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Effectiveness of a locally developed ethephon formulation on yield and related latex physiological factors of *Hevea brasiliensis*

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Abstract

Ethephon is an essential agrochemical in low intensity harvesting of rubber (Hevea brasiliensis). Currently the total requirement for rubber industry is being imported in ready-mixed form adding a considerable cost to the plantations. Therefore, a new ethephon formulation was developed locally and the present study aimed to assess its effectiveness under Sri Lankan condition.

The newly developed ethephon formulation was tested against a commercially available formulation with a small-scale field trial. No significant variation was observed in sucrose availability in laticifers with the new ethephon formulation. Significantly higher thiol and lower inorganic phosphorous contents of latex in trees may ensure long-term sustainability of the new ethephon formulation as a yield stimulant in rubber. Average dry rubber content of latex and latex volume obtained from a tree was comparable with both formulations. Accordingly, dry rubber yield resulted from trees applied with new ethephon formulation was comparable with the existing formulation and average values were 83.22 g and 86.67 g, respectively for new and existing formulations.

Key words: 2-choloroethylphosphonic acid, ethephon, exploitation, *Hevea*, low intensity harvesting, rubber, stimulation

Introduction

Stimulation based low intensity harvesting (LIH) systems designed with various combinations of cut lengths, frequency of tapping and stimulation techniques are accepted by the growers as modern exploitation techniques to overcome constrains such as high cost of production (COP), lack of skilled harvesters and high bark consumption rates in rubber plantations. Suitable stimulation protocol is used with LIH systems to overcome low yields due to lowering the harvesting intensity thus to achieve comparable yields to that of conventional tapping *i.e.* S/2 d2 system (Gao *et al*., 2018). A wide spectrum of chemical compounds including ethylene generating compounds, auxins, auxin analogues, herbicides and inorganic salts had been tried as yield stimulants from the beginning of rubber plantation industry. Few of them were ethylene generators while others appeared to be more or less phytotoxic which may induce endogenous ethylene production. Ethephon (2-chloroethylphosphonic acid) was found superior to all other chemicals and even today ethephon is the only stimulant used in commercial application. Hence, nowadays ethephon has become an essential agrochemical used in harvesting of rubber. Ethephon stimulation based LIH systems enhance the sustainability of rubber farming with a better income to the harvester and lower cost of production (COP) to the management.

Ethephon is a plant growth regulator with systemic properties, penetrates into the plant tissues, translocate and in the presence of water. It progressively decomposed to ethylene (Tseng *et al.*, 2000), which is a kind of plant hormone that affects the biochemical and physiological status of the tree resulting in high yields.

It is a whitish solid readily soluble in aqueous solutions and stable below pH 3.5 (Anon., 1987) and could not be applied on trees as it is. So it is usually mixed with an inert material *i.e.* methyl cellulose, starch, palm oil or a mixture of such materials to make it more viscous enabling easy application on bark of tree whilst increasing the slow release properties.

Stimulation effect of ethephon depends on the length of cut and frequency of tapping or combination of them (Njukeng *et al.*, 2011). A large number of low intensity systems have been used with different levels of ethephon in many rubber growing countries (Karunai-chamy *et al.*, 2001; Kewi & Sivakumaran, 1994; Rodrigo *et al*., 2011; Xuehua *et al.*, 2004). Judicious application of ethephon with correct harvesting systems may only give long term sustainable yields.

In Sri Lanka ethephon based low intensity harvesting systems *i.e*. S/2 d3 (Nugawela *et al*., 2000), S/2 d4 (Rodrigo *et al*., 2011) and S/4 d3 (Rodrigo *et al*., 2012) have been recommended and currently adopted in plantations in an increasing trend. Total requirement of the ethephon to Sri Lankan rubber plantation industry is presently imported and marketed at a price of about LKR 1000 per kg. Some Regional Plantation Companies import 3 to 6 MT of ethephon annually (personal communication) and CIF value of such amount is about 1-2 Mn LKR (1USD = 180 LKR). In view of minimizing the cost involved, a formulation of ethephon was developed locally and the present study aimed to assess its suitability under field conditions in Sri Lankan rubber plantations.

Materials and Method

A new formulation with 2.5% ethephon has been developed by Rubber Research Institute of Sri Lanka by using concentrated ethephon available in the market. Mixture of carbohydrate derivatives (methyl cellulose, starch and xanthan gum) were used to increase the viscosity of mixture thus improve the slow release properties of the new formulation. Organic acids were used to reduce the pH to prevent decomposing of ethephon. By using motorized blender all the ingredients were thoroughly mixed to give about 1200 cP viscosity and final ethephon concentration of the mixture was set to 2.5% ± 0.1%.

Rainguarded monoclonal mature rubber field replanted in 2011 with RRIC 121 in Gallewatta Division of Dartonfield Estate was selected for testing the efficacy of new ethephon formulation developed by the Rubber Research Institute of Sri Lanka. Ethephon-Plus currently available water-based commercial ethephon mixture in the local market was used for comparison as the control. Both treatments were tested using a randomized complete block design (RCBD) with three replicates comprising 10 trees in each plot. Efficacy was tested using recommended protocol for S/2 d4 system in Sri Lanka with application of 2.5% ethephon, monthly. The amount applied per tree per application was 1.6 g (Rodrigo *et al.*, 2011).

Analyses of latex samples were done in each tapping day. Latex was collected into vessels immersed in ice between 5th and the 35th minutes after tapping and immediately taken to the laboratory for analysis. Extractions were prepared by coagulating the latex samples with 2.5% tricloroacetic acid (TCA). Standard test methods were used for analysis of sucrose (Scott and Melvin, 1953), inorganic phosphorous (Taussky and Shorr, 1953) and thiol (Boyne and Ellman, 1972). Standard laboratory method (Anon., 1984) was used to analyse dry rubber content of latex. Plugging index was determined by measuring the initial flow rate and total volume of latex obtained as described by Milford *et al.* (1969). Applied area of the bark has been frequently observed for any fungal or bacterial growth.

Performance of the new formulation was statistically compared with the existing formulation by performing a paired t-test for each variable tested using Genstat 16th edition.

Results and Discussion

Generally, the stimulants are known to enhance yield by increasing latex regeneration, flow rate and duration of latex flow (Lacrotte *et al*., 1985). Physiological parameters of latex are associated with either latex regeneration or latex flow or both effects. Ultimately the productivity of the tree is a combined effect of all these factors. In plants, the sucrose produced by photosynthesis is finally the basic molecule in all synthesis. In *Hevea,* sucrose is metabolized into polyisoprene in the latisifers cells (Bealing, 1976; Tseng *et al.,* 2000). Sugar content in laticifers positively correlates with isoprene production (Lacrotte *et al*., 1985; Mesquita *et al*., 2006).

Average sucrose content of latex of trees applied with new and existing formulations were 3.47 mM and 3.97 mM, respectively and statistically comparable. In both formulations, latex sucrose content increased immediately after ethephon application and tended to decrease with time (Fig. 1a). The massive outflow of latex induced by stimulation leads necessarily to an increase in the anabolic activities in the cells and specially biosynthesis of rubber and proteins involved in this renewal (Mesquita *et al*., 2006). Tupy (1973) explained that rise in latex pH after stimulation results in an increase in invertase activity which, intensify sucrose mobilization and transported towards vessels where regeneration of latex and metabolism activated. Increase of the activity of invertase; the key enzyme of glycolysis leads to increased production of pyruvate and ATP. Availability of these molecules enhances mevalonate production and ultimately the rubber biosynthesis (d'Auzac, 1989).

Latex thiols consist of cysteine, methionine and glutathionine which are able to neutralize various forms of reactive oxygen species that harms membranes of latex organelles thus promoting colloidal stability and flow of latex hence, directly correlate with production (De Costa *et al.*, 2006; Jacob *et al*., 1986). Variation of latex thiol content with application of new formulation showed an increase with time (Fig. 1b) and average of trees applied with new formulation was 230% higher than that with existing formulation. This ability of the new formulation is highly favorable to remove reactive oxygen species evolved during rubber production and may lower the incidence of tapping panel dryness.

Latex inorganic phosphorous may reflect its energy metabolism and significantly correlates with latex production in trees (Eschbach *et al.*, 1984). Ethephon stimulation activates the laticifer metabolism and also increases the inorganic phosphorous content (d'Auzac and Pujarniscle, 1959). Both formulations showed a similar pattern of variation in latex inorganic phosphorous content. However, in trees applied with the new ethephon formulation, latex inorganic phosphorous content was significantly lower than that with the existing ethephon formulation (Fig. 1c). This reveals that energy needed for latex regeneration is comparatively lower in trees applied with new ethephon formulation.

Ethylene is thought to enhance yield by delaying plugging of latex vessels (Emuedo *et al.*, 2017; Gao *et al*., 2018) and enhancing both initial flow rate (de Jonge, 1955) and duration of flow (Coupe, *et al*., 1976 &1977; Coupe & d'Auzac, 1974). Researchers commonly accept that the increase of yield is mainly due to the extension in drainage area (Pakianathan *et al*., 1976; Ribaillier & d'Auzac, 1970).

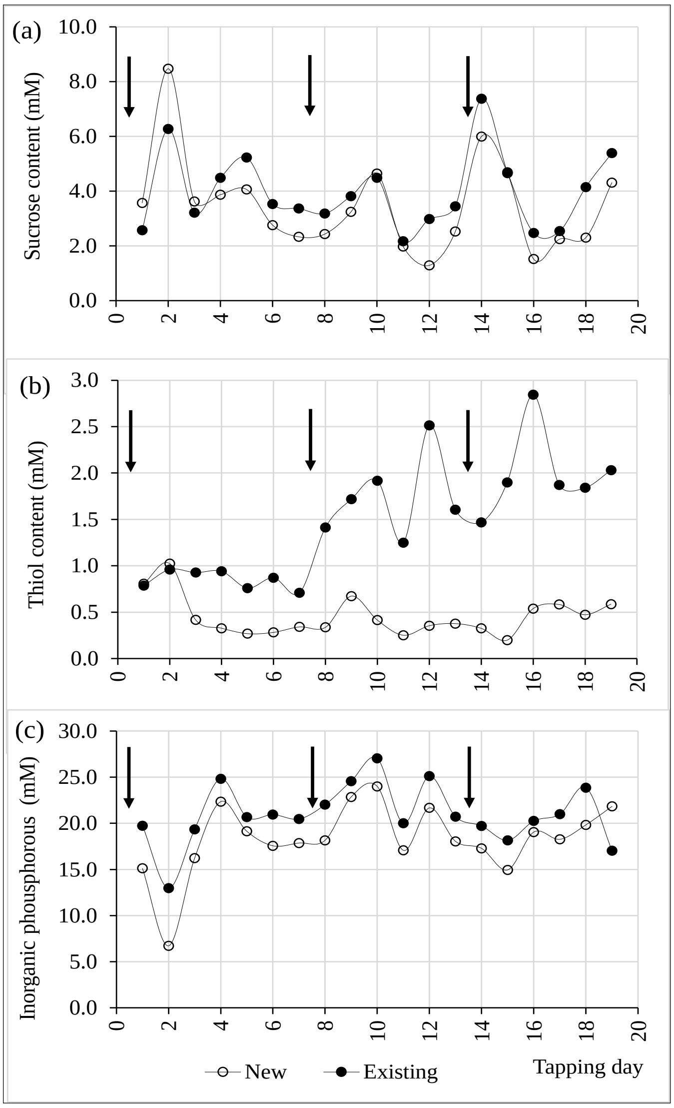

Fig. 1. Variation of latex **(a).** sucrose, (**b).** thiol and **(c).** inorganic phosphorous contents of trees stimulated with two ethephon formulations (Time of ethephon application is indicated by arrows)

Duration of latex flow with existing ethephon formulation was significantly lower than that with new formulation. However, the average difference is 19 min. (Fig. 2a). Immediately after stimulation, average latex flow duration extended to 3.8 hrs and 3.7 hrs with new and existing formulations, respectively.

At the end of first month, the flow duration decreased up to 2.4 hrs and 2.0 hrs, respectively (Fig. 2a). Average initial flow rate of trees applied with new ethephon showed statistically significant decrease over existing formulation (Fig. 2b). Respective average values of new and existing formulations were 4.32 ml/min. and 4.74 ml/min. (Fig. 2a). Plugging index of trees showed a significant difference among two ethephon formulations with averages of 1.96 and 2.36 with new and existing formulations, respectively (Fig. 2c).

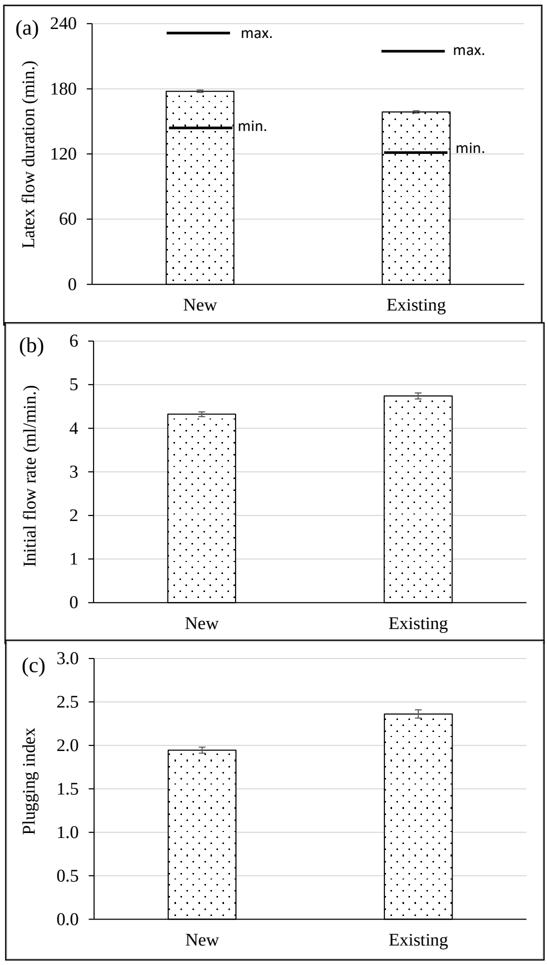

Fig. 2. Average **(a).** latex flow duration, **(b).** initial flow rate and **(c).** plugging index of trees stimulated with two ethephon formulations

Pattern of variation of latex volume of trees applied with new ethephon formulation was more or less similar to the existing formulation. With both formulations latex volume showed a significant increase after ethephon application and gradually decreased with time. Average daily volume of latex per tree with application of new and existing formulations was 208 ml and 222 ml, respectively and statistically comparable (Fig. 3a). Immediately after stimulation, observed maximum latex volumes with new and existing formulation were 380 ml and 433 ml, respectively whilst minimum values *i.e*. 112 ml and 120 ml observed towards the next application (Fig. 3a). Irrespective of the formulation, average daily volume of a tree increased by 155%, immediately after ethephon application.

With application of ethephon, dry rubber content (DRC) tended to decrease immediately and then increased towards the next application. The DRC of latex varied in a similar pattern with both ethephon formulations and significant variation has not been observed among two formulations (Fig. 3b). However, throughout the period, DRC did not fall below 35% at any instance with both formulations (Fig. 3b).

Dry rubber yield obtained from a tree with both ethephon formulations was statistically comparable. Average daily dry rubber yield of a tree was 83.22 g and 86.67 g, respectively with new and existing formulations (Fig. 3c). After stimulation, dry rubber yield with existing formulation increased to a value around 162 g/tree and yield with new formulation was 149 g/tree. At the end of first month towards next ethephon round, dry rubber yield decreased to 48 g/tree with both formulations.

During the period of investigations any fungal or bacterial growths have not been observed in ethephon applied area of the bark confirms that there is no effect on bark of tree.

Results revealed that new ethephon formulation is capable in resulting comparable yields to the existing formulation. Latex DRC and volume of latex did not show any significant variation among the two formulations. Significantly lower inorganic phosphorous content with new formulation indicates lower energy requirement in metabolic process of biosynthesis. So far, a stimulant capable in increasing similar higher amount of latex thiol has not been reported. Increased thiol content together with low inorganic phosphorous content of latex in trees applied with the new ethephon formulation may ensure long term sustainability of health of rubber tree. With the new formulation, initial flow rate increased significantly and comparatively higher plugging index in existing ethephon formulation applied trees lower the latex flow time than in the trees applied with the new formulation. Although, the duration of flow has extended with the new formulation, it would not affect significantly on time taken for commercial latex harvesting as the difference is less than 20 minutes. According to the average daily yield per tree observed, yield that could be obtained from a tree (@ 80 tapping days/yr under S/2 d4 system) with new and existing formulations accounted for

6.76 kg and 7.00 kg and corresponds to productivity values of 2,702 kg/ha/yr and 2,799 kg/ha/yr (@ tapping stand of 400 trees/ha), respectively. Annually about 30MT of 2.5% formulated ethephon is imported for rubber plantations in Sri Lanka. If we could produce this quantity locally by importing active ingredient in 40% concentration, the quantity to be imported will reduce by sixteen times. Further investigations are needed to assess long- term sustainability of the new ethephon formulation with advanced features developed by the Rubber Research Institute.

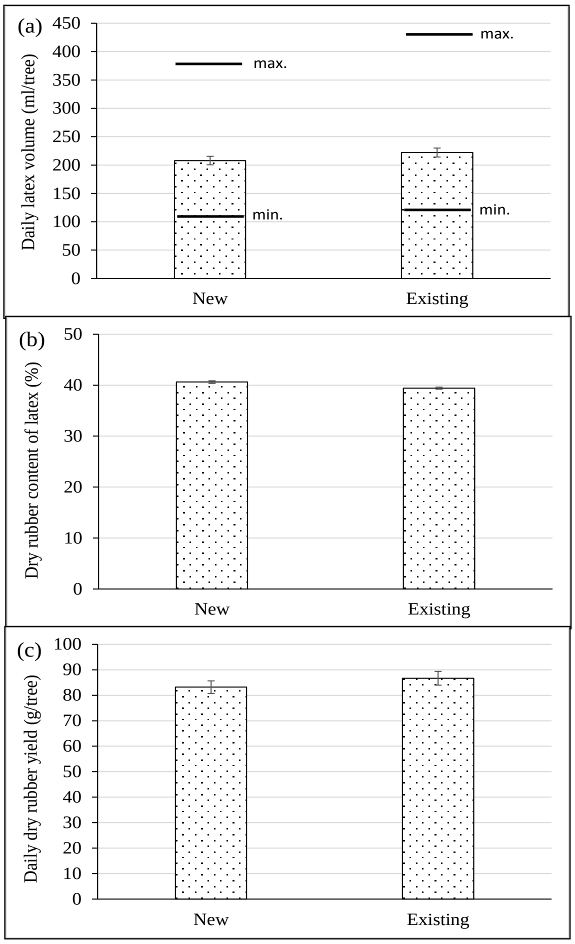

Fig. 3. Average **(a).** latex volume, **(b).** latex dry rubber content and **(c).** daily dry rubber yield of trees stimulated with two ethephon formulations

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