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RESEARCH ARTICLE

Replacing traditional half spiral cut by a quarter cut with Ethephon; a simple approach to solve current issues related to latex harvesting in rubber industry

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Abstract: Harvesting rubber latex is rather labour intensive since trees are traditionally tapped half spiral, once in two days (S/2 d2) resulting in unnecessary waste of tree bark. High cost of production, shortage of harvesters and reduced economic lifespan are the key issues in rubber plantations related to harvesting. Low intensity harvesting (LIH) systems (i.e. either reduction in harvesting frequency and/or tapping cut length) of rubber appear to be a practical solution to these issues by bringing down the labour requirement and the cost of production. Of these, only the reduction in harvesting frequency has been tried in Sri Lanka. Hence, the present study was aimed to develop new LIH systems with shorter tapping cuts.

This study comprised two stage stimulant (Ethephon) based field trials to evaluate a wide range of LIH systems. The overall yield given by traditional S/2 d2 was used as the standard in evaluation. Stimulation protocols of different harvesting systems were adjusted from time to time to achieve this standard. In addition, growth and physiological parameters of latex and the financial viability of the principal system were also assessed.

Among the LIH systems tested, S/4 d3 (tapping quarter spiral once in three days) was successful in providing benefits, such as increase in both overall profits and harvesters' income and reduction in harvesting cost and overall cost of production. The overall bark consumption was also greatly reduced. Above all, it allows tapping the virgin bark of base panels for over 24 years. Popularization of this approach is proposed after large scale commercial testing.

Keywords: Ethephon, *Hevea brasiliensis*, low intensity harvesting, rubber, stimulation.

INTRODUCTION

Being an essential raw material for most commodities required in modern day life, the demand for rubber is ever increasing leading to more and more people being attracted to plant rubber (*Hevea brasiliensis*). The biggest challenge in rubber cultivation is the latex harvesting since its share in the production cost is over 30 % at commercial level. It is quite labour intensive utilizing over 60 % of worker force. In general, it requires about 0.6 workers per hectare per day (Rodrigo, 2011). The demand for wage increases is quite frequent, creating an increasing trend in cost of latex harvesting. In addition, it requires a greater level of skill resulting in shortage of skilled harvesters (Rodrigo *et al.*, 2004).

In latex harvesting, half of the circumference of the trunk is generally tapped at a frequency of once in two days (S/2 d2). Each harvester is given two blocks of trees (tapping blocks), each having ca. 300 trees. Removal of the skill factor has not been successful and not cost effective in instances where it has been tried (i.e. mechanized tapping). Hence there has been an international focus to improve the efficiency in the usage of available skilled harvesters through the introduction of low intensity harvesting systems (LIH). In LIH, there are three options, i.e. reducing the frequency of harvesting, referred to as low frequency harvesting (LFH), or reducing the tapping cut length or both. Reduction in the harvesting frequency is made by extending the time gap between two consecutive harvestings over two days.

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Instead of half spiral, attempts have been made to reduce the cut length to quarter spiral or even less in high panels of the rubber tree (Ahamad *et al*., 1991; Vijayakumar *et al*., 2001). By any of the above methods, a greater number of trees can be allocated to each harvester hence the worker requirement is significantly reduced. As could be expected, the reduction in harvesting frequency and cut length has a negative impact on latex yield. In order to compensate for the yield loss associated with this reduced intensity, yield stimulants are applied in a judicious manner. Ethylene is the choice stimulant, which enhances latex production in the laticiferous system in the rubber tree bark (de Fay & Jacob, 1989). Application of ethylene in gas form is not simple and hence, ethephon (2-choloroethyl phosphonic acid) in the form of a liquidized paste is applied on the bark in different formulations to facilitate slow release of ethylene inside the bark.

In base panels, reduction in harvesting intensity has mainly been tried with reducing only the frequency between consecutive tappings. Two LFH systems have been developed in Sri Lanka, namely, tapping the tree once in three days (S/2 d3) or four days (S/2 d4) (Nugawela, *et al.*, 2000; Rodrigo, 2009). Further reduction in harvesting frequency has been established elsewhere i.e. tapping a tree once in 6 days (S/2 d6) is recommended in both India (Vijayakumar *et al*., 2004) and China (Xuehua *et al*., 2004). No records are available on successful reduction in tapping cut length in base panels in Sri Lanka. However, in high panel harvesting, quarter and one eighth spiral tapping cuts have been introduced with ethephon (Ahamad *et al*., 1991; Vijayakumar *et al*., 2001) and ethylene (Sivakumaran, 1991), respectively. Considering the risk of over stimulation, application of ethylene gas has been confined to latter stages of latex harvesting. With that background, the present study was aimed at developing a suitable LIH system with shorter tapping cuts for base panel harvesting with ethephon stimulation.

METHODS AND MATERIALS

The study comprised two stages, the initial screening for suitable LIH systems and a large scale testing of the most promising systems.

Screening of LIH systems

The experiment was established in the Kuruwita sub station of the Rubber Research Institute of Sri Lanka (RRISL) in 2008, with a newly opened tapping field of clone RRIC 121. Shorter cuts of quarter spiral (S/4) and one eighth spiral (S/8) were tapped at frequencies of once in three (d3), four (d4) and six (d6) days together with the standard half spiral alternate day tapping (S/2 d2) system. Each treatment/system was introduced to plots having 10 trees and replicated three times. To begin with, minimal levels of stimulants were applied for LIH systems; with that, S/4 and S/8 in d3 had monthly application of 2.5 % and 5 % ethephon, respectively. In d4, S/4 and S/8 were given 5 % ethephon monthly and in two week intervals. In d6 frequency, only S/4 cut was tested with application of 5 % ethephon biweekly. Thereafter, stimulations were adjusted from time to time, to achieve the yield level given by the standard S/2 d2 system. Details of the tapping systems are given in Table 1.

The amount of latex harvested from each treatment plot was assessed in terms of percentage of dry rubber content (% DRC) and yield per tree per tapping (GTT). The intake per harvester (IPH) and the yield per tree per annum (YPT) were derived by multiplying the GTT with the standard number of trees per tapping block (i.e. 300) and the standard number of tapping days in a year for the particular harvesting frequency, respectively. Total number of potential tapping days for a year was considered as 360 (with rainguards) with 180, 120, 90 and 60 tappings/year for d2, d3, d4 and d6 frequencies, respectively. Thereafter, the yield per hectare per annum (YPH) was estimated with the knowledge of YPT and tree density per hectare (400 trees/hectare). The growth of rubber trees in terms of girth and bark thickness increments was measured at 150 cm height of the trunk using a standard measuring tape and a bark gauge, respectively at six months intervals. Further, bark consumption (i.e. linear length and area of bark consumed) in each harvesting system was assessed at the same time intervals.

Large scale testing of LIH with shorter tapping cuts

Out of the systems tested, S/4 d3 and S/4 d4 showed comparatively better performances and hence were selected for large scale testing. These two systems were tested together with the traditional S/2 d2 in a mature RRIC 121 field at Kuruwita substation of the Rubber Research Institute commencing from October, 2009. Each system was tested in three tapping blocks each having 100 trees. In S/4 d3, trees were stimulated with 2.5 % ethephon at two weeks intervals, whilst 5 % ethephon was used at every two tappings in S/4 d4. In addition to the growth and yield parameters measured in the initial screening, physiological parameters of latex were assessed in these two promising harvesting systems using standard methods, namely, pH (Jenway 3051, Jenway

Table 1: Yield parameters of different stimulation protocols in shorter tapping cuts. Codes ET, wk, % DRC, YPT, IPH and YPH refer to ethephon, weeks, percentage dry rubber content in latex, yield per tree per year, intake per harvester per day and yield per hectare per year, respectively.

Tapping system	Stimulation protocol	DRC (%)	YPT (kg)	IPH (kg)	YPH (kg/ha./yr.)	% YPT recovered over S/2 d2 harvesting*
S/4 d3	2.5 % ET Monthly	39.36	2.83	7.03	1134	68
	5.0 % ET Monthly	39.90	3.91	9.70	1565	70
	2.5 % ET every 2wk	39.97	5.82	14.42	2326	83
S/8 d3	2.5 % ET every 2wk	39.73	2.09	5.19	838	50
	5.0 % ET Monthly	39.67	2.06	5.11	825	50
	5.0 % ET every 2wk	40.00	2.29	5.68	917	43
	5.0 % ET weekly	40.00	2.49	6.17	995	47
	5.0 % ET every 3 taps	39.98	3.22	7.99	1289	58
	5.0 % ET every 2 taps	40.00	3.25	8.06	1301	60
S/4 d4	5.0 % ET Monthly	39.43	2.18	7.28	873	53
	5.0 % ET every 2wk	39.76	3.17	10.56	1267	59
	5.0 % ET every 3 taps	39.92	3.39	11.30	1356	59
	3.3 % ET every 2 taps	39.88	4.90	16.32	1958	66
	5.0 % ET every 2 taps	39.96	4.21	14.03	1683	63
S/8 d4	5.0 % ET every 2wk	39.87	1.53	5.11	614	37
	5.0 % ET weekly	40.00	1.85	6.17	740	35
	5.0 % ET every 2 taps	40.00	2.28	7.93	952	43
S/4 d6	5.0 % ET every 2wk	39.21	1.85	9.26	741	45
	5.0 % ET weekly	39.33	1.96	9.82	786	37
	5.0 % ET every 2taps	40.00	2.04	10.21	817	37

* This was calculated based on the YPT of S/2 d2 at corresponding time periods.

Co., UK), sucrose (Scott & Melvin, 1953), thiol (Boyne & Ellman, 1972) and inorganic phosphorous (Taussky & Shorr, 1953) content. Incidence of tapping panel dryness (TPD) was assessed visually at the beginning and end of the experiment.

Data analyses

Data analyses were descriptive, particularly for derived parameters. ANOVA was performed for basic parameters together with the mean separation (Dunnett's test) using the statistical package SAS system 9.2. Out of the two LIH systems tested on a large scale, only the S/4 d3 was able to provide a yield, comparative to that is given by the traditional S/2 d2, and the financial viability of this system was assessed on a short-term basis, i.e. for a year. Considering the local applicability and importance, the financial analysis was performed in Sri Lankan rupees (conversion rate: US$ 1 = Rs. 130). The tapping cost was based on recently introduced daily wage of workers (Rs. 572/=), the payment made for latex brought above the norm (Rs. 15 per kg above 7 kg norm) and the cost of ethephon application (chemical cost + labour cost). Overall, overhead costs (i.e. general charges), cost on mature area upkeep and manufacturing charges were considered to remain unchanged across the harvesting systems. Summation of these values [Rs. 107.15 per kg (Perera, 2009)] and the total tapping cost was taken as the overall cost of production (COP).

RESULTS

There was a progressive increase in latex yields in terms of YPT, IPH and YPH with the increasing levels of stimulation in all systems tested in the initial screening of shorter tapping cuts (Table 1). All these parameters of S/4 d3 system changed by nearly 100 % with the increase in frequency of ethephon application (2.5 % concentration) from monthly to biweekly intervals. Among all systems screened, S/4 d3 was the best performing LIH system and at the final stimulation protocol tested, it provided over 80 % of the yield of the traditional S/2 d2. The next best in the screening programme was S/4 d4. Although it showed ca. 100 % yield increase with the increase in ethephon application frequency (5 % concentration) from monthly to eight day (in every two tappings) intervals, the final yield given was less than 70 % of that was given by the traditional S/2 d2. With S/4 cut length, d6 frequency was not effective even with the highest concentration and frequency of the stimulant used (i.e. 5 % ethephon application at weekly intervals) providing only 37 % of the yield of traditional S/2 d2. In the initial screening, S/8 tapping cut length did not provide sufficient yields with both d3 and d4 frequencies. With the highest stimulation levels tested, i.e. 5 % ethephon in every two tappings, S/8 d3 and S/8 d4 systems provided only 60 % and 43 % of the yield of the traditional S/2 d2 system, respectively (Table 1). In all the systems tested, % DRC never reduced below 35 % and the average values were above 39 % (Table 1).

The growth of rubber trees monitored in terms of annual girth increment was comparable among the harvesting systems tested and the average value varied only between 2 cm to 2.59 cm. Similarly, the increase in bark thickness remained at 1 mm per year in all treatments tested (Table 2). Shaving thickness per tapping was greater in both shorter tapping cuts and reduced tapping frequencies. The highest shaving thickness was recorded in S/4 d6 system whilst the lowest was in S/2 d2. When the length of tapping cut was changed from S/4 to S/8 with d3 frequency, the increase in shaving thickness was 26 %. The associated change under d4 frequency was 13 %. However, the annual bark consumption (linear length) declined greatly with the lowering of harvesting frequency. The lowest value 9.14 cm was recorded in S/4 d6 system. The average percentage reduction in annual bark consumption from d2 to both d3 and d4 frequencies remained at ca. 17 %. Overall area of bark consumed declined dramatically when both tapping cut length and frequency were reduced. Therefore, the lowest overall bark consumption was recorded in S/8 d4 (Table 2).

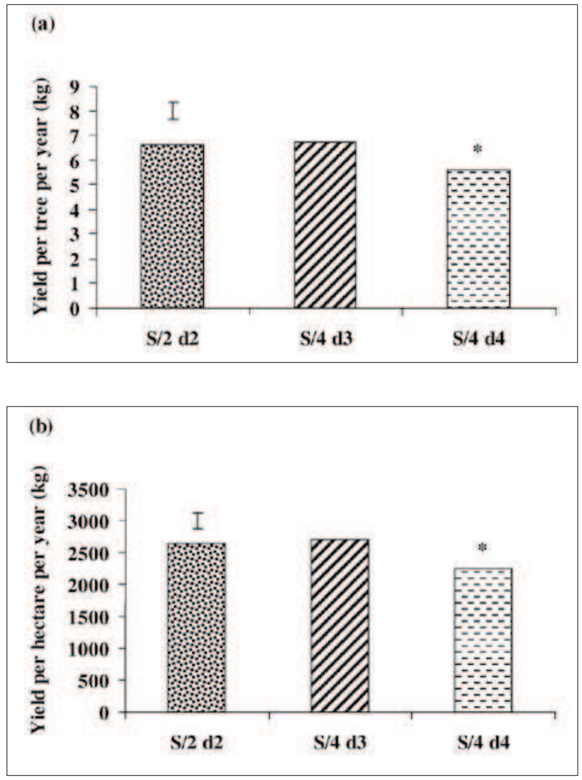

Figure 1: Latex yield in different harvesting systems a) on tree and b) hectare basis. (Error bars indicate the minimum significant difference and the symbol '*' is to show the significant difference ($p < 0.05$) of the respective mean value from the mean of S/2 d2 system.)

Table 2: Bark consumption and growth parameters of the harvesting systems tested

Tapping system	Annual bark consumption (cm)	% Area of the panel consumed per year	Shaving thickness per tapping (cm)	Girth increment per year (cm)	Bark thickness increment per year (mm)
S/2 d2	18.01	7.50	0.104	2.59	1
S/4 d3	14.09	2.93	0.121	2.18	1
S/8 d3	17.77	1.85	0.153	2.32	1
S/4 d4	12.59	2.62	0.145	2.20	1
S/8 d4	14.28	1.49	0.164	2.27	1
S/4 d6	9.14	1.90	0.160	2.00	1

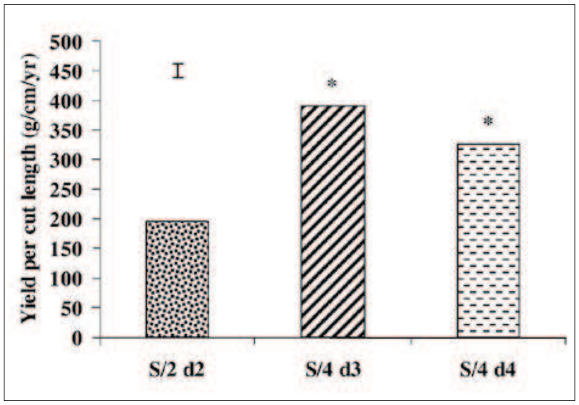

Figure 2: Yield per unit cut length in different harvesting systems (Error bars indicate the minimum significant difference and the symbol '*' is to show the significant difference ($p < 0.05$) of the respective mean value from the mean of S/2 d2 system.)

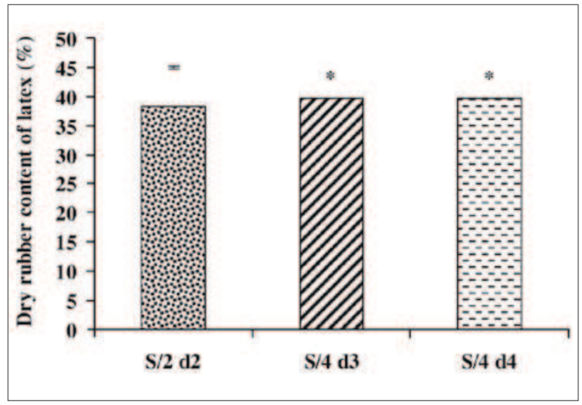

Figure 3: Dry rubber content in latex in different harvesting systems (Error bars indicate the minimum significant and the symbol '*' is to show the significant difference ($p < 0.05$) of the respective mean value from the mean of S/2 d2 system.)

Table 3: Bark consumption of different low intensity harvesting systems tested

Tapping system	Bark consumption Annual (cm)	Bark consumption Per tapping (cm)	Estimated years for harvesting both panels (virgin and renewed)	% Increase over S/2 d2 harvesting
S/2 d2	22.75	0.135	21.10	-
S/4 d3	18.95	0.165	50.64	140.00
S/4 d4	16.64	0.191	57.70	173.46

Table 4: Comparison of the incidence of tapping panel dryness (TPD) between low intensity harvesting systems and the traditional S/2 d2 system

Tapping system	% Trees affected
S/2 d2	1.3
S/4 d3	1.6
S/4 d4	1.2

In large scale testing, S/4 d3 system has given comparable yields in terms of YPT and YPH to S/2 d2 (Figure 1). However, latex yields of S/4 d4 were significantly less than that was given by S/2 d2. The yield per tree per year in S/2 d2 was 6.62 kg whilst the value of S/4 d3 and S/4 d4 was 6.76 kg and 5.60 kg, respectively. Yield per unit cut length was significantly higher in both low intensity tapping systems with values ca. 200 % and 168 % greater over S/2 d2 in S/4 d3 and S/4 d4, respectively (Figure 2). Dry rubber content (% DRC) in large scale tested systems were above 35 % and also, both low intensity systems showed significantly higher values than that in S/2 d2 system (Figure3).

Shaving thickness per tapping was slightly higher in both low intensity systems than in S/2 d2 in large scale testing, however linear length of annual bark consumption was less in both low intensity systems tested (Table 3). Whilst latex harvesting could continue for more number of years with LIH (above 100 % increase over the traditional S/2 d2 system), it is estimated that virgin bark tapping could be carried out for ca. 25 years in S/4 d3 and for 29 years in S/4 d4 (Table 3). Trees affected with TPD were at marginal level in all harvesting systems tested with values below 2 % (Table 4).

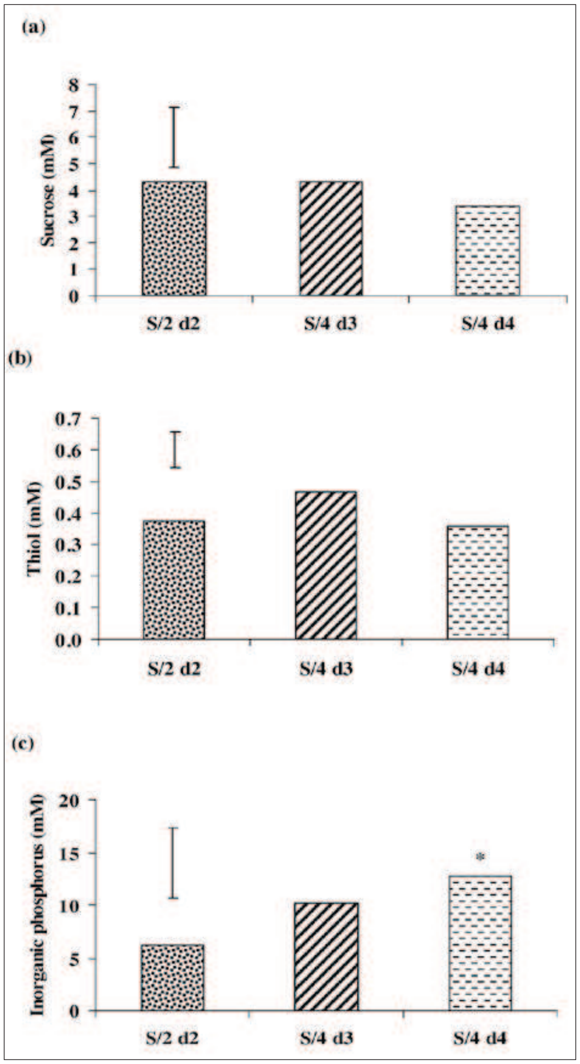

Figure 4: Comparison of latex physiological parameters, (a) sucrose, (b) thiol and (c) inorganic phosphorus content of latex (Error bars indicate the minimum significant difference and the symbol '*' is to show the significant difference ($p < 0.05$) of the respective mean value from the mean of S/2 d2 system.)

Among the latex physiological parameters, sucrose and thiol levels of LIH systems were comparable with those of traditional S/2 d2 with the average values of 3.85 and 0.41 mm, respectively. Nevertheless, the level of inorganic phosphorous increased with reduction in harvesting intensity and it was significantly higher in S/4 d4 than in S/2 d2 system (Figure 4).

Table 5: Summary of the financial analyses made on the S/4 d3 tapping system

Item	S/2 d2	S/4 d3
Intake per harvester (kg)	11	17
Harvesters' income (Rs/day)	632.00	722.00
Tapping cost with stimulation (Rs/kg)	57.45	42.82
Cost of stimulation (Rs/kg)		
(for chemicals)	0.00	1.54
Cost of stimulation (Rs/kg)		
(for labour)	0.00	4.50
Total cost of production (Rs/kg)	163.84	154.21
Profit /hectare/yr (Rs)	890,154/=	937,712/=

Financial analyses made for the S/4 d3 harvesting system in large scale testing showed that tapping cost and overall cost of production are ca. 14.68 % and 5.89 % less, respectively, than those of the traditional S/2 d2 system (Table 5). However, harvesters' income has increased by Rs. 86/= per day and the overall profit by Rs. 47,558/= per hectare per year in S/4 d3.

DISCUSSION

Like any other agribusiness, rubber plantations should be competitive in all aspects as it is the best approach for sustainability. Particularly in human resource management, worker use efficiency and worker satisfaction/motivation are the key issues to be tackled. Obviously, LIH systems are capable of reducing the number of workers required in rubber plantations, increasing the worker use efficiency. Among the LIH systems tested, S/4 d3 was found to be 5.34 % more profitable than the traditional S/2 d2 system whilst enhancing worker use efficiency and improving harvesters' living standards through increased wages. Unlike in the traditional S/2 d2, in the case of S/4 d3 system, there were additional costs involved for the application of stimulants (i.e. for ethephon and labour) and for incentive payments for harvesters. However, that additional cost was less than the overall cost reduction in labour, resulting in a) reduced harvesting cost, b) overall cost of production and c) increased profits.

Being d3 instead of d2 in the traditional system, worker requirement is reduced by 1/3. Since more latex is harvested by a worker per day, the daily income of harvesters is higher as shown in the present study. In S/4 d3 system where low frequency was associated with shorter tapping cut, harvesters' income has increased while the harvesting cost decreased only due to the reduction in harvesting frequency. With no change in the size of tapping block, reduction in tapping cut length, i.e. quarter cut, had no influence on either harvesters' income or harvesting cost. Nevertheless, there is a potential to increase the tapping block size as the time taken for tapping a tree is reduced in quarter cut. On average, 25 seconds are taken for the whole operation in tapping a tree without walking from a tree to another (Silva, 2007). Assuming 2/3 of this time utilized for the shaving (i.e. tapping itself), it could be possible to increase tapping block size from 300 to 417 trees. Thus, worker use efficiency in latex harvesting will increase further, providing an added payment to the harvester for the additional latex brought in, and also enhancing the overall profit.

With comparable yields and reduction in tapping cost, the net income per hectare (overall profit) was higher in the newly developed S/4 d3 than the traditional S/2 d2 system. Since the additional payment made to harvesters for the latex brought above the norm is less than the net income from such latex, the harvesting costs are always less in LIH systems. In the estate used for the present study, Rs. 15/= was paid for an additional kilogram of rubber latex above the level of 7 kg. The harvesters' income is always higher in any LIH system because of the additional latex brought in. At the present price of latex, (i.e. Rs. 500/= per kg), some estates pay harvesters more for the additional latex harvested. In such cases, the harvesters' income will be much higher than the value recorded for S/4 d3 although it will reduce the additional profit received. Under any circumstances, both the overall profit and harvesters' income will depend on the yield potential of the rubber field. Higher the yield, greater the profit and harvesters' income. Reduction in tapping cost associated with the reduction in harvesting intensity, has also been recorded elsewhere (Soumahin *et al*., 2009).

With the prevailing very high price for natural rubber latex, even a marginal decline in overall yield of LIH affects the profitability despite the reduction in harvesting cost. This was observed in S/4 d4 where yield decline was substantial enough to conceal the benefit of low harvesting cost. Further analyses showed that a maximum of 1.5 % decline in yield could be tolerable in S/4 d4 to obtain the same profit given by S/2 d2. Even at such yield level, harvesters' income will increase by 21.9 % showing the benefits of LIH. One would suggest increasing the stimulation level further to achieve the required yield level in S/4 d4. However with given high dose of stimulants (5 % ethephon at every two tappings), it is rather sceptical to develop this system further to obtain the required yield level. In S/4 d3 system, the relative yield level for comparable profit with S/2 d2 is 98.1 %.

Yield stimulants in rubber are generally used to increase the latex yield, however it has subsequently caused reductions in yields (Tupy, 1973; Abraham *et al*., 1976; Tupy & Primot, 1976). Such yield declines in following years have had a close association with the yields in previous years (Eschbach & Lacrotte, 1989) indicating the over-harvesting/stress factor in the long term. Therefore, yield stimulants should be used carefully only to the extent of harvesting the potential yield of the tree. Being the time tested, the yield given by the S/2 d2 could be considered as the safe level. In this context, yield per tree for a specific period (YPT) (in general, for a year) is the prime factor of concern as it shows the overall productivity. When the harvesting frequency is reduced in LIH systems, the increase in yield per tree per tapping (GTT) is expected to be substantial enough to produce a similar amount of YPT that is given by the traditional S/2 d2 system.

Shorter tapping cut length together with the reduction in tapping frequency in S/4 d3 provides the best option to increase the economic lifespan of the rubber tree with minimum labour use. Although increase in shaving thickness was prominent with decrease in tapping frequency, its effect is marginal when compared to the overall bark saving. The expected years in base panel harvesting on virgin bark exceed 24 years in the promising S/4 d3 system and as such, the renewed bark tapping could be ignored, if there is no intention to extend the lifespan of the rubber tree over 30 years. With renewed bark tapping, rubber trees could be kept over 50 years in S/4 d3 system. Any delay in the commencement of tapping in renewed bark provides additional time period for it to regenerate. Towards the end of tapping, even the virgin bark would develop further. With that, higher yields could be expected in the long run in S/4 d3 than what was observed in this study.

Since the yield was given through a quarter spiral cut (instead of half spiral), yield per unit cut length has been very much higher in S/4 d3 system. According to the latex physiological parameters, stimulation levels associated with both LIH systems have had no adverse effect on tree health. Values recorded for % DRC in all harvesting systems were in the safe level and in most occasions, it was higher than the % DRC of S/2 d2. In general, if the tree is under stress due to over exploitation of latex, then the sucrose level should tend to decline due to the difficulty in sustaining the increase in demand for it in latex synthesis (Jacob *et al*., 1988). No such effect was observed in the present study and both sucrose and thiol of latex in LIH systems were comparable with those in the traditional S/2 d2. Similar findings have been recorded in Côte d'Ivoire with different genotypes of rubber (Obouayeba *et al.*, 2010; Traoré *et al.*, 2011). Inorganic phosphorous in latex tended to be higher in LIH systems than in S/2 d2 and particularly in S/4 d4, where the difference was significant. This indicates the increased level of energy (ATP/NADP) for latex synthesis in LIH (Jacob *et al*., 1989) since more latex is to be extracted on each tapping day. More importantly, there was no indication of increased incidence of TPD affected trees in LIH systems, reconfirming the safety of stimulation protocols. In general, incidence of TPD tends to decline with the reduction in harvesting intensity (Obouayeba *et al.*, 2011).

The large scale commercial testing of S/4 d3 system with stakeholder participation should be the next step. This could be used to increase rubber growers' confidence and also to fine tune the protocol, if required. Undoubtedly, it will act as a popularization programme too. Since the present study was confined to the Wet Zone of Sri Lanka, testing of S/4 d3 may also to be extended to drier areas where expansion of rubber cultivation in the country is focused.

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