Original Research Article

Agronomic potential of some rubber tree clones (*Hevea brasiliensis*) of the fast metabolic activity class in the absence of hormonal stimulation in southwestern of Côte d'Ivoire

Abstract

Fast-metabolism clones of rubber tree (*Hevea brasiliensis*) are appreciated for their good agronomic performance with little hormonal stimulation, due to their high intrinsic metabolic activity. They are highly demanded and therefore exposed to a significant risk of overexploitation. In order to solve this problem, a study was carried out in a "*one tree plot*" design with clones IRCA 111, IRCA 130 and PB 260 planted at a density of 510 plants/ha in southwestern of Côte d'Ivoire for nine years. A single tapping system, that is every four days (d4) with different hormonal stimulation regimes (0/y; 2/y; 4/y; 6/y; 8/y; 13/y; 18/y; 26/y and 39/y), was applied to all treatments. The parameters measured in rubber trees were rubber yield, radial vegetative growth, physiological profile and sensitivity to tapping panel dryness. The results indicated that non-stimulated rubber trees of clones IRCA 111 and IRCA 130 showed the best rubber yields while two annual stimulations were necessary for clone PB 260. Moreover, the lack of hormonal stimulation had no negative impact on the vegetative growth, physiological profile and sensitivity to tapping panel dryness of those rubber trees. Clones IRCA 111 and IRCA 130 can therefore be tapped in S/2 d4 without hormonal stimulation.

Keywords: Fast-metabolism clones, *Hevea brasiliensis*, hormonal stimulation, rubber yield, vegetative growth, physiological profile, tapping panel dryness, Côte d'Ivoire.

1.Introduction

Rubber tree clones (*Hevea brasiliensis*) of the fast-metabolism class, including IRCA 18, IRCA 111, IRCA 130, PB 255, PB 280, PB 330 and PB 260, are generally appreciated for their good agronomic performance and especially their rapid yield increase [1,2]. These clones are characterized by a easy flow, thus a high intrinsic yield and have a good activating capacity of latex-producing metabolism in the absence of

hormonal stimulation. Fast-metabolism clones require, therefore, very little or no hormonal stimulation for giving a good level of rubber yield. This is plausible especially as the recent works of Diarrassouba and Traoré [3,4] showed that clones PB 235 and PB 260 of the fast metabolic activity class having sufficient intrinsic energy ensures good rubber yield with a very low stimulation regime. Moreover, Lacote *et al*. [5] showed that the intrinsic energy of fast-metabolism clones is such that some of them, including clone IRCA 130, tapped in d4 do not need hormonal stimulation. Indeed, rubber productivity without hormonal stimulation is significantly higher than that of all stimulation regimes applied.

The conclusions of those works are interesting and likely especially as it is assumed that tapping, due to the stress it induces, activates the metabolism of latex vessels along with hormonal stimulation, by producing ethylene. Indeed, ethylene, produced and released, during stress in the tissues, activates the whole biosynthetic process of the cis-polyisoprene molecule or rubber [6,7]. It is as if tapping alone provides so sufficient metabolic energy that hormonal stimulation even at very low regime would be harmful; since it can lead to an excess of energy which may lead to physiological fatigue [8] and tapping panel dryness [2,9,10,11,12].

The availability of metabolic energy activating the rubber biosynthetic process varies according to the metabolic activity class of the clone [13] and within the same class [5,14]. In the perspective of rubber tapping ecological management, it would be wise and efficient to exploit, on the one hand, the activation potential of latex-producing metabolism by tapping and, on the other hand, the capacity of active or fast-metabolism clones to achieve a good level of rubber yield with little or no hormonal stimulation. Given the high cost of stimulants and their adverse effects, in the more or less long term, on the yield, the applicator and the environment, it is therefore necessary to know whether the proven fact that clone IRCA 130 does not need hormonal stimulant may be extended to other clones of this metabolic activity class.

In order to address this concern, several experiments testing different latex harvesting technologies including non-stimulated treatment on clones IRCA 111, IRCA 130 and PB 260 of the fast metabolic activity class, were conducted for nine years in SCASO (former HEVEGO) in southwestern of Côte d'Ivoire.

2.Material and methods

2.1.Material

The plant material used consisted of three clones from the active or fast metabolic activity class of *Hevea brasiliensis* Muel. Arg. These are clones IRCA 111, IRCA 130 and PB 260.

- Clone **IRCA 111** was created in Côte d'Ivoire in 1975 by crossing PB 5/51 and RRIM 605. It was planted for the first time in CCGE in 1983. This clone shows a very good vegetative vigor in immature period [2] and an average annual increase after opening higher than those of clones GT 1 and PB 235 with a tendency to bend at 10 years. It has low sucrose content but relatively higher than that of PB 235 and is part of active or fast-metabolism clones [15]. Its yield expressed in grams per tree per tapping is very high. It has a sensitivity to tapping panel dryness that increases with the latex harvest period [2].
- Clone **IRCA 130** was created in Côte d'Ivoire in 1975 by crossing PB 5/51 and IR 22. It was planted for the first time in CCGE in 1983. It has a rapid height growth and is part of fast-metabolism clones. It is a vigorous clone with a beautiful crown and a slightly bent trunk [15]. Its yield expressed in grams per tree by tapping is very high. It has a good physiological profile at latex harvesting commencement. It has a relative sensitivity to breakage due to wind.
- Clone **PB 260** (Prang Besar 260) is the result of PB 5/51 x PB 49 crossing. It is originally from Malaysia. Its vegetative growth before tapping commencement switches from average to good. After tapping commencement, it remains average. Its yield commencement is fast. It is a vigorous and high yielding clone. It is sensitive to tapping panel dryness and is moderately resistant to wind damage [16]. It requires a moderate stimulation regime.

2.2.Methods

2.2.1.Experimental design and treatments

The experimental design used was the mono tree or "*one tree plot design*", that is to say, a tree makes up a repetition. In that respect, 330 trees were selected based on the homogeneity of their girth at 1m 70 above the ground, their yield without stimulation and their tapping panel dryness rate. On each plot, the selected trees were divided into 10 separate treatments at the rate of 33 trees (repetitions) per treatment.

A single tapping system was applied to all the trees of all treatments, tapping every four days (d4) with one day of rest per week and different hormonal stimulation regimes. A non-tapped absolute control was included to allow the monitoring of rubber trunk isodiametric growth, in order to better understand the effect of treatments (Table 1).

The trees of the experiment were planted at a density of 510 trees per hectare (7 m x 2.8 m). For nine years, the tapping technique followed the classic pattern of tapping panels conduct in use in Côte d'Ivoire [17].

2.2.2.Measurements

Rubber yield

Rubber yield was assessed per treatment. The coagulum, extracted at the following tapping, was collected, weighed monthly (fresh weight, F.W.) and stored. The transformation coefficient, dry rubber percentage of a given sample of fresh rubber, was used to calculate the dry rubber yield for each pattern. It has been calculated from a sample of coagulum per treatment. Each sample was weighed, crimped, dried at 80 °C in an oven for 24 hours and reweighed [18].

The dry rubber yield was expressed in grams per tree per tapping (g/t/t).

Trunk isodiametric growth

For each treatment, the trunk girth at 1.70 m was measured on each tree at the beginning of experiment and at the end of physiological cycle (January to February), before the start of annual defoliation. The average annual increase has been expressed (cm/year).

Measurements of latex physiological parameters

Form physiological parameters of the latex were analyzed once a year in November. They are the dry rubber content and the sucrose, inorganic phosphorus and thiol groups content in the latex. Some latex collected by pricking under the tapping panel (downward tapping), according to the "latex micro diagnosis" method [18] (LMD) was used to determine the values of physiological parameters.

Measurement of the dry content

The dry matter content of the latex was determined by weighing 1 ml of fresh product in a 10-ml pillbox, before and after heating at 80 °C for 24 h.

Determination of sucrose, inorganic phosphorus and thiol compounds

Sucrose contents, inorganic phosphorus and thiol groups were measured out from the TCA serum obtained after latex coagulation in trichloroacetic acid (TCA). These contents, expressed in millimoles per liter of latex ($mmol.l^{-1}$), were measured out by the anthrone method developed by Ashwell [19] the Taussky and Shorr method [20] and the Boyne and Ellman method [21], respectively for sucrose, inorganic phosphorus and thiol groups.

The interpretation of physiological parameter values took into account the reference values set by Jacob *et al*, [22].

Visual estimate of tapping panel dryness

The quick survey method by visual assessment helps report the appearance and the progress of tapping panel dryness [23]. For each tree tapped, a number ranging from 0 to 6 was assigned, proportional to the length of tapping cut affected by tapping panel dryness (Table 2).

For each plot, the exact count of the condition of trees was carried out and the rates of total diseased cut length (DCL %) and completely dry trees were determined for each treatment.

2.2.3.Statistical Analyses

Data on rubber yield, trunk isodiametric growth, latex micro diagnosis and tapping panel dryness statement were processed using the statistical software STATISTICA 7.5. An analysis of variance was performed and the level of significance of differences between averages was estimated by the NEWMAN-KEULS test for a threshold of 5%. For the comparison of percentages, the average comparison test by means of the least significant difference (Lsd) at the threshold of 5% was used.

3.Results

3.1.Rubber yield

The average annual rubber yields of clones IRCA 111, IRCA 130 and PB 260 were significantly influenced by the hormonal stimulation regime after nine years of experiment. They ranged from 47 to 58 g/t/t, 37 to 49 g/t/t and 54 to 70 g /t/t respectively for clones IRCA 111, IRCA 130 and PB 260. The trees of non-stimulated treatment (0/y) gave rubber yields that were the highest and statistically superior to those of trees stimulated in clones IRCA 111 and IRCA 130. However in clones PB 260, the stimulation regimes 2/y; 4/y and 6/y resulted in yields that were significantly superior to those of treatments. Irrespective of the clone, the lowest rubber yields were obtained with the high annual stimulation frequency (18/y; 26/y and 39/y; Table 2).

3.2.Radial vegetative growth of rubber trees

The average annual increase was significantly influenced by the tapping commencement of trees in clones IRCA 111, IRCA 130 and PB 260. Non-tapped trees had an average annual increase rate statistically superior to those trees tapped regardless of the clone. The different hormonal stimulation frequencies applied to clones IRCA (111 and 130) did not significantly affect the average annual growth of trees. However, in clone PB 260, the non-stimulated trees had an average annual increase statistically equivalent to that of stimulated trees 2/y and significantly superior to those of the other stimulated trees. In addition, the variation due to girthing rate was clear with eight distinct classes (Table 3).

3.3.Physiological parameters of rubber trees

3.3.1.Clone IRCA 111

Dry Rubber Content (DRC): the dry rubber content of the trees of clone IRCA 111 ranged from 46.91 to 58.56% according to the different treatments after nine years of experiment (Table 4). These rates were very high regardless of the latex harvesting technology. The non-tapped trees had the highest rate (58.56%), which was statistically superior to those of the other treatments. The lowest dry rubber contents were obtained with stimulated trees 2 and 4/y.

Sucrose Content (Suc): the average sucrose content of clone IRCA 111 trees ranged from 5.90 to 19.77 mmol.l^{-1} based on the treatments after nine years of experiment (Table 4). The non-tapped trees (control) showed a high (19.77 mmol.l^{-1}) significantly higher than those of tapped trees. The non-stimulated and stimulated trees (2/y, 6/y, 13/y, 18/y, 26/y and 39/y) were superior to those of stimulated trees 4 and 8/y.

Inorganic Phosphorus (Pi) content: the average inorganic phosphorus content of clone IRCA 111 trees ranged from very high to high after nine years of experiment from 17.27 to 31.87 mmol.l^{-1} (Table 4). Highest levels were obtained in the non-stimulated trees (30.93 mmol.l^{-1}), non-tapped trees (29.79 mmol.l^{-1}) and stimulated 2/y (31.87 mmol.l^{-1}) and 18/y (30.92 mmol.l^{-1}). The lower values were obtained with the stimulated trees 26 (22.89 mmol.l^{-1}) and 39/y (17.27 mmol.l^{-1}).

Thiol groups (RSH) contents: the average thiol group content of the latex of clone IRCA 111 trees were significantly influenced by the latex harvesting technology and have, generally, increased according to the intensification of hormonal stimulation after nine years of experiment. They ranged from 0.36 (non-tapped treatment) to 0.56 mmol.l^{-1} (stimulated treatment 18/y) according to the treatment. These values are rated low to very low (Table 4).

3.3.2.Clone IRCA 130

Dry Rubber Content (DRC): the dry rubber content of the latex of clone IRCA 130 trees were significantly influenced by the different latex harvesting technologies ranging from 53.67 to 64.83 % (Table 5). The dry rubber content from non-tapped trees was high than the other treatments that were equivalent to each other.

Sucrose content (Suc): the average sucrose content of the latex of clone IRCA 130 trees, in accordance with those of fast metabolism clones ranged from high (9.10 mmol.l^{-1}) to very high (23.60 mmol.l^{-1} ; Table 5). The non-tapped trees (control) showed a very high latex sucrose content significantly superior to those of the latex of tapped trees.

Inorganic Phosphorus Content (Pi): the average content of inorganic phosphorus of the latex of clone IRCA 130 trees were significantly influenced by the different latex harvesting technologies. They ranged from high (22.33 mmol.l^{-1}) to very high (28.40 mmol.l^{-1}) respectively for treatments 13/y and 0/y (Table 5).

Thiol group contents (RSH): the average thiol group content of the latex of clone IRCA 130 trees ranged from medium to good at 0.65 to 0.77 mmol.l^{-1} (Table 5).

3.3.3.Clone PB 260

Dry Rubber Content (DRC): the dry rubber content of the latex of clone PB 260 trees were significantly influenced by the various latex harvesting technologies with variation of 46.96 to 59.57% (Table 6). The tapped trees, stimulated or not showed dry rubber content of latex statistically inferior to those of non-tapped trees.

Sucrose content (Suc): the different latex harvesting technologies had a significant impact on the average sucrose content of the latex of clone PB 260 trees with 23.54 mmol.l^{-1} in non-tapped trees (Table 6).

Inorganic Phosphorus content (Pi): the average inorganic phosphorus content of the latex of clone PB 260 trees were significantly influenced by the different treatments. They ranged from 20.01 to 35.66 mmol.l^{-1} (Table 6). These contents, very high for little stimulated or not stimulated treatments, had a tendency to decrease with strong hormonal stimulation frequencies.

Thiol group contents (RSH): the average thiol group contents of the latex of clone PB 260 trees were significantly influenced by the different treatments. They were low for all treatments (Table 6). However, the tapped trees, stimulated or not showed contents superior to that of the latex of non-tapped trees.

3.4.Sensitivity to rubber tree tapping panel dryness

The different latex harvesting technologies have had a significant impact on the rates of partial dry cut length and completely dry trees of clones IRCA 111 and PB 260 except for clone IRCA 130 (Table 7). The average rates of partial dry cut length ranged from 2.73 to 16.06% for clone IRCA 111, from 24.24 to 45.45% for clone IRCA 130 and 3.64 to 20.30% for clone PB 260. The non-stimulated treatments (0/y), have induced the lowest rates of partial dry cut length regardless of the clone. The stimulated treatments induced high rates of partial dry cut length.

The rate of completely dry trees have evolved in the same order as those partial dry cut lengths.

4.Discussion

4.1.Impact of different latex harvesting technologies on dry rubber yield and radial vegetative growth of fast metabolism clones of *Hevea brasiliensis*

The analysis of the average annual yield of rubber trees revealed that clones IRCA 111 and IRCA 130 have the best rubber yield in the absence of hormonal stimulation. These results suggest that these clones belong to the fast activity class basing on their yield with little hormonal stimulation as reported by Eschbach *et al*. [24]; Serres *et al*. [25]; 13 Jacob *et al*. [13] and Gohet *et al*. [8]. It means the metabolic activity governed by the intrinsic energy [5,26], was sufficient for clones IRCA 111 and IRCA 130 to reach maximum rubber yield. However, the low rubber yield shown by the non-stimulated treatment compared to stimulated treatments highlights the inadequacy of this intrinsic energy

necessary to a high yield in the case of PB 260. Thus, to compensate for the energy difference, some authors [27,28,29] have justified and proposed an exogenous energy provided by hormonal stimulation such as ethylene. For all the clones studied, hormonal stimulation resulted in average rubber yield decline which is a reflection of the depressive effect of high levels of stimulation on rubber yield. As stated by Gohet *et al*. [8], overstimulation results in a malfunction of the latex-vessel system characterized by the impossibility of raising the activation level of latex-producing metabolism by hormonal stimulation [4]. This causes either a physiological fatigue of overused latex-producing tissues, or a phytotoxic effect due to excessive use of Ethephon.

Moreover, some studies have highlighted the stimulating power of tapping which produces ethylene in the tissues of rubber trees through the stress it causes [6,7]. In the case of PB 260, therefore, a slight increase in the tapping frequency, particularly in d3, may be applied in the absence of hormonal stimulation.

Concerning the radial vegetative growth of trees of the clones studied, the average annual increase in girth of non-tapped trees was superior to that of tapped trees. This due to the fact that rubber tree tapping commencement results in the diversion of a fraction of photosynthetic assimilates, strictly allocated to the general metabolism of the tree and the primary biomass. Indeed, a strong competition for photosynthetic assimilates occurs between vegetative growth and rubber yield [8,30,31]. This is more likely especially as tapping commencement is inevitably accompanied by a reduction in the annual rate of vegetative growth [1,32,33].

4.2.Impact of different latex harvesting technologies on the physiological profile and sensitivity to tapping panel dryness of fast-metabolism clones of *Hevea brasiliensis*

Concerning the physiological profile, the very high level of dry rubber content observed in all the clones studied shows an increased biosynthesis of rubber within latex-vessels. However, the dry rubber content was higher in non-tapped trees. This is due, on the one hand, by the fact that there is no rubber export by harvest and, on the other hand, by the active nature of the latex-producing metabolism of these clones due to the

important and available intrinsic energy. The dry rubber content of the stimulated or non-stimulated trees has relatively decreased compared to that of non-tapped trees. This decrease in dry rubber content is explained by the fact that hormonal stimulation induces an increase of water transfers within latex-vessel tissues [6,35]. This process leads to latex dilution in time which is the source of lower dry rubber contents.

The sucrose content of the latex of the studied clones was medium to high. They were very high for non-tapped trees regardless of the clone. The stimulated trees have, on the whole, shown contents inferior to those of non-stimulated trees. These results are similar to those obtained by Lacrotte [6] and Traoré [4] who showed that all stimulated trees have a sucrose content of latex inferior to that of non-stimulated trees due to the use of sucrose for rubber biosynthesis. This result could be explained by the fact that ethylene stimulation strongly activates the metabolism leading to a strong conversion of the sucrose present in latex-vessels [5], into latex-producing rubber since sucrose is the raw material of the isoprene biosynthesis [36]. In the conditions of our experiment, the non-stimulated trees of clones IRCA 111 and IRCA 130 showed better yields compared to stimulated trees. This suggests a good supply and efficient use of sucrose for rubber yield in the absence of stimulation. This situation is probably the result of the fact that the intrinsic metabolic energy of these clones is sufficient for good biosynthesis of the latex-producing rubber. Indeed, these clones, due to their very active metabolism, transform very quickly the sucrose into rubber and respond only poorly to hormonal stimulation [8,13].

The inorganic phosphorus contents of the latex of trees, which are closely related to energy metabolism and rubber biosynthesis, reflect the intensity of regeneration within the latex-producing tissue [8]. For each of the clones studied, the inorganic phosphorus contents were high in non-stimulated trees as well as in stimulated trees. This result highlights the activating effect of metabolism by tapping, as shown by Obouayeba *et al*. [7] and Dick *et al*. [28]. Tapping, due to the stress it induces [37], might activate latex-vessels metabolism along with hormonal stimulation, by ethylene production. Indeed, as shown by Lacrotte [6], ethylene is a hormone that is produced and released during stress (tapping or stimulation) in the tissue to act by activating the entire biosynthetic process of the *cis*-polyisoprene molecule or rubber. This explains the good level of rubber yield noticed in clones IRCA 111, IRCA 130 and, to a lesser extent, clone PB 260 in the absence of hormonal stimulation. The

thiol group contents of the latex of trees were, generally, weak and in the same order of magnitude for all treatments regardless of the clone. The level of these contents reflects, indeed, a decline of the biological protection of lutoids [6].

As regards the sensitivity to tapping panel dryness, the results revealed low rates of partially dry and completely dry trees for the non-stimulated treatment and inferior to those of stimulated treatments in all the clones studied. These rates increased with the intensification of hormonal stimulation whatever the clone. This negative impact of hormonal stimulation on the occurrence of the tapping panel dryness supports the works of De Fäy [38], Chrestin [37] and Omokhaf [39], who showed that tapping panel dryness increases with the frequency of hormonal stimulation. Indeed, the tapping panel dryness is generally caused by overexploitation of the trees. The sensitivity of clones to tapping panel dryness according to the metabolic activity class, is due to the fact that they have low levels of thiol compounds as indicated by Chrestin [40]. According to the same author, these compounds favors the stability of lutoids and their low content causes decompartmentalization of those which are destroyed *in situ*. Lysis of lutoids leads to the coagulation of latex within the latex-vessels, resulting thereafter, in the stoppage of latex flow and, subsequently, tapping panel dryness. Furthermore, the rates of partially dry and completely dry trees, more or less important, observed in non-timulated trees highlights the specificity of the clones in this activity class as for their high sensitivity to tapping panel dryness [8,13].

5.Conclusion

This study was conducted in order to develop a latex harvesting system without hormonal stimulation and reach a good rubber yield for the clones of fast metabolic activity class. The results indicate that only clones IRCA 111 and IRCA 130 showed better rubber yield in the absence of hormonal stimulation after nine years of experiment in S/2 d4. The metabolic activity governed by the intrinsic energy was sufficient to enable these clones to better express their potentials unlike clone PB 260 which needed two annual stimulations for result.

Furthermore, the absence of hormonal stimulation favored the radial vegetative growth of trees while the increase in stimulation frequency had a depressive effect on the average annual growth of trees of the clones studied. In addition, non-stimulation had no negative impact on the physiological parameters and the sensitivity to tapping panel dryness of trees. This study has helped highlight the possibility of reaching a

maximum rubber yield in the absence of hormonal stimulation. Therefore, clones IRCA 111 and IRCA 130 can be tapped in S/2 d4 without hormonal stimulation.

References

1. Obouayeba S. et Boa D. Fréquence et repos annuel de saignée d'*Hevea brasiliensis*, clone PB 235, dans le sud-est de la Côte d'Ivoire. Cah Agric. 1993; 2 (6), 387 – 393.
2. Obouayeba, S., Soumahin E.F., Dobo M., Lacote R., Gabla O. et Doumbia A. Agronomic performance of clone IRCA 111 of *Hevea brasiliensis* under different frequencies of tapping and stimulation in South-West Côte d'Ivoire. J Rub Res. 2009;12 (2) : 93 - 102.
3. Diarrassouba M. Contribution à la définition de technologies de récolte du latex adaptées aux clones de *Hevea brasiliensis* Muell. Arg. (Euphorbiaceae) des classes d'activité métabolique active, modérée et lente. Thèse de Doctorat de l'Université Félix Houphouët Boigny– Abidjan (Côte d'Ivoire); 2013;207 p.
4. Traoré MS. Effets de différentes fréquences annuelles de stimulation éthylénique sur les paramètres agrophysiologiques des clones d'*hevea brasiliensis* müll. Arg. (Euphorbiaceae), PB 235, PB 260, GT 1 et PB 217 cultivés au sud-est de la Côte d'Ivoire. Thèse de Doctorat de l'Université Félix Houphouët Boigny– Abidjan (Côte d'Ivoire); 2014;161 p.
5. Lacote R, Gabla O, Obouayeba S, Eschbach JM, Rivano F, Dian K et Gohet E. Long-term effect of ethylene stimulation on the yield of rubber trees is linked to latex cell biochemistry. Field Crops Res. 2010;115 : 94-98.
6. Lacrotte R. Etude des relations entre la teneur en sucres du latex et la production : approche des mécanismes du chargement en saccharose des laticifères de *Hevea brasiliensis* Muell. Arg. Thèse de Doctorat d'Université, Université des Sciences et Technologies du Languedoc, Montpellier II; 1991;266 p.
7. Obouayeba S, Boa D et Keli ZJ. Adéquation entre quantité de pâte stimulante et production de caoutchouc d'*Hevea brasiliensis* dans le sud-est de la Côte d'Ivoire. Tropicultura. 1996;14 (2:) : 54 - 58.

8. Gohet E, Prévôt JC, Eschbach JM, Clément A et Jacob JL. Clone, croissance et stimulation, facteurs de la production de latex. Plant, Rech, Dévelop. 1996;3 (1): 30 – 38.
9. Compagnon P. Le caoutchouc naturel. Coste R ed, GP. Maisonneuve et Larose, Paris; 1986;595 p.
10. Obouayeba S, Soumahin EF, Okoma KM, N'guessan AEB, Lacote R, Coulibaly LF et Ake S. Relationship between the tapping cut length and the parameters of vegetative growth and rubber yield of *Hevea brasiliensis*, clones GT 1 and PB 235 in south-eastern of Côte d'Ivoire. J Crops Sci. 2011; 2 (2) : 27- 44.
11. Okoma KM, DIAN K, Obouayeba S, Elabo AAE. et N'guetta ASP. Seasonal variation of tapping panel dryness expression in rubber tree *Hevea brasiliensis* (Muell. Arg.) in Côte d'Ivoire. Agric Biol J North Amer. 2011;2 (3) : 559 - 569.
12. Traoré MS, Diarrassouba M, Obouayeba S, Dick KE, Soumahin EF et Coulibaly LF. Long-term effect of different annual frequencies of ethylene stimulation on rubber productivity of clone GT 1 of *Hevea brasiliensis* (Muell. Arg.) in south east of Côte d'Ivoire. Agric Biol J North Amer. 2011;2 (8) : 1251 - 1260.
13. Jacob JL, D'auzac J, Prévôt JC et Sérier JB. Une usine à caoutchouc naturel : l'hévéa. La recherché. 1995; 276 : 538 – 545.
14. Koffi KE, Dian K et Obouayeba S. La réponse à la stimulation des clones d'une même classe métabolique varie chez *Hevea brasiliensis* Muell. Arg. (Euphorbiaceae). Sci Nat. 2007;4 (1): 57-64.
15. Chapuset TH. Description des clones étudiés à grande échelle. Rapport CNRA-HEVEA. 2001;n° 01/01, 36 p.
16. Anonymous. Recueil de fiches de clones d'hévéa. Abidjan, Côte d'Ivoire : CIRAD – CP; 1993;170 p.
17. Gohet E, Lacrotte R, Obouayeba S, et Commère J. Tapping system recommending in West Africa. Proc Rubb Growers' Conf Rubb Res Inst Malaysia, ed, Kuala Lumpur, Malaysia;1991;10 p.
18. Jacob JL, Serres E, Prévôt JC, Lacrotte R, Clément-Vidal A, Eschbach JM. et D'auzac J. Mise au point du diagnostic latex. Agritrop. 1988;12 : 97 – 118.
19. Ashwell G. Colorimetric analysis of sugar. Methods Enzymol. 1957;3 : 73 - 105.
20. Taussky HH et Shorr EA. micro colorimetric method for the determination of inorganic phosphorus. J Biol Chem. 1953;202 : 675 - 685.

21. Boyne AF et Ellman GL. A methodology for analysis of tissue sulphydryl components. Anal Biochem. 1972;46: 639 - 653.
22. Jacob JL, Lacrotte R, Serres E, Roussel D. Les paramètres physiologiques du latex d'Hevea brasiliensis. Le diagnostic latex, ses bases, sa mise au point. IRCA, Document interne; 1987;41 p.
23. Van De Sype H. The dry cut syndroms of *Hevea brasiliensis*, evolution, agronomical and physiological aspects. C R Coll Physiol Amél Hévéa, Ed., IRCA-CIRAD, Montpellier, France; 1984;249-271.
24. Eschbach JM, Roussel D, Van De Sype H, Jacob JL et D'auzac J. Relationships between yield and clonal physiological characteristics of latex from *Hevea brasiliensis.* Physiol Vég. 1984;22 : 295 – 304.
25. Serres E, Lacrotte R, Prevot JC, Clement A, Commere J et Jacob JL. Metabolic aspects of latex regeneration in situ for three Hevea clones. Rubb Ind J. 1994;7 : 79 - 84.
26. Jacob JL, Prévôt JC et Kekwick RGO. General metabolism of *Hevea brasiliensis* latex (with the exception of isoprenic anabolism). Physiology of Rubber Tree Latex. J d'Auzac, JL Jacob, H Chrestin, eds, CRC Press Inc, Boca Raton, Floride, États-Unis; 1989;101 – 144.
27. Soumahin EF, Elabo AAE, Okoma KM, Atsin GJO, Dick AE et Obouayeba S. Yield response of low frequency upward tapping by increasing the tapping cut length in *Hevea brasiliensis* (clone GT 1) in south-eastern Côte d'Ivoire. *Rubb. Sci.*, 2014;27(2):193-201.
28. Dick AE, Traoré MS, Elabo AEA, Soumahin EF, Assi EGM, Atsin GJO, Allé YJ, N'guessan BEA, Kouamé C et Obouayeba S. Effets de différentes fréquences annuelles de stimulation éthylénique sur les paramètres agrophysiologiques et de sensibilité à l'encoche sèche de *Hevea brasiliensis* au sud-est de la Côte d'Ivoire : cas des clones PB 235 et PB 260 de la classe d'activité métabolique rapide. *Int. J. Biol. Chem. Sci.* 2014;8(3): 956-974.
29. Atsin GJO, Soumahin EF, Kouakou H T, Coulibaly LF, Traoré SM, Allé JY, N'guessan AEB, Kouamé C et Obouayeba S. Impact of reduced tapping frequency on agronomic, physiological and biochemical aspects of clone PB 260 of *Hevea brasiliensis* in the Centre West of Côte d'Ivoire. J Rubb Res 2014;17(1), 45–56.
30. Templeton JK. Partition of assimilates. J Rubb Res Inst Malaysia. 1969;21 : 259-273.

31. Obouayeba S, Boa D, Ake S, Lacote R. Influence of age and girth at opening on growth and productivity of Hevea. Ind J Rubb Res. 2002;15 (1): 66-71.
32. Paardekooper EC, Langlois SJC et Sompong S. Influence of tapping intensity and stimulation on yield, girth and latex constitution. In Proceedings of International Rubber Conference, Kuala Lumpur; 1975;2 : 290 p.
33. Obouayeba S. Contribution à la détermination de la maturité physiologique de l'écorce pour la mise en saignée d'*Hevea brasiliensis* Muell. Arg. (Euphorbiaceae) : normes d'ouverture. Thèse de Doctorat d'Université, Université de Cocody, Abidjan, Côte d'Ivoire; 2005;223 p.
34. Gohet E. La production de latex par *Hevea brasiliensis*. Relation avec la croissance. Influence de différents facteurs : origine clonale, stimulation hormonale, réserves hydrocarbonées. Thèse de Doctorat d'Université, Université Montpellier II. Sciences et techniques du Languedoc, France; 1996;343 p.
35. Njukeng NJ et Gobina MS. Effects of 2-chloroethylphosphonic acid formulations as yield stimulants on *Hevea brasiliensis.* Afr J Biotechnol 2007;6 (5) : 523-528.
36. Obouayeba S, Soumahin EF, Boko A MC, Gnagne YM et Dian K. Compensatory tapping systems to tappers rarity applied to the clone PR 107 of *Hevea brasiliensis* (Muell. Arg.) : I. Assessment of 21 years of exploitation. Proceedings of International Natural Rubber Conference, Ho Chi Minh City, Vietnam; 2006;36 – 46.
37. Chrestin H. La stimulation à l'éthrel de l'hévéa ; jusqu'où ne pas aller trop loin. Caouth Plast 1985;647/648 : 75 – 78.
38. De Fay E. Histologie comparée des écorces saines et pathologiques (maladie des encoches sèches) de l'*Hevea brasiliensis.* Thèse de Doctorat de 3ème cycle, USTL, Montpellier II; 1981;75 p.
39. Omokhaf KO. Preliminary investigation into tree dryness in Hevea brasiliensis by path analysis of tree dryness and latex parameters. Tropicultura. 2001;19, 1 - 4.
40. Chrestin H. Le compartiment vacuo-lysosomal (les lutoïdes) du latex d'*Hevea brasiliensis*, son rôle dans le maintien de l'homéostasie et dans les processus de sénescence des cellules laticifères. Thèse de Doctorat d'Etat Sci. Nat., Université Sci. Tech. Languedoc, Montpellier, France; 1984;575 p.

Tables

Table 1 : Treatments applied on clones IRCA 111, IRCA 130 and PB 260 during nine years of experimentation in southwestern Côte d'Ivoire.

N°	Latex harvesting technologies	Description
1	Control	Untapped trees
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, whithout stimulation
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, two applications per year
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, four applications per year
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, six applications per year
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, eight applications per year
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, 13 applications per year
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band,18 applications per year
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, 26 applications per year
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	Half spiral cut tapped at fourth daily frequency, six day in tapping followed by one day; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant* applied on panel on a 1 cm band, 39 applications per year

**The stimulant used is ELS 50 Double Red*

Table 2 : Annual mean dry rubber yield of clones IRCA 111, IRCA 130 and PB 260 of *Hevea brasiliensis* expressed in $g.t^{-1}.t^{-1}$ during nine years in southwestern Côte d'Ivoire

N°	Latex harvesting technologies	IRCA 111	IRCA 130	PB 260
1	Control (without tapping)	-	-	-
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	58 a	49 a	62 b
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	56 b	41 d	69 a
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	53 cd	41 d	70 a
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	54 c	37 f	69 a
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	52 d	46 b	63 b
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	56 b	39 e	62 b
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	51 e	38 ef	59 c
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	48 f	43 c	56 d
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	47 f	41 d	54 e

Means followed by same letters in each column are not significantly different (test of Newman -Keuls at 5%).

Table 3 : Annual average girth increment in cm/year according to the latex harvesting technologies applied to the clones IRCA 111, IRCA 130 and PB 260 during nine tapping years in southwestern Côte d'Ivoire

N°	Latex harvesting technologies	IRCA 111		IRCA 130		PB 260	
1	Control (without tapping)	-		-		-	
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	5.11	a	7.28	a	5.40	a
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	2.27	b	2.38	b	3.17	b
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	1.82	b	2.18	b	3.01	bc
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	2.01	b	2.25	b	2.80	c
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	1.23	b	2.20	b	2.69	cd
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	1.97	b	2.25	b	2.42	de
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	2.52	b	2.08	b	2.40	de
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	1.79	b	2.13	b	2.34	ef
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	1.68	b	2.10	b	2.13	ef

Means followed by same letters in each column are not significantly different (test of Newman -Keuls at 5%).

Table 4 : Physiological profile of latex according to the latex harvesting technologies applied to the clone IRCA 111 during nine tapping years in southwestern Côte d'Ivoire

N°	Latex harvesting technologies	DRC (%)	Suc (mmol.l-1)	Pi (mmol.l-1)	RSH (mmol.l-1)
1	Control (without tapping)	58.56 a	19.77 a	29.79 b	0.36 g
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	49.25 c	7.39 bc	30.93 ab	0.46 e
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	46.91 d	7.10 bc	31.87 a	0.5 c
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	47.10 d	6.35 c	27.95 c	0.46 de
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	49.04 c	6.99 bc	27.96 c	0.47 d
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	50.17 bc	5.9 c	29.73 b	0.46 e
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	51.03 b	7.11 bc	29.65 b	0.52 b
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	50.24 bc	7.99 b	30.92 ab	0.56 a
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	48.64 c	7.52 bc	22.89 d	0.47 de
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	48.47 c	7.18 bc	17.27 e	0.38 f

Means followed by same letters in each column are not significantly different (test of Newman -Keuls at 5%).

Table 5 : Physiological profile of latex according to the latex harvesting technologies applied to the clone IRCA 130 during nine tapping years in southwestern Côte d'Ivoire

N°	Latex harvesting technologies	DRC (%)		Suc (mmol.l-1)		Pi (mmol.l-1)		RSH (mmol.l-1)	
1	Control (without tapping)	64.83	a	23.60	a	25.57	abc	0.65	a
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	54.53	b	10.73	b	28.40	a	0.74	a
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	53.90	b	9.74	b	26.23	ab	0.74	a
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	57.13	b	9.25	b	25.40	abc	0.73	a
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	55.93	b	9.10	b	25.93	ab	0.69	a
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	55.63	b	10.00	b	25.43	abc	0.70	a
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	54.53	b	10.01	b	22.33	c	0.71	a
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	55.54	b	9.88	b	25.33	abc	0.71	a
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	55.47	b	11.27	b	22.83	bc	0.77	a
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	53.67	b	10.93	b	26.00	ab	0.67	a

Means followed by same letters in each column are not significantly different (test of Newman -Keuls at 5%).

Table 6 : Physiological profile of latex according to the latex harvesting technologies applied to the clone PB 260 during nine tapping years in southwestern Côte d'Ivoire

N°	Latex harvesting technologies	DRC (%)	Suc (mmol.l-1)	Pi (mmol.l-1)	RSH (mmol.l-1)
1	Control (without tapping)	59.57 a	23.54 a	35.66 a	0.37 d
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	50.05 bcd	10.39 b	31.14 ab	0.45 bcd
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	46.96 d	9.51 b	31.16 ab	0.47 abc
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	48.04 cd	9.60 b	30.34 ab	0.51 abc
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	49.99 bcd	9.36 b	27.50 abc	0.51 abc
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	50.83 bc	8.53 b	30.16 ab	0.48 abc
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	51.77 b	10.13 b	29.45 ab	0.53 ab
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	50.74 bc	10.90 b	29.76 ab	0.57 a
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	49.47 bcd	9.82 b	24.42 bc	0.48 abc
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	49.32 bcd	9.46 b	20.01 c	0.41 cd

Means followed by same letters in each column are not significantly different (test of Newman -Keuls at 5%).

Table 7 : Dry cut (%) and dry trees (%) of the clones IRCA 111, IRCA 130 and PB 260 of *Hevea brasiliensis* after nine years in southwestern Côte d'Ivoire

		IRCA 111		IRCA 130		PB 260	
N°	**Latex harvesting technologies**	**Dry cut (%)**	**Dry trees (%)**	**Dry cut (%)**	**Dry trees (%)**	**Dry cut (%)**	**Dry trees (%)**
1	Control (without tapping)	-	-	-	-	-	-
2	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 0/y	3.03 ab	3.03 ab	27.27 a	27.27 a	5.45 b	3.03 b
3	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 2/y	9.09 ab	9.09 ab	33.33 a	33.33 a	3.64 b	3.03 b
4	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 4/y	6.36 ab	6.06 ab	26.36 a	24.24 a	4.24 b	3.03 b
5	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 6/y	16.06 a	15.15 a	42.42 a	42.42 a	13.03 ab	12.12 ab
6	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 8/y	9.09 ab	6.06 ab	24.24 a	24.24 a	16.36 ab	6.06 ab
7	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 13/y	2.73 b	0.00 b	36.36 a	36.36 a	13.03 ab	9.09 ab
8	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 18/y	10.91 ab	9.09 ab	45.45 a	45.45 a	8.79 ab	6.06 ab
9	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 26/y	12.42 ab	9.09 ab	30.30 a	30.30 a	20.30 a	18.18 a
10	S/2 d4 6d/7 12 m/12 ET2.5% Pa1(1) 39/y	11.21 ab	9.09 ab	36.36 a	36.36 a	20.30 a	18.18 a

Means followed by same letters in each column are not significantly different according the least significant difference (lsd) at the threshold of 5%.