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EFFECTS OF MANAGEMENT PRACTICES AND TAPPING SYSTEM ON LATEX AND DRY RUBBER YIELDS OF RUBBER TREE CLONE RRIT 251

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ABSTRACT

The cultivation of *Hevea brasiliensis,* as the main source of natural rubber, is facing the tapping labor shortage and low dry rubber yield problems. Management practices and tapping system could nevertheless remedy these constraints. Accordingly, the study aimed to assess the latex and dry rubber yields of rubber trees clone RRIT 251 under different irrigation with fertilizer management methods and rubber tapping systems. The experiment was laid out in a split-plot design, 4 replications with 3 rubber trees per replication. Two main plot treatments: 1) application of irrigation combined with chemical and organic fertilizers treatment (IF) and; 2) no-irrigation-fertilizer treatment (NIF). Four subplot treatments: 1) (10 cm)S.d/3+ET – tapping 10 cm long of trunk girth (at 45° angle) above an installed bag of ethylene, for 1 day with 2 days interval; 2) (1/2)S.d/2 – tapping half of trunk girth every other day; 3) (1/2)S.2d/3, tapping half of trunk girth for 2 days with 1 day interval (the practice of most para rubber farmers) and; 4) (1/2)S.3d/4, tapping half of trunk girth for 3 days with 1 day interval. The controlled treatment was a combination treatment of NIFx (1/2)S.2d/3. The results showed that both IFx (10 cm)S.d/3+ET and IFx (10 cm)S.d/3+ET combination treatments had significant effects ($P \leq 0.01$) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield higher than the controlled treatment. IF treatment had a significant effect ($P \leq 0.01$) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yields higher than NIF treatment. Rubber tapping system under (1/2)S.3d/4 had a significant effect ($P \leq 0.01$) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield while it was significantly ($P \leq 0.01$) low under (1/2)S.d/2 as compared with the practice used of most farmers—(1/2)S.2d/3. It is concluded that the application of ethylene under IFx (10 cm)S.d/3+ET management is a better innovation and technology attributable to having 45% less time and less bark area consumed for tapping but with increased dry rubber yield, while IFx (1/2)S.2d/3 spent more time to increase the dry rubber yield, as compared with the controlled treatment.

Keywords: Ethylene, Fertilizer, Irrigation, Latex, Rubber

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INTRODUCTION

Rubber trees (*Hevea brasilliensis* Muell. Arg.) are mainly cultivated for latex production (Hytönen *et al.,* 2019). In terms of natural rubber, the world's supply reached 14.05 million tons in 2021. Thailand is the world's number one rubber producer, accounting for 38.2% or 4.76 million tons. Rubber is one of the major economic crops, covering a total harvesting area of 3.51 million hectares with a total rubber production of 4.89 million tons (Office of Agricultural Economics, 2023). Rubber Authority of Thailand (RAOT) developed a primary clone RRIT 251 with promising high yield potential (Susewee, 2001; Chotiphan *et al.,* 2023). By Thai's government policy, the clone RRIT 251 is extended and widely used in the new and replanting rubber plantations in Thailand (RAOT, 2016). The rubber trees clone RRIT 251 had rapid growth with dense canopy, and high latex yield (Susewee, 2001), but it was sensitive to xylem cavitation and water deficit, stomata of RRIT 251 then closed later than other clones (Rattanawong and Lekawipat, 2017). The clone RRIT 251 provided significantly dry rubber yield higher than that of the clone RRIM 600, which is the popular clone grown mostly in Thailand by about 58% (RRIT, 2011). As a result, the old rubber clone RRIM 600 was replaced by the clone RRIT 251 (Nhean *et al.*, 2017). However, the clone RRIM 600 tended to be more tolerant to water stress than the clone RRIT 251 (Sittichai and Sdoodee, 2013). With this reason, the plantation for the clone RRIT 251 should be irrigated to provide sufficient water during the dry season. Nevertheless, most of the growing rubber plantations in Thailand had unfertile soils that considerably affected the latex yield (Plukamphai, 2004). More fertilizer should be applied to the para rubber plantations especially to the mature rubber trees (Song *et al.*, 2022). The clone RRIT 251 was reported to have higher nitrogen use efficiency than that of the clone RRIM 600. The nitrogen cost of the clone RRIT 251 rubber tree was then lower than the clone RRIM 600 (Thitithanakul *et al.*, 2017). In the three years of tapping, the yields of both clones, RRIT 251 and PB 235, increased by 62% and 27% in comparison with the clone RRIM 600 (Chantuma *et al.*, 2019). Modern rubber farmers stimulate the trees with ethylene gas, which increases the latex yield of the 10-year-old trees or older (Lacote *et al.*, 2010). Latex is a cellular fluid consisting of a suspension of rubber hydrocarbon particles, represented by the formula ($C_5 H_8$)$_n$, in an aqueous medium (Varghese and Abraham, 2005). The rubber content of latex is a secondary metabolite in the rubber tree produced in the cytoplasm of highly specialized cells called laticifers located in the phloem, and the latex flows out when the rubber tree bark is tapped (Tungngoen *et al.*, 2011; An *et al.*, 2014). In terms of rubber plantation management practices to the rubber latex extraction, most farmers (76%) used the rubber tapping system with (1/2)S.2d/3, then followed by (1/2)S.3d/4 (20%), and others (4%) (Wiangsamut *et al.*, 2014). This indicated that the reported rubber tapping methods by the farmers was not in accordance with the Rubber Research Institute of Thailand (RRIT, 2011), which indicated that the recommended rubber tapping system for a rubber clone RRIT 251 was in the (1/2)S.d/2 and trees should not be tapped frequently due to an increase of tapping panel dryness (TPD). The TPD often occurs and virgin bark for tapping is over utilized (Michels *et al.*, 2012); consequently, produces short lifespans and rubber trees were cut down and replanted more often, reducing the income per planting cycle (Chantuma *et al.*, 2011, 2015). Low frequency tapping systems could then resolve these problems (Kudaligama *et al.*, 2010; Prasanna *et al.*, 2010; Atsin *et al.*, 2014; Soumahin *et al.*, 2020) while increasing the duration of the tapping on virgin bark. Low frequency tapping systems combine reduced tapping frequency with ethephon hormonal stimulation to improve yield at each tapping was introduced (Abraham *et al.*, 1968; Pakianatan *et al.*, 1976; d'Auzac *et al.*, 1997). These management practices have led to higher yield per tapping that compensates for the reduction in tapping frequency (Njukeng and Gobina, 2007a; Njukeng *et al.*, 2011c; Traore *et al.*, 2011; Samila *et al.*, 2017; Lacote *et al.*, 2019). In addition, Pushparajah and Haridas (1977) reported that the irrigation supply promoted rapid growth of the para rubber trees during the dry season. Wiangsamut *et al.* (2014) cited that rubber farmers in Chanthaburi province at the Eastern region of Thailand produced the high-quality rubber and processed rubber products, but are still encountering low rubber production per unit area. They furthermore reported that the agricultural practices with the inadequate water supply, lateritic soil, insufficient fertilizer application including improper tapping technique caused low latex production. Ethylene gaseous stimulation was also introduced to use in the process of rubber tapping to increase the latex production (Sinthurahat *et al.*, 1999). In addition, more rubber tappings are performed in the dry season than in the wet season, but with low soil moisture content as soil dries up day-to-day due to the rainless weather. The effects of irrigation combined with fertilizer, ethylene gas, and tapping system on latex and dry rubber yields of rubber tree clone RRIT 251, however, has remained unknown. Hence, the current research aimed to assess the latex and dry rubber yields of rubber tree clone RRIT 251 under different irrigation with fertilizer management methods as well as its rubber tapping systems.

MATERIALS AND METHODS

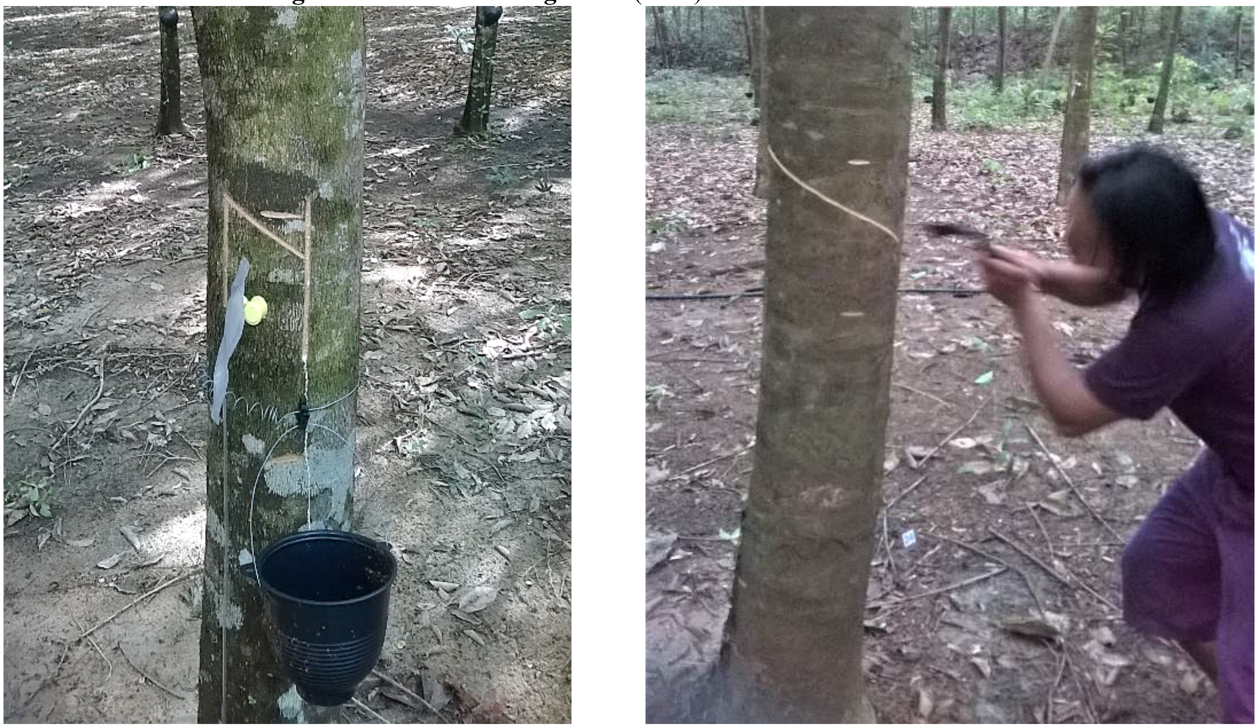
The experiment was conducted at a para rubber research plantation with 49 meters sea level elevation, at the Department of Crop Production and Landscape Technology, Faculty of Agro-Industrial Technology, Rajamangala University of Technology Tawan-ok Chanthaburi Campus in Chanthaburi, Thailand during the dry season period of a 3-year continuous experiments, from 2014 to 2017. However, the data gathered only derived from the last year's experiment, which consisted of 175 days, or from November 21, 2016 to May 14, 2017. The precipitation in November-December of 2016 and January-May 14, 2017 was low at 87.5, 2.1, 60.5, 7.1, 94.2, 110.4, and 121.7 mm, respectively. The relative humidity ranged from 73-88% at this dry season period. Temperature at day ranged from 34.5-35.7 °C while at night, it ranged from 16.6-23.0 °C. The rubber plantation had a sandy loam soil with pH 6.58, electrical conductivity of 0.11 mS/cm, organic matter of 2.19%, 107.84 mg P kg^{-1}, 139.98 mg K kg^{-1}, 1146.68 mg Ca kg^{-1}, and 54.35 mg Mg kg^{-1} (OARDR, 2016). No rubber tapping was made during the wet season. The plantation experiments were laid out in a split-plot design;

replicated 4 times with 3 para rubber trees per replication. There was a total of 96 para rubber trees of clone RRIT 251 used; 10-year-old trees with plant spacing of 3 m x 7 m, 65.1 cm in average trunk girth measured at 150 cm high from the ground. Two irrigation-fertilizer management (IFM) methods occupied the main plot treatments: 1) application of irrigation combined with chemical and organic fertilizers treatment, symbolized as IF and; 2) no irrigation-fertilizer treatment as a farmer's practice, symbolized as NIF. In the irrigation-fertilizer management plantations, each fertilizer basket (with spacing of 60 cm) was placed in the prepared hole in between rows of rubber trees (Figure 1). A drip irrigation head was placed on top of each fertilizer basket for irrigation supply. The chemical fertilizer formula of 18-5-30 [or 18% N-5% P_2O_5-30% K_2O was based on soil analysis done by the Office of the Agricultural Research and Development in Region 6 (2016)], was first applied on November 21, 2016 at the rate of 1000 grams (g) per tree per year—200 g were placed in a basket and 800 g were sown between baskets under the tree canopy. Simultaneously, organic chicken manure pellets were applied on the same day at the rate of 1000 g per tree per year—100 g were placed in a basket while 900 g were sown in between baskets under the tree canopy. Drip irrigation system was automatically supplied every day from 0800H-1600H (8 hours) for the entire dry season period.

The subplot treatments were the four rubber tapping systems (RTS): 1) tapping 10 cm long of trunk girth (at 45° angle) above an installed bag of ethylene (99.99%), for 1 day with 2 days interval [(10 cm)S.d/3+ET] as shown in Figure 2a; 2) tapping half of trunk girth every other day [(1/2)S.d/2]; 3) tapping half of trunk girth for 2 consecutive days with 1 day interval [(1/2)S.2d/3], which has been the practice of most farmers in rubber tapping system and; 4) tapping half of trunk girth for 3 consecutive days with 1 day interval [(1/2)S.3d/4]; remaining 3 RTS are shown in Figure 2b. Tapping was stopped on rainy days to prevent disease infection on the tapped stem surfaces during the dry season period. A combination treatment of NIFx(1/2)S.2d/3 was assigned to be the controlled treatment. The combination treatments of the irrigation-fertilizer management method and rubber tapping system are presented in Table 1. Data of para rubber parameters was gathered as follows: latex weight per tree (kg), dry rubber weight per tree (kg), latex yield (kg ha^{-1}), dry rubber yield (kg ha^{-1}), including the number of rubbers tapping per year in a unit of frequency (times).

All parameters were statistically analyzed through Statistix 7 (SXW) software. Means comparisons were performed using the Duncan's multiple range test at the 0.01 probability level. Relationships among all para rubber tree parameters were established through correlation analysis.

Figure 1. The prepared holes, with 60 cm spacing, in between rows of rubber trees for placement of fertilizer baskets for the irrigation-fertilizer management (IFM)



a B

Figure 2. Four rubber tapping systems as subplot treatments: a) [(10cm)S.d/3+ ET] and; b) [(1/2)S.d/2], [(1/2)S.2d/3], [(1/2)S.3d/4]

Table 1. Eight combination treatments of the irrigation-fertilizer management method and rubber tapping system.

Irrigation-fertilizer management method (IFM)	Rubber tapping system (RTS)			
	(10cm)S.d/3+ET	**(1/2)S.d/2**	**(1/2)S.2d/3**	**(1/2)S.3d/4**
IF	IFx(10cm)S.d/3+ET	IFx(1/2)S.d/2	IFx(1/2)S.2d/3	IFx(1/2)S.3d/4
NIF	NIFx(10cm)S.d/3+ET	NIFx(1/2)S.d/2	NIFx(1/2)S.2d/3	NIFx(1/2)S.3d/4

IF: application of irrigation combined with chemical and organic fertilizers treatment, NIF: no-irrigation-fertilizer treatment is a farmer's practice, (10cm)S.d/3+ET: tapping 10 cm long of trunk girth (at 45° angle) above an installed bag of ethylene (99.99%) for 1 day with 2 days interval, (1/2)S.d/2: tapping half of trunk girth every other day, (1/2)S.2d/3: tapping half of trunk girth for 2 consecutive days with 1 day interval, (1/2)S.3d/4: tapping half of trunk girth for 3 consecutive days with 1 day interval.

RESULTS

Overall, the application of irrigation combined with fertilizer and rubber tapping system with ethylene gas under IFx (10 cm)S.d/3+ET with the least frequency of rubber tapping per year (50 times) but consumed less bark area for tapping, and IFx (1/2)S.2d/3 with the most frequent rubber tapping per year (106 times) but consumed more bark area for tapping had a significant effect ($P \leq 0.01$) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield—higher than the controlled treatment under NIFx (1/2) S.2d/3 (Tables 2-6, respectively). With these results, IFx (10 cm) S.d/3+ ET had 45% less time consumption with increasing dry rubber yield of 10%; however, IFx (1/2)S.2d/3 spent 10% more time but with 16% increase of dry rubber yield, as compared with the controlled treatment. There were low values of latex weight per tree, dry rubber weight per tree, latex yield and dry rubber yield under NIFx(10cm) S.d/3+ ET, IFx(1/2)S.d/2 and NIFx(1/2)S.d/2, while there was no significant effect ($P>0.01$) of the irrigation-fertilizer management method and rubber tapping system on both IFx(1/2)S.2d/3 and NIFx(1/2)S.3d/4, as compared with the controlled treatment.

Regardless of rubber tapping system, the application of irrigation combined with fertilizer (IF) treatment had a significant effect ($P \leq 0.01$) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield which was higher than no irrigation-fertilizer (NIF) treatment (a farmer's practice) (Tables 2-5, respectively).

Table 2. Latex weight per tree (kg) influenced by different rubber tapping systems with and without irrigation and fertilizer application.

Irrigation-fertilizer management Method (IFM)	Rubber tapping system (RTS)				Mean[/2]
	(10 cm)S.d/3+ET	(1/2)S.d/2	(1/2)S.2d/3	(1/2)S.3d/4	
IF	17.39a[/1]	13.36c	15.21b	18.11a	16.02a
NIF	14.82b	10.41d	15.26b	15.45b	13.99b
Mean[/3]	16.11b	11.88d	15.24c	16.78a	

[1/] In the table of IFM x RTS means with not-the-same letter is significantly different (P≤0.01), [2/] in the column of IFM means with not-the-same letter is significantly different (P≤0.01), [3/] in the row of RTS means with not-the-same letter is significantly different (P≤0.01).

Table 3. Dry rubber weight per tree (kg) influenced by different rubber tapping systems with and without irrigation and fertilizer application.

Irrigation-fertilizer management method (IFM)	Rubber tapping system (RTS)				Mean[/2]
	(10 cm)S.d/3+ET	(1/2)S.d/2	(1/2)S.2d/3	(1/2)S.3d/4	
IF	6.95ab[/1]	5.99cd	6.51bc	7.32a	6.69a
NIF	5.55d	5.57d	6.33bc	6.35bc	5.95b
Mean[/3]	6.25b	5.78c	6.42b	6.84a	

[1/] In the table of IFM x RTS means with not-the-same letter is significantly different (P≤0.01), [2/] in the column of IFM means with not-the-same letter is significantly different (P≤0.01), [3/] in the row of RTS means with not-the-same letter is significantly different (P≤0.01)

Table 4. Latex yield (kg ha^{-1}) influenced by different rubber tapping systems with and without irrigation and fertilizer application.

Irrigation-fertilizer management method (IFM)	Rubber tapping system (RTS)				Mean[/2]
	(10cm)S.d/3+ET	(1/2)S.d/2	(1/2)S.2d/3	(1/2)S.3d/4	
IF	8,259.4a[/1]	6,346.9c	7,223.8b	8,601.9a	7,608.0a
NIF	7,041.3b	4,941.9d	7,248.0b	7,340.0b	6,643.0b
Mean[/3]	7,650.4b	5,644.4d	7,236.3c	7,971.0a	

[1/] In the table of IFM x RTS means with not-the-same letter is significantly different (P≤0.01), [2/] in the column of IFM means with not-the-same letter is significantly different (P≤0.01), [3/] in the row of RTS means with not-the-same letter is significantly different (P≤0.01)

Table 5. Dry rubber yield (kg ha^{-1}) influenced by different rubber tapping systems with and without irrigation and fertilizer application.

Irrigation-fertilizer management method (IFM)	Rubber tapping system (RTS)				Mean[/2]
	(10cm)S.d/3+ET	(1/2)S.d/2	(1/2)S.2d/3	(1/2)S.3d/4	
IF	3,301.25ab[/1]	2,845.38cd	3,092.63bc	3,475.31a	3,178.64a
NIF	2,635.38d	2,643.00d	3,005.63bc	3,017.56bc	2,825.39b
Mean[/3]	2,968.32b	2,744.19c	3,049.13b	3,246.44a	

[1/] In the table of IFM x RTS means with not-the-same letter is significantly different (P≤0.01), [2/] in the column of IFM means with not-the-same letter is significantly different (P≤0.01), [3/] in the row of RTS means with not-the-same letter is significantly different (P≤0.01)

Regardless of irrigation-fertilizer management method, the rubber tapping system under (1/2)S.3d/4 had a significant effect (P≤ 0.01) in enhancing latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield which was higher than under (1/2)S.2d/3, the practice of most farmers as a result of more frequent rubber tapping per year. On the other hand, lesser rubber tapping per year under (1/2) S. d/2 resulted in a significantly (P≤0.01) lower latex weight per tree, lower dry rubber weight per tree, lower latex yield, and lower dry rubber yield than under (1/2) S.2d/3 (Tables 2-6, respectively). Through correlation analysis, latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield significantly increased and positively correlated with the number of rubber tapping per year except those values under the application of ethylene treatment, (10 cm) S.d/3+ ET. The result of the least frequent rubber tapping per year with the application of ethylene treatment contributed to having significant latex weight per tree (P≤ 0.01) and latex yield higher than those under (1/2)S.2d/3, but its dry rubber was slightly lower as ethylene gas extracted more amount of water from the trees measured by the latex weight per tree, latex yield, dry rubber weight per tree, and dry rubber yield (Tables 2, 3, 4, 5, 6, and 7, respectively).

Table 6. Number of rubber tapping per year (times) influenced by different rubber tapping systems with and without irrigation and fertilizer application.

Irrigation-fertilizer management method (IFM)	Rubber tapping system (RTS)				Mean[2]
	(10cm)S.d/3+ET	(1/2)S.d/2	(1/2)S.2d/3	(1/2)S.3d/4	
IF	50[1]	71	95	106	81
NIF	50	71	95	106	81
Mean[3]	50	71	95	106	

[1] In the table of IFM x RTS means, [2] in the column of IFM means, [3] in the row of RTS means

Table 7. Relationships of number of rubber tapping per year, latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield.

	Dry rubber yield	Dry rubber weight per tree	Latex yield	Latex weight per tree
Dry rubber weight per tree	r =1.00[1]			
Latex yield	r =0.81	r =0.81		
Latex weight per tree	r =0.81	r =0.81	r =1.00	
Number of rubber tapping per year	r =0.41	r =0.41	r =0.23	r =0.23

[1] r is correlation coefficient (all values in the table are positive correlation coefficient)

DISCUSSION

The application of ethylene gas under IFx(10cm) S.d/3+ ET combination treatment to extract latex from para rubber trees clone RRIT 251 had less time consumption and obtained significant latex weight per tree (17.39 kg), dry rubber weight per tree (6.95 kg), latex yield (8,259.4 kg ha^{-1}), and dry rubber yield (3,301.25 kg ha^{-1}), which was higher than the controlled treatment (15.26 kg, 6.33 kg, 7,248 kg ha^{-1}, and 3,005.63 kg ha^{-1}, respectively). The number of times consumed in rubber tapping depends upon the taping system used— the least frequent rubber tapping per year (50 times) was under the application of ethylene gas (10 cm)S.d/3+ET tapping system, as compared with the rest of treatments. This was agreed by Chotiphan *et al*. (2023) who reported that daily latex yield of 8-year-old rubber trees of the clone RRIT 251 greatly increased when using lower frequency tapping on renewed bark. Good panel management combined with tailored stimulation and reduced frequency tapping showed greater efficiency. Soumahin *et al*. (2020) similarly narrated that low intensity tapping systems do not adversely affect the growth and physiological profile of trees instead they reduce the rate of tapping panel dryness. All tapping systems are profitable. Low intensity tapping systems reduced the need for tappers and thus, make up for a deficit and/or a high cost of tapping labour. Chantuma *et al.* (2011) further added that high frequency tapping system was just implemented to enhance harvesting i.e. daily tapping (d1), two days out of three (2d/3), and three days out of four (3d/4). But this high frequency tapping system affected time of latex regeneration and the growth life cycles of rubber trees due to the increase of tapping panel dryness (Obouayeba *et al.*, 2011). The tapping system of (10 cm)S.d/3+ET had the lowest frequency in rubber tapping as ET (ethylene gas) increased the duration of latex flow after tapping and its bark consumption was appreciably less than the other treatments. The tapping system of (10 cm)S.d/3+ET also decreased the duration of tapping for about 29% , 47% , and 50% compared with those tapping systems of (1/2)S.d/2, (1/2)S.2d/3, and (1/2)S.3d/4, respectively. The latex weight per tree, latex yield, dry rubber weight per tree, and dry rubber yield were not significantly (P>0.01) affected by ethylene gaseous stimulation compared with the conventional tapping system [(1/2)S.2d/3]. Ethylene stimulation increases the rubber latex yield of live rubberwood (*Hevea brasiliensis*) (Cherdchim and Satansat, 2016) and the latex production of young-tapping rubber tree was also increased by ethylene stimulation (Sainoi and Sdoodee, 2012) . Gohet *et al.* (1995) explained that the ethylene stimulation effect may vary with rubber tree clones. Studies showed that the ethylene released by ethephon increases the duration of latex flow after tapping by activating latex cell metabolism (Pakianatan *et al.*, 1976; Jacob *et al.*, 1989; d'Auzac *et al.*, 1997). Rukkhun *et al.* (2021) cited that ethylene stimulation in young-tapping rubber tree provided significantly highest averaged latex yield per tapping. d' Auzac (1989) further corresponded that ethylene reaction happened at the inner bark of the rubber trees to increase pressure and elasticity of laticiferous cell and consequently delayed the latex coagulation. Sivakumaran and Chong (1994) , Sivakumaran (2002) , Jetro and Simon (2007), Lacote *et al.*(2010), Njukeng *et al.* (2011b), Traore *et al.* (2011) collectively reported that the 2-chloroethylphosphonic acid (Ethephon or Ethrel) used as the chemical stimulants to enhance latex yield by increasing the duration of latex flow after tapping, reduced tapping frequency and increased land productivity. Hence, the application of ethylene gas under IFx(10cm)S.d/3+ET was considered to be a better innovation and technology in managing the farmers' rubber plantations than in IFx (1/2)S.3d/4 mainly due to the considerable decrease in the frequency of rubber tapping per year with increasing latex weight per tree, latex yield, dry rubber weight per tree, and dry rubber yield. Sinthurahat *et al.* (1999) supported the use of 2.5% ethephon together with the (1/2)S.d/2 tapping system which resulted in the increase of latex yield clone RRIM 600 compared with the other rubber tapping systems. The irrigation-fertilizer management method (IF) significantly improved latex and dry rubber weights of RRIT 251 better than the no-irrigation-fertilizer management method (NIF) . Due to the fact that the rubber trees under IF absorbed adequate water and nutrients (irrigation-fertilizer) based on their requirements, it resulted in a good tree growth in terms of latex weight, dry rubber weight, latex yield, and dry rubber yield. Accordingly, Vijayakumar *et al.* (1998) revealed that relieving of soil moisture stress by adequate irrigation can lead to better growth performance in the dry season than in the wet season. An adequate water supply eliminated foliar injury, increased leaf photosynthesis; consequently, the rubber trees are ready for tapping. Sdoodee *et al.* (2010) concurred that the new leaves of 12-year-old rubber trees rapidly emerged as adequate water was supplied which resulted in a slight increase of trunk girth. Likewise, Mak *et al.* (2008) found out that it significantly increased in trunk girth for the 8-year-old rubber trees. Rao *et al.* (1998) claimed that rubber trees are not irrigated during the dry season as the water table level continuously decreased, the soil moisture also decreased, and consequently slowed down the latex flow, thereby low latex yield. Mak *et al*. (2008) added that irrigation treatment increased the yield per tree per tapping, monthly production, and total rubber production per year. However, the percentage of dry rubber content (DRC) under no-irrigation was higher than those under irrigation treatment. Percentage of DRC was negatively correlated with both rubber yield and latex yield only under no-irrigation treatments. Total solid content and sucrose were not affected by irrigation and fertilizer treatments. In the irrigated plot, inorganic phosphate increased slightly higher than those of no-irrigation but the value was not significantly different among others. Girth of rubber increased as the result of irrigation application while percentage of tapping panel dryness under no-irrigation treatment was higher than with irrigation treatment. Nevertheless, there were no tapping panel dryness and disease infection on the tapped stem surface observed on the 8-10 years old para rubber trees clone RRIT 251 under all irrigation-fertilizer management methods and all rubber tapping systems for the entire 3-year continuous experiment periods, from 2014 to 2017. In the Northeastern Region of Thailand, Mangmeechai (2020) reported that the water requirement of rubber trees was 14,221 m^3 ha^{-1} $year^{-1}$, which was higher than that of other local crops (e.g., rice, sugarcane, corn, and cassava) during the dry season. Accordingly, Nakviroj *et al.* (2007) agreed that the chemical fertilizer containing 3 important nutrients (N, P, and K) applied together with manure resulted in the increase of cassava yield with 56.4% compared with the application of chemical fertilizer containing only 3 important nutrients. In the same way that Chaichuay *et al.* (2013) adduced the significantly highest plant growth and a high yield quality of the emperor banana was obtained as a result of chicken manure applied together with chemical fertilizer treatment compared with non-fertilizer treatment. Organic fertilizer applied together with chemical fertilizer increased the highest cassava yield due to the organic fertilizer released the micronutrients to the plants, consequently the cassava plants grew bigger (Wargiono and Ispandi, 2007). In like manner that Nakviroj *et al*. (2007) acknowledged the application of complete chemical fertilizers of N, P, and K with an additional 12.5 t ha^{-1} of mulniciple compost, or with about 18.75 t ha^{-1} of incorporated cassava stalks (leaves and stems), resulted in the best growth and highest cassava root yields of 30-50 t ha^{-1}, which is considerably higher than the yield of 20-30 t ha^{-1} obtained with only complete chemical fertilizers. Ginting *et al*. (2023) has proven that younger than 20-year-old rubber trees increase of latex and dry rubber yield significantly were given nutrient solution by injection without dilution of nutrient solution, by infusion with the dilution of nutrient solution at 20 ml L^{-1}, and by no-application of nutrient solution. The heights of the infusion on the trunk at 50 cm from the ground with the dilution of nutrient solution at 10 ml L^{-1} gave the effect on the highest latex and dry rubber yield. The concentrate of 20 ml L^{-1} nutrient solution in infusion application on the trunk of tapping panel dryness gave the effect on higher latex yield than normal rubber tree of the older than 20-year-old rubber trees. Backhaus (2013) and Asawatreratanakul *et al*. (2003) confirmed that the para rubber tree is cultivated for its latex; optimum latex production, therefore, is of utmost importance to plantation producers as it constitutes the main source of revenue and it is currently the only economically viable source of natural rubber. This natural rubber is widely used in industries attributable to its good yield of rubber and the excellent physical properties of its rubber products.

Conclusion: Results indicated that IFx (10 cm)S.d/3+ET and IFx (10 cm)S.d/3+ET had significantly enhanced the latex weight per tree, dry rubber weight per tree, latex yield, and dry rubber yield. However, the application of ethylene under IFx (10 cm)S.d/3+ET management was therefore a better innovation and technology than IFx (1/2)S.2d/3 due to having 45% less time and less bark area consumption for tapping with increasing dry rubber yield. Therefore, it is suggested that IFx (10 cm)S.d/3+ET [or tapping 10 cm long of trunk girth (at 45° angle) above an installed bag of ethylene (99.99%) for 1 day with 2 days interval] was the most appropriate management practices that can be adopted to be a guideline for farmers who grow rubber trees clone RRIT 251 under rubber price fluctuation and tapping labor shortage in Thailand.

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