Journal of Experimental Agriculture International

43(7): 27-44, 2021; Article no.JEAI.72379
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Contribution to Natural Rubber Production without Exogenous Hormonal Stimulation

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2021/v43i730711
Editor(s):
(1) Dr. Bishun Deo Prasad, Bihar Agricultural University, India.
Reviewers:
(1) Kuswanto, M.Si, Jambi University, Indonesia.
(2) Faiq Mohammed Sarhan Al-Zwainy, Al-Nahrain University, Iraq.
Complete Peer review History: https://www.sdiarticle4.com/review-history/72379

Original Research Article

Received 08 June 2021
Accepted 12 August 2021
Published 28 August 2021

ABSTRACT

Rubber production and especially its increase absolutely depend on the activation of the latex-producing metabolism. Can the latex-producing metabolism activation mechanism developed by rubber tree lead to higher yield without exogenous hormonal stimulation? In order to verify this decisive hypothesis, several works, carried out for nine years in Southern Côte d'Ivoire, were conducted on some 15 clones (IRCA 18, IRCA 209, IRCA 111, IRCA 130, PB 235, PB 260, PB 280, PB 330, PB 310; GT 1, BPM 24, RRIC 100; PB 217 and PR 107) of the three metabolisms respectively, active, moderate and slow, with two main statistical designs. On a small scale, in a "one-tree plot" design, the same latex harvesting system, tapping in d4 with different hormonal stimulation regimes (0/y; 2/y; 4/y; 6/y; 8/y; 13/y; 18/y; 26/y, 39/y and 78/y), has been applied to all treatments. In a randomized complete block design, different tapping frequencies (d2, d3, d4, d5 and d6) and hormonal stimulation (0/y, 4/y, 8/y and 10/y) were applied. Whatever the stimulation regime, the average $g.t^{-1}.t^{-1}$ of the unstimulated control (56) of the active metabolism clones (PB 235, PB 310, IRCA 111 and IRCA 130) over 9 years was statistically the same order that of the

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stimulated patterns (54). The average $g.t^{-1}.t^{-1}$ of the control (60) was lower than that of the highest yielding stimulated patterns (67) of the clones (PB 330, PB 280, PB 260, IRCA 18 and IRCA 209). The average $g.t^{-1}.t^{-1}$ of the unstimulated control (49) was significantly lower than that of the highest yielding stimulated treatment (57) of moderate metabolism clones (GT 1, BPM 24 and RRIC 100). The average $g.t^{-1}.t^{-1}$ of the unstimulated control (39) was significantly lower than that of the highest yielding stimulated treatment (70) of slow metabolism clones (PB 217 and PR 107). On a large scale and at tapping frequency (d2), the unstimulated latex harvesting system (d2 0/y) showed an average yield of (2341; 2266 and 1849 $kg.ha^{-1}.year^{-1}$ for the active, moderate and slow metabolisms, respectively) statistically comparable to those of the highest yielding tapping frequencies d3, d4, d5 and d6 all latex harvesting systems combined for the clones studied (2388; 2348 and 2256 $kg.ha^{-1}.year^{-1}$). These results show that it is possible to produce natural rubber without exogenous hormonal stimulation by judiciously playing on tapping intensity.

Keywords: Rubber production; Latex-harvesting system without exogenous hormonal stimulation; Côte d'Ivoire.

1. INTRODUCTION

Rubber tree, which scientific name is *Hevea brasiliensis* Muell. Arg., belongs to the Euphorbiaceae family. It is a forest tree, originating from Amazonia in South America, in present-day Brazil. It is almost exclusively grown for its latex, which is the main source of natural rubber [1-3]. In rubber trees, the yield, unlike other plants that yield fruit, seeds, roots or tubers, etc., is inevitably the result of performing tapping [4-8]. This consists in making an incision or a cut known as tapping panel in the bark of the tree trunk; resulting in latex flow [4;5]. Rubber tree is a plant that responds well to hormonal stimulation (Fig. 1) regardless of the origin and/or nature of the stimulant [9-12] and whose improvement in rubber yield is highly dependent on hormonal stimulation [9,11,12,13,6,14-21]. Thus, nowadays and in a systematic way, a strategy of hormonal stimulation of the yield is added to the tapping system [22,23,16,21]. Hormonal stimulation, through the production of ethylene, a plant hormone released by hydrolysis in the bark tissues, is responsible for the activation of the latex-producing metabolism. This is, through the activation of homoplastic ATPase, which alkalinizes the cytosol, at the origin of latex yield and its increase [24,25]. The activation of the latex-producing metabolism stems from three (3) sources; an endogenous one, intrinsic to the plant and two exogenous ones, provided by tapping (physical or mechanical stimulation, [8] and exogenous hormonal stimulation (chemical stimulation, from chloro 2 ethylphosphonic acid (Ethephon).

The external materialization of metabolic activation is given by the Pi content of the latex, which is closely related to rubber yield.

Since ethylene is produced from any stress phenomenon [24,6,26], its volume or quantity is likely to depend on the magnitude and/or the nature of such stress. However, several authors [25,27-29] have shown that ethylene plays a leading role in the activation process of the latex-producing metabolism. It is increasingly plausible that the volume of ethylene determines the level of activation of latex-producing metabolism in *Hevea brasiliensis* and therefore governs rubber yield and its magnitude.

Tapping alone, a latex harvesting technology without hormonal stimulation, produces ethylene, since it causes stress in the tree, called mechanical or physical stimulation [24,27,6,26], whose volume and subsequent rubber yield depend on the frequency at which tapping is performed [30].

Can the extent of the stress have caused by frequency-dependent tapping, the predominant role of ethylene in the process and the mechanism of activation of the latex-producing metabolism developed by the rubber tree lead to increased rubber production without exogenous hormonal stimulation? In order to check this decisive hypothesis, the analysis and formulation of intermediate hypotheses of the results of several works carried out for nine years in Southeastern and Southwestern Côte d'Ivoire, were carried out.

1.1 Objectives of the Approach

1.1.1 Main objectives

Produce natural rubber without exogenous plant hormone.

1.1.2 Specific objectives

- Assess the effect of downward tapping at frequency d4 with or without hormonal stimulation at different frequencies on rubber yield, radial vegetative growth, and sensitivity of rubber trees to tapping panel dryness
- Assess the effect of the different downward tapping frequencies, d2, d3, d4, d5 and d6, stimulated or not stimulated, on rubber productivity, radial vegetative growth, physiological profile and sensitivity of rubber trees to tapping panel dryness

These specific objectives are based on the following assumptions:

Does the tapping of *Hevea brasiliensis* clones at frequency d4 without exogenous hormonal stimulation result in more significant rubber yield, without prejudice to rubber trees?
Does the tapping of *Hevea brasiliensis* clones at frequency d2, without exogenous hormonal stimulation; result in more significant rubber yield, without prejudice to rubber trees?

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material used consisted of thirteen (13) rubber tree clones distributed among three metabolic activity classes. These included:

- For the fast metabolic activity class: IRCA 18, IRCA 111, IRCA 130, IRCA 209, PB 235, PB 260, PB 280, PB 310 and PB 330;
- For the moderate metabolic activity class: GT 1, RRIC 100 and BPM 24;
- For the slow metabolic activity class: PB 217 and PR 107.

2.2 Experimental Design and Treatments

Two experiments were conducted on the same plant material (same clones of the metabolic activity class) over the same period of 9 years.

Experiment 1: Effect of downward tapping at frequency d4 with or without hormonal stimulation at different frequencies on the agronomic parameters and sensitivity of rubber trees to tapping panel dryness.

The experimental design was the single tree or “single-tree plot design”, that is, one tree represents a repetition. In that respect, 363 trees from each plot were selected based on girth and sanitary status criteria. The selected trees should be as homogeneous as possible outside border trees and those adjacent to trees attacked by root rot caused by *Fomes lignosus*. The trees were tapped when their average girth, 1 m above ground, were greater than or equal to 50 cm. On each plot, the selected trees were divided into 11 separate treatments, at a rate of 33 trees (repetitions) per treatment (Table 1).

Experiment 2: Effect of the different frequencies of downward tapping d2, d3, d4, d5 and d6, stimulated or not, on the agronomic and physiological parameters as well as those of rubber tree sensitivity to tapping panel dryness.

The experimental design was Randomized Complete Blocks of six treatments and four repetitions (Table 2). Each elementary plot had 100 trees, that is, a trial surface area of 4.7ha on average. The homogeneity of the plant material was previously checked before the start of trials. The selected trees should be as homogeneous as possible regarding the absence of diseases. The selection focused on measuring tree girth at 1 m above ground at the establishment of the trial and then at 1.70 m above ground during the experiment.

2.2.1. Parameters measured

For each parameter, the annual average of the measurements carried out was selected.

2.2.2 Yield

The rubber yield of each treatment was weighed every 4 weeks using a scale. Fresh rubber samples were taken for each treatment so as to determine the conversion factor that was used to calculate the dry rubber yield in kilograms per hectare per year ($kg.ha^{-1}.year^{-1}$).

2.2.3 Isodiametric growth

The girth of the trunk at 1.70 m above ground was measured on each treated tree during the tapping and then at the end of the physiological cycle, before the beginning of the dry season. The average increase in girth (cm) after nine years of experiment was determined by the following relation:

Gi (cm/year) = $G_n - G_{n-1}$.

Where G_n is the mean girth of trees of the year n and G_{n-1}, the mean girth of trees of the year n-1.

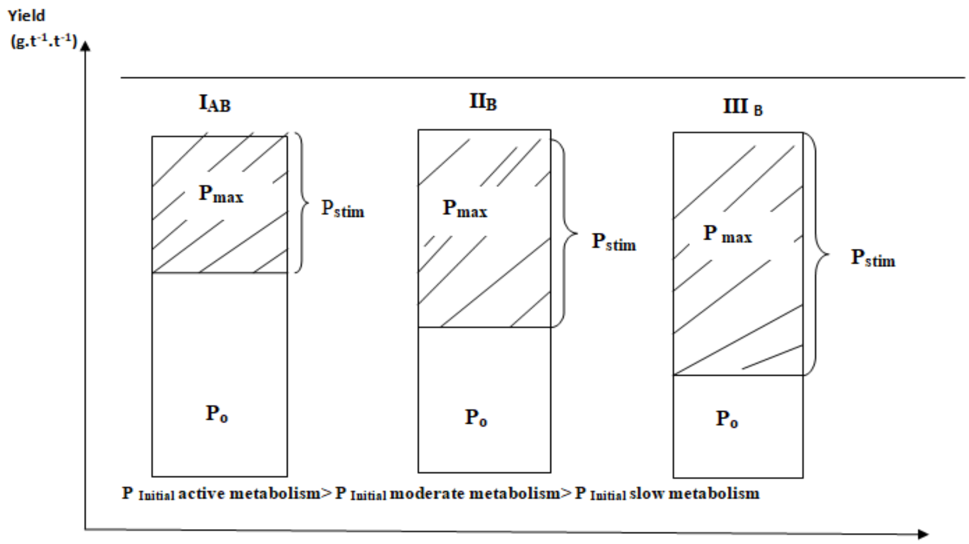

Fig. 1. Yield in g.t^{-1}.t^{-1}de of slow, moderate and active-metabolism Hevea brasiliensis, tapped in d/4 g t^{-1} t^{-1} : gram per tree per tapping

2.2.4 Visual estimation of tapping panel dryness

The quick survey by visual estimation was used to account for the onset and progress of tapping panel dryness [31]. For each tapped tree, a number between 0 and 6 was assigned, the meaning of which was as follows:

- 0, for a healthy tapping panel,
- 1, for a dry panel over 1 to 20% of its length (10% on average),
- 2, for a dry panel over 21 to 40% of its length (30% on average),
- 3, for a dry panel over 41 to 60% of its length (50% on average),
- 4, for a dry panel over 61 to 80% of its length (70% on average),
- 5, for a dry panel over 81 to 99% of its length (90% on average),
- 6, for a totally dry tapping panel.

For each plot, the accurate count of the condition of trees was made and the percentage of total length of diseased panel (DT %) for each treatment was calculated as follows:

D.C (%) = (0,1n1 + 0,3n2 + 0,5n3 + 0,7n4 + 0,9n5 + n6 + DT) x N-1

With: N: Total number of trees; n_i: Number of trees per class of tapping panel dryness; DT: Number of trees which tapping has been already stopped because of total tapping panel dryness (Dry Trees). The coefficients 0.1, 0.3, 0.5, 0.7, 0.9 and 1 were defined as the average percentage of tapping panel dryness of the class considered. For each treatment, the percentage of trees completely dry (TPD) was determined by the following relation:

TPD (%) = (n_6 + DT) x N^{-1}

2.3 Latex Micro-Diagnosis

From the latex collected, dry rubber content as well as sucrose (Suc), inorganic phosphorus (Pi) and thiol group (R-SH) contents were determined annually using the Latex Micro-Diagnosis (MDL) method. The determination of dry rubber content was made according to the method described by [32], while sucrose, inorganic phosphorus and thiol group contents were obtained, according to [33], [34] and [35], respectively. The MDL data were analyzed based on the reference values established by [36] and interpreted according to the Roussel's interpretation diagram [36].

2.3.1 Determination of best latex harvesting systems

In order to determine the best latex harvesting systems, the physiological parameters taken into account in carrying out the latex micro-diagnosis (dry rubber content, sucrose, inorganic phosphorus and thiol groups) and the ones relating to yield, isodiametric growth and

Table 1. Description of the different treatments applied for nine years of experiment

No.	Treatments	Description
1	Absolute control	Not tapped
2	S/2 d4 6d/7 12 m/12. *nil stimulation*	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; nil stimulation
3	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 2/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; two stimulations per year
4	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 4/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; four stimulations per year
5	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 6/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; six stimulations per year
6	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 8/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; eight stimulations per year
7	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 13/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; 13 stimulations per year
8	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 18/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; 18 stimulations per year
9	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 26/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; 26 stimulations per year
10	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 39/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; 39 stimulations per year
11	S/2 d4 6d/7 12 m/12.ET2.5% Pa1(1) 78/y	Downward half-spiral tapping every four days, six days out of seven with one day off per week, 12 months out of 12; 2.5% Ethephon stimulation; 1 g of stimulating mixture per tree on a 1 cm-wide strip; 78 stimulations per year

Table 2. Description of the different treatments applied for nine years of experiment 2

No.	Treatments	IS (%)	Description
1	S/2 d2 6d/7 12m/12, *nil stimulation*	100	Downward half-spiral tapping every other day, six days out of seven with one day off per week, 12 months out of 12; nil stimulation.
2	S/2 d3 6d/7 12m/12 ET2.5% Pa1(1) 4/y	67	Downward half-spiral tapping every three days, six days out of seven, 12 months out of 12; 2.5% Ethephon stimulation applied on the tapping panel at a rate of 1 g of stimulant on a 1 cm-wide strip; 4 stimulations were performed per year
3	S/2 d4 6d/7 12m/12 ET2.5% Pa1(1) 4/y	50	Downward half-spiral tapping every four days, six days out of seven, 12 months out of 12; 2.5% Ethephon stimulation applied on the tapping panel at a rate of 1 g of stimulant on a 1 cm-wide strip; 4 stimulations were performed per year .
4	S/2 d4 6d/7 12m/12 ET2.5% Pa1(1) 8/y	50	Downward half-spiral tapping every four days, six days out of seven, 12 months out of 12; 2.5% Ethephon stimulation applied on the tapping panel at a rate of 1 g of stimulant on a 1 cm-wide strip; 8 stimulations were performed per year .
5	S/2 d5 6d/7 12m/12 ET2.5% Pa1(1) 8/y	40	Downward half-spiral tapping every five days, six days out of seven, 12 months out of 12; 2.5% Ethephon stimulation applied on the tapping panel at a rate of 1 g of stimulant on a 1 cm-wide strip; 8 stimulations were performed per year .
6	S/2 d6 6d/7 12m/12 ET2.5% Pa1(1) 10/y	33	Downward half-spiral tapping every six days, six days out of seven, 12 months out of 12; 2.5% Ethephon stimulation applied on the tapping panel at a rate of 1 g of stimulant on a 1 cm-wide strip; 10 stimulations were performed per year .

sensitivity to tapping panel dryness were involved. The average values of these parameters were subjected to an analysis of variance. This made it possible to classify the different latex harvesting technologies according to their effect on the parameters studied. The best latex harvesting technologies were those which have resulted in:

- High rubber yield level;
- Low incidence on isodiametric growth;
- Low sensitivity to tapping panel dryness, expressed by low percentages of DT;
- Good physiological profile with dry rubber content, sucrose, inorganic phosphorus and thiol contents ranging from medium to high.

2.4 Statistical Analysis

Rubber yield data, latex micro-diagnosis, isodiametric growth of tree trunks were analyzed using the XLSTAT-Pro 7.5 statistical software. The Student-Newman-Keuls test and the one of Scheffe were used to distinguish the groups at 5% threshold. For percentages (sensitivity to tapping panel dryness, dry rubber content), the Kruskal Wallis test at 5% threshold was used to determine significant differences.

3. RESULTS

3.1 Effect of Downward Tapping at Frequency d4 with or without Hormonal Stimulation at Different Frequencies on rubber productivity, radial Vegetative Growth and Rubber Tree Sensitivity to Tapping Panel Dryness.

3.1.1. Active or fast-metabolism clones

3.1.1.1 Rubber yield at tapping

Rubber yield results expressed in $g.t^{-1}.t^{-1}$ from 10 downward tapping trials in d4; 3 tappings per fortnight, that is, 50% tapping intensity, for 9 years, distributed over two sites (Site 1 in the southeast, site 2 in the southwest) covering 9 clones (PB 235, PB 260, PB 280, PB 310, PB 330, IRCA 18, IRCA 111, IRCA 130 and IRCA 209) lead to the following observations (Table 3):

- the average $g.t^{-1}.t^{-1}$ over 9 years of the stimulated patterns, the most yielding ones (56), irrespective of the stimulation regime, clones (PB 235, PB 310, IRCA 111 and IRCA 130) were statistically of the same order of magnitude as that of the unstimulated control (56);
- the average $g.t^{-1}.t^{-1}$ over 9 years of the stimulated patterns, the most yielding ones (67) regardless of the stimulation regime, clones (PB 330, PB 280, PB 260 (Sites 1 and 2), IRCA 18 and IRCA 209) was 12% statistically lower than the unstimulated control (60).

3.1.1.2 Radial vegetative growth

These results obtained with tapping at 50% intensity applied to active (fast)-metabolism clones showed that radial vegetative growth was good overall, all active latex-producing metabolic groups put together (Table 4). Better still, the unstimulated latex harvesting system (control) had an annual average girth increment that supplanted the one of the stimulated latex harvesting system, regardless of the active-metabolism group. Indeed, the annual average girth increment of the control for the highly active latex-producing metabolism (2.9 $cm.year^{-1}$) was 7% higher than that of the highest yielding stimulated pattern of this metabolic group (2.7 cm $.year^{-1}$). Similarly, the annual average girth increment of the control for the active latex-producing metabolism (3.1 $cm.year^{-1}$) was 11% higher than that of the stimulated pattern, the highest yielding of this metabolic group (2.8 $cm.year^{-1}$). The unstimulated latex harvesting system (control) was not more detrimental to radial vegetative growth than any other stimulated latex harvesting system, regardless of the active latex-producing metabolism, on the contrary.

3.1.1.3 Sensitivity to tapping panel dryness

The results regarding tapping panel dryness rate expressed as a percentage (%) of 10 downward tapping trials in d4, that is, 50% tapping intensity, for 9 years, distributed over two sites (Site 1 in the southeast, Site 2 in the southwest) on very active and active-metabolism clones lead to the following observations (Table 5):

- for very active-metabolism clones overall, the average tapping panel dryness rate, all latex harvesting technologies combined, reached 9.10%. This rate was high and considered to be at the limit of the acceptable level because it was greater than 5% regardless of the experiment plot.

Overall, this average rate increased with the intensity of latex harvesting technology. Treatment K (d4-78/y) had the highest rate (13.95%). This high rate was followed by those of treatments J (d4-39/y; 13.74 %), H (d4-26/y, 10.73%) and C (d4-4/y, 10.55%). The lowest tapping panel dryness rates were shown by treatments E (d4-8/y, 4.74%) and G (d4-18/y, 6.36%).

- For active-metabolism clones, latex harvesting technologies had a significant impact on diseased tapping panel length rates after nine years of experiment. The average dry rubber content was low (5.63%), and varied regardless of the latex harvesting technology. Treatment K (d4-78/y) had the highest rate (10.33 %).

3.1.2 Moderate-metabolism clones

3.1.2.1 Rubber yield at tapping

The results regarding rubber yield expressed in $g.t^{-1}.t^{-1}$ of 5 downward tapping tests; 3 tapping's per fortnight, that is, 50 % tapping intensity, for 9 years, distributed over two sites (site 1 in the southeast, site 2 in the southwest, case of clone GT 1) involving 3 clones (GT 1, BPM 24, RRIC 100) lead to the following observations (Table 3):

- The average $g.t^{-1}.t^{-1}$ over 9 years of stimulated patterns, the highest yielding one (60) regardless of the stimulation regime was 20% greater than that of the unstimulated control (50);

3.1.2.2. Radial vegetative growth

These results obtained with tapping at 50% intensity applied to moderate-metabolism clones showed that radial vegetative growth was quite good overall with 2.13 ± 0.45 $cm.year^{-1}$ (Table 4). Better still, the unstimulated latex harvesting system (control) had an annual average girth increment that outweighed that of the stimulated latex harvesting system, the highest yielding one. Indeed, the annual average girth increment of the control (3.0 $cm.year^{-1}$) was 13% higher than that of the stimulated pattern, the highest yielding one (2.6 $cm.year^{-1}$). The unstimulated latex harvesting system (control) was not more detrimental to radial vegetative growth than all other stimulated latex harvesting systems, on the contrary.

3.1.2.3. Sensitivity to tapping panel dryness

Sensitivity to tapping panel dryness, expressed by the average rate of diseased tapping panel length (DT, %) of the experiment, over the 9 years was low. Indeed, the average rate of L.E.M which reached 4.13%, was low. Diseased tapping panel length rates were influenced by latex harvesting technology. K (d4-78/y; 7.41%), J (d4-39/y; 6.63%) and C (d4-4/y; 6.37%) showed the highest rates of tapping panel dryness (Table 5).

3.1.3 Slow-metabolism clones

3.1.3.1 Rubber yield at tapping

Rubber yield results expressed in $g.t^{-1}.t^{-1}$ from 3 downward tapping trials in d4; 3 tapping's per fortnight, that is, 50% tapping intensity, for 9 years, distributed over two sites (Site 1 in the southeast, site 2 in the southwest; case of the clone PB 217) involving 2 clones (PB 217 and PR 107) lead to the following observations (Table 3):

The average $g.t^{-1}.t^{-1}$ over 9 years of stimulated patterns, the highest yielding one (70.20) regardless of the stimulation regime was 78% greater than that of the unstimulated control (39.50);

3.1.3.2 Radial vegetative growth

These results obtained with tapping at 50% intensity applied to slow-metabolism clones showed that radial vegetative growth was quite good overall with 2.37 ± 0.57 $cm.year^{-1}$ (Table 4). Better still, the unstimulated latex harvesting system (control) had an annual average girth increment that outweighed that of the stimulated latex harvesting system, the highest yielding one. Indeed, the annual average girth increment of the control (3.4 $cm.year^{-1}$) was 22% higher than that of the stimulated pattern, the highest yielding one (3 $cm.year^{-1}$). It is also observed that the more stimulation in the year, the less the trees grow. The unstimulated latex harvesting system (control) was not more detrimental to radial vegetative growth than all other stimulated latex harvesting systems, on the contrary.

3.1.3.3 Sensitivity to tapping panel dryness

The results obtained with 50% tapping intensity applied to slow-metabolism clones generally showed that the average tapping panel dryness, all latex harvesting technologies combined, was 7.77% overall (Table 5). This rate was high and considered to be at the limit of the acceptable level because it was greater than 5% regardless of the latex harvesting technology. Overall, this average rate varied with the intensity of the latex harvesting technology. Treatment K (d4-78/y) expressed the highest rate (13.21%). This high rate was followed by those of treatments J (d4-39/y; 12.43 %), H (d4-26/y, 8.83%), C (d4-4/y, 7.4%), D (d4-6/y, 6.97%), E (d4-8/y; 6.38%) and F (d4-13/y; 6%). The lowest tapping panel dryness rates were shown by treatments G (d4-18/y, 4.8%) and B (d4-2/y, 5.99%).

3.2. Effect of the Different Downward Tapping Frequencies d2, d3, d4, d5 and d6 Stimulated or not on Rubber Yield, Radial Vegetative Growth, Physiological Profile and Rubber Tree Sensitivity to Tapping Panel Dryness

3.2.1 Active or fast-metabolism clones

3.2.1.1 Dry rubber yield expressed in kg.ha^{-1}.year^{-1}

The annual average rubber yield, all latex harvesting technologies and all clones combined, of active-metabolism clones reached 2310 kg.ha^{-1}.year^{-1}. It did not significantly vary depending on the latex harvesting technology. The rubber yield was lower especially as the latex harvesting technology was of low intensity with regard to the control (Treatment 2, Table 6). Treatment 2 (d3-4/y) showed the relatively highest yield (2388 kg.ha^{-1}.year^{-1}), followed by treatments 1 (d2 *nil stimulation*, 2341 kg.ha^{-1}.y^{-1}), 3 (d4-4/y) and 4 (d4-8/y), 5 and 6 (d5 and d6 respectively).

3.2.1.2 Radial vegetative growth

The annual average tree girth increment, all latex harvesting technologies and all clones combined (Table 7), of active-metabolism clones (PB 235, PB 260, PB 280, PB 310, PB 330, IRCA 18, IRCA 209, IRCA 111 and IRCA 130) reached 2.9 ± 1.69 cm.year^{-1}. There were no significant differences between the latex harvesting technologies, although the average annual tapping increments of every other day without rubber production stimulation (3.1 cm.year-1) recorded the highest and statistically similar value to the other treatments.

3.2.1.3 Physiological profile

After nine years of experiment, the average dry rubber content of the latex expressed by active-metabolism clones was very high (51.3%). No effect of applied treatments was observed on the dry rubber content. The average sucrose content (7 mmol.l^{-1}) of the latex of trees subjected to different latex harvesting technologies was average as reported in Table 8. The sucrose consumption induced by the different latex harvesting technologies made it possible to differentiate three groups. The first group formed from treatment (d2-0/y), was characterized by a sucrose content equal to 7.9 mmol.l^{-1}. Treatments (d4-4/y; d5-8/y; d6-10/y) made up the second group with respective contents of 7.4; 7 and 7.1 mmol.l^{-1}. The third group of treatments (d3-4/y; d4-8/y) was marked by sucrose contents ranging between 6 and 6.4 mmol.l^{-1}. The average inorganic phosphorus (Pi) contents of tree latex were influenced by the latex harvesting technology and ranged from 20.1 (lower) to 23.1 mmol.l^{-1} (high). Treatments (d 2 0/y; d 3 -4/y; d 4 - 8/y: and d 5 - 8/y mmol.l^{-1}) with respective values 23.1; 22.9; 23 and 22.3 mmol.l^{-1} allowed very high and statistically greater contents than those of treatments (d4-4/y, 21.8 and d6-10/y, 20.1 mmol.l^{-1}). The average thiol content (RSH) of tree latex was low (Table 8, 0.52 mmol.l^{-1}). However, the average thiol content of the latex of control trees (d2-0/y) was high (0.68 mmol.l^{-1}) and statistically greater than the other treatments which were identical.

3.2.1.4 Sensitivity to tapping panel dryness

Overall, in downward tapping, the average tapping panel dryness rate of the trees of clones IRCA 18, IRCA 111, IRCA 130, PB 235, PB 260, PB 280, PB 310, PB 330 and IRCA 209 all latex harvesting technologies combined, reached 4.9% (Table 9). Overall, this average rate increased with the intensity of the latex harvesting technology. Nil hormonal stimulation treatment, with 100% tapping intensity, expressed the highest rate (7.9%). This high rate was followed by those of treatments 2 (d3-4/y; 5.5%) and 4 (d4-8/y; 5.6%) which were statistically similar to each other. The lowest tapping panel dryness rates were shown by treatments 3 (d4-4/y, 3.9%), 5 (d5-8/y, 3.50%) and 6 (d6-10/y; 3.1%). The latter were statistically identical to each other.

3.2.2 Moderate-metabolism clones

3.2.2.1 Dry rubber yield expressed in kg.ha^{-1}.year^{-1}

The annual average yield of dry rubber, all latex harvesting technologies and all clones combined,

Table 3. Annual average dry rubber yield expressed in $g.t^{-1}.t^{-1}$ in downward tapping of slow, moderate and active-metabolism clones for nine years in southwestern Côte d'Ivoire

		Average dry rubber yield ($g.t^{-1}.t^{-1}$)			
No.	**Treatments**	**Very active metabolism**	**Active metabolism**	**Moderate metabolism**	**Slow metabolism**
A	Unstimulated 0/Y	55.83	59.82	49.58	39.47
B	ET 2.5 % Pa 1(1) 2/Y	55.65	64.8	55.02	50.47
C	ET 2.5 % Pa 1(1) 4/Y	55.25	66.83	58.22	56.17
D	ET 2.5 % Pa 1(1) 6/Y	55.83	66.28	59.74	60.63
E	ET 2.5 % Pa 1(1) 8/Y	55.25	65.62	58.48	66.47
F	ET 2.5 % Pa 1(1) 13/Y	53.35	65.63	58.96	67.07
G	ET 2.5 % Pa 1(1) 18/Y	52.4	62.03	57.04	70.2
H	ET 2.5 % Pa 1(1) 26/Y	50.63	60.45	55.3	67.9
J	ET 2.5 % Pa 1(1) 39/Y	49.9	58.48	52.67	62
K	ET 2.5 % Pa 1(1) 78/Y	53.53	63.77	56.93	62.61
	Average	53.76	63.37	56,19	60.3

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y: 26 stimulations per year, 39/y: 39 stimulations per year and 78/y: 78 stimulations per year

Table 4. Annual average tree trunk girth increment depending on the treatments applied after nine years of experiment

		Annual tree trunk girth increment ($cm.year^{-1}$)			
No.	**Treatments**	**Very active metabolism**	**Active metabolism**	**Moderate metabolism**	**Slow metabolism**
-	Not tapped	6	5.3	5.3	4.6
A	Unstimulated 0/Y	2.9	3.1	3	3.4
B	ET 2.5 % Pa 1(1) 2/Y	2.7	2.9	2.6	3
C	ET 2.5 % Pa 1(1) 4/Y	2.7	2.8	2.5	2.9
D	ET 2.5 % Pa 1(1) 6/Y	2.7	2.6	2.3	2.6
E	ET 2.5 % Pa 1(1) 8/Y	2.7	2.5	2.1	2.4
F	ET 2.5 % Pa 1(1) 13/Y	2.6	2.5	2	2.1
G	ET 2.5 % Pa 1(1) 18/Y	2.5	2.2	1.8	2.1
H	ET 2.5 % Pa 1(1) 26/Y	2.5	2.3	1.7	2
J	ET 2.5 % Pa 1(1) 39/Y	2.4	2.1	1.7	1.6
K	ET 2.5 % Pa 1(1) 78/Y	2.2	2	1.6	1.6
	Average	2.59	2.5	2.13	2.37

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y: 26 stimulations per year, 39/y: 39 stimulations per year, and 78/y: 78 stimulations per year

Table 5. Average diseased tapping panel length and dry rubber trees after nine years of experiment under different hormonal stimulation regimes

No.	Treatments		Very active metabolism		Active metabolism		Moderate metabolism		Slow metabolism	
			DT (%)	Dry tree (%)	DT (%)	Dry tree (%)	DT (%)	Dry tree (%)	DT (%)	Dry tree (%)
A	Unstimulated 0/Y		7.22	0	2.78	0	2.49	0	5.71	0
B	ET 2.5 % Pa 1(1)	2/Y	7.96	0	3.65	0	2.92	0	5.99	0
C	ET 2.5 % Pa 1(1)	4/Y	10.55	0	6.39	0	6.37	0	7.4	0
D	ET 2.5 % Pa 1(1)	6/Y	8.16	0	3.75	0	2.3	0	6.97	0
E	ET 2.5 % Pa 1(1)	8/Y	4.74	0	3.71	0	3.09	0	6.38	0
F	ET 2.5 % Pa 1(1)	13/Y	7.6	0	4.29	0	3.25	0	6	0
G	ET 2.5 % Pa 1(1)	18/Y	6.36	0	4.67	0	0.94	0	4.8	0
H	ET 2.5 % Pa 1(1)	26/Y	10.73	0	6.8	0	5.94	0	8.83	0
J	ET 2.5 % Pa 1(1)	39/Y	13.74	0	9.93	0	6.63	0	12.43	0
K	ET 2.5 % Pa 1(1)	78/Y	13.95	0	10.33	0	7.41	0	13.21	0
	Average		9.10	0	5.63	0	4.13	0	7.77	0

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y: 26 stimulations per year, 39/y: 39 stimulations per year and 78/y: 78 stimulations per year. ExS (%) : average dry rubber content of latex expressed as percentage ; Sac (mmol.l^{-1}) : average sucrose content of the latex expressed in millimole 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 6. Annual average dry rubber yield expressed in kg.ha^{-1}.year^{-1} in downward tapping of slow, moderate and active-metabolism clones for nine years in southwestern Côte d'Ivoire

Treatments	Average dry rubber yield (kg.ha^{-1}.year^{-1})		
	Active metabolism	Moderate metabolism	Slow metabolism
S/2 d2 6d/7 *nil stimulation*	2341 a	2266 a	1849 a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	2388 a	2348 a	2256 a
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	2363 a	2257 a	2015 a
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	2350 a	2280 a	2166 a
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	2276 a	2234 a	2018 a
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	2239 a	2021 a	1856 a
Average	2310	2234	2026

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y:26 stimulations per year and 39/y: 39 stimulations per year.

Table 7. Average tree trunk girth increment values (cm.year^{-1}) of active, moderate, and slow-metabolism clones in downward tapping of the treatments for nine years in southwestern Côte d'Ivoire

Treatments	Girth increment (cm.year^{-1})		
	Active metabolism	**Moderate metabolism**	**Slow metabolism**
S/2 d2 6d/7 *nil stimulation*	3.1 a	2.6a	2.8 a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	2.9 a	2.3 a	2.4 a
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	2.9 a	2.4 a	2.6 a
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	2.9 a	2.3 a	2.6 a
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	2.8 a	2.3 a	2.6 a
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	2.9 a	2.5 a	2.8 a
Average	2.9	2.4	2.6

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y: 26 stimulations per year and 39/y: 39 stimulations per year an

Table 8. Average values of the physiological parameters of the latex of active, moderate and slow-metabolism clones in downward tapping, subjected to different latex harvesting technologies for nine years of experiment

Treatments	Active metabolism				Moderate metabolism				Slow metabolism			
	Ex.S	**Suc**	**Pi**	**Rsh**	**Ex.S**	**Suc**	**Pi**	**Rsh**	**Ex.S**	**Suc**	**Pi**	**Rsh**
S/2 d2 6d/7 *nil stimulation*	49.1 a	7.9 a	23.1 a	0.68 a	46.8 c	9.2 a	16.1 a	0.78 a	47.1 a	14.8 a	24.3 a	0.80 a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	50.6 a	6.4 b	22.9 a	0.52 b	48.5 bc	8.7 a	19.3 a	0.56 b	48.3 a	12.4 b	25.2 a	0.70 b
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	50.3 a	7.4 ab	21.8 ab	0.50 b	49.7 ab	9.2 a	19.6 a	0.59 b	50.9 a	13.4 a	23.1 a	0.68 b
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	50.7 a	6.0 b	23.0 a	0.49 b	49.8 ab	8.5 a	18.1 a	0.57 b	51.0 a	12.8 b	23.0 a	0.67 b
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	53.2 a	7.0 ab	22.3 a	0.46 b	49.6 ab	8.6 a	18.4 a	0.53 b	51.9 a	10.6 c	22.5 a	0.67 b
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	53.8 a	7.1 ab	20.1 b	0.48 b	51.6 a	9.1 a	17.1 a	0.54 b	52.2 a	10.4 c	21.8 a	0.65 b
Average	51.3	7.0	22.2	0.52	49.3	8.9	18.1	0.6	50.2	12.4	23.4	0.69

The same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). ExS (%) : average dry rubber content of latex expressed as percentage ; Suc (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 millimoles per liter ; R-SH (mmol.l^{-1}) : average thiol group content of the latex expressed in millimoles per liter.

Table 9. Average tapping panel dryness rates of the trees of active, moderate, and slow-metabolism clones in downward tapping, depending on the treatments, for nine years in the southwestern Côte d'Ivoire

Treatments	Tapping panel dryness rate (%)		
	Active metabolism	**Moderate metabolism**	**Slow metabolism**
S/2 d2 6d/7 *nil stimulation*	7.9 a	5.4 a	3.8 a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	5.5 b	3.6 b	2.1 b
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	3.9 c	2.4 c	2.1 b
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	5.6 b	3.3 bc	2.6 b
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	3.5 c	2.2 c	2.4 b
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	3.1 c	1.9 c	2.0 b
Average	4.9	3.15	2.5

In the same column, the averages followed by the same letter are not significantly different (Newman-Keuls test at 5%). 0/y: nil stimulation; 2/y: two stimulations per year; 4/y: four stimulations per year; 6/y: six stimulations per year; 8/y: eight stimulations per year; 13/y: 13 stimulations per year; 18/y: 18 stimulations per year; 26/y: 26 stimulations per year and 39/y: 39 stimulations per year.. ExS (%) : average dry rubber content of latex expressed as percentage ; Sac (mmol.l^{-1}) : average sucrose content of the latex expressed in millimole 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 lite reached 2234 kg.ha^{-1}.year^{-1}. This yield did not distinguish the latex harvesting technologies (Table 6). Treatment 2 (d3-4/y) showed the relatively highest yield (2348 kg.ha^{-1}.year^{-1}), followed by treatment 1 (d2 *nil stimulation*, 2266 kg.ha^{-1}.year^{-1}), 3 (d4-4/y) and 4 (d4-8/y), 5 and 6 (d5 and d6 respectively). From the control, the rubber yield was lower especially as the latex harvesting technology was of low intensity (Treatment 2, Table 6).

3.2.2.2 Radial vegetative growth

All latex harvesting technologies and all clones combined (Table 7), the annual average girth increment of the trees of moderate-metabolism clones GT1, RRIC 100 and BPM 24a reached 2.4 ± 1.02 cm.year^{-1}. There were no significant differences between the latex harvesting technologies, although the mean annual increases in tapping circumference of every second day without stimulation of rubber production recorded the highest but statistically similar values to the other treatments.

3.2.2.3 Physiological profile

The average dry rubber content of latex expressed by moderate-metabolism clones was very high (49.3%). With moderate-metabolism clones, tree responses to the different latex harvesting technologies have helped divide the latter into four groups (Table 8). Group 1 with treatment (d6-10/y) was characterized by 51.6 % dry rubber content. Treatments (d4-4/y; d4-8/y; d5-5/y) expressed equivalent dry rubber contents ranging between 49.6 and 49.8%. Group 3 described by 48.5% dry rubber content was composed of treatment (d3-4/ y). Finally, group 4 consisted of treatment (d2-0/y, 46.8%). The average sucrose and inorganic phosphorus (Pi) contents of the latex, which had a medium level, were unaffected by the latex harvesting technology (Table 8). The average thiol content (RSH) of tree latex had a medium level (Table 8, 0.6 mmol.l^{-1}). However, the average thiol content of the latex of control trees (d2-0/y) was high (0.78 mmol.l^{-1}) and statistically greater than that of the other treatments whose contents were identical.

3.2.2.4 Sensitivity to tapping panel dryness

Overall, in downward tapping, the average dry rubber content of the trees of moderate-metabolism clones GT 1, RRIC 100 and BPM 24, all latex harvesting technologies combined, reached 3.15 ± 0.90% (Table 9). Overall, this average rate increased with the intensity of the latex harvesting technology. Nil hormonal stimulation treatment, with 100% tapping intensity, expressed the highest rate (5.4%). This high rate was followed by those of treatments 2 (d3-4/y; 3,6%) and 4 (d4-8/y; 3,3%) which were statistically similar. The lowest tapping panel dryness rates were shown by treatments 3 (d4-4/y, 2.4%), 5 (d5-8/y, 2.2%) and 6 (d6-10/y; 1.9%). The latter were statistically identical to each other.

3.3 Slow-metabolism Clones

3.3.1 Dry rubber yield expressed in kg.ha^{-1}.year^{-1}

The annual average dry rubber yield, all latex harvesting technologies and all clones combined, reached 2026 kg.ha^{-1}.year^{-1}. This yield did not distinguish the latex harvesting technologies (Table 6). Treatment 2 (d3-4/y) showed the relatively highest yield (2256 kg.ha^{-1}.year^{-1}), followed by treatment 4 (d4 8/y; 2166 kg.ha^{-1}.year^{-1}), 5 (d5-8/y) and 3 (d4-4/y). There was no significant difference between the treatments (Treatment 2, Table 6).

3.3.2 Radial vegetative growth

All latex harvesting technologies and all clones combined, the annual average girth increment of the trees of clones PB 217 and PR107 reached 2.6 ± 1.01 cm.year^{-1} (Table 7). It has not varied significantly from one latex harvesting technology to another, although the annual average increments of every other day tapping without rubber yield stimulation and treatment 6 recorded the highest and statistically similar values.

3.3.3 Physiological profile

The average dry rubber content and the average inorganic phosphorus content (Pi) of the latex were very high, with respective values of 50.2% and 23.4 mmol.l $^{-1}$. They were all of the same order of magnitude (Table 8). With slow-metabolism clones, tree responses to the different latex harvesting technologies has helped divide them into three groups (Table 8). Group 1 with treatments (d2-0/y and d4-4/y), was characterized by sucrose contents ranging from 13.4 to 14.8 mmol.l^{-1}. Treatments (d-4/y and d4-8/y) expressed equivalent contents ranging between 12.4 and 12.8 mmol.l^{-1}. Group 3, described by sucrose content ranging between

10.4 and 10.6 $mmol.l^{-1}$, was composed of treatments d6-10/y and d5-8/y. The average thiol content (RSH) of tree latex was low (Table 8, 0.69 $mmol.l^{-1}$). However, the average thiol content of the latex of control trees (d2-0/y) was high (0.8 $mmol.l^{-1}$) and statistically greater than the other treatments which were identical to each other.

3.3.2 Sensitivity to tapping panel dryness

Overall, in downward tapping, the average tapping panel dryness rate of slow-metabolism clone trees (PB 217 and PR 107), all latex harvesting technologies combined, was 2.5% (Table 9). Overall, the average rate increased with the intensity of the latex harvesting technology. Nil hormonal stimulation treatment, with 100% tapping intensity, expressed the highest rate (3.8%) and statistically greater than the other treatments which were identical to each other. This high rate was followed by those of treatments 4 (d4-8/y; 2.6%) and 5 (d5-8/y; 2.44%) which were statistically similar to each other. The lowest tapping panel dryness rates were shown by treatments 3 (d4-4/y, 2.19%), 5 (d5-8/y, 2.4%) and 6 (d6-10/y; 2.0%). The latter were statistically identical to each other.

4. DISCUSSION

We have to answer this main and very important concern "Is it possible to produce natural rubber without exogenous hormonal stimulation?"

Our results obtained with 50% tapping intensity applied to active (fast)-metabolism clones showed that there is a very strong presumption about the production of natural rubber without exogenous hormonal stimulant in downward tapping from clones of this metabolic class. Indeed, these results clearly indicate that more than a third of the 8 clones (PB 235, IRCA 111 and IRCA 130) of this metabolic class can yield natural rubber, only by tapping at frequency d4, 50% tapping intensity. Since the rubber yield of the control, tapped in d4, unstimulated (56 $ga^{-1}.year^{-1}$) was statistically identical to that of the stimulated treatments, the highest yielding (56 $ga^{-1}.year^{-1}$). It appears that with these clones, the traumatism caused to the rubber tree by tapping has caused some stress which led to the production of metabolic energy and ethylene, [29;37;24;27;38;39;6] necessary at this yield level, which equals the one of the highest yielding of stimulated treatments. We are able to say that this endogenous metabolic energy (Pi_0; [40] and volume of ethylene produced ($V_{ethylene\ 0}$) have been sufficient to ensure good rubber yield, without the exogenous hormonal stimulation having occurred. We suggest that these clones thus form thus the subclass of very active or very fast-metabolism clones.

In the case of the other clones of the active metabolic class, the endogenous metabolic energy (Pi_0) and ethylene volume produced ($V_{ethylene0}$) were not sufficient to ensure good rubber yield, without exogenous hormonal stimulation being necessary. This group of clones requires exogenous hormonal stimulation at tapping frequency d4. They thus form the subclass of active or rapid-metabolism clones. However, given the small difference (12%) between the unstimulated control and the stimulated pattern, the highest yielding one, this differential can be bridged, by the judicious choice of a tapping intensity ranging between 50 and 67%, for 2/3 clones of this active metabolic class. For this purpose, the assumption "Can the tapping of *Hevea brasiliensis* clones at frequency d4 without exogenous hormonal stimulation help get higher rubber yield, without prejudice to rubber trees?" is fulfilled for the fast-metabolic class clones.

Concerning moderate and slow-metabolism clones, the presumption also exists especially for the moderate-metabolism class, but further investigations should be undertaken. The reason is that the principle of metabolic functioning of latex-vessel cells having led to the determination, overall, of three exogenous hormonal stimulation regimes of rubber yield relative to the three metabolic classes is the same for the tapping intensity to be applied to the clones of these metabolic classes. This is the case, especially as our results relating to tapping at different frequencies d2, d3, d4, d5 and d6 stimulated or not revealed that all the tapping frequencies stimulated or not, whatever the metabolic activity class, showed rubber yields that were statistically similar to that of the control, d2 unstimulated (Fig. 2). This was the case, despite the productivity gap of 22%, concerning slow-metabolism clones, between d2 without hormonal stimulation (1849 $kg.ha^{-1}.year^{-1}$) and the highest yielding treatment (d3 stimulated, 2256 $kg.ha^{-1}.year^{-1}$). Our results make it possible to say, for this purpose, that the intrinsic metabolic energy and the volume of ethylene produced by tapping at frequency d2, unstimulated, are of almost the same order of magnitude as those released and/or produced, both by tapping at frequencies d3, d4, d5 and d6 stimulated and by hormonal stimulation. This result is supported by those of Obouayeba and Boa, 1993 who indicate that the unstimulated tapping frequency d2 is more productive than the unstimulated one d3, both frequencies are also more productive than the stimulated tapping's at frequencies d4 and d6. It is also confirmed and corroborated by those of [40] who mention that in downward tapping d4, the yield in $g.t^{-1}t^{-1}$ of clone IRCA 130 supplants that of all other stimulated patterns, even at 78 stimulations per year. This clone does not need exogenous hormonal stimulation then. And moreover, the tapping at frequency d2 without yield hormonal stimulation did not have an unfavorable effect on radial vegetative growth. Furthermore, it arose an acceptable sensitivity to tapping panel dryness, supported by a physiological profile more balanced than that of all the other stimulated tapping frequencies, this allows us to say that the second hypothesis "Does the tapping of *Hevea brasiliensis* clones at frequency d2, without exogenous hormonal stimulation help get higher rubber yield, without prejudice to rubber trees?" is also verified. Our results report that the tapping at unstimulated frequency d2 gives rubber yield irrespective of the latex-producing metabolism of the *Hevea brasiliensis* clone at least statistically similar to that of the highest yielding stimulated or unstimulated treatment(s). The results show that tapping alone, in particular at frequency d2, allows rubber yield, without exogenous hormonal stimulation.

These results are important and are based on the works of several authors including. [41,42,30,43,26,8,44,45] These works, which are as varied as they are relevant in their field of investigation, highlight two indispensable notions, the very foundation of our study: i) activation of the latex-producing metabolism, key process of natural rubber yield, ii) tapping, inevitable operation to get natural rubber, without exogenous hormonal stimulation of natural rubber yield. Tapping is endowed with the ability to activate, itself, the whole process of rubber yield. This, through the production of ethylene and all the underlying energy and environmental conditions that accompany, feed and maintain the entire process of developing the very important molecule of cis-polyisoprene, which is natural rubber. In all likelihood, moderate and slow latex-producing-metabolism clones require tapping intensity ranging between 60 and 100% for yielding sufficient rubber without exogenous hormonal stimulation. The intrinsic metabolic energy is therefore the very essence of the process or processes leading to the answer to our main hypothesis.

We have just shown that it is possible to produce natural rubber by the single and unique tapping operation by judiciously selecting the tapping intensity.

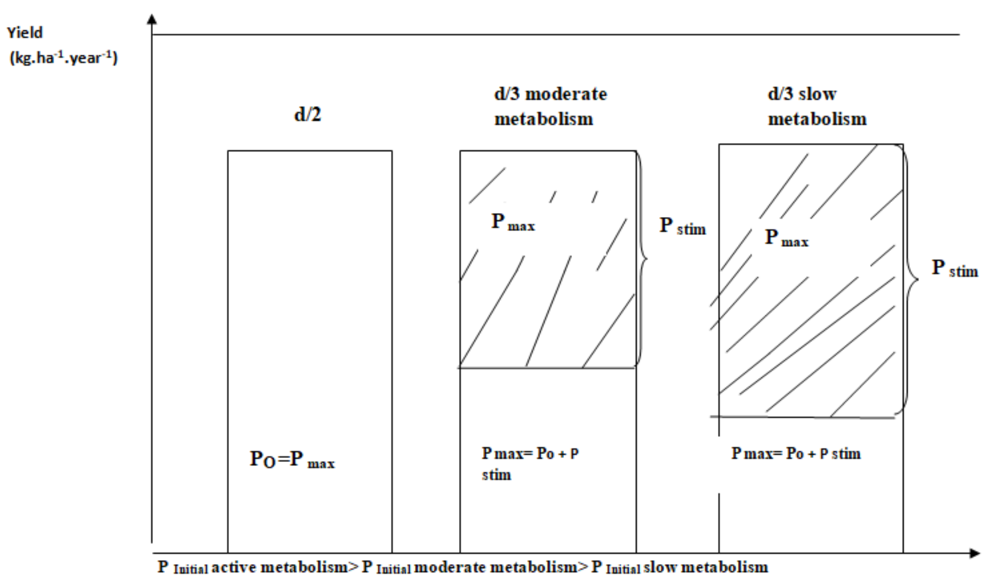

Fig. 2. Yield in kg.ha^{-1}.year^{-1} of slow, moderate and active-metabolism *Hevea brasiliensis*, tapped in d/2 Kg^{-1} ha^{-1} y^{-1}: kilogram per hectare per year

5. CONCLUSION

The purpose of the study was to show that rubber tree can lead to greater yield without exogenous hormonal stimulation. The results of this study showed that the average $g.t^{-1}.t^{-1}$ over 9 years of the unstimulated control (56) was statistically of the same order of magnitude as that of the stimulated patterns (56), regardless of the stimulation regime of active-metabolism clones (PB 235, PB 310, IRCA 111 and IRCA 130). The average $g.t^{-1}.t^{-1}$ of the control (60) was lower than that of the highest yielding stimulated patterns (67) of clones (PB 330, PB 280, PB 260, IRCA 18 and IRCA 109) and statistically different from that of the unstimulated control. The average $g.t^{-1}.t^{-1}$ of the unstimulated control (49) was significantly lower than that of the highest yielding stimulated treatment (57) of moderate-metabolism clones (GT 1, BPM 24, RRIC 100), that is, a rubber yield gap of 16% to the benefit of stimulation. The average $g.t^{-1}.t^{-1}$ of the unstimulated control (39) was significantly lower than that of the highest yielding stimulated treatment (70) of slow-metabolism clones (PB 217 and PR 107), that is, a yield gap of 79% to the benefit of stimulation. On a large scale and at tapping frequency (d2) the unstimulated latex harvesting system (d2 0/y) showed an average yield of (2341; 2266 and 1849 $kg.ha^{-1}.year^{-1}$ respectively for active, moderate and slow metabolisms) statistically comparable to the highest yielding tapping frequencies d3, d4, d5 and d6 all latex harvesting systems combined with the studied clones (2388; 2348; 2256 $kg.ha^{-1}.year^{-1}$) . These results really show that it is possible to produce natural rubber without exogenous hormonal stimulation by judiciously playing on tapping intensity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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