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Long Term Effect of Low Frequency Tapping Systems Applied to Rubber Tree (*Hevea brasiliensis*), Clone RRIT 251, on Agronomic Performance in Upper Southern Thailand

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Abstract

Clone RRIT 251, a primary clone, was developed by RAOT (Thailand) with promising high yield potential. Low frequencies of tapping (LFT) was tested using 8-year-old trees to characterize the performance of the clone RRIT 251 under such latex harvesting systems. The aim of the study was to assess the response of the yield to LFT related to some biochemical indicators of the latex cells' metabolism. The experiment was established at the Sithiporn Kridakorn Research Station of Kasetsart University, Prachuap Khirikhan Province, Thailand. The experimental randomized Fisher block design consisted of the 3 treatments. These were abbreviated to T1: S/2 d2 opening BO-1 at 1.5 m, T2: S/2 d3 ET 2.5 % Pa1 (1) 6/y opening BO-1 at 1.3 m and T3: S/2 d4 ET 2.5 % Pa1 (1) 8/y opening BO-1 at 1.2 m. Three replications were conducted with 55 trees per treatment in each experimental plot. Analysis of variance (ANOVA; F test) has been used to compare treatments using Duncan's multiple range test (DMRT) at a significant level of $p < 0.05$. Results showed that daily yield greatly increased when using lower tapping frequencies. More than 10 years of tapping, panel management and location of the tapping cut on the panel in downward tapping have significantly impacted yield. Tapping on virgin bark at d3 and d4 frequencies gave higher yield than d2 frequency on renewed bark. Good panel management, combined with tailored stimulation and reduced tapping frequency showed greater efficiency. Results were encouraging. It might be considered that these low tapping frequencies systems can be tested by smallholders and then transferred at the farm gate in Thailand.

Keywords: Low frequency tapping systems, *Hevea brasiliensis*, Clone RRIT 251

Introduction

The rubber tree, *Hevea brasiliensis* (Muell.) Arg., is the major crop for smallholders in Thailand, which is the largest producer of natural rubber in the world [1]. Rubber tree is mainly grown for the production of latex. In Thailand, farmers used a one third-spiral downward system; S/3, with a frequency of a daily tapping, 2 days in tapping followed by 1 day tapping rest in 3 days; 2d/3 7d/7 [2]. Latex is extracted using a multi-annual tapping system that can continue for 15 - 30 years [3]. Tapping system efficiency is an important factor for the latex production of rubber tree. To increase their household incomes, rubber farmers follow a latex harvesting system that is more intensive than the method recommended by the Rubber Research Institute of Thailand (RRIT) [4]. RRIT recommends a tapping frequency of not more than 2 days with 1 day off. Most farmers use higher-frequency tapping system to compensate for the reduction of tapping days that leads to a loss of revenue due to weather variability and rubber price fluctuations. High-latex tapping frequency systems gives good cumulative yield per year due to the high number of tapping days but yield per tapped tree and per tapping is low with inefficient labor productivity. Moreover, such a system may have an adverse effect on the physiology of the rubber trees and the duration of tapping of the trees. Tapping panel dryness often occurs and virgin bark for tapping is overutilized [5]. Many farmers are not skilled in tapping regenerated bark. As a result, rubber trees have shorter producing lifespans and rubber fields are cut down and replanted more often, reducing income per planting cycle [6,7].

Low frequency tapping (LFT) systems could resolve these issues [8-12] while increasing the duration of the tapping on virgin bark. LFT systems combine reduced tapping frequency with ethephon hormonal stimulation to improve yield at each tapping [13-19]. This leads to higher yield per tapping that compensates for the reduction in tapping frequency [20-26]. The RRIT 251 clone is a new promising high latex yield group of RRIT's recommendation clones [27]. There is widely used for new planting or replanting in Thailand [28]. The RRIT 251 clone is known for their performance, rapid growth with dense canopy, and high latex yield [27]. For some physiology traits, RRIT 251 was sensitive to xylem cavitation and also sensitive to water deficit, stomata of RRIT 251 closed later than other clones [29]. The objectives of this paper were to (i) assess the feasibility of low frequencies tapping (LFT) for clone RRIT 251 and its impact on yield and latex cells functioning in a traditional area of cultivation, southern Thailand.

Materials and methods

The experiments were carried out at Sithiporn Kridakorn Research Station of Kasetsart University, Bang Saphan Noi destrict, Prachuap Khirikhan Province, in upper southern Thailand using clone RRIT 251 and applies all stages of this research. Trees were planted at 8×2.5 m^2 spacing. The randomized Fisher block design included 3 treatments and 3 replications. There were 55 trees per treatment in each plot (**Table 1** and **Figure 1**).

Table 1 Experimental treatments.

Treatment	Tapping System and Description	TI*
T1	S/2 d2 (half spiral downward at alternate daily tapping), nil stimulation. Opening BO-1 at 1.50 m from ground (Control)	100
T2	S/2 d3 ET 2.5 % Pa1(1) 6/y (half spiral downward at 3rd daily tapping, stimulated with ethephon with 2.5 % active ingredient with 1 g of stimulant applied on panel on 1-centimeter band, 6 applications per year) Opening BO-1 at 1.30 m from ground	67
T3	S/2 d4 ET 2.5 % Pa1(1) 8/y (half spiral downward at 4th daily tapping, stimulated with ethephon with 2.5 % active ingredient with 1 g of stimulant applied on panel on 1-centimeter band, 8 applications per year) Opening BO-1 at 1.20 m from ground	50

Note: *TI is tapping intensity.

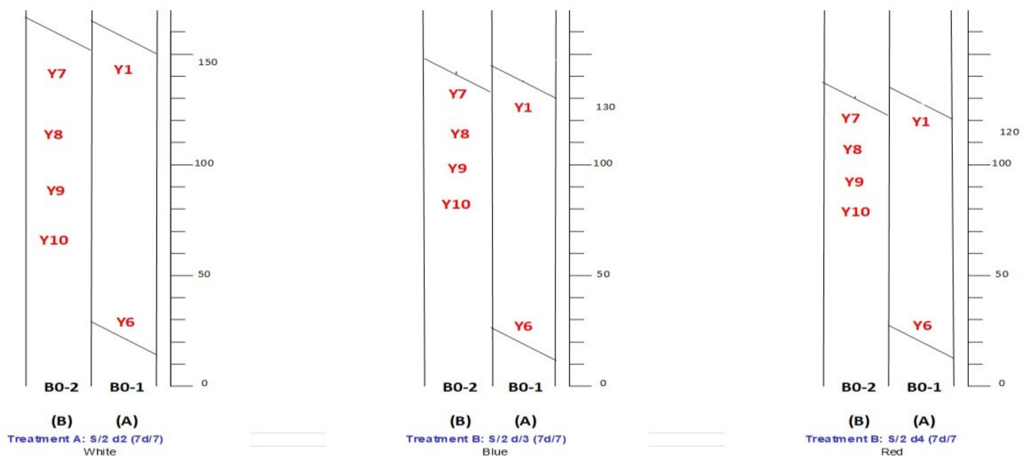

Figure 1 Tapping panel management according to tapping frequency. A: S/2 d2, B: S/2 d3, C: S/2 d4 for over the 10-year period. Years 1 to 6 on panel BO-1; the 1st tapping panel, then years 7 to 10 on panel BO-2; the 2nd tapping panel.

Data collection and analysis

In Sithiporn Kridakorn Research Station, latex yield was calculated from each plot by weighing each tapping. Total solid content was measured from a bulk sample taken in each treatment to convert fresh weights into dry rubber. The biochemical parameters of the laticiferous vessels were measured according to the CIRAD method [30,31]. The latex diagnosis was performed each year in September or October during the most regular and high yielding period. In each subplot, a composite sample was obtained from 10 randomly selected tapped trees and 10 drops of latex were collected from each tree. The latex diagnosis (LD) parameters were measured using the [32] for sucrose (SUC), the [33] for Pi and the [34] for RSH. Sucrose, thiols and inorganic phosphorus contents were expressed in millimoles per liter of latex ($mmol.1^{-1}$).

Bark consumption (cm) was measured on the tapped panel every year from the beginning to the end of the tapping period. Tapped trees were counted twice a year in each plot.

Statistical analysis

Analysis of variance (ANOVA; F test) has been used to compare treatments using Duncan's multiple range test (DMRT) at a significant level of $p < 0.05$, using the R statistical software package (version 3.4; R Core Team, 2017).

Results and discussion

We assumed that using an ethylene generator, 2-chloroethylphosphonic acid (ethephon), applied to the tapping panel, will increase latex yield at each tapping while reducing tapping frequency with a consequence of increasing labor productivity and compensating the less number of tapping days on the cumulated yield in a year of tapping [35-41]. For the reason, we compared tapping frequencies on clone RRIT 251, a primary clone, developed by RAOT (Thailand) with promising high yield. Some former studies showed that the ethylene released by ethephon increases the duration of latex flow after tapping by activating latex cell metabolism [14,15,18,19] until a limit to avoid any adverse effect on the latex cells functioning. Gohet *et al*. [42] reported that the ethylene stimulation effect may vary with rubber tree clones. Therefore, we used a tailored stimulation rate to clone RRIT 251 when using a lower tapping frequency than d2 in our trial. Low frequencies of tapping (LFT) was tested using 8-year-old trees to characterize the performance of the clone RRIT 251 under such latex harvesting systems.

Treatments with a lower tapping frequency and hormonal stimulation showed the highest latex yield at each tapping (g $tree^{-1}$ $tapping^{-1}$) due to ethephon stimulation (**Figure 1**). The yield at each tapping (g $tree^{-1}$ $tapping^{-1}$) on panel 1 BO-1 (Y1 - Y6) showed significant differences among the 3 tapping systems (**Table 2**). Treatment T3 (S/2 d4 with ET 2.5 % 8Y) provided the highest latex yield in year 1 to year 6, while T2 (S/2 d3 with ET 2.5 % 6Y) and T3 provided higher latex yield than T1 (S/2 d2). On the tapping panel 2 BO-2 (Y7 - Y10) the latex yield (g $tree^{-1}$ $tapping^{-1}$) showed significant differences among the tapping systems. Treatment T3 had the highest latex yield and T1 had the lowest (**Table 2**). T3 had the highest overall average latex yield (127.3 g $tree^{-1}$ $tapping^{-1}$) with an increase of +57 %, followed by T2 (118.1 g $tree^{-1}$ $tapping^{-1}$) with an increase of +45 % of T1. (**Figure 2**). Similarly, [43] and [44] reported that 2-chloroethyl phosphonic acid increased rubber yield due to hormonal stimulation which prolonged the period of latex flow by activating latex cell metabolism [3,22,45]. Results showed enhanced yield per tree and per tapping to compensate for reduction in the tapping frequency [3,21,22,46,47]. Accordingly, over the 10-year period of tapping, the yield per tree (g $tree^{-1}$) of treatment T2 was significantly higher than T1 (**Table 3**). With the lowest tapping frequency at d4, T3 showed cumulated yield of 8 % lower than the control treatment with d2 frequency.

Table 2 Average latex yield (g $tree^{-1}$ $tapping^{-1}$) over the 10-year tapping period.

Year			Latex yield (g $tree^{-1}$ $tapping^{-1}$) – Tapping system: T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1)	2010 - 2011	58.4 c	98.1 b	113.3 a	4.98	*
	(Y2)	2011 - 2012	68.5 b	111.5 a	118.3 a	7.80	*
	(Y3)	2012 - 2013	74.81b	115.5 a	119.8 a	6.59	*
	(Y4)	2013 - 2014	80.2 b	115.6 a	124.3 a	5.21	*
	(Y5)	2014 - 2015	84.34 b	119.2 a	128.5 a	4.49	*
	(Y6)	2015 - 2016	88.5 b	121.5 a	130.3 a	3.81	*

Year		Latex yield (g tree^{-1} tapping^{-1})				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	90.4 b	125.7 a	135.1 a	3.64	*
	(Y8) 2017 - 2018	89.9 c	121.9 b	134.9 a	3.55	*
	(Y9) 2018 - 2019	88.2 c	124.2 b	133.9 a	3.53	*
	(Y10) 2019 - 2020	90.0 c	124.6 b	134.9	3.50	*
	Average for 10 years	81.32 b	118.10 a	127.32 a	4.47	*

Note: * = Significant difference of average value among treatments ($p < 0.05$).
Different letters within a column showed significant difference of average values among treatments by DMRT ($p < 0.05$).

Table 3 Average cumulative yield (g tree^{-1}) over the 10-year tapping period.

Year		Cumulative yield (g tree^{-1})				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	6,462.9	7,552.5	7,022.0	5.47	ns
	(Y2) 2011 - 2012	8,713.4	10,757.5	8,355.1	10.32	ns
	(Y3) 2012 - 2013	10,083.6 a	10,985.2 a	8,983.6 b	4.09	*
	(Y4) 2013 - 2014	11,126.6 a	10,409.6 a	9,357.9 b	4.21	*
	(Y5) 2014 - 2015	10,817.2 a	11,360.6 a	9,237.3 b	4.76	*
	(Y6) 2015 - 2016	12,018.4 a	11,423.0 b	9,653.5 c	1.95	*
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	10,936.6 b	13,166.5 a	11,080.0 b	5.79	*
	(Y8) 2017 - 2018	8,718.4	9,120.1	8,425.8	5.73	ns
	(Y9) 2018 - 2019	6,717.2 b	8,371.1 a	7,091.1 b	6.34	*
	(Y10) 2019 - 2020	8,707.1 a	7,362.5 b	7,335.8 b	2.75	*
	Average for 10 years	94,002.0 b	100,508.5 a	86,542.1 c	2.45	*

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

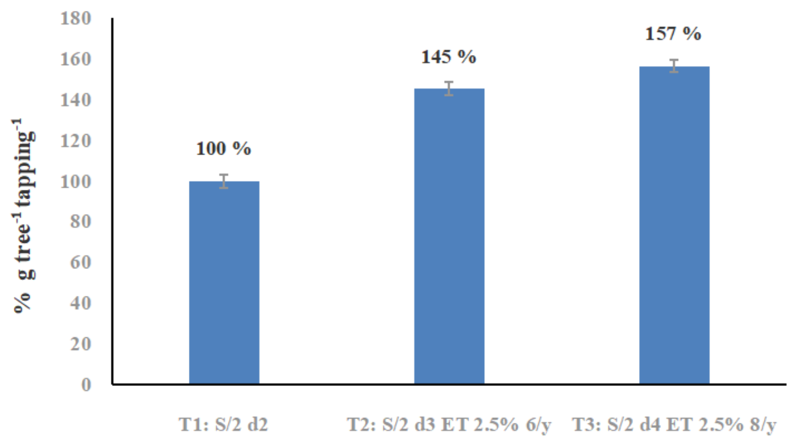

Figure 2 Average latex yield per tree per tapping (g tree^{-1} tapping^{-1}) for 10 years of downward tapping on virgin bark.

On panel 1 BO-1 (Y1 - Y6) (**Table 3**) there was no significant differences between year 1 and year 2. Differences appeared in year 3, year 4 and year 5 between T3 and T1 and T2. On panel 2 (BO-2) (Y7 - Y10), T2 had the highest cumulative yield followed by T1 and T3. Over the 10-year tapping period, T2 had the highest cumulative yield, while T3 had the lowest cumulative yield related to the lowest number of tappings. Reduction of the number of tapping days to d4 (**Table 5**) combined with use of hormonal stimulation was not completely compensated by increase of g tree^{-1} tapping^{-1} to sustain the cumulated yield. Indeed, there was no recovery of the loss of tapping due to rainy days during the trial period. Therefore, the number of tappings was significantly lower for T2 and T3 than T1. The gap between T3 and T2 (–22 %) in the number of tapping over the period was significantly higher than between T3 and T1 (–40 %).

The dry rubber content (DRC) showed significant differences over the 10-year tapping period (**Table 4**). T3 had the highest DRC (41.71 %) followed by T2 (41.25 %). T1 had the lowest of DRC (40.98 %).

Bark consumption showed significant differences (**Table 6**). The d2 tapping frequency (T1) showed the highest bark consumption over the 10-year tapping period. Reduction of bark consumption using lower tapping frequency increases the life span of tapped trees. Less bark consumption also provides increased time for bark renewal [11].

Table 4 Average dry rubber content over the 10-year tapping period.

	Year	Dry rubber content (%)				
		Tapping system				
		T1: S/2 d2	**T2: S/2 d3 ET 2.5 % 6/Y**	**T3: S/2 d4 ET 2.5 % 8/Y**	**C.V.**	**F-test**
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	37.69 a	37.03 c	37.17 b	0.0654	**
	(Y2) 2011 - 2012	38.92	38.66	39.01	0.5481	ns
	(Y3) 2012 - 2013	39.56 b	39.95 a	40.31 a	0.4063	*
	(Y4) 2013 - 2014	40.08 c	40.60 b	41.32 a	0.3692	*
	(Y5) 2014 - 2015	40.86 c	41.60 b	42.22 a	0.3532	*
	(Y6) 2015 - 2016	41.82 c	42.61 b	43.14 a	0.2878	*
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	41.88 c	43.36 b	42.75 a	0.2495	*
	(Y8) 2017 - 2018	42.63 c	42.91 b	43.42 a	0.1894	*
	(Y9) 2018 - 2019	43.09 c	43.29 b	43.76 c	0.1757	*
	(Y10) 2019 - 2020	43.29 c	43.54 b	44.02 a	0.1652	*
	Average for 10 years	40.98 c	41.25 b	41.71 a	0.2388	*

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
** = Significant difference of average value among treatments ($p < 0.01$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Table 5 Average number of tapping days over the 10-year tapping period.

	Year	Number of tappings (day)				
		Tapping system				
		T1: S/2 d2	**T2: S/2 d3 ET 2.5 % 6/Y**	**T3: S/2 d4 ET 2.5 % 8/Y**	**C.V.**	**F-test**
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	107 a	76 b	53 c	0.0376	*
	(Y2) 2011 - 2012	104 a	78 b	65 c	4.85	ns
	(Y3) 2012 - 2013	113 a	91 b	72 c	0.0050	**
	(Y4) 2013 - 2014	110 a	88 b	64 c	0.0131	**
	(Y5) 2014 - 2015	93 a	71 b	60 c	0.0278	**
	(Y6) 2015 - 2016	111 a	84 b	70 c	0.0243	**
	Total number of tappings Y1 - Y6	747 a	577 b	453 c	0.0921	**

Year		Number of tappings (day)				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	108 a	89 b	68 c	0.0128	**
	(Y8) 2017 - 2018	100 a	78 b	63 c	0.1221	**
	(Y9) 2018 - 2019	89 a	71 b	58 c	0.0120	**
	(Y10) 2019 - 2020	81 a	56 b	47 c	0.6381	ns
	Total number of tappings Y7 - Y10	456 a	340 b	271 c	0.1421	**
	Average for 10 years	1204 a	918 b	724 c	0.921	**

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
** = Significant difference of average value among treatments ($p < 0.01$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Table 6 Average annual bark consumption (cm) over the 10-year tapping period.

Year		Bark consumption (cm)				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/y	T3: S/2 d4 ET 2.5 % 8/y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	28.4 a	20.7 b	17.5 c	7.59	**
	(Y2) 2011 - 2012	23.7 a	16.5 b	15.0 c	2.75	**
	(Y3) 2012 - 2013	21.7 a	17.1 b	13.9 c	3.01	*
	(Y4) 2013 - 2014	18.0 a	13.7 b	9.2 c	4.37	*
	(Y5) 2014 - 2015	16.0 a	12.3 b	11.3 c	3.95	*
	(Y6) 2015 - 2016	14.7 a	11.7 b	10.2 c	2.69	*
	Total number of tappings Y1 - Y6	122.7 a	92.1 b	77.3 c	1.20	**
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	17.4 a	14.8 b	11.6 c	2.30	*
	(Y8) 2017 - 2018	19.0 a	13.0 b	11.7 b	5.60	*
	(Y9) 2018 - 2019	19.0 a	14.3 b	12.7 b	5.01	*
	(Y10) 2019 - 2020	26.9 a	19.5 b	18.9 b	5.10	*
	Total number of tappings Y7 - Y10	82.5 a	61.6 b	54.9 c	3.45	*
	Average for 10 years	204.3 a	153.2 b	132.1 c	1.85	**

Note: * = Significant difference of average value among treatments ($p < 0.05$).
** = Significant difference of average value among treatments ($p < 0.01$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Biochemical indicators of latex cell functioning did not show significant differences between the tapping systems. Sucrose loading was sufficient to sustain sucrose content in latex cells under hormonal stimulation (**Table 7**). Sucrose transportation within the latex cells was secured [48]. Inorganic phosphorus content of T2 and T3 did not differ from T1, indicating that latex cell metabolism was controlled by hormonal stimulation to activate rubber biosynthesis, leading to significant yield at each tapping (**Table 8**) and using sucrose in latex metabolism increased efficiency. This indicates that increasing latex yield by increasing metabolic activity (Pi) [49] with ethylene stimulation was not detrimental to the sucrose balance in latex cells. Thiol contents did not display significant differences over the 10-year period on tapping panels BO-1 and BO-2 between treatments (**Table 9**). No physiological stress was developed due to the use of hormonal stimulation [18]. Latex harvesting systems with a lower tapping frequency compensated by a tailored hormonal stimulation were not detrimental to latex cell biochemical parameters. Moreover, metabolic activity of the latex cells was sustained and balanced [3,44]. Latex diagnosis (LD) profiles were logical regarding the observed production [3,18,30,50]. The d4 tapping frequency showed slightly higher Suc and DRC and lower Pi content. Therefore, ethephon stimulation might not be sufficient to achieve cumulative yield higher than the control treatment T1 (S/2 d2 nil stimulation).

Table 7 Average sucrose content over the 10-year tapping period.

Year		Sucrose content (mM)				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	4.95	5.17	4.66	11.42	ns
	(Y2) 2011 - 2012					
	(Y3) 2012 - 2013	11.56 a	8.23 b	8.38 b	4.76	*
	(Y4) 2013 - 2014	14.91	16.32	19.65	14.57	ns
	(Y5) 2014 - 2015	18.80	16.22	16.89	14.12	ns
	(Y6) 2015 - 2016	21.38	19.54	12.08	33.29	ns
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	17.60	14.79	16.20	10.99	ns
	(Y8) 2017 - 2018	8.92	7.54	7.89	47.22	ns
	(Y9) 2018 - 2019	4.01	5.65	3.06	36.00	ns
	(Y10) 2019 - 2020	15.10	13.65	14.95	17.41	ns

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Table 8 Average inorganic phosphorus content over the 10-year tapping period.

Year		Inorganic phosphorus content (mM)				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5 % 6/Y	T3: S/2 d4 ET 2.5 % 8/Y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	6.89 b	12.17 a	14.74 a	10.34	*
	(Y2) 2011 - 2012					
	(Y3) 2012 - 2013	22.74	21.81	22.28	9.43	ns
	(Y4) 2013 - 2014	23.33	29.22	33.85	20.15	ns
	(Y5) 2014 - 2015	29.17	27.86	28.79	17.83	ns
	(Y6) 2015 - 2016	31.82	34.61	39.48	16.74	ns
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	26.42	27.74	29.87	11.53	ns
	(Y8) 2017 - 2018	14.50	13.85	10.03	43.09	ns
	(Y9) 2018 - 2019	7.57	15.67	12.81	27.83	ns
	(Y10) 2019 - 2020	16.28	17.27	17.18	16.18	ns

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Table 9 Average thiol contents over the 10-year tapping period.

	Year	Thiol contents (mM)				
		Tapping system				
		T1: S/2 d2	T2: S/2 d3 ET 2.5% 6/Y	T3: S/2 d4 ET 2.5% 8/Y	C.V.	F-test
Panel 1 BO-1 downward (Y1 - Y6)	(Y1) 2010 - 2011	0.1485	0.2149	0.1799	12.69	ns
	(Y2) 2011 - 2012					
	(Y3) 2012 - 2013	0.2984	0.2720	0.2316	11.24	ns
	(Y4) 2013 - 2014	0.2124 b	0.1924 b	0.2798 a	12.28	*
	(Y5) 2014 - 2015	0.2456	0.2016	0.2512	8.70	ns
	(Y6) 2015 - 2016	0.3004	0.3826	0.4016	10.91	ns
Panel 2 BO-2 downward (Y7 - Y10)	(Y7) 2016 - 2017	0.2947	0.2747	0.2973	7.39	ns
	(Y8) 2017 - 2018	0.4173	0.1053	0.1096	134.58	ns
	(Y9) 2018 - 2019	0.0950	0.1368	0.0862	25.42	ns
	(Y10) 2019 - 2020	0.1781	0.2162	0.1846	7.60	ns

Note: ns = Non-significant difference of average value among treatments ($p > 0.05$).
* = Significant difference of average value among treatments ($p < 0.05$).
Different letters within a column show significant difference of average values among treatments by DMRT ($p < 0.05$).

Conclusions

Reduction in tapping frequency can be compensated by tailored use of ethephon stimulation for clone RRIT 251 even more with +7 % in g/tree over the 10-year period of tapping, when using a d3 tapping frequency in the condition of our experience. The d4 tapping could not completely reach the cumulated yield of the control d2 tapping frequency –8 % in g/tree. Results showed that daily yield greatly increased using lower tapping frequencies. During more than 10 years of tapping, panel management and location of the tapping cut on the panel in downward tapping can significantly affect yield. Tapping on virgin bark using d3 and d4 frequencies gave a more favorable yield than d2 frequency on renewed bark. Good panel management combined with tailored stimulation and reduced tapping frequency showed greater efficiency. Results were encouraging and might support a transfer of technology (TOT) to smallholders in demonstrative plots in Thailand. The clone RRIT 251 is eligible to the low harvesting tapping system, with a tailored use of hormonal stimulation, to increase the daily income of the tappers.

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