Latex Diagnosis at the Whole Trunk Level under Different Tapping Systems in Young-tapping Rubber Trees

Raweerat Rukkhun[1], Nuttapon Khongdee[2], Kesinee Iamsaard[3], Nipon Mawan[4], Thongchai Sainoi[5], Sayan Sdoodee[1]

10.18805/IJARe.A-592

ABSTRACT

Background: Numerous rubbers tapping systems have been developed to increase latex yield. The objectives were (i) to test the efficiency of stimulation tapping systems and (ii) to describe the sucrose balance between supply and demand in the latex-producing bark of the rubber tree.

Methods: The experiment was conducted at Thepa Research Station in Songkhla province. Eleven-year-old of RRIM600 clone was investigated. The experiment was designed as One Tree Plot Design (OTPD) with 4 tapping systems (Treatment; T) and 4 replications. Treatments were T1: S/3 2d/3, T2: S/6 d3, T3: S/6 d3 with RRIMFLOW and T4: S/6 d3 with LET.

Result: S/6 d3 with RRIMFLOW tapping system in young-tapping rubber tree provided significantly highest averaged latex yield per tapping. The average cumulative latex yield was no significant difference comparing with the traditional tapping system. Rubber girth increment had no significant difference among treatments (P>0.05). An averaged sucrose distribution in the trunk level of none stimulation treatments were high to very high sucrose values; however, it was medium sucrose values in the stimulation treatments. Inorganic phosphorus distribution in the trunk level showed medium to high values. Hence, the finding indicated that the use of ethylene stimulation together with tapping system should be considered for rubber tree and to control the balance of sucrose content in the trunk level of rubber tree.

Key words: *Hevea brasiliensis*, Inorganic phosphorus, Latex yield, Sucrose content, Tapping systems.

INTRODUCTION

Rubber tree (*Hevea brasiliensis* Muell. Arg.) is one of the significant economic crops of Thailand. Rubber tree has been traditionally grown in the south of Thailand, where most of the planting area has a humid condition. Rubber production has a substantial impact on the rural economy and rural poverty because producers are mainly smallholder farmers who account for more than 85% of the total area of rubber plantation in Thailand (Chantuma *et al.*, 2011). Usually, the rubber needs approximately 6 years to be able to start a latex tapping. However, traditional rubber tapping method could not maximize the latex yield potential and thereafter, farmers receive such unsatisfied latex yield. Therefore, numerous tapping systems have been developed to increase tapping capacity (Sainoi and Sdodee, 2012).

Leconte *et al.* (2006) revealed that Thai smallholder farmers use ethylene or ethephon stimulation to increase latex tapping potential. The chemical stimulants have been used to enhance latex yield by increasing the duration of latex flow after tapping, reduced tapping frequency and increased land or labour productivity (Sivakumaran and Chong, 1994; Sivakumaran, 2002; Jetro and Simon, 2007; Lacote *et al.,* 2010; Njukeng *et al.,* 2011; Traore *et al*., 2011). In addition, ethylene reaction at the inner bark, increased pressure and elasticity of laticiferous cell, decreased the coagulate of latex. Recently, the RRIMFLOW and LET equipment have been commercially adopted by rubber smallholders in Thailand. The RRIMFLOW system could enhance latex yield and increase the income of tappers around two to three-fold but it has not widely known due to data limitation presented on this aspect in various publications about the RRIMFLOW system (Sivakumaran 2002; Sivakumaran *et al.,* 2007 referred by Sainoi and Sdoodee, 2012).

Rubber growth and yield production require assimilates from photosynthesis, mainly in the form of sucrose. A bark area where the rapid movement of latex near the region of the tapping cut could occur “a potential displacement area”.

[1]Agricultural Innovation and Management Division (Plant Science), Faculty of Natural Resources, Prince of Songkla University, Hat Yai, Songkhla 90112, Thailand.
[2]Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany.
[3]Department of Soil and Environmental Sciences, National Chung Hsing University, Taichung, Taiwan.
[4]Department of Agronomy, Faculty of Agriculture, Khon Kaen University, Khon Kaen, 40002, Thailand.
[5]Horticulture Research Institute, Lat Yao, Chatuchak, Bangkok 10900, Thailand.

Corresponding Author: Nuttapon Khongdee, Institute of Agricultural Sciences in the Tropics (Hans-Ruthenberg-Institute), University of Hohenheim, Stuttgart, Germany. Email: nuttaponkhongdee@gmail.com

How to cite this article: Rukkhun, R., Khongdee, N., Iamsaard, K., Mawan, N., Sainoi, T. and Sdoodee, S. (2021). Latex Diagnosis at the Whole Trunk Level under Different Tapping Systems in Young-tapping Rubber Trees. Indian Journal of Agricultural Research. 55(1): 59-66. DOI: 10.18805/IJARe.A-592.

Submitted: 24-08-2020 **Accepted:** 26-11-2020 **Online:** 28-01-2021

Chantuma *et al.* (2006) reported that sucrose content was depleted below and above the tapping cut as a consequence of latex regeneration process. Nevertheless, none of these works concurrently described the sucrose balance at the rubber trunk level (Pakianathan *et al.* 1975; Tupy, 1973; Silpi *et al.* 2001 referred by Chantuma *et al.* 2006). Therefore, the aims of the present study were (i) to test the efficiency of stimulation tapping systems improving the latex yield per tree and (ii) to describe the sucrose balance between supply and demand in the latex-producing bark of the rubber tree. In this study, Ethylene gaseous stimulation was applied to study the influence on sucrose content for the latex regeneration under the different tapping systems.

MATERIALS AND METHODS

A two-year experiment (2012 and 2013) was carried out at the Thepa Research Station, Prince of Songkla University, Thailand, which is favourable for rubber cultivation (Fig 1a). The rubber trees clone RRIM 600 were planted in 2001 with the tree spacing of 7 × 3 m. At the measuring period, the averaged trunk girth at 1.70 m above ground was around 50.1 cm. The soil property at the test site was characterized as Coated, isohyperthermic, Typic Quartzipsamments. Soil texture was a sandy loam with pH 5.5. The experimental design was "One Tree Plot Design" (OTPD) comprising 4 replicates per treatment. There were four treatments (T1-T4) which modified from Vijayakumar *et al.* 2009 and Sopchoke, 2010 as follows: T1 = S/3 2d/3 (1/3 spiral downward cut at two days tapped by one day rest), T2 = S/6 d3 (1/6 spiral downward cut at every three days tapped), T3 = S/6 d3 ETG99% RRIMFLOW-60- 36/y (9d), (1/6 spiral downward cut at every three days tapped; stimulated by Ethylene gas of 99% RRIMFLOW system active quantity with 60 ml, 36 applications per year at 9-day interval), T4 = S/6 3d. ETG60% LET -40- 48/y (6d) (1/6 spiral downward cut at every three days tapped; stimulated by Ethylene gas of 60% LET system active quantity with 40 ml, 48 applications per year at 6-day interval).

The installation positions of RRIMFLOW and LET equipment were followed the commercial recommendation. The layout of the tapping panel is shown in Fig 1b. The latex yield was collected from the cup lumps, which later used to determine dry rubber production in gram per tree per tapping (g tree^{-1} tapping^{-1}) and kilogram per tree (kg tree^{-1}). The other parameters of girth increment (measured at 1.70 m height above ground). Latex diagnosis was carried out from October 2012 to July 2013 to determine sucrose and inorganic phosphorus content as followed Gohet and Chantuma, (1999).

This experiment was comparing between 3 tapping panels in one tree including panel A, B and C and 6 tapping panelsin one tree including panel A, B, C, D, E and F. Rubber latex was sampled from each tapping panel starting from 15 cm from the ground to 3 meters of rubber tree height. Sampling points were every 15 cm height of each tapping panel as followed by Chantuma *et al*. (2006) (Fig 1b). Fig 1b shows only an example layout for 3 tapping panels; however, 6 tapping panels is also a similar concept. On each rubber tree, ten latex drops were collected from each sampling position to measure latex sucrose (Suc) and inorganic phosphorus (Pi), using latex diagnosis (LD) technique as the method described by Gohet and Chantuma, (1999). Pi is an indicator of latex metabolic activity and Suc is precursor molecule of the latex rubber synthesis were presented and discussed hereafter.

Growth and latex yield of rubber were statistically analyzed by ANOVA. Least Significant Different Test (LSD) was used to perform differences among treatments at $P \leq 0.01$ and $P \leq 0.05$.

RESULTS AND DISCUSSION

Rubber production

The averaged rubber production (g tree^{-1}tapping^{-1}) showed significantly differences among the four treatments, as shown in Table 1. T3 provided the highest average rubber production (113.29 g tree^{1} tapping^{-1}). While, T2 expressed lower averaged rubber production (48.15 g tree^{-1} tapping^{-1}) than the other treatments (T1, T3 and T4). In addition, averaged rubber production under the ethylene gaseous stimulation treatments in RRIMFLOW (T3) and LET (T4) were significantly higher than non-ethylene gaseous stimulation treatments (T1 and T2) (Table 1).

It was evidentially that the cumulative rubber production (kg tree^{-1}) were significantly different among the four treatments ($P<0.05$) (Table 2). The T3 treatment provided

Table 1: Comparison of average rubber production (g tree^{-1} tapping^{-1}) of rubber trees in the four treatments.

Treatment	Average rubber production (g tree^{-1} tapping^{-1})
T1: S/3 2d/3	53.60^{b}
T2: S/6 d3	48.15^{b}
T3: S/6 d3. ETG99% RRIMFLOW -60- 36/y (9d)	113.29^{a}
T4: S/6 d3. ETG60% LET -40- 48/y (6d)	97.79^{a}
F-Test	**
C.V. (%)	29.23

** = Significant difference at $P \leq 0.01$. Means with different letters in the same column indicate significant difference, DMRT.

Table 2: Comparison of cumulative rubber production (kg tree^{-1}) of rubber trees in the four treatments.

Treatment	Cumulative rubber production (kg tree^{-1})
T1: S/3 2d/3	3.06^{a}
T2: S/6 d3	1.69^{b}
T3: S/6 d3. ETG99% RRIMFLOW -60- 36/y (9d)	3.97^{a}
T4: S/6 d3. ETG60% LET -40- 48/y (6d)	3.42^{a}
F-Test	**
C.V. (%)	23.22

** = Significant difference at $P \leq 0.01$. Means with different letters in the same column indicate significant difference, DMRT.

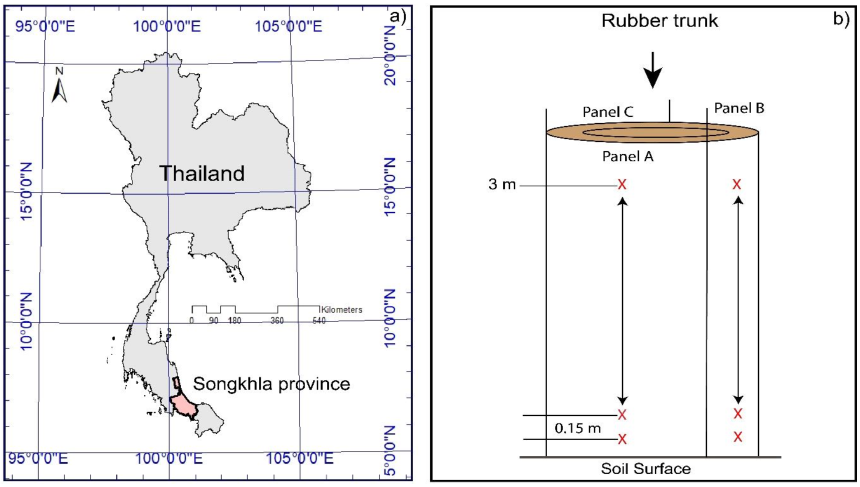

Fig 1: Experimental location and layout of tapping panels.

Note: Rubber trunk is divided into 3 tapping panels including panel A, B and C around a tree. X represent latex sampling points for sucrose and phosphorus contents. Sampling points are collected from 0.15 m to 3 meters.

the highest cumulative rubber production (3.97kg tree^{-1}). However, the tapping system (T3 and T4) expressed non-significant difference of the averaged rubber production from the conventional tapping system (T1).

The ethylene gaseous stimulation treatments (RRIMFLOW and LET) provided more rubber latex production per tapping than the conventional tapping (none stimulation). This is because the ethylene could increase the latex yield by 1.5 to 2 folds in rubber tree, leading to improving the supply of carbon source (such as Acetyl coenzyme A) for rubber biosynthesis (Yeang, 2005; Zhu and Zhang, 2009). In addition, Sainoi and Sdoodee, (2002) indicated that latex production of young-tapping rubber tree was increased by ethylene stimulation.

Rubber growth

There was no significant difference between girth increment among the four treatments (Fig 2). Ethylene did not affect the growth rates of tapped trees (Silpi *et al.* 2006) and ethephon concentrations had no adverse effects on rubber tree health (Prasanna *et al.* 2010).

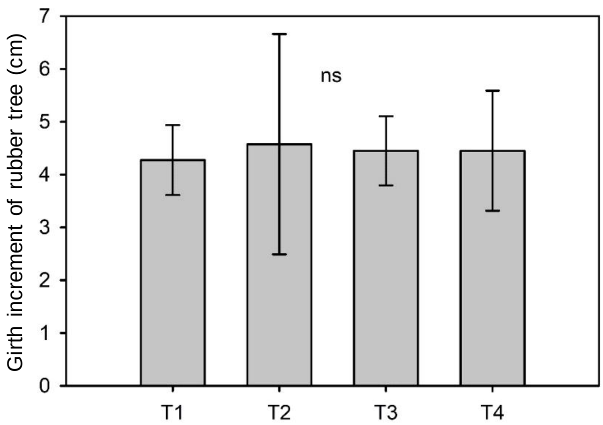

Fig 2: Girth increment of rubber tree.

Note: ns = non-significant differences $P \leq 0.05$, Bars = Standard error.

The sucrose content distribution along the trunk

The latex metabolic status within the rubber trunk was evaluated by comparing sucrose (Suc, mM.l^{-1}) values measured in each sampling position. By comparing 3 and 6 tapping panels within a tree, the results were presented in Fig 3 and Fig 4. For 3 tapping panels within a tree (T1), the averaged latex sucrose content was 20.1 mM.l^{-1} (Fig 3A). The result was clearly shown that Suc value was highest in panel C (23.5 mM.l^{-1}), while, panel A was lowest (17.0 mM.l^{-1}). Moreover, the average of Suc value increased from lower part to higher part of the rubber tree (8.2 - 20.2 mM.l^{-1}). For 6 tapping panels within a tree (T2), the sucrose content value was 22.1 mM.l^{-1} (Fig 3B). Panel D, Suc value was highest (29.6 mM.l^{-1}), while, Suc value was the lowest in panel A (13 mM.l^{-1}). Besides, the average of Suc value above the tapping panel was higher (15.9 mM.l^{-1}) than below the tapping panel (5.2 mM.l^{-1}).

The averaged sucrose content of T3 (6 tapping panels within a tree together with RRIMFLOW stimulation) was 10.3 mM.l^{-1} (Fig 4A). On panel A, the Suc value was highest (11.3 mM.l^{-1}), whereas panel E was the lowest (9.4 mM.l^{-1}). The sucrose content above the tapping panel (12.3 mM.l^{-1}) was higher than below the tapping panel (8.5 mM.l^{-1}). For T4 (6 tapping panels within a tree together with LET),the average sucrose content was 14.9 mM.l^{-1} (Fig 4B). Suc value on panel E was highest (17.2 mM.l^{-1}), but panel C was lowest (12.8 mM.l^{-1}). In addition, the sucrose content above the tapping panel (14.5 mM.l^{-1}) was higher than below the tapping panel (8.6 mM.l^{-1}). However, the distribution of average sucrose contents in young-tapping rubber trees of T1 and T2 were higher than T3 and T4.

The inorganic phosphorus content along the trunk

The latex metabolic status within the trunk bark was evaluated by comparing with inorganic phosphorus (Pi, mM.l^{-1}) values

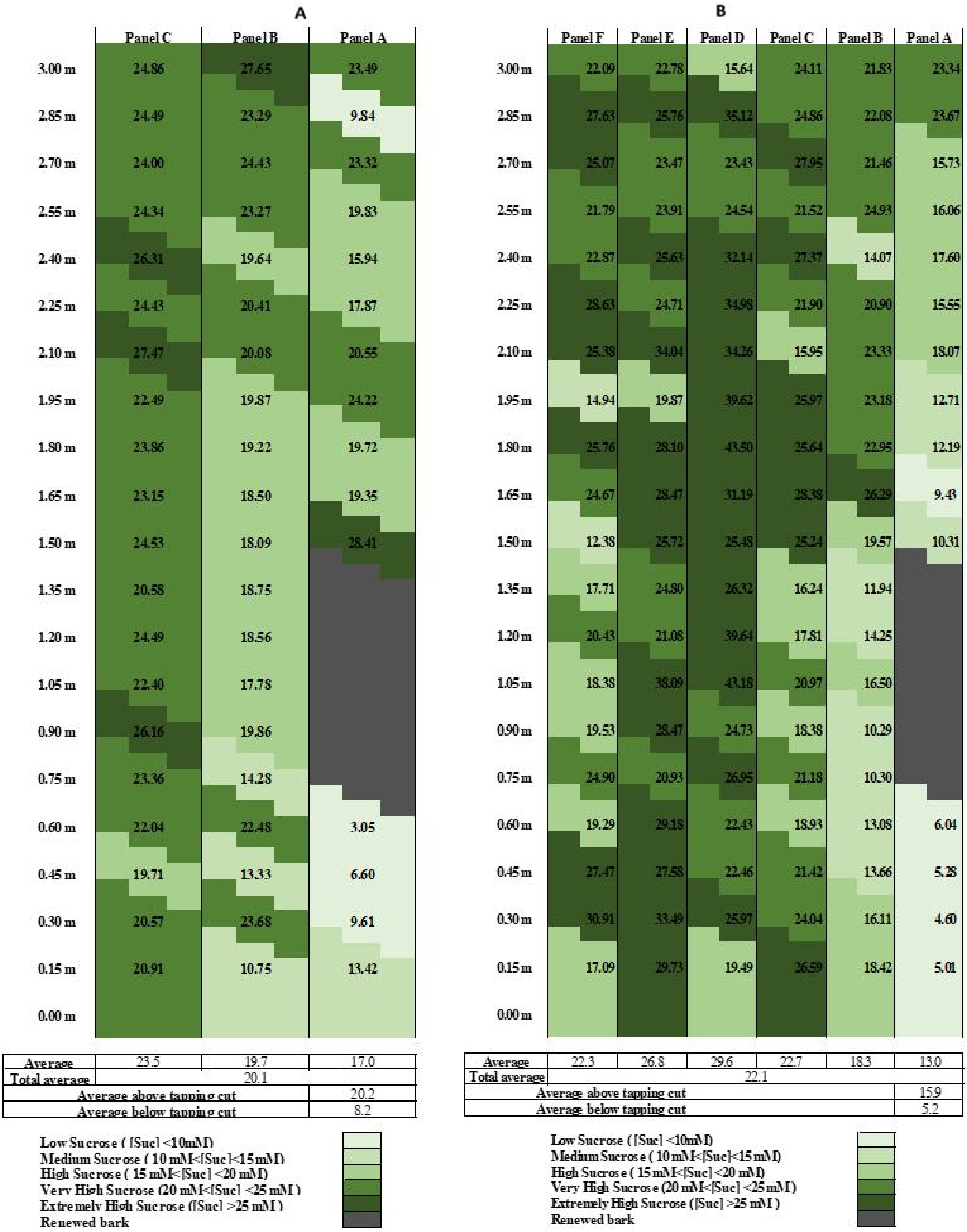

Fig 3: Distribution of latex sucrose content in the young-tapping rubber trees (A): S/32d/3 and (B): S/6d3.

A

	Panel F	Panel E	Panel D	Panel C	Panel B	Panel A
3.00 m	11.98	11.46	10.25	10.86	13.06	9.87
2.85 m	10.34	8.20	10.96	8.18	11.08	12.45
2.70 m	10.45	5.81	11.44	11.56	13.17	11.95
2.55 m	11.17	9.92	11.39	13.05	16.99	11.69
2.40 m	10.65	11.80	10.70	11.20	9.55	11.07
2.25 m	9.56	12.17	12.70	10.58	14.10	15.50
2.10 m	8.87	7.01	10.83	7.44	12.23	11.81
1.95 m	11.68	10.80	13.69	16.22	9.98	13.74
1.80 m	12.81	10.54	11.38	9.81	9.48	14.70
1.65 m	10.75	11.47	10.82	10.93	11.31	13.31
1.50 m	10.55	10.80	10.25	7.94	10.11	9.40
1.35 m	11.52	8.07	10.38	9.91	9.09	
1.20 m	9.88	8.71	7.95	7.81	10.33	
1.05 m	10.21	9.86	7.80	11.22	10.38	
0.90 m	7.36	8.29	10.02	9.10	10.45	
0.75 m	14.43	9.39	10.40	8.31	7.85	
0.60 m	9.94	8.02	7.73	8.58	6.97	10.21
0.45 m	8.08	9.62	8.31	7.56	9.08	6.80
0.30 m	8.63	7.91	10.90	10.45	6.82	8.73
0.15 m	8.87	7.71	9.79	9.14	8.73	8.28
0.00 m						
Average	10.4	9.4	10.4	10.0	10.5	11.3
Total average	10.3					
Average above tapping cut						12.3
Average below tapping cut						8.5

- Low Sucrose ([Suc] <10mM)
- Medium Sucrose (10 mM<[Suc]<15 mM)
- High Sucrose (15 mM<[Suc] <20 mM)
- Very High Sucrose (20 mM<[Suc] <25 mM)
- Extremely High Sucrose ([Suc] >25 mM)
- Renewed bark

B

	Panel F	Panel E	Panel D	Panel C	Panel B	Panel A
3.00 m	17.89	16.07	16.74	15.61	16.28	16.24
2.85 m	16.74	17.66	10.10	16.24	12.95	13.27
2.70 m	16.07	13.83	14.38	15.49	15.71	10.63
2.55 m	14.59	12.91	16.40	16.64	17.87	14.00
2.40 m	14.47	18.76	12.78	15.58	16.79	16.17
2.25 m	18.14	16.56	12.10	13.83	15.03	13.05
2.10 m	13.46	14.68	13.44	11.24	25.93	11.08
1.95 m	13.32	18.35	13.15	12.13	16.63	16.62
1.80 m	13.20	18.16	16.21	11.52	14.14	13.08
1.65 m	15.79	21.81	26.89	12.84	16.73	16.62
1.50 m	13.36	14.10	13.85	15.02	14.99	18.87
1.35 m	16.04	18.03	14.26	9.52	15.82	
1.20 m	16.20	19.10	15.41	13.87	17.00	
1.05 m	14.05	18.71	13.31	13.24	14.45	
0.90 m	13.67	17.99	18.10	12.13	13.67	
0.75 m	13.43	17.73	31.88	11.98	14.81	
0.60 m	8.55	13.83	16.50	12.41	8.58	5.45
0.45 m	16.85	17.73	18.26	9.03	7.53	9.58
0.30 m	16.81	18.04	17.24	9.21	11.03	11.77
0.15 m	21.23	20.21	14.17	9.35	9.77	7.55
0.00 m						
Average	15.2	17.2	16.3	12.8	14.8	12.9
Total average	14.9					
Average above tapping cut						14.5
Average below tapping cut						8.6

- Low Sucrose ([Suc] <10mM)
- Medium Sucrose (10 mM<[Suc]<15 mM)
- High Sucrose (15 mM<[Suc] <20 mM)
- Very High Sucrose (20 mM<[Suc] <25 mM)
- Extremely High Sucrose ([Suc] >25 mM)
- Renewed bark

Fig 4: Distribution of latex sucrose content in the young-tapping rubber trees (A): S/6 d3. ETG99% RRIMFLOW -60- 36/y (9d) and (B): S/6 d3. ETG60% LET -40- 48/y (6d).

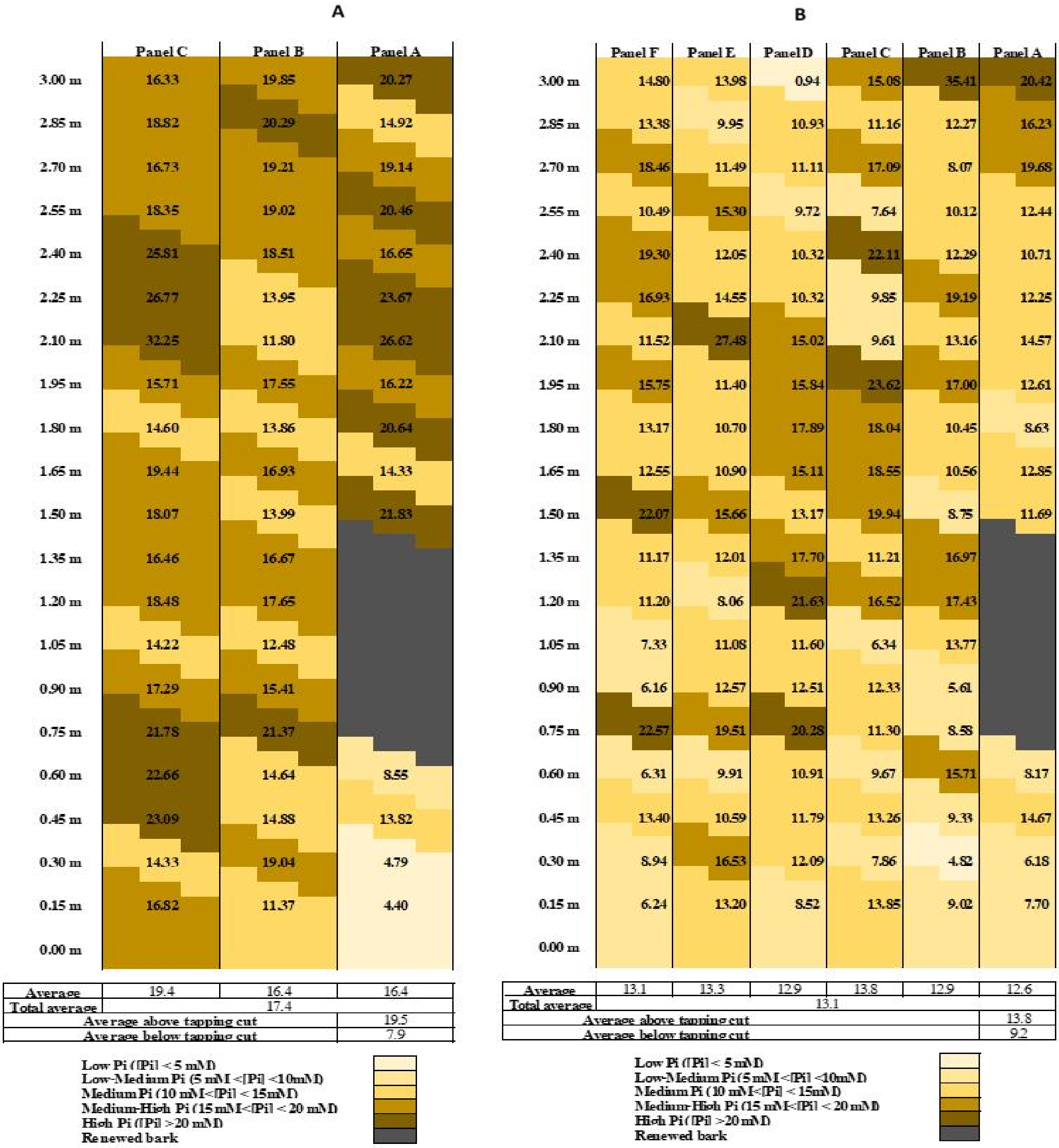

Fig 5: Distribution of latex Inorganic phosphorus content in the young tapping rubber trees (A): S/32d/3 and (B): S/6 d3.

measured in each sampling position (Fig 5 and 6). The averaged Pi values of T1 was17.4 mM.l^{-1} (Fig 5b). Panel C showed the highest value of Pi (19.4 mM.l^{-1}), while the lowest values were found on panel A and B. The average value of Pi above the tapping panel (19.5 mM.l^{-1}) was higher than below the tapping panel (7.9 mM.l^{-1}). For T2, the averaged Pi value was13.1 mM.l^{-1} (Fig 5B). For this tapping system, panel C showed highest Pi value (13.8 mM.l^{-1}), while panel A was having lowest Pi value (12.6 mM.l^{-1}). In addition, the averaged Pi value above the tapping panel (13.8 mM.l^{-1}) was higher than below the tapping panel (9.2 mM.l^{-1}). The averaged Pi value of T3 was 15.5 mM.l^{-1} (Fig 6A). This tapping system revealed that Pi value of panel C was highest (16.7 mM.l^{-1}) while Pi value was the lowest on panel E (14.8 mM.l^{-1}). Besides, the averaged Pi value above the tapping panel (15.5 mM.l^{-1}) was lower than below the tapping panel (15.8 mM.l^{-1}). It was different with T1 and T2 which the Pi values were higher on above part than below part of the tapping panels.

The averaged Pi value of T4was 19.1 mM.l^{-1} (Fig 6B). The highest Pi value was found on panel B (21.6 mM.l^{-1}) while Pi value expressed lowest on panel C (17.0 mM.l^{-1}). The averaged Pi value above the tapping panel (19.2 mM.l^{-1}) was higher than that of below the tapping panel (16.0 mM.l^{-1}).

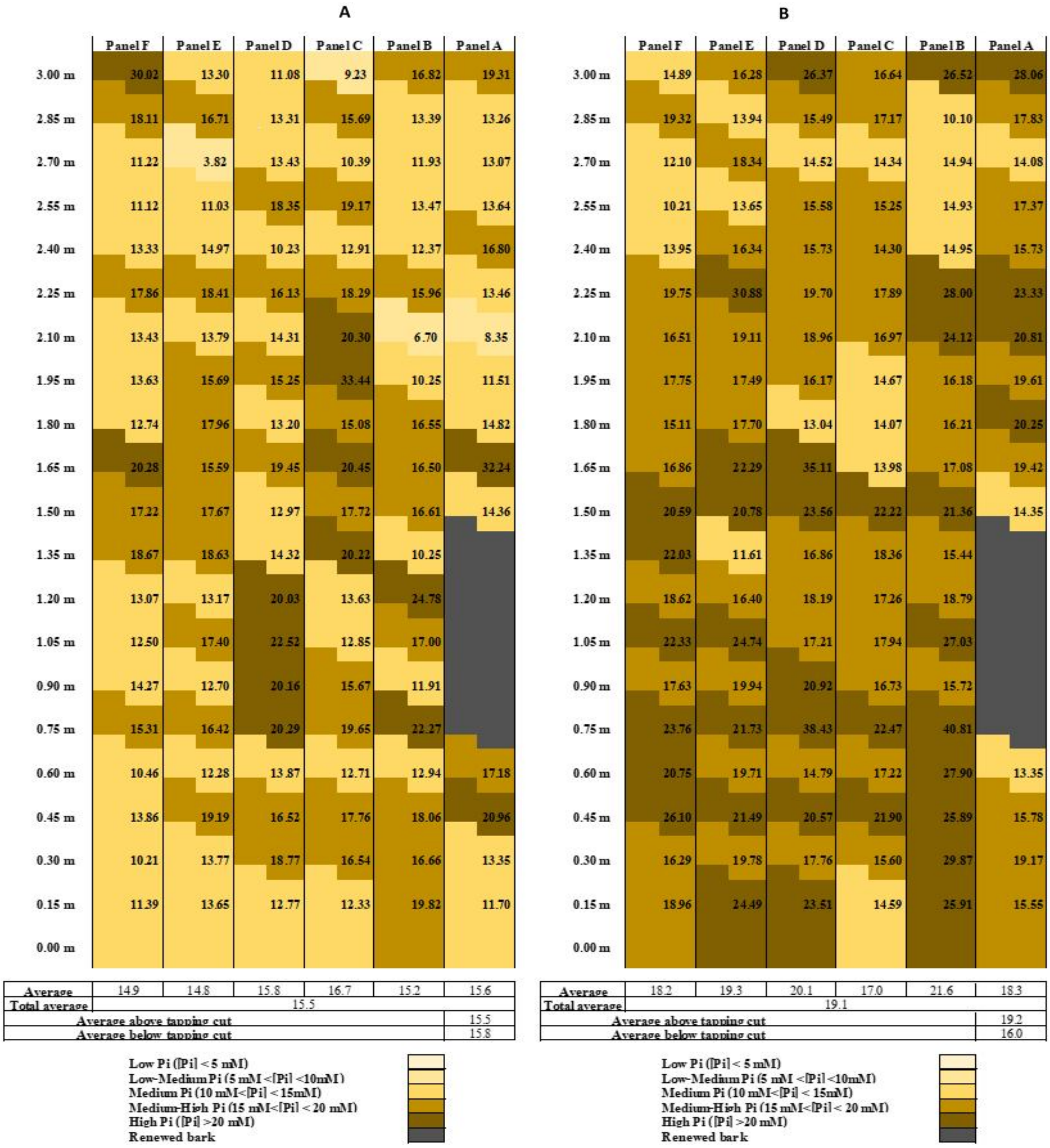

Fig 6: Distribution of latex Inorganic phosphorus content in the young tapping rubber trees (A): S/6 d3. ETG99% RRIMFLOW -60- 36/y (9d) and (B):S/6 d3. ETG60% LET -40- 48/y (6d).

Distribution of latex sucrose contents in the young-tapping rubber trees of the four treatments, sucrose contents above the tapping panel was higher than below the tapping panel because below the tapping panel induced the metabolic activity. Sucrose is needed by latex cells for latex regeneration(Conte and Carroll, 2013). The ethylene stimulation treatments in RRIMFLOW and LET, sucrose content was low near the tapping cut or whole trunk scale. It reflected that high rate of latex regeneration was produced, leading to a higher average rubber production per tapping (Silpi *et al.* 2001).

Distribution of latex inorganic phosphorus contents in the young-tapping rubber trees of the four treatments, the latex inorganic phosphorus contents above the tapping panel was higher than below the tapping panel because latex inorganic phosphorus contents are involved in increasing metabolic activity. So, a lower of inorganic phosphorus content near the tapping panel are linked to actual latex regeneration area. However, the conventional tapping system expressed lower inorganic phosphorus contents on below the tapping panel than the ethylene stimulation treatments (RRIMFLOW and LET) because ethylene increase the turgor presser in the latex vessel leading to high of inorganic phosphorus content in the trunk scale.

CONCLUSION

The tapping system with RRIMFLOW treatment (S/6 d3. ETG 99% RRIMFLOW -60- 36/y (9d) in the young-tapping of rubber trees enhanced rubber production in gram per tree per tapping and led to compensate the rubber production in kilogram per tree. Tapping systems were no adverse impact on rubber girth increment (*P*>0.05). The distribution of sucrose contents was high in the conventional tapping systems (T1 and T2) and was middle value in the stimulation tapping systems (T3 and T4). All tapping systems expressed middle to high values of inorganic phosphorus contents. The finding concluded that latex stimulation by RRIMFLOW and LET increased rubber latex yield. Latex physiology was affected by the stimulated treatments; however, this may lead to a negative impact on rubber life cycle in the long term. Long term investigation of tapping system with stimulants should be considered for sustainable rubber production.

ACKNOWLEDGEMENT

This work was supported by the budget revenue of Prince of Songkla University.

REFERENCES

Chantuma, P., Thaniswanyangkura, S., Kasemap, P., Gohet, E. and Thaler, P. (2006). Distribution pattern of latex sucrose content and concurrent metabolic activity at the trunk level on different tapping systems ad in latex producting bark of *Hevea beasiliensis*. Kasetsart Journal (Natural Science). 40: 634-642.

Chantuma, P., Lacote, R., Leconte, A. and Gohet, E. (2011). An innovative tapping system, the double cut alternative, to improve the yield of Hevea brasiliensis in Thai rubber plantations. Field Crops Research. https://doi.org/10.1016/j.fcr.2011.01.013.

Conte, M. Lo and Carroll, K.S. (2013). The chemistry of Thiol oxidation and detection. In: Oxidative Stress and Redox Regulation. https://doi.org/10.1007/978-94-007-5787-5_1.

Gohet, E. and Chantuma, P. (1999). Microdiagnostic latex training RRIT-DOA: Proceedings of the training RRIT-DOA 1999 Conference Chachoengsao. (pp. 112-118).

Jetro, N.N. and Simon, G.M. (2007). Effect of 2-chloroethylphosphonic acid formulations as yield stimulants on *Hevea brasiliensis*. African Journal of Biotechnology. 6: 523-528.

Lacote, R., Gabla, O., Obouayeba, S., Eschbach, J.M., Rivano, F., Dian, K. and Gohet, E. (2010). Long-term effect of ethylene stimulation on the yield of rubber trees is linked to latex cell biochemistry. Field Crops Research. 115: 94-98.

Leconte, A., Vaysse, L., Santisopasri, V., Kruprasert, C., Gohet, E. and Bonfils, F. (2006). On farm testing of ethephon stimulation and different tapping frequencies, effect on rubber production and quality of rubber. Proceedings of the Franco-Thai Project 2005-2008 conference, Thailand. (pp. 95-97).

Njukeng, J.N., Muenyi, P.M., Ngane, B.K. and Ehabe, E.E. (2011). Ethephon stimulation and yield response of some *Hevea* clones in the humid forests of south west Cameroon. International Journal of Agronomy. 2011: 1-5.

Prasanna, W.R.A.C., Rodrigo, V.H.I., Abeysinghe, D.C. and Kudaligama, K.V.V.S. (2010). Stimulant levels to be used with two low intensity harvesting (LIH) systems of rubber under wet and intermediate zones of Sri Lanka. Proceedings of the 15th International Forestry and Environment Symposium, University of Sri Jayewardenepura 2010 Conference Sri Lanka. pp. 265-272.

RRIT. (2011). Thailand Rubber Statistics. Ministry of Agriculture and Cooperative Department of Agriculture. Rubber Research Institute of Thailand, Bangkok, Thailand.

Sainoi, T. and Sdoodee, S. (2012). The impact of ethylene gas application on young- tapping rubber trees. Journal of Agricultural Technology. 8: 1497-1507.

Silpi, U., Chantuma, P., Kosaisawe, J., Thanisawantangkura, S. and Gohet, E. (2001). Distribution pattern of latex sucrose and metabolic activity in response to tapping and ethrel stimulation in latex producing bark of *Hevea brasiliensis* Müll. Arg. In Annual IRRDB Meeting 2001. Montpellier, France.

Silpi, U., Thaler, P., Kasemsap, P., Lacointe, A., Chantuma, A., Adam, B., Gohet, E., Thanisawanyangkura, S. and Améglio, T. (2006). Effect of tapping activity on the dynamics of radial growth of *Hevea brasiliensis* trees. Tree Physiology. 26: 1579-1587.

Sivakumaran, S. and Chong, K. (1994). Yield Stimulation in Rubber: Current Status and Improvements for Enhanced Productivity. In: Proceedings of the International Planters Conference, Malaysia. 396-408.

Sivakumaran, S. (2002). Exploitation systems to maximize yield productivity and enhance profitability in rubber. In: Global Competitiveness of Indian Rubber Plantation Industry: Rubber Planters' Conference, [C. Kuruvilla Jacob (Eds.)], Kottayam, India. (pp. 163-174).

Sopchoke, P. (2010). International Symbol of Harvesting Technology. Para Rubber Bulletin. 31: 34-45.

Traore, M.S., Diarrassouba, M., Okoma, K.M., Dick, K.E., Soumahin, E.F., Coulibaly, L.F. and Obouayeba, S. (2011). Long-term effect of different annual frequencies of ethylene stimulation on rubber productivity of clone GT1 of *Hevea brasiliensis* (Muell. Arg.) in south east of Cote d'Ivoire. American Journal of Agricultural and Biological Science. 2: 1251-1260.

Vijayakumar, K.R., Gohet, E., Thomas, K.U., Xiaodi, W., Sumarmadji, Rodrigo, L., Thanh, D.K., Sopchoke, P., Karunaichamyand, K.S.T.K. and Akbar, S.Md. (2009). Special communication: Revised international notation for latex harvest technology. Journal of Rubber Research. 12:103-115.

Yeang, H.Y. (2005). The kinetics of latex flow from the rubber tree in relation to latex vessel plugging and turgor pressure. Journal of Rubber Research. 8:160-181.

Zhu, J. and Zhang, Z. (2009). Ethylene stimulation of latex production in *Hevea brasiliensis*. Plant Signal Behavior. 4: 1072-1074.