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Relationship between latex harvesting intensity and tapping panel dryness expression of *Hevea brasiliensis* Muell. Arg clone GT 1 in southeastern Côte d'Ivoire

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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 clone GT1, moderate-metabolism one, was studied in the southeastern region of Côte d'Ivoire. The rubber trees were planted according to the single-tree experimental design, "single-tree plot design", a tree constituting a repetition, and 31 trees per treatment, selected on the basis of girth and health status criteria. The parameters measured were rubber yield, girth increment, physiological condition and sensitivity to tapping panel dryness. The results obtained showed that the latex harvesting system (S/2 d/3 6d/7 AND 10 % Pa 1 (1) 1/w) significantly induced little tapping panel dryness (0.18 %) than that of the control (S d/1 6d/7 unstimulated, 1.43 %). Its rubber productivity was good (62 $g.t^{-1}.t^{-1}$) and it mainly induced less stress that could cause physiological fatigue or even tapping panel dryness. Moreover, rubber yield, radial vegetative growth, physiological parameters of the latex and tapping panel dryness rate were influenced by both treatments applied to GT 1. Furthermore, medium and high sucrose (16.5 %) and thiol group (0.51 $mmol.l^{-1}$) contents of the latex regarding the treatment (S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w), were decisive in the response to this stimulation. The sensitivity to tapping panel dryness was in very close linear relation with the latex harvesting intensity to which clone GT 1 was subjected.

Keywords: *Hevea brasiliensis*, physiological profile, tapping panel dryness, Côte d'Ivoire

1. Introduction
Rubber tree (*Hevea brasiliensis* Muell, Arg.), a species of the Euphorbiaceae family, is almost exclusively cultivated for its latex which is the main source of natural rubber (Rajagopal *et al.*, 2003; Devi *et al.*, 2003; Rodrigo *et al.*, 2004, 2011, Ahoba, 2011). Natural rubber is an important raw material in industry. It accounts for 70% of tire manufacturing in the tire industry (Cirad, 2004). Tires made from natural rubber are more resistant to tearing than synthetic rubber tires (Pathiratna *et al.*, 2007). Natural rubber is also essential in several uses (de Padirac, 1986) [9] including airplane tires, surgical 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 comprehensive program since the introduction in 1955 of this important agricultural enterprise (Monnier, 1974) with the aim of diversifying crops and helping to cope with the increasing world demand of natural rubber. The Ivorian yield reached 603 000 tons of natural rubber in 2017 (APROMAC, 2018, personal paper), exceeding the forecasts which were of the order of 600 000 tons by 2020 and consolidating its position as the leading producer of natural rubber in Africa and 7th in the world (Koulibaly *et al.*, 2016). Natural rubber is Côte d'Ivoire's fourth largest export product and generates more than 100 billion CFA francs. Despite the honorable rank of the country, Ivorian natural rubber yield accounts for only 2.2 % of world yield (Anonymous 1, 2016) [1]. In order to further increase its share of natural rubber yield, Côte d'Ivoire, which has experienced significant growth in rubber-growing areas (Toguila *et al.*, 2016), needs to improve exploitation through more professional management of plantation in order to increase their yields. This naturally involves the implementation of cultural practices

including the application of latex harvesting systems recommended by research. These good practices indeed make it possible to limit consequently the incidence of tapping panel dryness syndrome which develops much more quickly with the important proportion of plantations (Omokhafe, 2000, 2004, Okoma *et al.*, 2009; 2011) [27, 28] belonging to smallholders.

Tapping panel dryness in *Hevea brasiliensis* is an extremely complex physiological syndrome that has given rise to a great deal of works (Jacob *et al.*, 1994, Okoma *et al.*, 2008, 2009, Obouayeba *et al.*, 2009, 2011, 2016) [15, 26, 18, 28]. The phenomena resulting therefrom can, in some cases, lead the diseased trees to decrease latex production which 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 latex yield losses of about 20 thousand tons per year (Dian, 1997) [11]. Currently, tapping panel dryness is the major concern of rubber growers in the world. As tapping panel dryness seems to come from the management of latex harvesting systems or technologies (Obouayeba 2011, personal paper) [28], the best approach would be to reach the determination of stress limits, manageable by clones according to their latex-producing metabolism, stemming from such latex harvesting systems (Chrestin, 1985) [12]. Thus, in order to determine the latex harvesting system which induces less tapping panel dryness, i.e., the latex harvesting technology resulting in higher rubber yield, while reducing the expression of tapping panel dryness, a study was carried out on the experimental site of Anguédédou in the southeastern Côte d'Ivoire, in order to allow rubber tree growers to make choices that lead to optimal management of plantation potentialities.

2. Material and methods

2.1. Plant material

The plant material used consisted of *Hevea brasiliensis* (Mueller Argoviensis Euphorbiaceae) clone GT 1, belonging to vegetative growth classes (Obouayeba *et al.*, 2000; Obouayeba, 2005) [21, 22] and of moderate metabolic activity (Jacob *et al.*, 1988) [14]. Its choice is motivated by its hardiness, which makes it the most planted clone in the country, giving it a good and stable stand of tapped trees (Chapuset *et al.*, 2001) [8].

2.2. Methods

2.2.1. Area of study

The work was carried out in Côte d'Ivoire (West Africa). This country is located in the Gulf of Guinea and extends over a surface area of 322,462 km^2. Its boundaries roughly form a square between the coordinates of 2°30 and 8°30 west longitude, 4°30 and 10°30 north latitude, with a coastline of 550 km in the south. Two main types of plant landscapes share the Ivorian territory: a forest one and a savanna one. The first one corresponds to the southern half of Côte d'Ivoire and is attached to the Guinean domain. The second occupies the northern half of Côte d'Ivoire and is attached to the Sudanese domain (Monnier, 1983) [18]. The Ivorian rubber-growing industry is made up of the forest zone of the mountainous west and the lower Côte d'Ivoire. The climate of the region is humid subtropical with four seasons clearly differentiated by their rainfall pattern: two dry seasons and two rainy seasons (Eldin, 1971). The soils are predominantly ferralitic (Keli *et al.*, 1992) [16]. The different trials were conducted in the locality of Anguededou in southeastern Côte d'Ivoire, whose characteristics are as follows:

- a cleared rain forest;
- ferralitic soils highly desaturated and little gravelly;
- precipitations in the order of 1800 to 2000 mm of rainfall per year;
- an average temperature of 26°C;
- an insolation between 2000 and 2100 hours per year;
- a relative humidity of 90 %.

2.2.2. Experimental protocol

The experiment was set up in April 1990 and the rubber trees started to be tapped in September 1996 for 6 months with clone GT1. The experimental design carried out on the experimental site of the CNRA/Anguededou research station in southeastern Côte d'Ivoire, was that of the single-tree, "single-tree plot design" a tree constituting a repetition, and 31 trees, a treatment, selected on girth and health status criteria. On each plot, the selected trees were divided into two distinct treatments.

Table 1: List of the different treatments applied to clones GT 1 for six months of experiment (Vijayakumar *et al.*, 2009) [39]

Latex harvesting technique	Tapping intensity (%)	Description
A* S d/1 6d/7 unstimulated (control)	400	full-spiral downward tapping every day with 1 day off per week, zero annual application.
B* S/2 d/3 6d/7 ET 10 % Pa 1 (1) 1/w	67	half-spiral downward tapping every 3 days with 1 day off per week; 10% Ethephon stimulation at the rate of 1 g of stimulant mixture per tree on a 1 cm-wide strip, 1 application per week.

The stimulant paste consisted of palm oil-Ethrel mixture, whose active ingredient is Ethephon.

Treatment B trees were tapped on Mondays and Thursdays (same tapper for the trial).

2.2.3. Measurements made

2.2.3.1. Rubber yield

The harvest was recorded tree by tree, with one check every week. It was collected on-farm in a coagulated state. This coagulation was done naturally in polyethylene bags or "polybags". The cumulative daily yield representing the mass of fresh material produced per treatment, was weighed using a scale before and after creping so as to determine the conversion factor (CT). This conversion factor (CT), which is the dry matter percentage of a given sample of fresh rubber, was used to calculate dry rubber yield in gram per tree and biweekly ($g.t^{-1}.bh^{-1}$); in gram per tree per tapping ($g.t^{-1}.t^{-1}$), it reports the amount of dry rubber expressed in grams (g) that a tree has produced in one tapping.

2.2.3.2 Rubber tree trunk thickness growth

Rubber tree trunk thickness growth was measured from girth measurements at 1.70 m above ground, using tape measures. The monthly average girth increment after six months of

experiment was expressed in centimeters per month ($cm.m^{-1}$). (Obouayeba *et al.*, 1996) [19].

2.2.3.3. Tapping panel dryness survey

It was carried out at the beginning and the end of the experiment then, once a month. The survey was performed by visually estimation of the unproductive tapping panel length under the effect of treatments, in order to determine the percentages of diseased panel length (LEM). Indeed, the observer followed the tapper and assigned a mark between "0" and "6" to each tapped rubber tree depending on the significance of the unproductive tapping panel length. These marks are defined as follows:

"0" indicated a normal flow of latex over the entire length of the tapping panel which was said to be safe.

1. "1" meant that 1 to 20% of the tapping panel length was dry;
2. "2" meant that 21 to 40% of the tapping panel length was dry;
3. "3" meant that 41 to 60% of the tapping panel length was dry;
4. "4" meant that 61 to 80% of the tapping panel length was dry;
5. "5" meant that 81 to 100% of the tapping panel length was dry;
6. "6" meant that the tree was tapped, but did not yield latex and the tapping would therefore be stopped.

Fallen, broken trees or the ones affected by foliar diseased were not taken into account. The percentage of diseased panel length (LEM) for each treatment was determined from the following formula: LEM (%) = (0.1 n1 + 0.3 n2 + 0.5 n3 + 0.7 n4 + 0.9 n5 + n6 + ES) x N^{-1}

N: total number of rubber trees tested; ni: number of trees per class of tapping panel dryness; ES: number of trees whose tapping has been stopped for total tapping panel dryness.

For each treatment, the percentage of totally dry trees (Dry trees %) was determined by the following relationship:

Dry trees (%) = 100 x (n6 + ES) x N^{-1}

ES: number of trees for which the tapping has already been stopped due to total tapping panel dryness

N: total number of trees

n6: number of trees affected by tapping panel dryness class marked 6 totally dry trees not yet stopped

2.2.3.5. Determination of the physiological parameters of the latex

The most important physiological parameters of the latex, due to their involvement in mechanisms related to rubber yield, were analyzed once a week. These included dry rubber and sucrose, inorganic phosphorus and thiol group contents of the latex. The latex taken by stinging under the tapping panel (downward tapping), according to the "latex micro-diagnosis" (MDL) method, made it possible to determine the quantities of physiological parameters (Jacob *et al.*, 1988, Prévôt *et al.* 1986) [14, 33]. The dry rubber content was determined from a 1-ml latex sample of each treatment rubber trees. This latex was weighed in glass pill boxes before and after being placed in an oven at 80°C for 24 hours. The dry rubber content (Ex.S) expressed as a percentage was defined by the following formula: Ex.S (%) = (Dry latex mass / Fresh latex mass) x 100.

Moreover, a 1-ml latex sample was mixed with 9 ml of 2.5% trichloroacetic acid (TCA) in glass pill boxes. Trichloroacetic acid caused latex coagulation, whose serum content was "expressed" by means of metal forceps. The coagulated latex (rubber) was separated from the TCA and the resulting solution was filtered through cotton to remove impurities, including rubber particles remaining in suspension. The filtrate obtained called "trichloroacetic serum" was used for determining sucrose, inorganic phosphorus and thiol groups of the latex.

2.2.3.6. Determination of the sucrose of the latex

The sucrose of the latex was determined by the Anthrone method developed by Ashwell in 1957 [3]. In the presence of concentrated sulfuric acid hexoses dehydrated into furfural which reacted with Anthrone giving a blue-green color whose absorbance was measured spectrophotometrically at wavelength λ = 627 nm. Using glass test tubes, a volume of 50 µl of the TCA serum of the treatments was added respectively to 450 µl of 2.5 % TCA against 0.5 ml of 2.5 % TCA for the control. Three (3) ml of Anthrone reagent were introduced into all the tubes. The solutions were homogenized and then heated in a water bath for 5 min at a temperature of 37°C. After cooling, the optical densities (OD) were read spectrophotometrically at wavelength λ = 627 nm. Fructose, which is one of the constituents of sucrose (sucrose = glucose + fructose), dehydrated easily. As for the second constituent, glucose, its reaction required heating. Fructose (without heating) or all of the hexoses (fructose and glucose) could therefore be determined separately if the solutions were heated. The sucrose content of the latex was then determined and then expressed in millimoles per liter of latex ($mmol.l^{-1}$) from the determination of solutions of the calibration range.

2.2.3.7. Determination of the inorganic phosphorus of the latex

The inorganic phosphorus of the latex was determined by the ammonium molybdate method developed by Taussky and Shorr in 1953 [37]. Phosphorus formed a complex with molybdate and vanadate giving a yellow color, whose absorbance was measured by the spectrophotometer at wavelength λ = 410 nm. In glass test tubes, a volume of 0.5 ml of TCA serum from the treatments against 0.5 ml of distilled water for the control, was added to 1 ml of 2.5% TCA. Three (3) ml of phosphorus reagent were then introduced into all the tubes. The solutions were homogenized and then the optical densities (OD) read in the spectrophotometer at wavelength λ = 410 nm. The Pi content of the latex was then determined and susequently expressed in millimoles per liter of latex ($mmol.l^{-1}$) from the determination of solutions of the calibration range**.**

2.2.3.8. Determination thiol groups of the latex

The thiol groups of the latex were determined by the Boyne and Ellman (1972) [4] method using dinitro-2.2-dithio-5.5'-dibenzoic acid (DTNB). Indeed, the thiol groups (R-SH) reacted with the DTNB to give the nitro-2-thio-5-benzoic acid (TNB) whose absorbance was measured spectrophotometrically at wavelength λ = 410 nm (Ellman's reaction). In glass test tubes, a volume of 1.5 ml of TCA serum from the treatments against 1.5 ml of 2.5 % TCA for the control, was added to 1 ml of 2.5 % TCA. Fifty (50) µl of DTNB were then introduced into all the tubes. The

solutions were homogenized and then the optical densities (OD) read in the spectrophotometer at wavelength λ = 410 nm. The content of thiol groups of the latex was then determined and susequently expressed in millimoles per liter of latex (mmol.l^{-1}) from the determination of solutions of the calibration range.

3. Statistical analyses

Rubber yield, isodiametric growth of the trunk, latex micro-diagnosis, and diseased panel length data were processed using STATISTICA 7.5 software. An analysis of variance was performed and the significance level of the differences between averages was estimated by the NEWMAN-KEULS test at 5% threshold.

4. Results

4.1. Rubber yield

4.1.1. Per tree and per tapping (g.t^{-1}.t^{-1})

The average yield per tree and per tapping over the six months of experiment (45 ± 11.63 g, Table 1) was good for this moderate-metabolism clone (GT 1). It was influenced by the different technologies of intensive latex harvesting. In fact, the g.t^{-1}.t^{-1} of the control plot (A * S d/1 6d/7 nil stimulation, 27) of an average level was statistically lower than that of the treatment (B * S/2 d/3 6d/7 and 10% Pa 1 (1) 1/w, 62).

4.1.2. Per tree and biweekly (g.a^{-1}.bh^{-1})

For six months of experiment, the average yield per tree and biweekly (488), all intensive latex harvesting technologies combined, was average (Table 1). It varied depending on the latex harvesting technology. Indeed, the highest yield was obtained with the plot (B * S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w; 711 g.t^{-1}.bh^{-1}), statistically higher than the yield of the control treatment (A * S d/1 6d/7 nil stimulation, 265 ga^{-1}.bh^{-1}).

4.1.3. Radical vegetative growth of trees

The results obtained showed that with an average monthly girth increment of 0.19 cm.month^{-1}, all intensive latex harvesting systems combined, the radial vegetative growth was average (Table 1). The highest monthly average tree growth value was obtained with the control plot (A * S d/1 6d/7 nil stimulation, 0.21 cm.month^{-1}). In fact, the lowest monthly vegetative growth was observed with the treatment (B * S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w; 0.17 cm.month^{-1}), statistically lower than that of the control treatment.

Table 2: Average rubber yield and monthly average growth of clone GT1 subjected to two intense latex harvesting systems after six months of experiment

Treatments	Yield (g.t^{-1}.t^{-1})	Yield (g.t^{-1}.bh^{-1})	Incr. (cm.month^{-1})
A*S d/1 6d/7 nil stimulation (control)	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 ± 11.63	488 ± 154	0.19 ± 0.19

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

4.2. Physiological parameters of the latex

At the beginning as well as at the end of experiment, all trees had high dry rubber contents (41.8%, Table 2 and 3). The treated trees (B * S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w) showed, at the beginning of the trial, dry rubber contents statistically identical to that of the control treatment (A* S d/1 6d/7 nil stimulation). They were then significantly different at the end of experiment.

Overall, the sucrose contents of the latex were good (16.05 m.mol.l^{-1}, Table 2 and 3). Indeed, at the beginning of experiment, the sucrose contents of the latex were high (Table 2 and 3) and statistically equivalent to each other. At the end of the trial, there was a drop in the contents. The sucrose content of the latex of the plot (B* S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w) was statically lower than that of the control (A* S d/1 6d/7 nil stimulation).

The inorganic phosphorus contents of the latex were average in the beginning and low at the end of the trial (Table 2 and 3). The trees of the plot (B* S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w) showed inorganic phosphorus contents statistically identical to that of the control (A* S d/1 6d/7 nil stimulation) at the beginning of the trial and different at the end. Thiol compound contents were average at the beginning and at the end of experiment (Table 2 and 3). There was no significant difference at the beginning of the trial between the contents of these compounds in the different latex harvesting systems tested, but there was some at the end of the trial.

Table 3: Physiological profile of clone GT 1 subjected to two intense latex harvesting systems after two weeks of experiment

Treatments	Ex.S (%)	Sac (mmol.l^{-1})	Pi (mmol.l^{-1})	R-sh (mmol.l^{-1})
A* S d/1 6d/7 nil stimulation (control)	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, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%). Ex.S (%): average dry rubber content expressed as a percentage; Sac (mmol.l^{-1}): average sucrose content of the latex expressed in millimoles per liter; Pi (mmol.l^{-1}): average inorganic phosphorus content of the latex expressed in millimole per liter; R-sh (mmol.l^{-1}): average thiol group content of the latex expressed in millimole per liter

Table 4: Physiological profile of clone GT 1 subjected to two intense latex harvesting systems after six months of experiment

Treatments	Ex.S (%)	Sac (mmol.l^{-1})	Pi (mmol.l^{-1})	R-sh (mmol.l^{-1})
A* S d/1 6d/7 nil stimulation (control)	40.8± 2.13 ab	13.41 ± 2.23 a	10.4 ± 2.2 b	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

In the same column, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%). Ex.S (%): average dry rubber content expressed as a percentage; Sac (mmol.l^{-1}): average sucrose content of the latex expressed in millimoles per liter; Pi (mmol.l^{-1}): average inorganic phosphorus content of the latex expressed in millimole per liter; R-sh (mmol.l^{-1}): average thiol group content of the latex expressed in millimole per liter

4.3. Sensitivity to tapping panel dryness

Both intensive latex harvesting technologies had a significant impact on the average rates (31%) of tapping panel length of clone GT 1 (Table 4). Unstimulated trees of the treatment (A* S d/1 6d/7 nil stimulation), showed a high rate of diseased tapping panel (38%) significantly higher than the one of trees stimulated once a week (B* S/2 d/3 6d/7 and 10% Pa 1 (1) 1/w, 23.43%).

The average rate of totally dry trees was relatively low (0.81%). The unstimulated treatment (A* S d/1 6d/7 nil stimulation, 1.43%) induced an average rate of dry trees statistically higher than that of the other treatment (B* S/2 d/3 6d/7 and 10% Pa 1 (1) 1/w, 0.18%).

Table 5: Sensitivity to tapping panel dryness and dry trees of clone GT 1 subjected to two intense latex harvesting systems after six months experiment

Treatments	LEM (%)	Dry trees (%)
A* S d/1 6d/7 nil stimulation (control)	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, the averages followed by the same letter are not significantly different (Newmann-Keuls test at 5%). LEM (%) and Dry trees (%): diseased panel length expressed as a percentage and totally dry tree rates in percentages.

4.4. Relationship between latex harvesting intensity and tapping panel dryness rate

Latex harvest intensity is in a positive linear relationship with, i/ rubber yield expressed in g.t^{-1}.t^{-1} whose expression g.a^{-1}.s^{-1} = 80.3746 - 0.2692 IRL; ii/ the monthly average girth increment: Incr. = 0.1488 + 0.0003 IRL; iii/ diseased panel length (LEM): LEM (%) = 27.3989 + 0.0527 IRL; and iv/ the rate of dry trees (Dry T): Dry T (%) = -0.4497 + 0.0094 IRL.

5. Discussion

5.1. Effect of latex harvesting intensity on agrophysiological parameters and tapping panel dryness

In the plants of the treatment (B* S/2 d/36 d/7 AND 10% Pa 1 (1) 1/w), the decrease in sucrose content was intensified by biweekly stimulation. Indeed, the exogenous ethylenic stimulation very strongly activated the metabolism of clone GT 1, since it intrinsically has an average level of energy thus justifying the moderate activation of its latex-producing metabolism in the absence of exogenous hormonal stimulation. Consequently, the sucrose found in the latex vessel cells was highly metabolized to give rubber, since the latex vessels benefited from two sources of ethylenic stimulation (Silpi *et al.*, 2006) [34]. In contrast, in those of the unstimulated treatment, there was an accumulation of intra-latex-vessel sucrose probably due to overexploitation of the latex vessel system. This was characterized by the impossibility of any increase in metabolism, the activation of which would have reached the ceiling, leading to a limitation of the transformation of the available intra-latex-vessel sucrose into rubber (Jacob *et al.*, 1994, Gohet, 1996) [15, 13]. 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 nil stimulation) led to a major runaway of the latex-producing metabolism, which led to the decrease in thiol group contents of the trees of this pattern. This is explained by the fact that the repeated and consecutive tappings have caused the instability of latex colloids, thus making easier latex coagulation and resulting in a slowing down of its flow (Chrestin, 1985, Obouayeba *et al.*, 1996) [12, 19]. Indeed, the intensification of the clone metabolism by intensive tapping lead to an increasingly intense stress, resulting in a weakening of the protective systems and causing "physiological fatigue". As a result, there was a fall in the number of antioxidant molecules intended to neutralize toxic forms of oxygen produced during intensification of the metabolism (Chrestin, 1884, Chrestin *et al.*, 1984) [5, 6]. Our results indicate that, in clone GT 1, the exacerbation of tree sensitivity to tapping panel dryness is proportional to the number of tappings during experiment (A* S d/1 6d/7 nil stimulation). The sensitivity of clones to tapping panel dryness is often related to the fact that they have low thiol compound contents as indicated by Chrestin (1985) [12]. According to the same author, the low content of the latex in thiol compounds, antioxidants, making easier the stability of lutoids, leads to decompartmentalisation of the latter which are destroyed *in situ*. The rubber-producing systems are destabilized and weakened, thus leading to physiological fatigue that may cause tapping panel dryness.

The latex harvesting systems studied on clone GT 1 were very intensive, including daily tapping without exogenous hormonal stimulation, which certainly explains the relatively high tapping panel dryness rates recorded over a short period. Considering the magnitude of the tapping intensity applied to clone GT 1 trees, the tapping panel dryness rate expressed by them, and the fairly well-balanced physiological profile, we conclude that clone GT 1 is moderately sensitive to tapping panel dryness. This conclusion corroborates and confirms the one already mentioned by several authors (Anonymous 2, 1993, Traore *et al.*, 2011) [2, 38].

5.2. Hypothesis relating to the origin of tapping panel dryness

In this regard, tapping panel dryness is a recurring problem related to the management of natural rubber yield in rubber tree plantations in general, and particularly in those of the non-industrial rubber-growing industry. To this end, it constitutes an almost daily concern in plantation management with regard to their productivity and sustainability. Our experimental results showed that the latex harvesting systems applied to clone GT 1 were intense indeed. In fact, the tapping intensity of both latex harvesting technologies was 400% and 67% respectively, which shows the very intense nature of tapping. Since it is assumed that in terms of tapping intensity, the tapping is considered intense when it exceeds 60%, (Sethuraj 1988, Sivakumaran *et al.*, 1988) [35, 36]. The treatments studied exceed the level of intense tapping and can be taken for very intense treatments especially for the first treatment which appears at least six times more intense than the second one. However, $g.t^{-1}.t^{-1}$ is inversely proportional to tapping intensity (Jacob *et al.* 1988, Obouayeba *et al.*, 2006) [14, 29], our results corroborate those of other authors (Obouayeba and Boa, 1993, Obouayeba *et al.* al., 1996) [19, 20]. This linear relationship is described by the expression ES = a + b IRL. This gives in relation to our study the following expressions: LEM (%): 27.3989 + 0.0527 IRL; Dry T (%) = -0.4497 + 0.0094 IRL. Our results really show that tapping intensity and/or latex harvesting system intensity is responsible for the occurrence and exacerbation of tapping panel dryness. They corroborate those of the works of several authors (Lacote *et al.*, 2009, Obouayeba *et al.*, 2006) [29]. These results, by clearing up the doubt about the effect of tapping only, on the occurrence and amplification of tapping panel dryness, reject the idea that Ethephon-based hormonal stimulation would be solely responsible for tapping panel dryness and its aggravation. Indeed, it is almost established that the occurrence of tapping panel dryness is due to the intensity of both tapping and hormonal stimulation. To this end, it should be noted that hormonal stimulation stemming from the application of stimulant paste of anthropogenic origin, external to the plant, could be called exogenous stimulation. Whereas, the one resulting from tapping would be designated as endogenous hormonal stimulation. This leads us to formulate a decisive hypothesis: Might tapping panel dryness be the result of the management of the stress undergone by rubber tree during its exploitation (tapping and/or stimulation)? This hypothesis is underpinned by some certainties:

- Tapping always causes trauma or stress (Chrestin, 1985) [12] 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 latex-producing metabolism leading to the production of natural rubber. Thus, when the rubber tree is tapped, 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, whose volume of is likely to affect the quality of its management and its consequences. Whereas Ethephon-stimulated latex harvesting systems have two sources of ethylene release; one from Ethephon hydrolysis and the other from the chemical stress induced by Ethephon molecule, the nature of which will cause a trauma to the tree. Here too, managing the total volume of both sources will determine the reaction or sensitivity to tapping panel dryness.

Conclusion

This six-month study on *Hevea brasiliensis* clone GT 1 subjected to two intensive latex harvesting technologies, showed that the latex harvesting system (S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w), significantly induced little tapping panel dryness (0.18 ± 0.22%) than the one of the control (S d/1 6d/7 unstimulated, 1.43 ± 1.45 %). Its rubber productivity was good (62 ± 16.32 $g.t^{-1}.t^{-1}$) and it mainly induced or caused less stress that may cause physiological fatigue, or even tapping panel dryness. Furthermore, rubber yield, radial vegetative growth, physiological parameters of the latex and tapping panel dryness rate were influenced by both treatments applied to GT 1. Moreover, average and high sucrose (16, 5 ± 3.01%) and thiol group (0.51 ± 0.13 $mmol.l^{-1}$) contents of the latex regarding the treatment (S/2 d/3 6d/7 AND 10% Pa 1 (1) 1/w), were decisive in the response to this stimulation. The sensitivity to tapping panel dryness was very closely related to the latex harvesting intensity to which clone GT 1 was subjected. Given the magnitude of the tapping intensity applied to clone GT 1 trees, the tapping panel dryness rate expressed by them, and the fairly well-balanced physiological profile, we can conclude that clone GT 1 is moderately sensitive to tapping panel dryness.

Conflict of interest

The authors do not declare any conflict of interest.

Author contributions

For this work, BEK and ZM carried out the entire sampling and took an active part in the data processing and the preparation of the document. As for LMI and BKE, they were very present in the data processing and the preparation of the final document. BKE made its research laboratory available to the team and provided the working equipment.

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