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Effects of Ethephon Stimulation and Cut Length by Vertically Tapping on Rubber Yield and Latex Quality

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***Abstract*— *Harvest of natural rubber is facing the problems of a declining rubber price, less favorable agro-climate, and skilled tapper labor shortage. Reduction in cost of latex harvest by tapping machine in a straight line with ethephon stimulant will make rubber production more cost effective. To evaluate the effect of ethephon stimulation and cut length by tapping in a straight line on rubber yield and latex quality, a comparison of vertically tapping practices was conducted in clone Reyan88-13. The results showed that the increase of dry rubber yield was significantly obtained by the increase of cut length and ethephon stimulation concentration. Moreover, the increase of cut length and ethephon stimulation concentration significantly resulted in an increase of Cu^{2+} content, while the increase of ethephon stimulant concentration significantly led to a decrease in dry rubber content and Mg^{2+} content, but increase in thiols content. And also ethephon stimulation decreased consistently tear strength values, increased tensile strength and tensile permanent set values. The new tapping practice by vertically tapping with long cut length and high concentration of ethephon stimulant can be an alternative to relieve the stress of tapping complexity and tapper shortage.*

***Keywords*— Cut length, Ethephon stimulation, Vertically tapping, Rubber yield, Latex quality.**

I. INTRODUCTION

Natural rubber (*Hevea brasiliensis*) is an important industrial crop cultivated in tropical and subtropical areas for natural rubber production(Liu, 2016). In China, rubber cultivation are facing many challenges such as the declining rubber price, low comparative benefits, high tapping cost, aging of tapper, labor shortage, low level of mechanization management, loss of enterprises, low enthusiasm of farmers for planting rubber and a large number of abandoned rubber plantations. To mitigate the effect of low rubber prices, low frequency tapping systems combined with proper ethephon stimulation (Sainoi et al., 2017; Soumahin et al., 2014; Xie et al., 2017; Zaw et al., 2017) to decrease the time spent on field and different tapping tools such as electric tapping knife (Ru et al., 2018), and automatic tapping machine (Zhang et al., 2019) to increase the tapping labor productivity are researched and developed. At present, the production and management of natural rubber is still dominated by manpower, with a very low degree of mechanization. The cost of rubber tapping accounts for 60% of the natural rubber production cost (Huang et al., 2019) and it is urgent to accelerate the process of mechanization. However, the existing rubber cutting method is still adopted with the traditional spatial curve to cut the bark and collect latex of the trunk, requiring cut depth, thickness and evenness, whatever the frequency of latex harvesting system and tapping knife. Therefore, the current design of automatic tapping technology or device has to be very complex, which leads to the high production cost of related devices and is difficult to be popularized in field production.

The study reported herein investigated a simplified cutting technology by tapping in a straight line (vertically tapping), which could be more suitable for the simple mechanical operation. To evaluate the effect of ethephon stimulation and cut length by tapping in a straight line on rubber yield and latex quality, a comparison of vertically tapping practices was conducted in clone Reyan88-13.

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II. MATERIALS AND METHODS

Thirty-three years-old trees of clone Reyan88-13 were planted and never tapped at the experimental nursery of Rubber Research Institute of Chinese Academy of Tropical Agricultural Science in Danzhou, Hainan, China. The girth of these trees were measured and grouped randomly before tapping. These trees were regularly tapped in a straight line (vertically tapping) at 0.5S, 1S and 1.5S cut lengths in the field, every three days, without ethephon(no stimulation) and with 0.5% ethephon stimulation at 1st-13th tapping (Figure 1).

No stimulation

0.5% ethephon stimulation

Cut length **0.5S** **1S** **1.5S**

Fig.1. The representative view of vertically tapping with no stimulation and 0.5% ethephon stimulation at 0.5S, 1S and 1.5S cut lengths in the field. Slope of tapping cut(90°) denotes vertically tapping. 0.5S, half girth; 1S, girth; 1.5S, 1.5 girth.

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Then at 14-26th tapping, trees tapped at 1S and 1.5S cut lengths with 0.5% ethephon stimulation were given with 1.5% ethephon stimulation. Each treatment contained three trees, and latex samples from these three trees were separately collected every tapping for dry rubber yield, dry rubber content, latex physiological parameters. Dry rubber yield, dry rubber content, latex physiological parameters according to the conventional method (M. et al., 1984; Xiao and Xiao, 2010). Determination of chemical and physical properties of dry rubber are tested according to the national standard method (GB/T 531.1-2008,GB/T528-2009 and GB/T3512-2001). Physical and mechanical properties of raw rubber and vulcanizate were performed by Shandong Qibiao Testing Co., Ltd., Qingdao, China.

III. RESULTS AND DISCUSSION

Cut length and Ethephon Stimulation Influence Dry Rubber Yield Effect of cut length on dry rubber yield in 26 tapping numbers demonstrated the same upward trend whatever ethephon stimulation with (Figure2A,B and Figure3D).

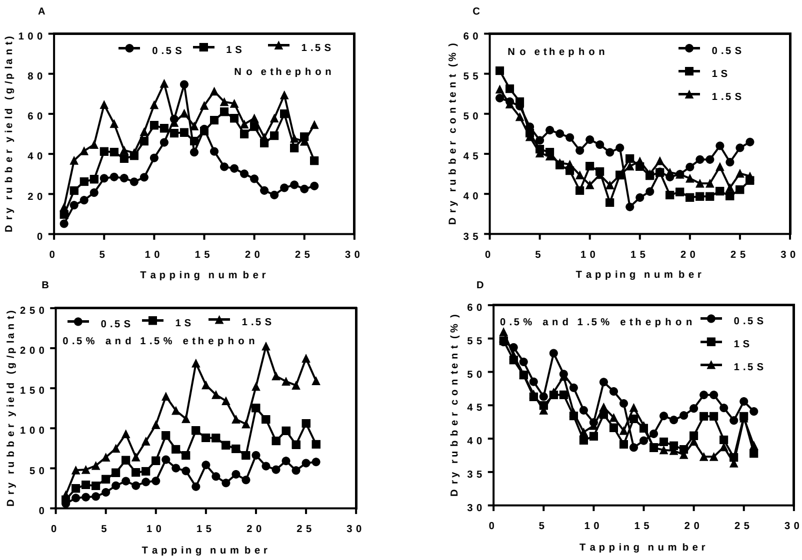

Fig.2. Changes in dry rubber yield and dry rubber content of vertically tapping with no stimulation, 0.5% and 1.5% ethephon stimulation at 0.5S, 1S and 1.5S cut lengths. 0.5S, half girth; 1S, girth; 1.5S, 1.5 girth. At 14-26th tapping, trees tapped at 1S and 1.5S cut lengths with 0.5% ethephon stimulation were given with 1.5% ethephon stimulation(B, D), respectively.

The 1.5S cut length gave the highest dry rubber yield (Figure3D). With no stimulation dry rubber yield of 1.5S cut length was 73.94% (P<0.01) more than that of 0.5S cut length, and 21.07% (P<0.05) more than that of 1S cut length, respectively, and dry rubber yield of 1S cut length was 43.67% (P<0.01) more than that of 0.5S cut length. With 0.5% ethephon stimulation the dry rubber yield of 1.5S cut length was 166.36% (P<0.01) more than that of 0.5S cut length, and 66.07% (P<0.01) more than that of 1S cut length, respectively. There was no significance between the dry rubber yield of 0.5S and 1S cut length with 0.5% ethephon stimulation. With 1.5% ethephon stimulation the dry rubber yield of 1.5S cut length was 222.51% (P<0.001) more than that of 0.5S cut length with 0.5% ethephon stimulation, and 70.52% (P<0.01) more than that of 1S cut length with 1.5% ethephon stimulation, respectively, and the dry rubber yield of 1S cut length with 1.5% ethephon stimulation was 89.13% (P<0.01) more than that of 0.5S cut length with 0.5% ethephon stimulation. At the same cut length of 1.5S , the dry rubber yield with no stimulation was 37% (P<0.05) less than that with 0.5% ethephon stimulation (Figure3A), 43.88% (P<0.001) less than that of 1S cut length, and 62.25% (P<0.001) less than that of 1.5S with 1.5% ethephon stimulation (Figure 3C).

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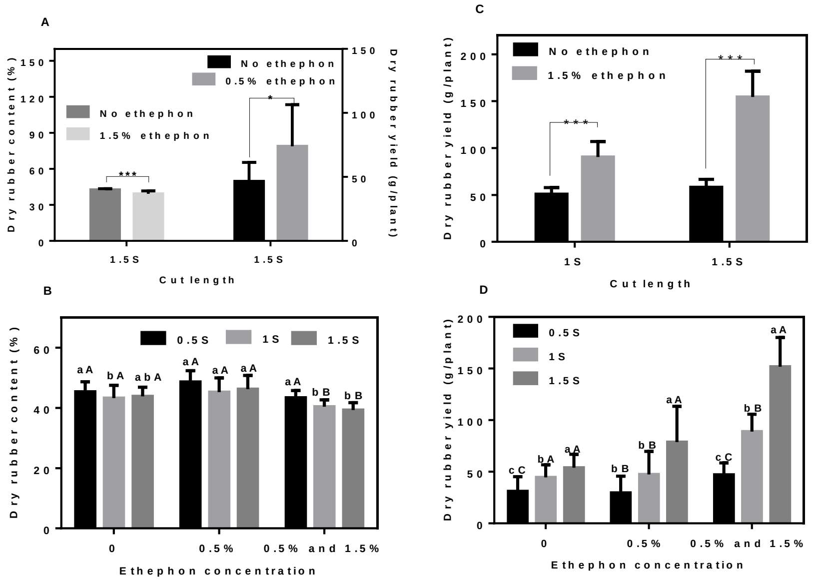

*Fig.3. Comparison of dry rubber yield and dry rubber content at different cut length and ethephon stimulation. In the 0.5% and 1.5% group columns (B , D), 0.5S with 0.5% ethephon, 1S and 1.5 S with 1.5% ethephon, respectively. Data of 1.5% ethephon stimulation are means of 14st- 26th tapping numbers measured. Means ± SD, *P < 0.05, **P < 0.01, ***P < 0.001. Different small letter indicates significant difference (P < 0.05), different capital letter indicates extremely significant difference (P < 0.01 or P < 0.001).*

The increase of dry rubber yield in this study was obtained by the increase of cut length and ethephon stimulation concentration. The reduction of the tapping cut length induces losses in rubber yield (Obouayeba et al., 2011). However, Soumahin et al.(2014) reported long cut length caused losses of rubber yield, which was conducted at low frequency tapping. The ethephon (a phytohormone ethylene generator), as a stimulant of latex production in *Hevea brasiliensis*, has been widely used in commercial latex production, by prolongation of latex flow, acceleration of the laticifer water circulation, sucrose metabolism, production, scavenging of reactive oxygen species assembly, depolymerization of the latex actin cytoskeleton, and latex regeneration (An et al., 2015; ANAÏS et al., 2010; Nie et al., 2016; Tang et al., 2010; Zhu and Zhang, 2009), to increase latex yield in rubber tree plantations.

Cut Length and Ethephon Stimulation Influence Dry Rubber Content Effect of cut length on dry rubber content in 26 tapping numbers demonstrated the same upward trend whatever ethephon stimulation (Figure2C, D and Figure3B). The 0.5S cut length gave the highest dry rubber content (Figure3B). As seen in Figure3B, with no stimulation the dry rubber content of 0.5S cut length was 4.78% (P<0.05) more than that of 1S cut length, and the dry rubber content of 0.5S cut length with 0.5% stimulation was 7.24% (P<0.05) that of 1S cut length with 1.5% stimulation, and 10.32% more than that of 1.5S cut length with 1.5% stimulation, respectively. There was no significance in dry rubber content between 0.5S and 1.5S, 1S and 1.5S cut length with no ethephon stimulation, among 0.5S, 1S and 1.5S cut length with 0.5% ethephon stimulation, 1S and 1.5S cut length with 1.5% ethephon stimulation, respectively. While at the same cut length of 1.5S, the dry rubber content with no stimulation was 8.25% (P<0.001) more than that with 1.5% ethephon stimulation (Figure3A).

The increase of dry rubber yield with the increase of cut length and ethephon stimulation concentration resulted in an decrease in dry rubber content, which indicated very strong correlations were determinate between tapping intensity and rubber yield, between tapping intensity and dry rubber content (Obouayeba et al., 2011).

Cut length and Ethephon Stimulation Influence Biochemical Parameters of Latex There was no significant impact on initial latex flow velocity, sucrose contents and inorganic phosphorus (data not shown). Effect of cut length on Cu^{2+} content with 0.5% and 1.5% ethephon stimulation in 13 tapping numbers was shown in Figure4A. As seen in Figure4B, Cu^{2+} content of 0.5S cut length with

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0.5% ethephon stimulation was 19.59% (P<0.001) less than that of 1S cut length with 1.5% ethephon stimulation, and 44.72% less than that of 1.5S cut length with 1.5% ethephon stimulation, respectively. At 1.5S cut length Cu^{2+} content with no stimulation was 41.08% (P<0.001) less than that with 1.5% ethephon stimulation (Figure4C). Cu^{2+} content of rubber latex was positively correlated with intensity of ethylene stimulation within limits (Xiao and Xiao, 2010) and could be considered as a standard of tapping intensity in long-term latex flow (Wei et al., 2015). In the present study, the increase in the concentration of ethephon stimulant and cut length led to an increase in Cu^{2+} content, which reflected the increase dry rubber yield.

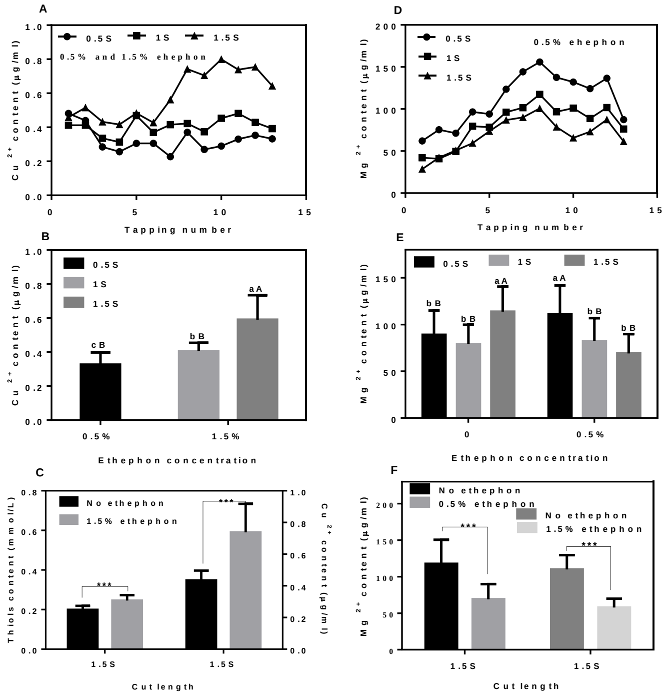

*Fig.4. Changes in Cu^{2+} content(A) and Mg^{2+} content(D) and comparison of thiols content(C), Cu^{2+} content(D) and Mg^{2+} content(D, E, F) with different cut length and ethephon stimulation. Data of thiols content are means of 14^{th}- 26^{th} tapping numbers measured. Tapping number of Cu^{2+} content are the 11^{th} to 26^{th}, and data of Cu^{2+} content are means of 11^{th} to 26^{th}. Data of Mg^{2+} content(E) with are means of 1^{st}- 26^{th} tapping numbers measured. Data of Mg^{2+} content(F) with no and 0.5% ethephon at 1.5S cut length are means of 1^{st}- 13^{th} tapping numbers measured. Data of Mg^{2+} content(F) with no and 1.5% ethephon at 1.5S cut length are means of 14^{th}- 26^{th} tapping numbers measured. Means ± SD, ***P < 0.001.*

Effect of cut length on Mg^{2+} content with 0.5% or 1.5% ethephon stimulation in 13 tapping numbers was shown in Figure4 D. As shown in Figure4E, with no stimulation Mg^{2+} content of 1.5S cut length was 27.89% (P<0.01) more than that of 0.5S cut length, 43.85% (P<0.01) more than that of 1S cut length, while at 0.5% ethephon stimulation Mg^{2+} content of 0.5S cut length was 26.39% (P<0.01) more than that of 1S cut length, 60.33% (P<0.01) more than that of 0.5S cut length. There was no significance in Mg^{2+} content between 0.5S and 1S cut length with no ethephon stimulation, between 1S and 1.5S cut length with 0.5% ethephon stimulation, respectively. As shown in Figure4F, at 1.5S cut length Mg^{2+} content of means of 1^{st}- 13^{th} tapping numbers measured with no stimulation was 70.18% (P<0.0001) more than that with 0.5% ethephon stimulation. Moreover, at 1.5S cut length Mg^{2+} content of means of 14^{th}- 26^{th} tapping numbers measured with no stimulation was 89.93% (P<0.05) more than that with 1.5% ethephon stimulation. Mg^{2+} content of rubber latex was negatively correlated with latex yield (Subronto, 1978) and high Mg^{2+} content lead to latex flow barrier at the cut (Xiao and Xiao, 2009). In the present study, an increase in the concentration of ethephon stimulant led to an decrease in Mg^{2+} content, which affected the increase of dry rubber yield.

At 1.5S cut length thiols content with no stimulation was 19.13% (P<0.001) less than that with 1.5% ethephon stimulation (Figure4C). Thiols can delay latex coagulation and normally the higher thiols content means the more

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latex (Jacob and Lin, 1987). In the present study, an increase in the concentration of ethephon stimulant led to an increase in thiols content, which reflected the increase dry rubber yield.

Ethephon Stimulation Influence Physical and Mechanical Properties of Raw Rubber and Vulcanized Rubber Ethylene stimulation acts by increasing 1atex flow to the cells of inner bark from the latex cells, increasing yield and may affect the physical properties of rubberwood. As shown in Table1, at 1st- 26th tapping numbers, with 0.5% ethephon stimulation there were some different increase in mooney viscosity (ML, 3.03%), plastic starting value (Po, 1.55%), tensile strength (6.67%), tensile permanent set (TPS, 15.79%), snapping back rate (SNR, 5.33%), while decrease in tear strength (TS, 1.43%) and elongation at break (EB, 4.62%), compared to the values with no ethephon stimulation. It was deduced that rubber with 0.5% ethephon stimulation had better anti-oxidation and anti-aging properties and less mechanical properties such as tightness cross-link (Wang et al., 2014). At 14th- 26th tapping numbers, with 1.5% ethephon stimulation there were different increase in plasticity retention index (PRI, 1.11%), Modulus at 100 % (2.85%), tensile strength (5.16%), elongation at break (EB, 2.94%), and tensile permanent set (TPS, 22.22%), while decrease in mooney viscosity (ML, 1.98%), plastic starting value (Po, 2.20%), and tear strength (TS, 1.39%), snapping back rate (SNR, 5.13%), and shore A (3.75%) when compared to the values with no ethephon stimulation, which rubber with 1.5% ethephon stimulation showed more mechanical properties such as tightness cross-link and better flexibility. Shore-A hardness refers to the resistance to deformation by external force, which is closely related to other mechanical properties such as tear strength and flexibility (Li, 2007). Our findings showed that shore A and tear strength values reduced was attributed to higher modulus values of vulcanized rubber in accordance with the report (Akçakale and Bülbül, 2017).

Taken together, in this study, ethephon stimulation decreased consistently tear strength values and increased tensile strength and tensile permanent set values. The effect of ethephon concentrations on raw rubber and vulcanized rubber was obviously significant.

Table1. Comparison of physical and mechanical properties of raw rubber and vulcanized rubber. Slope of tapping cut(25°) denotes horizontally tapping and slope of tapping cut(90°) vertically tapping. Mooney viscosity=ML, Plastic starting value=Po, Plasticity retention index = PRI, Elongation at break =EB, Tensile permanent set=TPS, Tear strength =TS, Snapping back rate=SNR.

		Raw rubber			Vulcanized rubber						
Tapping numbers	Ethephon application	ML(1+4)100℃	Po	PRI（%, 134℃30min）	Modulus at 100 %/MPa	Tensile strength /MPa	EB (%)	TPS（%）	TS (KN/m)	SNR(%)	Shore A
1-13	0	99	45.3	55	10	15	650	9.5	70	75	78
	0.5%	102	46	55	10	16	620	11	69	79	78
14-26	0	101	45.5	53.9	10.5	15.5	680	9	72	78	80
	1.5%	99	44.5	54.5	10.8	16.3	700	11	71	74	77

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IV. CONCLUSION

The current problem of tapping complexity and tapper shortage can be solved by tapping machine in vertical tapping line with long cut length and high ethephon stimulation. However, ethephon stimulation decreased consistently tear strength values and increased tensile strength and tensile permanent set values. Moreover, there was no significant impact on initial latex flow velocity, sucrose contents and inorganic phosphorus.

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