IJSRM
INTERNATIONAL JOURNAL OF SCIENCE AND RESEARCH METHODOLOGY
An Official Publication of Human Journals

Human Journals
Research Article
October 2016 Vol.:4, Issue:4

Exploitation System Based on Leaves Development Dynamic of Clones BPM 1 in North Sumatera, Indonesia

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Submission: 7 October 2016
Accepted: 12 October 2016
Published: 25 October 2016

HUMAN JOURNALS

www.ijsrm.humanjournals.com

Keywords: rainfall, leaf fall, leaf flush, leaf mature, sucrose, inorganic phosphate, thiol

ABSTRACT

Latex Production of rubber is highly influenced by applied exploitation system and annual rainfall pattern. Different annual rainfall pattern causes latex peak production follow the dynamics of leaves development. This research aims to determine the effect of physiology and latex production of clone BPM 1 on applied exploitation system according to the dynamic of leaves development. This research was conducted at two locations, namely Indonesian Rubber Research Institute Sungai Putih, North Sumatera and PT. Perkebunan Nusantara III, North Sumatra Regency from August 2014 to July 2015. The research uses Split Block Design in a randomized complete block design with three replications and two factors. The main plot is exploitation system, comprising of two levels namely downward tapping on quarter-spiral (S/4d3), and upward tapping on quarter-spiral (S/4Ud3). The subplots are stimulant application, consisting of four levels namely ethephon 2.5% applied once for 15 days (ET/15d), gas stimulant applied once for 9 days (ETG/9d), gas stimulant applied once for 18 days (ETG/18d), and gas stimulant applied once for 27 days (ETG/27D). The results show that annual rainfall patterns affect the dynamic of leaves development and divide the development phase of the rubber leaves into leaf fall, leaf flush and leaf mature. The optimum exploitation systems of clones BPM 1 to increase latex production is upward tapping on quarter-spiral (S/4U), application of stimulant with ethephon (ET) at leaf fall, and gas stimulants (ETG) at leaf flush and leaf mature.

INTRODUCTION

Latex production of rubber is strongly influenced by applied exploitation system. Rubber tapping philosophy is harvest the latex as much as and as often as possible in latex vessels but does not cause fatigue physiological effects on the tree to obtain optimum productivity (Sumarmadji 2000). Therefore, applied rubber exploitation system has important role to optimize the potency. One of the efforts is apply stimulant combined with low intensity tapping system and stimulant application management according to potential production and clone typology (Herlinawaty & Kuswanhadi 2012).

For rubber, each clone has specific physiological characteristics that cause different responses to a given system of exploitation. High metabolism clones tend to be responsive to high tapping interval but less responsive to stimulants application, while moderate and low metabolism clones tend to be responsive to the stimulant application but require longer tapping interval. Based on such physiological characteristics, plant response to potential production and tapping system is generally divided into slow starter and quick starter clones (Herlinawaty & Kuswanhadi 2012). Azwar & Suhendry (1998) stated that quick starter clones were characterized by production peak obtained at the beginning of tapping period, while slow starter clones tend to have production peak at the middle tapping cycle.

Several studies have shown that the production of latex is also influenced by agro-climate factors (Roux *et al*. 2000; Gireesh *et al*. 2011). Periodically, rubber plant will experience leaf fall, leaf flush (formation of young leaves), and leaf mature according to rainfall changes, and it is unique character of rubber plants that are not found in other plantation crops. Different annual rainfall pattern causes latex peak production follow the dynamics of leaves growth and development (Woelan *et al*. 2013; Junaidi *et al*. 2014).

In Sri Lanka, Gunasekara *et al*. (2013) showed that clones of RRIC and RRISL series have different responses to the dynamics of leaves growth and development. In Indonesia, research on the same subject is still very limited. Clones tests are generally not considered yet specific response of each clone to the dynamics of leaves growth and development due to changes in annual rainfall. As so far, research reports are still limited to exploitation system that applied on clones, but it has never been done research on the influence of latex exploitation system based on the dynamics of leaves growth and development.

This research is important because, on the commercial scale, production of latex is strongly influenced by the growth and development that follows changes in annual rainfall. Gireesh *et al*. (2011) state that the growth and the production of latex were important agronomic variables were strongly influenced by annual rainfall patterns and applied exploitation system. Due to the reasons, this research aims to determine physiological and latex production responses to applied exploitation system according to the dynamics of leaves development. This research was expected able to be used as reference that actual harvest management required a more detailed approach to the dynamics of leaves development that follows changes in annual rainfall so that the system of exploitation is more effectively to increase the production of latex.

MATERIAL AND METHODS

The research was conducted at two locations, namely Indonesian Rubber Research Institute Sungai Putih, North Sumatera and PT. Perkebunan Nusantara III, District of Galang, Deli Serdang Regency, North Sumatra from August 2014 to July 2015.Physiologyobservation was conducted at the Laboratory of Indonesian Rubber Research Institute Sungai Putih.

Materials for field activities include rubber 15 years of age, planting space 2.5 m x 5 m. The clone is clone BPM 1 (low metabolism clone). The stimulant is ethephon liquid active ingredient (2-cloro acid ethyl phosphate) 2.5% and gas stimulants (± 100%). The material for Laboratory physiology analysis is TCA (trichloroacetic acid), sulfuric acid (H_2SO4 70%), dithiobis- nitrobenzoic acid (DNTB), formic acid, alcohol 96%, glycerine, KOH 50%, $HN0_3$65%, and distilled water.

This research uses Split Block Design in a randomized complete block design with three replications and two factors. The main plot is exploitation system, comprising of two levels namely downward tapping on quarter-spiral(S/4d3), and upward tapping on quarter-spiral (S/4Ud3). The subplots are stimulant application, consisting of four levels namely ethephon 2.5% applied once for 15 days (ET/15d), gas stimulant applied once for 9 days (ETG/9d), gas stimulant applied once for 18 days (ETG/18d), and gas stimulant applied once for 27 days (ETG/27D).

Application of liquid and gas stimulants

Application of liquid stimulant at lower tapping area (B0-1) was performed using Grove application technique (Ga), that is by pulling the clot latex over tapping grooves beforehand, while liquid stimulant applications at upper area (H0-1) is using bark application techniques, by scraping the skin over tapping area around of 1.5 cm, then smeared with stimulant. Concentration of liquid stimulants is 2.5% with an application frequency once for 15 days (Junaidi *et al*.2010).

Application of gas stimulant was conducted by installing gas applicator at the position of 15-20 cm above tapping area and 6-7.5 cm to the left. Such application was conducted in accordance with the treatment. Refilling of gas stimulant was performed after three times of tapping (9 days once), 6 times taped (18 days), and 9 times taped (27 days). The stimulant is ethylene gas with a concentration of 99% as much as 300cc (Figure 2).

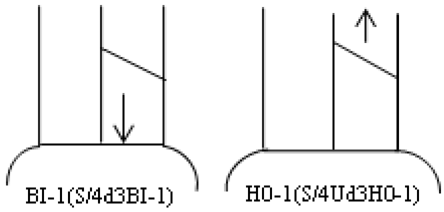

Figure 1. Sketch of exploitation systems

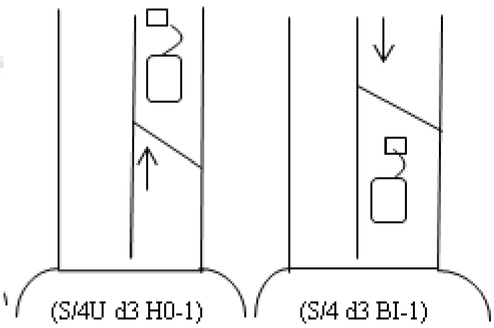

Figure 2. Gas stimulant applicator layout on each tapping system

Measurement of Sucrose (mM), Phosphorus inorganic (Pi) (mM), and Thiols (mM)

Content of Sucrose, inorganic phosphorus (Pi) and thiols was measured by latex diagnosis using sample of TCA latex serum (trichloroacetic acid). This serum made by mixed evenly 1 mL of latex and 9 mL of TCA in a film bottle to form gum wad and TCA serum. Then, the wad of gum in the solution was taken and TCA serum filtered using filter paper and then analyzed for the content of sucrose, inorganic phosphorus (Pi) and thiol.

Sucrose content (mM) were measured using Anthrone method, that is TCA serum taken as much as 150 mL (2.5% TCA solution is added to the total volume 150 mL) and added with 3 ml of Anthrone reagent, then stirred using vortex. After that, heated by soaking in boiling water for 15 minutes and cooled again by immersing in water. Absorbance was measured at λ627 nm with spectrophotometer Beckman DU 650.

The content of inorganic phosphorus (Pi) was measured using Taussky and Shorr method based on the principle binding by ammonium molybdate that reduced by $FeSO_4$ in acid reaction to form blue color, then the absorbent measured at λ 627 nm with spectrophotometer Beckman DU 650.

The levels of thiol (R-SH) measured using McMullen method, that is sample was taken as much as 1.5 mL (added with TCA solution 2.5% to a total volume of 1.5mL), plus a DTNB 10 mM75µL and plus 0.5 M of Tris buffer solution as much as 1.5 mL, then stirred evenly using vortex, and the solution was allowed to stand at room temperature for 30 minutes. The absorbance is read at λ 421 nm using spectrophotometer Beckman DU 650 or measured from TCA serum based on the principle that the reaction uses dithiobis-nitrobenzoic acid (DTNB) to form yellow TNB which absorbed at λ 421 nm using spectrophotometer Beckman DU 650.

Dry Rubber Content (DRC) (%)

Dry rubber content was measured using McMullen method, that is take 10g sample of latex, then placed in a beaker and add 10 mL of distilled water, then heated on a hot plate and added with formic acid 5%. The solution stirring gradually until perfectly lumps formed and the serum is clear. Latex lump is milled with DRC mill to form a rubber sheet with a thickness of 0.6-1.0 mm. The rubber sheet is dried at 100°C for 30 minutes, then cooled in desiccators (at room temperature). Dry rubber content is then calculated using the formula (DW / WW) x 100%, where DW stands for dry weight and WW for wet weight.

LatexProduction (g t^{-1} t^{-1})

To obtain the production of latex, field data of latex production observation was multiplied by DRC and then calculated using DRC formula, namely BK = B x DRC. Then the production of latex grams per tapping per tree (g t^{-1} t^{-1})is calculated by BK divided by the number of taped trees and the number of tapping days using formulas as follow: BK / (Σp / Σs).Where: BK = dry weight (g), BW = wet weight (g), DRC= dry rubber content (%), Σp= number of trees), and Σs= the number of tapping days.

Data Analysis

Data were analyzed using ANOVA; further testing used Least Significant Difference (LSD) at 5% significant level. Data were analyzed using the Statistical Analysis System (SAS) Software 9.1. (SAS 2004).

RESULTS AND DISCUSSION

Dynamics of Leaves Development

Development of rubber leaves is greatly influenced by annual rainfall patterns. Annual rainfall pattern during the period of 2014-2015 is presented in Figure 3.

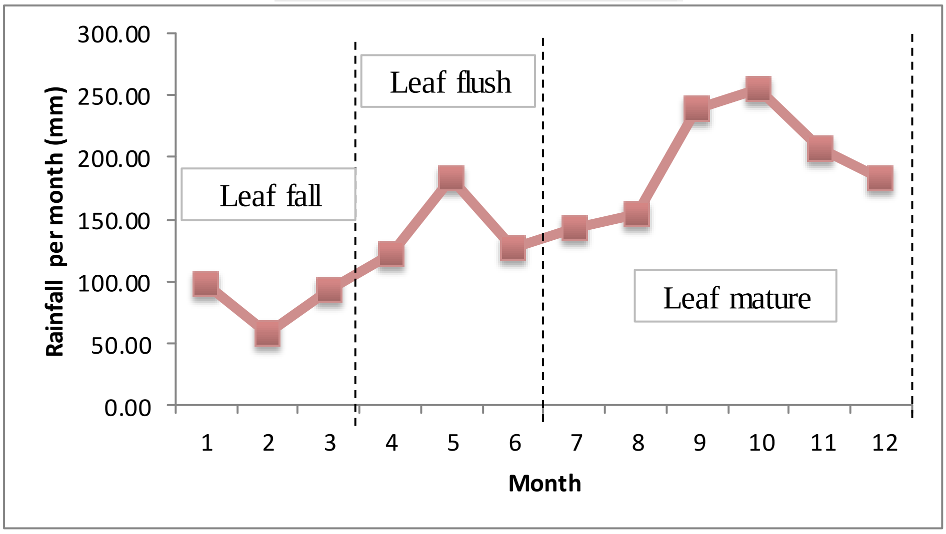

Figure 3. Monthly rainfall (mm) during 2014-2015 in Sungei Putih Plantation, Deli Serdang, North Sumatera

Figure 3 shows that the lowest rainfall occurs in January to March and the highest in October. Low rainfall in January to March was causing rubber plants naturally experiencing leaf fall to reduce transpiration due to drought stress. Leaf fall is one form of rubber adaptation to drought stress.

In April to June, there is increased the amount of rainfall (Figure 3), so that the rubber plant that had shed most of their leaves, began to enter the phase of new leaves growth (leaf flush). In these months, rubber begun has a lot of leaves, but still bright green in color. Then, with the increasing rainfall from July to December (Figure 3), the leaves is also changing the color, from light green, to dark green, as the leaves are experiencing growth and development into mature leaves. Siregar (2014) found that on rubber clones PB 260 and RRIC 100, annual rainfall pattern correlated with the growth of leaves.

Latex physiology

Latex physiology has close relationship with the ability to synthesize assimilate into the material forming the latex. Some physiological characteristics have an important role in latex formation namely content of sucrose, inorganic phosphate, and thiol (Woelan *et al.* 2013).

Statistical analysis showed that exploitation system has significant effect on the content of sucrose of clone BPM 1 at leaf fall and leaf flush, but has not significant effect at leaf mature (Table 1). The highest sucrose, either leaf fall or leaf flush, was found in the exploitation system S/4U d3 ET/15d. The highest sucrose content is found at leaf flush, comparing than leaf fall and leaf mature, namely 14.50 mM and the lowest is at leaf fall, namely 3.38 mM.

Table 1 Latex physiology characters of clone BPM 1 based on dynamics of development of the rubber leaf age of 15 years

Treatment	Dynamics of development of the rubber leaf								
	Leaf fall			Leaf flush			Leaf mature		
	Sucrose	Pi	Thiol	Sucrose	Pi	Thiol	Sucrose	Pi	Thiol
	……………………………………………….(mM)……………………….								
S/4 d3 ET/15d	4.50^{abc}	21.23^{cd}	0.40	13.88^{a}	23.79^{d}	0.39^{ab}	8.42	22.33^{cd}	0.36^{abc}
S/4Ud3ET/15d	6.90^{a}	23.37^{bc}	0.39	14.50^{a}	30.08^{a}	0.33^{c}	6.96	26.74^{a}	0.34^{cd}
S/4 d3 ETG/9d	5.97^{abc}	21.51^{cd}	0.40	11.15^{b}	16.06^{e}	0.33^{c}	7.32	24.06^{abc}	0.35^{bc}
S/4U d3 ETG/9d	6.33^{ab}	27.14^{a}	0.40	11.60^{b}	28.13^{ab}	0.42^{a}	7.48	21.37^{cd}	0.30^{e}
S/4 d3 ETG/18d	3.90^{bc}	20.50^{cd}	0.38	8.10^{c}	24.60^{cd}	0.40^{a}	8.31	23.11^{bcd}	0.39^{a}
S/4U d3 ETG/18d	3.38^{c}	25.57^{ab}	0.40	11.60^{b}	26.54^{bcd}	0.36^{bc}	6.53	20.84^{d}	0.31^{ed}
S/4 d3 ETG/27d	3.69^{c}	22.07^{cd}	0.42	9.94^{bc}	23.32^{d}	0.39^{ab}	8.08	25.50^{ab}	0.37^{ab}
S/4U d3 ETG/27d	4.01^{bc}	20.31^{d}	0.38	9.94^{bc}	27.80^{abc}	0.36^{bc}	7.65	23.35^{bcd}	0.32^{ed}

Note: In the same column, values with different indices are significantly different from one another at the *Duncan* test at $P \leq 0.05$

High levels of sucrose at leaf flush with length of tapping groove S/4 is because clone BPM 1 is slow metabolism type and more responsive to short incision with relatively low intensity of stimulants application (Junaidi *et al.* 2010) and is supported by the availability of adequate water and the presence of leaves in the canopy at leaf flush causes the plant is able to form sucrose.

Based on rainfall data from SeiPutih and PTPN III, it was known that the monthly average of rainfall during leaf flush is 122.32-183.68 mm which indicates that the rubber under sufficient water conditions. Gao *et al*. (2006) found that adequate water availability will affect the balance of sucrose in plant cells and facilitate the formation of sucrose. This is confirmed by Sumarmadji (2007); Junaidi *et al*. (2010); Siregar (2012); Woelan *et al*. (2012);

which shows that rainfall and the presence of leaves in the canopy resulted in increased levels of sucrose.

Low levels of sucrose at leaf fall are caused by drought, affecting the physiological processes. Toruan-Matthew *et al*. (2001) state that plants experience drought resulted in a decrease in the content of photosynthate due to low rate of photosynthesis.Hufstetler *et al.* (2007) state that the physiologic effects of drought are the change of water potential, osmotic potential, and turgor potential of cells, which affects the absorption and translocation of mineral, transpiration and photosynthesis and Photosynthate translocation.

Exploitation system has significant effect on inorganic phosphate; either at leaf fall, leaf flush or leaf matures (Table 1). The highest levels of inorganic phosphate is obtained in the system of exploitation S/4U d3 ET/15d at leaf flush and leaf mature, while at leaf fall, the highest levels of inorganic phosphate is obtained in the system of exploitation S/4U d3 ETG/9d.

High inorganic phosphorus (Pi) reflects active metabolism due to phosphate function in phosphorylation and as energy forming component (Sumarmadji 2007). High in the Pi will support the ongoing metabolic processes primarily related to Latex biosynthesis (Woelan *et al*. 2013). Further consequence of the increase in the Pi has increased consumption of sucrose in the process of Latex regeneration (Gohet *et al*. 2008).

Sufficient availability of sucrose for latex synthesis is one important factor to keep the synthesis take place in continuous manner and rubber produce latex optimally. According to Sumarmadji (1999), high sucrose levels in rubber will not necessarily have high latex yield because not directly related to production potential, even it can describe low actual production due to a number of sucrose may be not synthesized into latex. Table 2 show that where the highest production of latex found in the treatment of tapping system S/4U d3 ETG/27dat leaf mature.

Higher levels of inorganic phosphorus (Pi) during leaf flush and leaf mature than leaf fall may due to water availability and sufficient raw materials, resulting in increased energy within the plants to absorb P from the soil. Internal P content, remobilization and translocation in the plant depends on the availability of water (Zambrosi *et al*. 2012). On the other hand, according to Vandecar *et al*. (2009), high demand on inorganic phosphate for rubber occurs during the wet months (CH> 100 mm per month).

Table 1 shown that the exploitation system has significantly effect on thiol levels for clone BPM 1 at leaf flush and leaf mature, but not at leaf fall. The highest thiol levels were obtained in the system of exploitation S/4U d3 ETG/9d at leaf flush and S/4 d3 ETG/18d at leaf mature, namely 0.42mM and 0.39 mM respectively. Based on the thiol levels, application of gas stimulants did not have negative impact on thiol level because still within optimum levels, namely 0.40-0.90 mM (Jacob *et al*. 1989). In addition, clone BPM 1 has low metabolism which responsive to stimulants and in the long term has no negative effect on latex cell (Lacote *et al.* 2010).

At the time of leaf fall, exploitation system did not significantly affect the thiol levels (Table 1) due to low monthly rainfall, namely <100 mm per month, so that the plants suffer from drought. Drought will trigger plants protect themselves by producing metabolites include thiol (Scartner *et al*. 2014).

Latex Production (g t^{-1} t^{-1})

Observations on latex production for clones BPM 1 shown that the exploitation system is significantly affected the production of latex, either at leaf fall, leaf flush, and leaf mature. The highest latex production found in the system of exploitation S/4Ud3 ET/15d at the time of leaf fall, S/4U d3 ETG/9d at leaf flush, and S/4U d3 ETG/27D at leaf mature (Table 2).

Table 2 Yield and dry rubber content of clone BPM 1 based on dynamics of development of the rubber leaf age of 15 years

Treatment	Yield (g p^{-1} s^{-1})			Dry rubber content (DRC) (%)		
	Leaf fall	Leaf flush	Leaf Mature	Leaf fall	Leaf flush	Leaf Mature
S/4 d3 ET/15d	11.50[b]	7.65[c]	19.76[b]	35.74[b]	35.34[b]	34.63[a]
S/4Ud3ET/15d	14.75[a]	12.76[a]	29.71[ab]	34.60[bc]	35.19[b]	32.88[abc]
S/4 d3 ETG/9d	13.11[ab]	8.31[bc]	27.09[ab]	39.77[a]	38.44[a]	33.70[abc]
S/4U d3 ETG/9d	13.94[ab]	14.34[a]	32.42[ab]	34.90[bc]	30.13[c]	30.11[d]
S/4 d3 ETG/18d	11.88[b]	8.01[bc]	19.37[b]	33.92[bc]	31.28[c]	35.57[a]
S/4U d3 ETG/18d	12.30[ab]	11.66[abc]	27.78[ab]	29.76[d]	31.09[c]	30.15[d]
S/4 d3 ETG/27d	11.41[b]	7.98[bc]	18.02[b]	32.27[cd]	30.71[c]	34.30[ab]
S/4U d3 ETG/27d	12.21[ab]	11.95[ab]	36.20[a]	32.37[cd]	30.43[c]	31.04[bcd]

Note: In the same column, values with different indices are significantly different from one another at the *Duncan* test at $P \leq 0.05$

The higher production of latex by application of ethephon stimulants at leaf fall is due to drought thus gas stimulant becomes less effective. Allegedly during the drought, applied gas stimulant is more quickly to evaporate and cannot be used by plants optimally.

Latex production is higher at leaf flush and leaf mature than leaf fall due to higher rainfall (Figure 3) and higher number of leaves. This indicates that the amount of rainfall and leaves triggers increased production of latex. High rainfall will lead to the availability of sufficient water for the needs of rubber, while higher number of leaves means better photosynthesis, in turn, increase the production of latex. In India, Kshirsagar (2005) found that rainfall and presence of leaves in the canopy will affect the increased photosynthetic capacity and the production of latex.

Due to the taping system, upward tapping on quarter-spiral(S/4U) increased the production of latex than short downward tapping because the distance between tapping area and plant canopy is closer and the latex flow is not interrupted due to upward tapping cause smaller gravity force and in turn the latex flow will faster and optimize the production of latex (Junaidi 2010).In addition, the application of gas stimulant is more effective to support latex production during leaf flush and leaf mature through the effect on latex flow and regeneration, thus expanding the drainage of latex (Krishnakumar *et al*. 2011).

Results of statistical analysis show that the system of exploitation has significant effect on DRC either at leaf fall, leaf flush, and leaf mature. The highest DRC value was obtained in the system of exploitation S/4 d3 ETG/9d at leaf fall and leaf flush, while S/4 d3 ET/15d produces the highest DRC at leaf mature.

At the time of leaf fall and leaf flush, DRC is higher than at leaf mature because increase in DRC is as plant responses to organize physiological processes continuously. This response is known as ‘anansi static’, which enable plant to survive by waiting for water availability for leaf growth (Hochachaka & Samero 1984).

DRC and production have negative correlation. Table 2 shown that the highest DRC value found at leaf fall, while the highest production of latex found at leaf mature.DRC is also related to the water content, where the higher the value of DRC, the low water content of plants. This causes DRC value at the time of leaf fall higher than leaf matures, because at leaf fall, plants experience drought due to lower rainfall than at leaf mature (Figure 3).

CONCLUSION

The research showed that annual rainfall patterns affect the dynamics of leaves growth and development and divide leaf development phase of rubber into leaf fall, leaf flush and leaf mature. Optimum exploitation systems of clones BPM 1 to increase the production of latex is upward tapping on quarter-spiral (S/4U), by application of ethephon stimulants (ET) at the time of leaf fall, and gas stimulants (ETG) at leaf flush and leaf mature.

ACKNOWLEDGEMENTS

We would like to thank the Ministry of Research, Technology and Higher Education Republic of Indonesia for the funding of this research through higher education council scholarship scheme.

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