Trunk Injection as Green Technology to Improve Rubber Latex Production of *Hevea brasiliensis*

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Abstract

Fertilization as simple procedure that is vital in enhancing latex production. The method used the injection and infusion approach as a green technological endeavor to fertilize mineral nutrients to boost latex production in rubber trees, which has involved injecting fertilizer straight into the trunk. As a result, it did not pollute the soil as an indicator of the employment of green technologies. The research was conducted from April to August 2015 in Perkebunan Nusantara VIII, West Java, Indonesia. The nutrient solution in various concentrations was applied by infusion or injection at the rubber trunk. The nutrient solution contained N, P, K, Ca, Mg, S, Fe, B, Cu, Zn, Mn, and Mo. The results showed that on lower 20 years old rubber increase of latex and dry rubber yield significantly in the trees that were given nutrient solution by injection without dilution of nutrient solution, and by infusion with the dilution of nutrient solution at 20 mL.L-1 and no applied 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 give the effect on the highest latex and dry rubber yield. Concentrate of 20 mL.L-1 nutrient solution in infusion application on the trunk of tapping panel dryness gives the effect on higher latex yield than normal rubber tree of the upper 20 years old

Keywords
Green Technology, Injection, Latex Yield, Mineral Nutrients, Trunk

1. Introduction

Rubber plantations are the second largest commodity in Indonesia after oil palm plantations for superior agricultural products. Furthermore, for the past five years, Indonesia has been the world's second-largest producer of natural rubber, trailing only Thailand (Zuhdi, 2021). However, the productivity level per hectare of Indonesian rubber crop yields is low compared to other competitor countries in ASEAN, such as Vietnam and Malaysia, which have rubber productivity of 400 kg/ha higher. In contrast, Vietnam and Malaysia have fewer rubber plantations than Indonesia, with 1,080,212 hectares and 655,819 hectares, respectively (Harahap & Segoro, 2018; Direktorat Jenderal

Perkebunan, 2019; Hertina et al., 2021). The South Sumatra province, which has the largest rubber plantation area and top contributor to rubber commodities in Indonesia, has a plantation area of 1,305,699 hectares. This paradox is confirmed by the 1.3% annual growth in plantation areas over the last five years (Badan Pusat Statistik Provinsi Sumatera Selatan, 2020; Hertina et al., 2021).

In 2014, the average rubber productivity in Indonesia was 1,053 kg.ha-1.year-1, and West Java had the highest at 1,351 kg.ha-1.year-1 (Direktorat Jenderal Perkebunan, 2015). Indonesia's average rubber productivity slightly dropped in 2020, to roughly 1000 kg.ha-1.year-1, and West Java Province had dropped to 968 kg.ha-1.year-1 (Direktorat Jenderal Perkebunan, 2020). Before the study, a preliminary survey revealed that latex production ranged from 150 to 200 mL. The range quantity of products is similar to 22.5–30.0 g. tree-1. tapping-1 rubber with a 15% dry rubber content.

In addition to productivity and area issues, the industry's demand for natural rubber commodities has also been replaced by synthetic rubber made from crude oil. In the industrial business, natural rubber raw materials in the latex form have substituted each other. This condition continues due to changes in crude oil prices in the market. The disruption of the supply of latex raw materials on the market caused by plant diseases and weather also affects the stability of demand for natural rubber in the industrial market (Kampan, 2018; Indonesia Investments, 2018; Kurnia et al., 2020). Latex production in rubber trees is a vital raw material in the manufacturing industry, especially the automotive industry. However, the domestic market's consumption power of rubber is developing slowly and is difficult to expand (Indonesia Investments, 2018; Kurnia et al., 2020).

In our previous studies, plantation productivity can be increased by using Agricultural Information System (Soeparno et al., 2018), Expert System for precision agriculture (Putra et al., 2021), Artificial Intelligence in agroindustry (Harsawardana et al., 2020; Firmansyah et al., 2021; Herman et al., 2021), Genomic Research in agriculture (Baurley et al., 2013; Baurley et al., 2014; Baurley et al., 2018), and software for fertilization system (Putra et al., 2020; Firmansyah et al., 2021). This paper focuses on fertilization to increase the productivity of rubber trees in Indonesia, most of which are superior clones. Superior rubber clones absorb more nutrients than the parent plant seeds. Consequently, fertilization is the essential aspect of rubber tree productivity (Daslin, 2015; Darojat & Sayurandi, 2019; Rochmah & Ramdani, 2020). Mineral nutrients are also very vital for rubber trees as growth nutrients and latex biosynthesis.

The addition of fertilizers and minerals is expected to improve root intake's ability to absorb nutrition sources, allowing rubber plants to maintain their nutrient balance. However, direct fertilization on the roots is not optimal because it takes time to circulate nutrients throughout the rubber tree body, especially in the bark. The bark of the rubber tree contains latex vascular cells that synthesize rubber particles (cis polyisoprene) in determining the amount and quality of natural rubber (Priyadarshan, 2011; Woelan et al., 2013). Indirectly, inadequate fertilization might contribute to water pollution in the rubber plantation area. Excessive fertilizer use, particularly chemical fertilizers, can promote eutrophication and influence groundwater acidity (Saraswati, 2012; Xia et al., 2020). To boost latex production capacity while reducing environmental effects, we require an optimal fertilization approach straight via the bark of rubber trees.

In the rubber sector, fertilization such as injection and infusion on the stems have been extensively employed. This method of fertilizer application uses liquid or diluted fertilizer, which is then injected or pumped straight into the stem vascular. As a result, this method can be employed as a simple solution for overcoming the optimization of fertilization on rubber plants with a latex vascular system in the trunk that impacts the products. In this study, we use the method of fertilizing mineral nutrients by injection and infusion on rubber trees, which are one of the most massive raw materials for the manufacturing industry in Indonesia, to boost latex production.

2. Literature Review

2.1 Latex Yield of Rubber (*Hevea brasiliensis*)

Latex is formed by specialized cells called laticifers that are found within the bark of the rubber tree Hevea brasiliensis. The amount of latex recovered after each tapping is determined by the convenience with which the latex flows, the duration of the flow, and the rate at which the tree regenerates latex (Njukeng et al., 2011). The implementation of proper applicable soil management measures is required for the success of rubber metabolism; at low soil moisture levels, the rate and duration of latex flow are greatly reduced. (Akpan et al., 2007; Njukeng et al., 2011).

Mineral nutrient supply strongly affects leaf area and the rate of photosynthesis (Cakmak & Engels, 1999). Nutrients via stem flow are important in plants that receive little or no external sources of essential nutrients (Adedeji & Gbadegesin 2012). The availability of carbohydrates in the tissues involved in latex synthesis is essential for rubber production. Carbohydrate is the primary metabolite of photosynthesis and provides the material basis for rubber trees' yield formation. Mineral elements are essential not only for the rubber tree to provide nutrients, but also an important factor affecting photosynthesis (Xu et al., 2007). The dynamics of carbohydrate reserves appear an indication to assess the long-term performance of latex synthesis (Chantuma et al., 2009; Chow et al., 2012). In the synthesis of rubber, the disaccharide type of carbohydrate has a unique precursor, sucrose. Sucrose must pass the plasma membrane via specialized sucrose transporters before it can be metabolized in laticifers (Dusotoit-Coucaud et al., 2009). The invertase and sucrose synthase process in latex, as well as the anatomical characteristics of the bark, were studied in order to determine a possible association with latex synthesis (Mesquita et al., 2006; Silpi et al., 2006; Dusotoit-Coucaud et al., 2010).

Latex is obtained by tapping the bark periodically (Njukeng et al., 2011). Rubber tree laticiferous cells can be stimulated, causing physiological and biochemical changes that contribute to increased latex yield (Chantuma et al., 2009). The higher production of rubber was found in plants with a higher number of laticiferous vessels and thickness of bark (De Souza et al., 2014).

TPD (Tapping Panel Dryness) is a condition in which there is no latex flow, resulting in a significant reduction in latex production (Liu et al., 2015; Putranto et al., 2015; Nie et al., 2016). Other signs and symptoms include brown bast, thickening, and flaking of the bark (Liu et al., 2015).

Many physiological and biochemical changes have been reported during the development of TPD, including a decrease in sucrose and dry matter in the latex, as well as an increase in inorganic phosphorus (Putranto et al., 2015). The expression of genes involved in latex manufacturing was dramatically reduced in fully dried panel trees. Furthermore, the transcriptomes used in this work provide useful information for identifying genes linked to TPD (Liu et al. 2015). TPD is driven in part by ethylene stimulation. Stimulants lead to the accumulation of aerobic metabolic products in the laticifers, which induces the TPD to generate. In the laticifer of the rubber tree, ethylene stimulation of latex production is linked to a rapid importation and metabolism of sucrose, which enhances the availability of acetyl-CoA and ATP for rubber biosynthesis (Sainoi & Sdoodee, 2012; Nie et al., 2016).

2.2 Trunk Injection and Infusion

The injection approach was initially used in the Buitendag and Bronkhorst citrus tree research, where pesticide liquid was injected directly into tree trunks or branches using plastic syringes (Buitendag et al., 1980). In Darvis' research, the injection method was re-applied by inserting a bottle of phosetyl-Ca and phosetyl-Al into avocado plants. The bottle is drained in an infusion tube and injected into the trunk of the avocado tree to avoid infection with microorganisms from water molds (Phytophthora cinnamomi) (Darvas & Bezuidenhout, 1987). At the beginning of the research report, this method was frequently utilized for therapeutic actions/treatment of plant diseases, especially those that attack the trunks. However, this method can be applicated to introduce plant nutrients directly through plant trunks (de la Parra and Calderon 1992). In Toerien and Slabbert's study, macronutrient phosphorous liquid was added in the form of phosphoric acid H3PO3 and H3PO4 to meet the nutritional needs of avocado plantations (Toerien and Slabbert, 1984).(Figure 1)

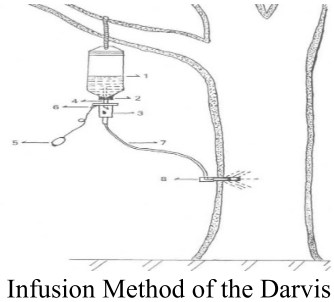

Figure 1. Schematic of the Injection and Infusion Method of the Darvis Study (de la Parra and Calderon 1992)

The effectiveness of this method depends on the hardness of the wood structure, and the narrowness of the sap-conducting tissue (xylem) makes it difficult for a fluid nutrient or agrochemical to flow into the stem (de la Parra and Calderon 1992). Therefore, an arborjet creates holes in the tree trunk to access the sapwood layer by injecting it. Sapwood, which has a good criteria location for trunk injection, is substantial for nutrient transmission and storage in the plant vascular system (Luaces et al., 2020). In addition to the tree trunk, the size of the hole and the injection needle have significant factors in the method's effectiveness. Large holes and syringe needles will require a longer healing time and risk damaging more vascular tissue. And the liquid injection will be problematic with smaller holes and syringe needles and will take a long time (Zamora & Escobar, 2000; Berger & Laurent, 2019). Other factors such as tree species also affect the effectiveness of the trunk injection method. All types of angiosperm plants commonly can be applied to this method. However, while injecting agrochemicals into tree trunks, it is vital to consider the tree's morphology and physiology, and environmental conditions (Berger & Laurent, 2019). (Figure 2)

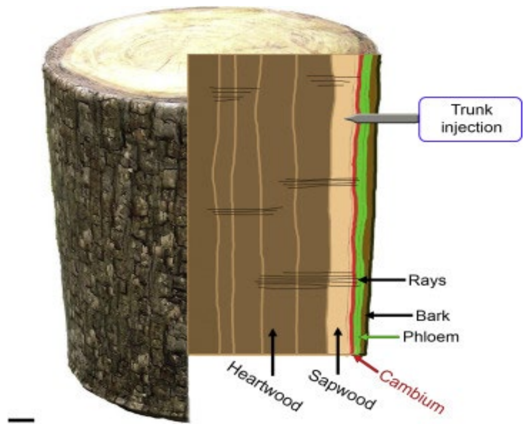

Figure 2. Schematic of Target Administration of Nutrient or Pesticide Liquid in the Injection-infusion Method on Sapwood in the Trunk Tree

The injection-infusion method is very environmentally friendly and minimizes pollution from chemicals used in agricultural activities. Chemicals that are sprayed directly into the soil, such as fertilizers and pesticides, can damage the ecosystem around agricultural land. As a result, pollution may have contaminated soil and water quality. In addition, groundwater and organisms are also poisoned by agrochemicals which are not administered effectively to the plant body. Therefore, trunk injection is an excellent way of fertilizing in modern agriculture.

3. Methodology

The experiment was carried out during April to August 2015 at the PTPN VIII Plantation, West Java Province, Indonesia. The rubber tree lower and upper 20 years old in three locations of plantation was used in the experiment. The study used 1200 rubber trees as a population in a 3-hectare area, and it was conducted by providing nutrients through the stems. Data for analysis purposes were randomly collected in each treatment tree with 10 point locations sampling as replication.

Mineral nutrient content, stock solution A: NH4+ = 0.19%, NO3+ = 1.56%, total Ca = 826.00 ppm, total Fe = 67.90 ppm, total Cu = 28.93 ppm, total Mn = 38.66 ppm, total Zn = 16.44 ppm, B and Mo = TE. Stock solution B: NH4+ = 0.01 %, NO3- = 0.75 %, total P2O5 = 1.02 %, total K2O = 2.41 %, total Mg = 735 ppm, SO4= 0.28 %.

Location Bunisari Lendra for lower 20 years old, there were three treatments (20 trees per treatment). The first treatment: A and B stock mixed in 100 times of water volume was applied for infusion treatment, characterized 5.52 in pH and 3.83 mS/cm in electrical conductivity. The second treatment: 10 mL stock A and 10 mL stock B without dilution put on the different holes on the trunk 50 cm above of ground for injection treatment. And the third treatment: no applied nutrient as control.

Location Bunisari Lendra for upper 20 years old (10 trees per treatment), there were six treatments: Infusion of 10 mL.L^{-1} (A and B stock) on trees of tapping panel dryness (TPD) and normal trees, 20 mL. L^{-1} (A and B stock) on both TPD and normal trees, 30 mL.L^{-1} (A and B stock) on both TPD and normal trees.

Location Bagjanagara for below 20 years old, there were seven treatments (10 trees per treatment). No infusion with lower tapping exploitation (LTE), Infusion position 10 mL.L^{-1} 50 cm from ground of the trunk (FGT) with LTE, Infusion position 10 mL.L^{-1} 50 cm FGT with upper tapping exploitation (UTE), Infusion position 10 mL.L^{-1} 75 cm FGT with LTE, Infusion position 10 mL.L^{-1} 75 cm FGT with UTE, Infusion position 10 mL.L^{-1} 100 cm FGT with LTE, Infusion position 10 mL.L^{-1} 100 cm FGT with UTE. Seven times tapping of latex yield was collected with conventional tapping system 1/2S3d.

In order to convert fresh weights into grams of dry rubber per tree, the latex yield from the cup was weighed and the total solid content was assessed from a bulk sample obtained in each treatment. The yield of latex and dry rubber was analyzed by analysis of variance (ANOVA) and least significant difference (LSD, P < 0,05).

4. Results and Discussion

4.1 Latex Yield and Dry Rubber with Trunk Injection

There was a significant difference in average cup latex among treatments during the experimental period. The injection of mineral nutrients on the trunk at 50 cm from ground treatment provided the highest both latex yield and dry rubber as shown in Table 1. These results showed that several mineral nutrients supply affected latex or rubber biosynthesis, while external sources of essential nutrients deficit (Cakmak & Engels, 1999; Adedeji & Gbadegesin, 2012).

Table 1. Latex Yield and Dry Rubber on Trunk Infusion and Injection of Minerals Nutrient Treatments. Location Bunisari Lendra for Lower 20 Years Old Trees

Treatments	Latex (g. tree^{-1}. tapping^{-1})			Dry rubber (g. tree^{-1}. tapping^{-1})		
	Min	Max	Mean	Min	Max	Mean
No applied nutrition	156.0	280.0	222.2*	28.1	56.0	44.0*
Infusion nutrition with dilution 100 times	280.0	370.4	329.4*	58.9	87.1	72.8*
Injection nutrition without dilution	395.6	440.2	424.9*	87.1	126.6	106.7*
LSD: Standard error			14.5			4.4

*significant difference at p-value < 0.05

Complete nutrition by injection (trunk injection) can boost nutrient uptake, particularly macronutrients, by roots from the soil. These nutrients (macro and micro) entering through the stem can maximize the performance of the metabolic "engine" in the leaves. This metabolism begins with an increase in the rate of photosynthesis, which produces glucose. The glucose is converted into sucrose products in large quantities so that the raw material for rubber biosynthesis is available (polyisoprene).

4.2 Tapping Panel Dryness and Bark Regeneration

The infusion of 10 mL.L^{-1} at normal trees and 20 mL.L^{-1} at TPD trees mineral nutrients concentration treatments provided a higher significantly latex yield and dry rubber as shown in Table 2. These results showed that sufficient mineral nutrients on the trunk affected cells metabolism and photosynthesis activities which improved sucrose supply and lead to bark regeneration, so latex production can occur, especially on the TPD trees (Cakmak & Engels, 1999; Xu et al., 2007; Adedeji & Gbadegesin, 2012).

Table 2. Latex Yield and Dry Rubber Affected by Infusion of Three Concentration of Mineral Nutrient on Both Tapping Panel Dryness and Normal Trees, Location Bunisari Lendra for Upper 20 Years Old Trees

Treatments	Latex (g.tree^{-1}.tapping^{-1})			Dry rubber (g.tree^{-1}.tapping^{-1})		
	Min	Max	Mean	Min	Max	Mean
Tapping panel dryness + 10 mL.L^{-1} nutrition	130.6	201.1	149.3*	27.4	44.3	33.5*
Normal + 10 mL.L^{-1} nutrition	152.3	210.6	167.6*	30.5	60.6	40.3*
Tapping panel dryness + 20 mL.L^{-1} nutrition	152.0	245.7	181.1*	37.1	71.3	46.1*
Normal + 20 mL.L^{-1} nutrition	115.4	203.6	145.2*	25.4	48.1	33.4*
Tapping panel dryness + 30 mL.L^{-1} nutrition	70.9	117.7	107.9*	19.8	32.9	26.7*
Normal + 30 mL.L^{-1} nutrition	96.0	131.9	113.7*	20.8	32.0	25.8*

LSD: Standard error			10.9			3.0

*significant difference at p-value < 0.05

One of the most common disease categories in rubber plantations is tapping panel dryness (TPD). TPD disease is caused by overexploitation of tapping. One of them is tapping is done every two days, and the use of stimulants without adequate fertilizer. Those actions make rubber plants experience fatigue and a lack of energy sources so that the tapping field is susceptible to infection by fungi and no longer produces latex. The application of nutrients using TPD-treated rubber trunks proved to be an effective method for cell regeneration in the tapping field. So that method returns to produce latex and can be tapped. Proven results are the same as healthy rubber trees.

4.3 Infusion Position and Tapping Exploitation

The treatments position of infusion at 50 cm to 75 cm from the ground with lower tapping exploitation expressed better latex yield and dry rubber as shown in Table 3. There was no information report referring to the theory about the result. However, latex yield and dry rubber tended to be increased under these treatments.

Table 3. Latex Yield and Dry Rubber Affected by Infusion position, Location Bagjanagara Lendra for Upper 20 Years Old Trees

Treatments	Latex (g.tree^{-1}.tapping^{-1})			Dry rubber (g.tree^{-1}.tapping^{-1})		
	Min	Max	Mean	Min	Max	Mean
No infusion nutrition with lower tapping exploitation	139.5	162.3	149.4*	36.4	48.0	41.4*
Infusion position (50 cm) with lower tapping exploitation	149.1	216.9	181.8*	49.3	78.1	65.1*
Infusion position (50 cm) with upper tapping exploitation	122.6	190.1	155.7*	47.8	67.8	57.8*
Infusion position (75 cm) with lower tapping exploitation	137.7	190.6	168.9*	53.1	78.1	65.4*
Infusion position (75 cm) with upper tapping exploitation	75.7	115.9	98.9*	25.7	43.7	35.4*
Infusion position (100 cm) with lower tapping exploitation	105.7	159.4	136.2*	30.7	54.9	41.0*
Infusion position (100 cm) with upper tapping exploitation	93.9	145.1	115.5*	33.8	50.8	42.5*
LSD: Standard error			7.4			2.8

*significant difference at p-value < 0.05

The application of nutrients is carried out on the xylem and moves from the bottom to the leaves. Meanwhile, sucrose, as a raw material for latex, circulates through the phloem. Because the two components carried by xylem and phloem go on separate pathways, they did not affect each other in our study. Thus, the nutrient infusion installations on rubber trunks are technically unrestricted; the main issue is to avoid interfering with tapping activities.

5. Conclusion

The results showed that on lower 20 years old rubber increase in latex and dry rubber yield significantly in the trees that were given nutrient solution by injection without dilution of nutrient solution at 20 mL, 424.9 g.tree^{-1}.tapping^{-1} for latex yield, 106.7 g.tree^{-1}.tapping^{-1} for dry rubber. By infusion with dilution of nutrient solution at 20 mL.L^{-1}, 329.4 g.tree^{-1}.tapping^{-1} for latex yield, 72.8 g.tree^{-1}.tapping^{-1} for dry rubber. No applied nutrient solution, 222.2 g.tree^{-1} tapping^{-1} for latex yield, 44.0 g.tree^{-1}tapping^{-1} for dry rubber. The heights of the infusion position on the trunk at 50 cm from the ground with LTE the dilution of nutrient solution at 10 mL.L^{-1} give the effect the highest latex and dry rubber yield. Concentrate of 20 mL.L^{-1} nutrient solution in infusion application on the trunk of tapping panel dryness gives the effect on higher latex yield than normal rubber tree of the upper 20 years old.

The limitation in the nutrients application through stems only use chemicals fertilizer, not organic fertilizers. The chemical fertilizers which were used for the nutrient sources in the form of water-soluble and ionized. These nutrients in the cations and anions form are the same as the nutrients absorbed through the roots. Furthermore, because overall nutrient requirements are inadequate to reach stem delivery, this technique is effective as a supplement. However, when combined with the application of fertilizer through the stem and simultaneously with the application of fertilizer through the soil, the effectiveness of nutrient utilization by rubber plants will be higher. The trunk injection approach is recommended to make it convenient and more practical to implement because it does not require an infusion installation.

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