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A review of low-frequency latex harvesting systems that lessen the tapper shortage problem of the smallholders' natural rubber production

Abstract. Smallholders' rubber production is encountering problems of skilled tapper shortage and high production costs resulting from increased worker wages and the substantial growth of new mature areas. Low-frequency latex harvesting system (LFLHS) effectively improves tapper productivity with long-term optimum yield by reducing the tapper requirement. LFLHS reduces tapper requirement by 33% to 67% of the conventional harvesting systems. Under the d3 (tapping every three days) frequency harvesting system, a tapper is assigned to cover three tasks, and his productivity is at least 30% higher than that of the d2 (alternative daily) frequency harvesting system. The cumulative yield of LFLHS is comparable to that of d2 frequency. It is economically profitable when the cumulative yield of LFLHS reaches 90% of the d2 frequency tapping as a break-even yield. Its low number of tapper requirement and high productivity saves tapping cost. 20% to 55% of tapping cost can be reduced by shifting the harvesting frequency from d2 to d3. The virgin bark of basal panels could be tapped at least four to ten years more than conventional tapping systems. The low bark consumption allows sufficient time for the regeneration of bark tissues resulting in a potentially higher yield from the renewed bark. Thus, sustainable economic yield is achievable for a productive lifespan of 30 to 35 years from the LFLHS. These advantages of LFLHS contribute to reducing the tapper requirement and cost of production, ensuring increased profits and a longer economic lifespan of rubber production.

Keywords: Latex harvesting system · Tapping cost · Tapper productivity · Tapper requirement

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Introduction

Hevea brasiliensis is an indispensable economic crop supplying natural rubber commodity for the production of various rubber products. Over 85% of the global natural rubber demand is supplied by smallholders who own small-scale farms of less than ten hectares, and most rely solely on rubber production for their primary income (Association of Natural Rubber Producing Countries, 2021). Thus, the natural rubber industry is vital in supporting millions of farmers' livelihoods with a significant income source (Fox and Castella, 2013). With the economic growth and industrialization in rubber-producing countries, demand for labor has increased, resulting in a significant rise in general wages since the year 2010s (Ra, 2014; Ali et al., 2020). Meanwhile, many extended areas, planted in recent decades when the rubber price was attractive, have reached the mature stage, requiring a considerable number of tappers for harvesting. The issues mentioned above are leading to a shortage of skilled workers for tapping, resulting in increased tapping cost, which constitutes around 70% of the total production cost (Vijayakumar et al., 2003). The problems have been aggravated under prolonged unstable rubber prices, affecting employment stability, particularly in smallholders' rubber production (Rodrigo et al., 2011).

To solve these issues, studies have introduced and looked into using low-frequency latex harvesting systems (LFLHS). This system reduces the tapper requirement and tapping cost compared to conventional tapping system, while also increasing land and labor productivity. Ultimately, this helps ensure the long-term profitability and resilience of rubber production (Soumahin et al., 2010; Zaw et al., 2017; Sainoi et al., 2017a). This article discusses the issues encountered by the smallholders and elaborates on the competitive advantages of LFLHS compared to the conventional tapping systems based on previous research.

Latex Harvesting

To obtain rubber latex, the bark of a mature rubber tree is shaved in a process called latex harvesting or tapping. This removes the ends of the latex vessels clogged with coagulated latex from the previous tapping. Once the tapping commences, fresh latex is released from the vessels and flows down into a container. Then, after a few hours, the latex vessels' ends are clogged again with the coagulated latex. There are different tapping systems adopted in an attempt to increase yield or improve profitability. A tapping system is considered ideal if it provides maximum yield at minimum tapping cost, while ensuring satisfactory tree growth, bark renewal, productive lifespan, and minimal occurrences of wounds on the tapping panels and physiological disorders (Vijayakumar et al., 2000).

When selecting tapping systems, it is important to consider multiple factors, including the cultivar planted, tree age, number of tappable trees, weather conditions, availability of skilled tappers, rubber prices, and wage agreements to ensure the optimal results. The number of tapped trees, the height, length, direction, and slop of the tapping cut, the frequency and time of tapping, panel changing, bark consumption, and yield stimulation are basic technical elements to assess the tapping quality (Malaysian Rubber Board, 2009).

Conventional Latex Harvesting Practices

Typically, latex harvesting commences six or seven years after planting to ensure economic yield. It is considered to begin a plot for tapping when at least 50 or 70% of the total trees reach 45-50 cm circumference at 150 or 170 cm height above the ground. The opening of tapping is carried out in a downward direction at 150 cm height from the ground with a 30 to 35 degree angle from high left to low right. A tapping system traditionally recommended in most rubber-producing countries is a downward tapping of a half spiral tapping cut length (S/2) with alternate daily tapping (one day tapping followed by a tapping rest day – d2) without any yield stimulation (Rodrigo et al., 2011). The trees being tapped are split into two plots, with each plot being tapped alternatively. This allows a tapper to cover two plots efficiently. However, some countries, where smallholders are the majority of the production share and their farms are not an economically manageable size, are practicing high-frequency tapping systems. such as daily tapping (d1), four-day tappings in five

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days (4d5), three-day tappings in four days (3d4), and two-day tappings in three days (2d3) (Chantuma et al., 2011). In addition, erratic weather, like a prolonged heavy rainy season that disturbs the regular tapping works, leads the high-frequency tapping systems after the rainy season to compensate for the tapping days lost. These tapping systems require a higher number of tappers for a certain number of tapped trees and less tapper productivity, resulting in a significant higher tapping cost (Zaw et al., 2017).

Mechanism of Latex Flow

Fresh *Hevea* latex in the latex vessels mainly consists of rubber globules, lutoid particles, and Frey-Wysssling particles by dispersing with other constituents – amino acids, inorganic acids, proteins, carbohydrates, resins, glucosides, tannins, and alkaloids. Mineral salts, proteins, and sucrose are also soluble in parenchyma and phloem cells beside the latex vessels (Gomez and Hamzah, 1989; Bottier, 2020).

Before tapping, latex vessels are under high hydrostatic pressure. Meanwhile, osmotic pressure from surrounding cells also makes the hydrostatic pressure higher. This causes an increase in phloem turgor pressure in the vessels. Generally, hydrostatic pressure in the latex vessels before tapping in the morning ranges between 10 and 15 atmospheres while the ambient pressure is low. When the vessel is tapped, the latex is released due to a high-pressure difference (An et al., 2014). Then, a fall in pressure in the latex vessels to the ambient follows, and consequently, it allows water from the surrounding tissues to flow into the latex vessels, causing the latex less viscous and an enhanced flowing of latex (Vijayakumar et al., 2000; Yeang, 2005). After a certain duration, latex flow slows down, and cessation of the flow follows. It is because of an inherent clotting mechanism in the latex vessels. While latex flows out, lutoid particles are ruptured and release destabilizing substances called hevein, a kind of protein, which flocculates and coagulates the latex near the cut ends in the vessels resulting in clogging the latex flow (Shi et al., 2016; Sainoi et al., 2017b). Tree assimilation, transport of sugars, and sink capacity are primary factors influencing latex regeneration (Silpi et al., 2007). The latex regeneration between the two tappings is related to the cellular metabolism of the laticifer system and physiological functioning of the tree (Chao et al., 2015). The complete regeneration of the latex in the vessels after one tapping was estimated to be around 48 to 72 hours, depending on the clonal latex metabolism capacity (Chantuma et al., 2022).

Yield Stimulation

The most common latex yield stimulant widely used in rubber production is 2-chloroethyl phosphonic acid which decomposes in the bark to release ethylene when applied, and extends the duration of latex flow by delaying the plugging of latex vessels (Zhu and Zhang, 2009). Due to the longer duration of latex flow, the amount of latex discharged increases during tapping. As latex production is associated with genetic features, environmental effects, and tapping systems, response to stimulation strongly depends on these different factors (Njukeng et al., 2011; Traore et al., 2011). Thus, stimulation must be applied cautiously by considering the yield potential of clonal typology with age, weather conditions, and tapping intensity.

Stimulation is an excellent means of removing limiting factors on latex flow. However, excessive use or misuse can lead to serious malfunctioning of the laticifers. Intensive stimulation causes an excessive outflow of latex, disorders the physiological state of the tree, and leads to degeneration of the laticiferous system in the bark (Jacob et al., 1989). In conventional tapping system like d2 frequency, yield stimulation is not recommended.

Low Frequency Latex Harvesting System

Implementing LFLHS means a reduction of tapping frequency which increases the number of days between two successive tappings, notably the latex regeneration period, resulting in higher yield per tree per tap and tapper productivity (Obouayeba et al., 2010; Karunaichamy et al., 2012). For conventional tapping with d2 frequency, the trees are split into two plots and tapped alternatively, with one plot being tapped each day. When tapping in d3 frequency (tapping every three days), the trees are divided into three plots, and each plot is then tapped once every three days.

Tapper Requirement. The LFLHS taps fewer trees per day in a certain productive area compared to the conventional system. This does not mean that the number of trees tapped by a tapper, known as the task size, is reduced. Under LFLHS, tapper is assigned to tap other tasks in the following days while the first task is resting, so that the trees of a certain task get more resting days for latex regeneration. Thus, LFLHS enables a tapper to cover more tasks. For instance, with the d3 frequency tapping system, one tapper can handle three tasks, while the d6 frequency tapping system allows one tapper to handle six tasks (Figure 1A). It highlights that the frequency of tapping plays a crucial role in determining the number of trees tapped per day and the number of tappers required (Zaw et al., 2017).

By switching from d2 to d3 tapping frequency, the tapper requirement can be reduced by 33% by increasing the number of tasks per tapper from two to three (Figure 1B). Similarly, under a d4 frequency, there is a 50% reduction in tapper requirement by increasing the land-man ratio by 50%.

Latex Production. Since LFLHS has a longer interval between two successive tappings to allow for regeneration of replenishing laticiferous content, which was removed from previous tapping, a reduction in tapping frequency generally produces a higher yield than normal tapping frequency. The yield per tree per tapping (g/t/t) for d3, d4, and d6 are 30 to 100% higher than the d2 frequency tapping (Kewi and Sivakumaran, 1994; Karunaichamy et al., 2012). Besides, the yield under LFLHS throughout the year was stable and increased in production trend (Leilani et al., 2015). A study of Jacob et al. (1989) observed that although LFLHS resulted in a high yield per tapping per tree (high tapper productivity), the interval between the two tappings longer than seven days led to a low yield significantly comparing between around 50 g/t/t under d4 frequency and around 30 g/t/t under d14 frequency tapping. The study noticed that a resting period of more than one week between two tappings did not result in a significantly higher yield due to a notable decrease in metabolic activity.

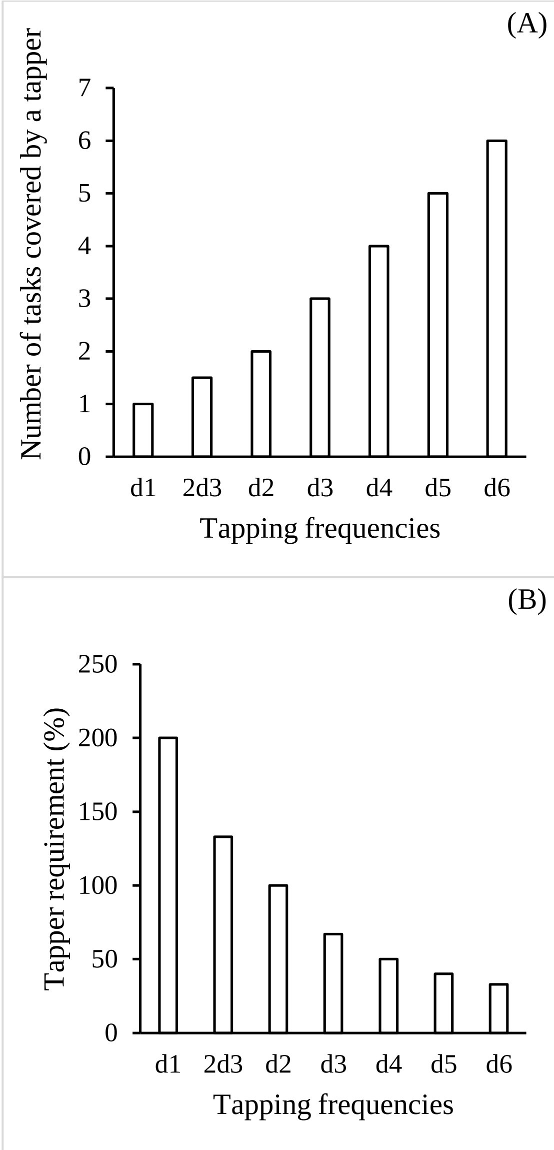

Figure 1. Number of tasks covered by a tapper (A) and tapper requirement in different latex tapping frequencies (B)

In a study of Thanh et al. (1996), cumulative yield (kg per tree per year) under d3 and d4 frequency tapping were respectively 93% and 86% of that obtained from the d2 tapping system. Nugawela et al. (2000) and Zaw et al. (2017) also found that cumulative yield from d3 frequency tapping was comparable and slightly higher than that of d2 frequency, while it was only 84-86% of 2d3 frequency tapping yield. Some studies suggested that it was economically profitable when the cumulative yield of LFLHS reached 90% of that of d2 frequency tapping, which was considered a break-even yield (Nayagam et al., 1986). Optimum land

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productivity could not be achieved without combination of the yield stimulation under LFLHS (Sivakumaran et al., 2002; Lacote et al., 2013). The main objective of stimulation in LFLHS is to compensate the yield loss caused by the fewer number of tapped trees and tapping days (Rodrigo, 2007). It is important to adjust the stimulation's frequency and concentration based on tree's physiological status associated to weather, clones, tree age, and tapping system (Lacote et al., 2013).

Tapping Cost and Tapper Income. Tapping cost is mainly associated with tapping frequency, tapper productivity, and payment system. LFLHS reduces the cost of tapping per unit production because of its low tapper requirement and high tapper productivity. With a certain higher productivity of the d3 frequency tapping system, the tapping cost could be reduced by about 20% from that of the d2 frequency tapping system (Nugawela et al., 2000). It was observed that the cost did not decrease under the product sharing payment system as it depended solely on rubber price (Zaw et al., 2017). However, the increased tapper productivity had a positive impact not only on the tapper income but also on the overall income of the farm in LFLHS. Tapper income is a crucial factor in addressing the skilled tapper shortage problem. Thus, some percentage of the benefits can be shared with skilled tappers as an incentive. In some estates, based on an over-targeted-yield-incentive system, tappers' income was attractive under LFHS as their daily productions (tappers' productivities) were higher than the normal targeted yield.

Bark Consumption and Productive Lifespan. Bark consumption is the thickness of bark shaved by tapping, depending on the tapper's skill and tapping frequency. The shaving should be thick enough to remove all plugged vessel ends for an optimum yield. In LFLHS, it needs to remove a slightly thicker bark shaving per tapping (Lacote et al., 2004). Table 1 shows the standard bark consumptions by different latex harvesting frequency. The monthly bark consumption in the d3 frequency was 15 to 40% less than the conventional high-frequency tapping systems. Rodrigo (2012) reported that although bark shaving per tapping in LFLHS was thicker than that of the conventional tapping, S/2, the effect was marginal compared to the overall bark saving per year by less frequency of tapping.

Table 1. Bark consumptions per tap and per month under different latex harvesting frequencies.

Latex harvesting frequency	Bark consumption per tap (mm)	Bark consumption per month (mm)
2d3	1.0-1.2	20-25 (125-133)
d2	1.0-1.2	15-20 (100)
d3	1.3-1.5	13-17 (85-86)
d4	1.5-1.7	12-15 (75-80)
d5	1.7-1.9	10-13 (65-67)
d6	1.8-2.0	9-11 (55-60)

Note: Figures in parenthesis represent percentage of d2 frequency.

With a significant decrease in bark consumption, the LFLHS is expected to have a longer economic lifespan. By using the S/2 d3 tapping system, the productive lifespan of the trees could be extended by at least four to eight years compared to the conventional S/2 d2 tapping system (Nugawela et al., 2000; Vijayakumar et al., 2003).

Table 2 shows the comparison of tapping years on the basal panel, at which tapping is started from 150 cm height from the ground, by different tapping systems. When comparing the tapping years of the S/2 d2 tapping system on virgin bark of basal panel, the tapping years of d3, d4, d5, and d6 frequency tapping systems can be extended from 4 to 10 years while high-frequency harvesting systems S/2 2d3 and S/3 2d3 can tap only 60% and 90% of the S/2 d2 tapping years, respectively. The slower rate of bark consumption gives enough time for the bark tissues to regenerate. This means that renewed bark could potentially produce a higher yield. As a result, the sustainable economic yield under LFLHS is expected for around 30-35 years.

Table 2. Tapping years on virgin bark of basal panels under different latex harvesting systems

Latex harvesting system	Tapping years on virgin bark of first basal panel	Expected tapping years on virgin bark of basal panels
S/2 2d3	3	6
S/3 2d3	3	9
S/2 d2	5	10
S/2 d3	7	14
S/2 d4	8	16
S/2 d5	10	20
S/2 d6	10	20

Conclusion

This review highlights the performance of LFLHS that reduces the tapper requirement without compromising the yield level, compared to the conventional tapping practice. In addition, it suggests with technical evidence that LFLHS can lead to sustainable economic yield over the productive lifespan. Thus, shifting from conventional harvesting systems to LFLHS is recommended as a sustainable manner to lessen the current problems of skilled tapper shortage and increased production cost, ensuring a longer economic lifespan of rubber production.

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