results of dryness incidence which were recorded after 14 years of stimulation showed that there were no significant differences between moderate stimulation treatments and corresponding unstimulated control trees. It is also apparent that tapping frequencies did not affect incidence of dryness. It is likely as confirmed in these studies that dryness incidence will not be of concern with low frequency systems over the long term due to several factors besides the known below average susceptibility of clone GT 1 to dryness incidence. The frequencies of tapping were not intense enough when compared to intensive tapping such as daily or double tapping daily that could result in higher incidence of dryness[9]. Further the yields of stimulated treatments irrespective of tapping frequencies were not markedly higher than that extracted from d/2-tapped control trees. It has in fact been suggested that dryness development might not be related to yield stimulation provided stimulation did not result in excessive rates of crop extraction above that of unstimulated trees or inherent genetic potentials[11].

Data obtained over the long term with clone GT 1 tapped on low frequency systems confirms that consistently higher yields per tapping can be obtained and this can translate into higher incomes for tappers, thus making employment in rubber areas attractive when compared to other plantation crops[3,4]. The long term data obtained over successive tapping panels would suggest that low frequency tapping systems in combination with adequate stimulation could be adopted on clone GT 1 to tackle the current constraint of tapper shortage without sacrificing profitability or returns per unit area when compared to d/2 tapping. The absence of any marked incidence of dryness over the long term coupled with other beneficial effects such as lower rates of bark consumption and longer economic life span for the *Hevea* trees, would make these systems very ideal for addressing current constraints faced by the rubber industry in Malaysia.

CONCLUSION

The long term yield data showed that low frequency tapping systems in combination with ethephon stimulation (2.5%) at four to six applications per year could increase yield per tree per tapping and yield per hectare over successive tapping panels. A sustained positive response to stimulation was obtained with d/4 frequency of tapping in contrast to poor or negative response recorded on later panels of trees tapped on d/2 frequency.

The expected increase in income of tappers arising from better tapper productivity with low frequency systems would make tapping an attractive employment while simultaneously reducing requirement for skilled tappers. It is apparent that economically viable yields per hectare can be obtained over the long term with low frequency systems, if progressive reduction in frequency of tapping is accompanied with appropriate increase in intensity of stimulation.

The lack of long term deleterious effects as reflected in insignificant differences in incidence of dryness between treatments and coupled with several other beneficial effects would necessarily render low frequency systems as attractive exploitation methods to tackle and overcome several prevailing limitations in the rubber industry.

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