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Relationship between the Intensity of Latex Harvesting and the Tapping Panel Dryness Expression of Clone GT 1 of *Hevea brasiliensis* Muell Arg in South-East Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration among all authors. Authors OS, KD and DM designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors LMI, KA and BEK managed the analyses of the study. Authors ABC and EJL managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Tapping panel dryness is an important limiting factor in rubber productivity of *Hevea brasiliensis*. In order to assess the sensitivity to this syndrome, the effect of two intensive latex harvesting technologies on moderately metabolized GT1 clone, has been studied in the South-Eastern region of Côte d'Ivoire. The rubber trees were planted according to the experimental mono-tree device, "One tree one plot design" a tree constituting a repetition, and 31 trees per treatment, selected on circumference and health status criteria. The parameters measured were rubber production, circumference increase, physiological profile and tapping panel dryness sensitivity. The results showed that induction of tapping panel dryness in latex harvesting system, S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/ w) was significantly low (0.18 ± 0,22 %) than that of the control (S d/1 6d/7 unstimulated, 1.43 ± 1.45 %). Productivity of this particular system was also good (62 ± 16.32 $g.a^{-1}.s^{-1}$) and it especially has less stress that can cause physiological fatigue, or even the notch dry. Otherwise, Rubber production, radial vegetative growth, physiological parameters of the latex and the tapping panel dryness rate were influenced by the two treatments applied to GT 1. In addition, the medium and high sucrose contents (16.5 ± 3.01%) and thiol group (0.51 ± 0.13 $mmol.l^{-1}$) of the latex in the treatment (S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w), were instrumental in the response to this stimulation. The sensitivity to the tapping panel dryness is in very close linear relation with the harvest intensity of the latex to which the GT 1 clone has been subjected. These results corroborate and confirm the moderate sensitivity to the tapping panel dryness of GT 1 clone.

Keywords: Hevea brasiliensis; physiological profile; tapping panel dryness; Côte d'Ivoire.

1. INTRODUCTION

Rubber (*Hevea brasiliensis* Muell, Arg.), Belonging to the Euphorbiaceae family, which is almost exclusively grown for its latex which is the main source of natural rubber [1-5]. Natural rubber is an important raw material in industry. It accounts for 70% of tire manufacturing in the tire industry [6]. Tires made from natural rubber are more resistant to tearing than synthetic rubber tires [7]. Natural rubber is also essential in several uses [8] including airplane tires, latex gloves, etc. thus showing its economic importance. The improvement of its productivity and the extension of the production area help maintain the balance between natural rubber and synthetic rubber.

Thus, Côte d'Ivoire has developed a vast program since the introduction in 1955 of this important agricultural speculation [9] with the aim of, crop diversification and help meet the ever-increasing global demand for natural rubber. Ivorian production reached 603 000 tons of natural rubber in 2017 [10], exceeding the forecasts which were of the order of 600 000 tones by 2020 and consolidating its position as the leading African producer of natural rubber and 7th worldwide [11]. Natural rubber is Ivory Coast's fourth largest export product and generates more than 100 billion CFA francs. In spite of this honorable rank that the country occupies, Ivorian natural rubber production accounts for only 2,2 % of world production [12]. To further increase its share of natural rubber production, Côte d'Ivoire, which has experienced significant growth in rubber acreage [13], must improve exploitation through more professional plantation management in order to increase yields. This naturally involves the implementation of cultural practices including the application of latex harvesting systems recommended by research. These good practices make it possible to limit consequently the incidence of the tapping panel dryness syndrome which develops much quicker with the important proportion of the plantations (4-8) pertaining to small and medium rubber trees.

The tapping panel dryness in *Hevea brasiliensis* is an extremely complex physiological syndrome that has given rise to a great deal of work [9,6,8]. The resulting phenomena can, in some cases, drive sick trees to decrease the production of latex that can become total, irreversible and thus present a strong economic handicap in plantations affected by this syndrome. It affects about 9 % of industrial plantation trees and more than 12 % of non-industrial plantation trees in Côte d'Ivoire, and leads to loss 20 thousand tons' latex production per year [14]. Currently, tapping panel dryness is the major concern of rubber growers around the world. As the dry notch seems to depend on the management of systems of latex harvesting technologies [15], personal communication), the best approach would be to determine the manageable limits of the clones according to their laticigenic metabolism, and resulted stress from latex harvesting systems [16]. So to determine the latex harvesting system inducing less tapping panel dryness, a study had been carried out at the experimental site of Anguédédou in the South- Côte d'Ivoire, to enable rubber growers to make choices that lead to optimal management of plantation potential.

2. MATERIALS AND METHODS

2.1 Plant Materials

The plant material used consists of clone GT 1 of *Hevea brasiliensis* (Mueller Argoviensis Euphorbiaceae), belonging to the vegetative growth classes [17,18] and of moderate metabolic activity [19]. Its choice has been motivated by its hardiness, which makes it the most planted clone in the country, giving it a good and stable stand of tippable trees [20].

2.2 Methods

2.2.1 Study site

The work was done in Côte d'Ivoire (West Africa). This country is located in the Gulf of Guinea and covers an area of 322,462 km^2. Its boundaries are approximately a square between the coordinates of 2 °30 and 8 °30 West longitude, 4 °30 and 10 °30 North latitude, with on the South, a coastline of 550 km. Two main types of plant landscapes share the Ivorian territory: one of forest and one of savanna. The first corresponds to the Southern half of Côte d'Ivoire is attached to the Guinean domain. The second occupies the Northern half of Côte d'Ivoire and is attached to the Sudanese domain [21]. The Ivorian rubber estate is made up of the forest zone of the mountainous West and the lower Ivory Coast. The climate of the region is humid subtropical with four seasons clearly differentiated by their rainfall pattern: two dry seasons and two rainy seasons [22]. The soils are predominantly ferralitic [16]. The different tests were conducted in the Anguededou locality in the South-East of Côte d'Ivoire, whose characteristics are as follows:

- A cleared rain forest;
- Ferralitic soils highly desaturated and little gravelly;
- an average annual rainfall of 1800 - 2000 mm;
- an average temperature of 26°C;
- an insolation between 2000 and 2100 hours per year;
- a relative humidity of 90%;

2.2.2 Experimental design and treatments

The experiment was set up in April 1990 and the rubber trees were torn tapping in September 1996 for 6 months with the GT1 clone. The experimental setup carried out on the experimental site of the CNRA / Anguédédou Research Station at Southeast of Côte d'Ivoire, was on «one tree one plot design" with a repetition consisting 31 trees per treatment selected on criteria of circumference and health status. On each plot, the selected trees were divided into two distinct treatments.

The stimulating paste consists of palm oil-Ethrel mixture; whose active ingredient is the ethephon. Treatment B trees are tapped on Mondays and Thursdays (one same lord for testing).

2.2.3 Measurements and data processing

2.2.3.1 Rubber production

Latex yield of each tree was measured by weighing the cumulative coagulated rubber at every two weeks' interval. Total solid content was measured from a bulk sample taken in each treatment in order to convert fresh weights into grams of dry rubber per tree. Latex yield has been expressed in grams per tree and biweekly ($g.a^{-1}.bh^{-1}$) and grams per tree per tapping ($g.a^{-1}.s^{-1}$).

2.2.3.2 Radial vegetative growth

The annual growth in centimeter (cm) and girth increment in centimeter per month ($cm.m^{-1}$) of the trees was assessed at the height of 1,70 m from the ground, during the six months of the experiment [23].

2.2.3.3 Visual estimation of the tapping panel dryness

Trees affected with TPD was assessed by visual estimation of dry-cut length on each tree which enables to report on the evolution of the symptom. On that respect, the trees tapped were rated from 0 to 6 in proportion to the progress of the incidance according to the code below. 0: healthy cut, normal flow all along the tapping cut6: completely dry cut.

• For each treatment, the percentage of live trees (Live Trees %) was determined by the following relationships:

NAV = N- NAS

NAV: number of live trees; N: total number of trees; NAS: number of dry trees.

%NAV = NAV x 100 x N-1

2.3 Latex Analysis

Clear serum has been extracted by coagulation latex sample with trichloroacetic acid(TCA). Latex diagnosis has been carried and as the parameters of sucrose [24], inorganic phosphorus [25] and thiols contents [26]. The results are stated in millimole per liter of latex (mmol.l^{-1}).To estimate the percentage of dry rubber in latex(DRC), latex samples was weighed before and after drying in oven at 80 °C for 24 h.

2.4 Statistically analysis

Data were analyzed using statistical software STATISTICA 7.5. An analysis of variance was performed and the significance level of the differences between the means was estimated by the NEWMAN-KEULS test at the 5 % threshold.

3. RESULTS

3.1 Rubber Yield

3.1.1 Evolution of the average biweekly production of rubber in $g.t^{-1}.bh^{-1}$

The average biweekly production expressed in gram per tree and per biweekly of clone GT 1, Overall, there was a rapid increase in production up to eighth week in control treatment (A* S d1 6d/7 *nil stimulation*) and tenth week in standard treatment (B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/w) which was not much prominent. Thereafter yield on served with both harvesting system gradually decreased and experienced a little rise during eighteenth to twenty second week in the plot tapped with B* S/2 d3 6d/7 ET10% Pa 1 (1) 1 / w (Fig.1).

3.1.2 Daily rubber production of a tree ($g.t^{-1}.t^{-1}$)

Despite of the harvesting system average daily yield per tree during six-month period was 45 ± 11.64 gand this was an acceptable level for a moderate metabolism clone (GT 1). However, two intensive latex harvesting systems practiced have been influenced the yield of the trees resulting 27 ± 6.95 in A* S d / 1 6d / 7 *nil stimulation* and 62 ± 13.62 in B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1 / w.

3.1.3 Grams per tree and biweekly ($g.t^{-1}.bh^{-1}$)

Despite of the treatment, biweekly yield per tree obtained was 488g ± 154 (Table 2). It varied according to latex harvesting technology. Indeed, the highest production (711g ± 239) was achieved with the (B* S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w; 711 $g.t^{-1}.bh^{-1}$harvesting system which was statistically superior to the production of the control treatment (A* S /1 6d / 7 without stimulation, 265 $g.t^{-1}.bh^{-1}$).

3.2 Radial Vegetative Growth

The results obtained showed that average monthly increase in circumference of trees of both latex harvesting systems was 0.19 $cm.m^{-1}$ (Table 2). The highest mean monthly tree growth value was obtained with the control plot (A* S d/1 6d/7 *nil stimulation*, 0.21 $cm.m^{-1}$) whilst it was the lowest monthly in Treatment B* S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w; 0,17 $cm.m^{-1}$ which was statistically different.

3.3 Physiological Parameters

At the beginning and the end of the experiment, all trees had comparatively higher dry rubber content and average was 41.8 % (Table 3 and 4). The treated trees (B* S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w) showed statistically identical dry extract levels at the beginning of the test. (A* S d/1 6d/7 without stimulation). They were then significantly different at the end of the experiment. Generally average sucrose content of the latex were in an acceptable level with an average of 16.05 $m.mol.l^{-1}$ (Table 3and 4). At the beginning of the experiment, sucrose contents of the latex were high (Table 3 and 4) and statistically comparable to each other. At the end of the experiment, there was a drop in sucrose content of system B* S/2 d/3 6 d/7 ET 10 % Pa 1 (1) 1 / w was statically lower than that of the control (A* S d/1 6d/7 without stimulation). The inorganic phosphorus contents of the latex were initially medium and low at the end of the test (Table 3 and 4). At the beginning of the experiment inorganic phosphorus content

Table 1. List of different treatments applied to GT 1 clone for six months of experimentation [17]

Latex harvesting technique	**Intensity of tapping (%)**	Description
A* S d1 6d/7 *nil stimulation* **(Co)**	400	Tapping into a whole downward spiral every day with 1 day of rest a week, zero annual application.
B* S/2 d3 6d/7 ET 10 % Pa 1 (1) 1/w	67	Tapping half-spiral descending every 3 days with 1 day of rest per week; with weekly application of 1 g of 10% ethephon as a 1 cm width band.

Table 2. Average rubber production and average monthly growth of g.t-1 clone subject to two intensive latex harvesting systems after six months of experimentation

Treatments	**Prod ($g.t^{-1}.t^{-1}$)**	**Prod ($g.t^{-1}.bh^{-1}$)**	**Acc ($cm.mont^{-1}$)**
A*S d/1 6d/7 without stimulation (Co)	27 ± 6,95 b	265 ± 69 b	0,21 ± 0,11 a
B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/w	62 ± 16,32 a	711 ± 239 a	0,17 ± 0,08 ab
Average	45 ± 11,64	488 ± 154	0,19 ± 0,19

In the same column, averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%). $g.t^{-1}.t^{-1}$: grams per tree and per tapping, $g.a^{-1}.bh^{-1}$: grams per tree and per biweekly, $cm.mois^{-1}$: centimeter per month. Acc: average growth

Table 3. Physiological profile of clone GT 1before subjected to tapped with two intense latex harvesting systems

Traitements	**DRC (%)**	**Suc ($mmol.l^{-1}$)**	**Pi ($mmol.l^{-1}$)**	**R-SH ($mmol.l^{-1}$)**
A* S d/1 6d/7 *nil stimulation* (Co)	41,3 ± 3,13 a	20,1 ± 4,23 a	16,5 ± 2,47 a	0,6 ± 0,05 a
B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/w	41,2 ± 3,40 a	19,4 ± 3,81 a	15,6 ± 3,01 a	0,6 ± 0,13 a
Average	41,25 ± 3,27	19,75 ± 4,02	16,05 ± 2,74	0,6 ± 0,09

In the same column, averages followed by the same letters are not significantly different (Newmann-Keuls test at 5%).DRC %: dry rubber content, Suc: sucrose content, Pi: inorganic phosphorus content and R-SH: thiol content of latex

Table 4. Physiological profile of clone GT 1 after subjected to tapped with two intense latex harvesting systems

Treatments	**DRC (%)**	**Suc ($mmol.l^{-1}$)**	**Pi ($mmol.l^{-1}$)**	**R-SH ($mmol.l^{-1}$)**
A* S d/1 6d/7 *nil stimulation* (Co)	40,8± 2,13b	13,41 ± 2,23 a	10,4 ± 2,2b	0,4 ± 0,05 b
B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/w	43,9 ± 1,40 a	11,6 ± 1,81 b	11,5 ± 1,01 a	0,51 ± 0,11 a
Average	42,35 ± 1,76	12,35 ± 2,02	10,95 ± 1,61	0,44 ± 0,08

DRC %: dry rubber content, Suc: sucrose content, Pi: inorganic phosphorus content and R-SH: thiol content of latex

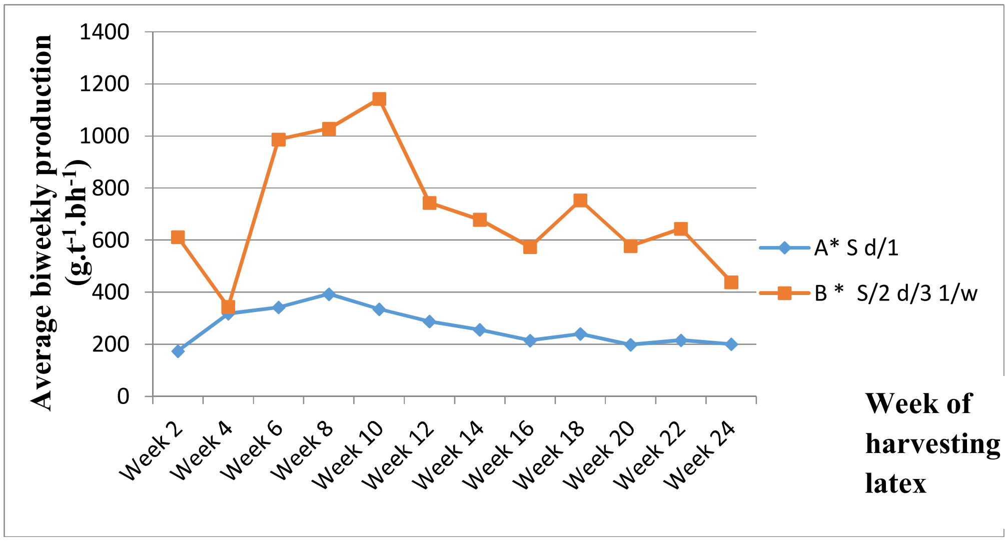

Fig. 1. Average biweekly production of the rubber GT 1 clone under different tapping system

of trees in the plot B* S/2 d/ 3 6d/7 ET 10% Pa 1 (1) 1 / was statistically comparable with that of the control (A* S d/1 6d/ 7) without stimulation but experienced a statistical difference at the end of six months. Similarly, latex thiol compounds were comparable initially and significant difference has been observed at the end of experiment (Table 3 and 4).

3.4 Tapping Panel Dryness

The two intensive latex harvesting technologies had a significant impact on the mean (31 %) tapping panel dryness of clone GT 1 (Table 5). Treatment with unstimulated trees (A* S d/1 6d /7 without stimulation), showed a high rate of tapping panel dryness (38 %) which was significantly higher than trees tapped with stimulated once a week (B* S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w, 23.43 %) harvesting technology.

The average rate of totally dry trees was low (0.81 %). In A* S d / 1 6d / 7 without stimulation, system dry trees observed was 1.43 % and it was a statistically significant increase over the harvesting technology B* S/2 d/3 6d/7 ET 10% Pa 1 (1) 1 / w, which showed 0.18 % dry trees.

3.4.1 Relation between harvesting intensity of latex and tapping panel dryness

The harvest intensity of latex is in a positive linear relationship with,

i / the rubber production expressed in $g.a^{-1}.s^{-1}$ expression $g.a^{-1}.s^{-1}$ = 80,3746 – 0,2692 IRL;

ii / the average monthly increase in circumference: Acc = 0,1488 + 0,0003 IRL;

iii / the sick slot length (LEM): LEM (%) = 27,3989 + 0,0527 IRL; iv / dry tree rate (Abr S): Arb S (%) = -0,4497 + 0,0094 IRL.

4. DISCUSSION

4.1 Effect of Latex Harvest Intensity on Agro-Physiological Parameters and Tapping Panel Dryness

The trees under treatment B* S/2 d/3 6 d/7 ET 10 % Pa 1 (1) 1 / w showed decrease in sucrose content with biweekly stimulation. Indeed, the exogenous ethylenic stimulation very strongly activates the metabolism of the clone GT 1. Since it intrinsically has an average level of energy thus justifying the moderate activation of laticigen metabolism to the absence of the hormonal stimulation exogenous. Therefore, sucrose present in the lactic cells is highly metabolized to give rubber and also these laticifers benefited from two sources of ethylenic stimulation [27]. On the other hand, in those of the unstimulated treatment, accumulation of intra laticiferous sucrose content is probably due to comparatively lower production in laticiferous system. This is characterized by the impossibility of further increase in the metabolism when trees reached to the breakeven point leading to a

Table 5. Incidence of tapping panel dryness and dry tree sensitivity of clone GT 1 subjected to two intense latex harvesting systems after six months' experimentation

Treatments	LEM (%)	dry tree (%)
A* S d/1 6d/7 *nil stimulation* (Co)	38 ± 22,69 a	1,43 ± 1,45 a
B* S/2 d/3 6d/7 ET 10 % Pa 1 (1). 1/w	23 ± 14,01 b	0,18 ± 0,22 b
Average	31 ± 18,35	0,81 ± 0,84

In the same column, averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%). LEM: diseased notch length expressed as a percentage; arb sec: percentage of fully dry trees

limitation in transformation of intra laticiferous sucrose to rubber [9,28]. This probably explains the level of its sucrose content observed. The increase in the number of tappings in the control treatment (S d/1 6d/7 without stimulation) led to a significant decrease in the laticigenic metabolism, which led to the decrease in thiol content of the trees of this motif. This is explained by the fact that, repeated and consecutive bleeding caused instability of latex colloids, thus promoting coagulation of the latex and reducing its flow [11,18]. Indeed, the intensification of the clone's metabolism by intensive tapping leads to an increasingly intense stress, resulting in weakening of the protective systems and resulting in "physiological fatigue". Therefore, there is a fall in the number of antioxidant molecules intended to neutralize the toxic forms of oxygen produced during the intensification of metabolism [29,30]. Our results indicate that, in clone GT 1, the exacerbation of the sensitivity of the trees to the tapping panel drynessis proportional to the number of tapping during the experiment (A* S d/1 6d/7 without stimulation). The tapping panel dryness sensitivity of clones is often related to the fact that they have low levels of thiol compounds Chrestin [11]. Low content of thiols in the latex that promoting the stability of lutoids leads to decompartimentation of laticifers which are destroyed in situ. When the rubber-producing systems are destabilized and weakened, it causes physiological fatigue leading to tapping panel dryness.

4.2 Assumption Relating to the Origin of the Tapping Panel Dryness

Tapping panel dryness is a recurring problem related to management of natural rubber plantations which may affect their productivity and sustainability. Our experimental results show that the latex harvesting systems applied to clone GT 1 were indeed intense. Indeed, the tapping intensity of the two latex harvesting technologies is 400 and 67%, respectively, which demonstrates the very intense nature of the tapping. Since it is assumed that tapping intensity is greater than 60 %, tapping is considered intense [31,32]. The treatments studied exceeded the level of intense bleeding and can be taken for very intense treatments especially for the first treatment which appears at least six times more intense than the second. Since $g.a^{-1}.s^{-1}$ is inversely proportional to tapping intensity [14, 28], our results corroborate those of other authors [33,34]. This linear relationship is described by the expression ES = a + b IRL. This gives in relation to our study the expressions: LEM (%): 27. 3989 + 0.0527 IRL; Arb S (%) = -0.4497 + 0.0094 IRL. Our results show that the tapping intensity and / or the intensity of the latex harvesting system is responsible for the occurrence and exacerbation of the tapping panel dryness and corroborate those of the work of several authors [35]. Physiological parameters of latex from Hevea brasiliensis. Their use in the study of the laticiferous system. Typology of functioning production mechanisms. Effects of stimulation. In: IRRDB physiology and latex harvest Meeting, [36]. These results, by raising the doubt about the effect of tapping alone, on the occurrence and amplification of the tapping panel dryness, reject the idea that Ethephon-based hormonal stimulation is responsible for the tapping panel dryness and its aggravation. Indeed, it is almost established that the occurrence of the tapping panel drynessis due to both the intensity of tapping and hormonal stimulation. This leads us to formulate a decisive hypothesis: would the dry notch not be the result of the management of the stress that the rubber would undergo during its exploitation (tapping and / or stimulation)? This hypothesis is underpinned by some certainties:

-tapping always causes trauma or stress [11] comparable to physical or mechanical stress.
-exogenous hormonal stimulation also induces a stress that can be called chemical stress.

Both stresses allow the release of ethylene which is a plant hormone, causing the activation of the laticigene metabolism leading to the production of natural rubber. Thus, when the rubber is bled, the stress it undergoes leads to the release of ethylene from a single source. Latex harvesting systems without exogenous hormonal stimulation have only one source of ethylene, the volume of which is likely to affect the quality of its management. While Ethephon-stimulated latex harvesting systems have two sources of ethylene release; one from the hydrolysis of Ethephon and the other from the chemical stress induced by the Ethephon application, the nature of which will cause a trauma to the tree. Here too, the management of the total volume of these two sources will determine the reaction or the sensitivity to the tapping panel dryness.

5. CONCLUSION

This study, which lasted in six months on *Hevea brasiliensis* clone GT1, was subjected to two intensive latex harvesting technologies. The results obtained showed that, the latex collection system (S/2 d/3 6d/7 ET 10% Pa 1 (1) 1/w), significantly induces little tapping panel dryness (0.18 ± 0.22 %) than that of the control (S d/1 6d / 7 unstimulated with 1,43 ± 1,45 %). Productivity of this clone is also in a satisfactory level (62 ± 16.32 $g.a^{-1}.s^{-1}$). It also has less stress that can cause physiological fatigue, or even the tapping panel dryness. Otherwise, Rubber production, radial vegetative growth, physiological parameters of the latex and the tapping panel dryness rate were influenced by the two treatments applied to GT 1. In addition, the medium and high sucrose contents (16.5 ± 3.01 %) and thiols (0.51 ± 0.13 $mmol.l^{-1}$) of latex in the treatment (S/2 d/3 6d/7 ET 10% Pa 1 (1) 1/w), were instrumental in the response to this stimulation. The sensitivity to the tapping panel dryness is in very close linear relation with the harvesting intensity of latex to which the GT1 clone has been subjected. Considering the magnitude of the tapping intensity applied to this clone, fairly well-balanced physiological profile with an increased rate of tapping panel dryness concluded that clone GT 1 clone is moderately sensitive to tapping panel dryness.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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