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Latex Harvesting Technologies Adapted to Clones IRCA18, IRCA 111, IRCA 130, PB 235 and PB 260 of *Hevea brasiliensis* (Rubber Tree) of the Class to Active Metabolism in South-Western Côte d'Ivoire

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Authors' contributions

This work was carried out in collaboration between all authors. Author SO designed the study and wrote the protocol. Authors MD and EFS managed the literature searches and wrote the first draft of the manuscript. Authors MD, JLE, MKO, CBYA and APO performed the statistical analysis. All authors read and approved the final manuscript.

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ABSTRACT

The rubber production falls due to the tapping panel dryness that has always been a major concern in rubber cultivation. This problem is acute when it is about clones of the class to active metabolisms which are very sensitive to tapping panel dryness. In response, this study was proposed to determine the latex harvesting technologies adapted to clones of this class, to the management of the availability of work tappers hand and socio-economic conditions of the Cote d'Ivoire. Treatments S/2 d2 6d/7 nil stimulation; S/2 d3 6d/7 ET2.5% Pa1(1) 4/y; S/2 d4 6d/7 ET2.5% Pa1(1) 4/y; S/2 d4 6d/7 ET2.5% Pa1(1) 8/y; S/2 d5 6d/7 ET2.5% Pa1(1) 8/y; S/2 d6 6d/7 ET2.5% Pa1(1) 10/y were tested in an experimental randomized complete blocks on the clones IRCA 111, IRCA 130 and PB 260. The parameters measured in rubber trees were rubber yield, radial vegetative growth and the tapping panel dryness. Results show that these clones are highly productive. The tapping panel dryness rates are relatively low than usual for the clones to active metabolism. Treatments S/2 d2 6d/7 nil stimulation and S/2 d4 6d/7 ET2.5% Pa1(1) 8/y would not be suitable to harvest latex of clones of this class because they are respectively consumer of bark (exhaustion source for the tree) and increases the rate of tapping panel dryness. Against the ground by S/2 d3 6d/7 ET2.5% Pa1(1) 4/y; S/2 d4 6d/7 ET2.5% Pa1(1) 4/y; S/2 d5 6d/7 ET2.5% Pa1(1) 8/y and S/2 d6 6d/7 ET2.5% Pa1(1) 10/y are best suited to harvest latex of clones of the active metabolism class because they generate large rubber production while maintaining a good vegetative growth with low dry notch rate.

Keywords: Hevea brasiliensis; latex harvesting technology; clones to active metabolism; tapping panel dryness; vegetative growth; Côte d'Ivoire.

1. INTRODUCTION

The latex production of rubber cultivation planting inevitably comes from tapping. It involves an incision (cut) from the bark tissues of the trunk [1-3]. Following the incision, the laticiferous vessels, which are specialized tissues with the specific cells producing rubber (laticiferous) are cut leaving expel (flow) latex [1] of which the natural rubber is extracted [3,4]. However, tapping trees plantation certainly produces rubber, but this production is limited [5]. It cannot be adjusted to the needs of users and especially the tapping can alone enable the recovery of the trees production potential [6]. Today and systematically, there is added to the tapping system, hormonal stimulation of the production of rubber [7-9]. This is to prepare stimulant pastes by diluting stimulant products ready to use or not to obtain concentrations of 2.5 or 5% of active substance (Ethephon) to be applied to the tree view to improve its productivity in rubber [10].

The practice of tapping or tapping system [7,8] and/or policy (strategy) of hormonal stimulation of the production of rubber can be a system or latex harvesting technology more or less intensively for a given clone. But the intensity of the regime (strong, moderate and low) of these two essential components of rubber production related or not, are highly dependent of intracellular metabolism of clone as shown by [6].

Whatever the cellular metabolism (metabolic activity of the clone class), any system or technology of harvesting latex excessive exhaust rubber, weakens and gives it a more or less reversible physiological tiredness leading standby if we are on the tapping panel dryness [11]. This therefore affects productivity and rubber production to more or less long-term. As rubber tree growing is a heavy investment for its amortization requiring management over the long-term, modern management of its production through the use of harvesting system adapted to the clone, including its cellular metabolism.

Clones of the active metabolism class, including IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260 are appreciated for their good agronomic performances and especially their rapid rise in production [12-14]. However, these benefits are quickly relegated to the background because of the very high sensitivity of the majority, if not almost all, clones of this class to the tapping panel dryness and breakage due to wind [11,13,15].

This sensitivity is further exacerbated as the latex harvesting system applied to them is more intensive. For household and continue to get them more rubber in relation to their potential, a half-dozen latex harvesting systems were studied for nine years to determine the best or the bests. This should enable the rubber growers to effectively deal with every situation that will face their plantations. This, especially since the two phenomena are at the base damage and less important productions recorded in rubber plantations. Today this issue and the availability of the work tappers hand always arise acutely in rubber growers. So [13] stated that the recommendation of a clone of *Hevea brasiliensis*, productive species of natural rubber and/or latex harvesting technology planter requires good productivity, sufficient hardiness (e.g. pathogen resistance, adaptability to eco-climatic conditions ...) and adequate economic longevity.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material is composed by clones IRCA18, IRCA 111, IRCA 130, PB 235 and PB 260, described as follows:

- IRCA18, (Institut de Recherche sur le Caoutchouc), developped in Côte d'Ivoire, is a progeny of PB 5/51 × RRIM 605. The latex diagnosis highlights a very active metabolism, easy flow but low sucrose reserves. This clone carries little stimulation. It has a very fast rise in production. It is sensitive to wind, and very sensitive to tapping panel dryness [16]. It is also strongly attacked by *Corynespora cassiicola* causing leaf fall;
- IRCA 111, a fast growing clone that could be tapping between 4.5 years and 5 years after planting. It is bred in Côte d'Ivoire and is a progeny of PB 5/51 x RRIM 605. It grows vigourously during tapping;
- IRCA 130 is from Côte d'Ivoire and is a cross between PB 5/51 × IR 22. More vigorous than the clone GT 1 (Gondang Tappen or GT), it is opening to five years. Rubber production is at the same level as that of clone PB 235 (Prang Besar or PB) for the first three years of exploitation. Its physiological profile is favorable to productivity over the long term although its rubber production input is very fast. The risk of dry trees of this clone is considered low given the favorable physiological profile;
- PB 235 clone is from Malaysia (Prang Besar), and is a cross between PB 5/51 × PB S/78. The virgin bark is smooth, fairly thick and tender. It poses no particular problem in tapping. The renewed bark is sometimes bulging. Clone trees are very vigorous [13,16,17] and, therefore, is working an average of four and a half years. Clone growth is very homogeneous. So a year after opening, 95 % of trees are being tapped. The metabolism of this clone is very active. The sugar levels are still relatively low and protective systems, which involves using very sparingly stimulation;
- The clone PB 260 is bred in Malaysia (*Prang Besar*) and is a progeny of PB 5/51 × PB 49. It is a ''quick starter'', with a very active metabolism. It grows vigourously during tapping. Tapping actives its laticiferous metabolism and it needs few stimulations when reducing the tapping frequency. Its intra-laticiferous sugar content is low when tapped and it couldn't afford to be too much stimulated. It is highly sensitive to tapping panel dryness [3].

2.2 Experimental Design

The trees of those different clones were planted at the density of 510 trees per ha (7 m x 2.8 m) since 1988 in straight lines. RCB (Randomized Complete Block) of 6 treatments and 4 repetitions were used as experimental design with around 100 trees per plot.

The test covers an average area of 4.7 ha. This trial was set up on the Gô research station in south-western Côte d'Ivoire.

The experiments were started in November 1993 at the opening of the trees at 1.20 m above the ground and were completed in October 2001 for the clone IRCA 111; from August 1998 to July 2006 for the clone IRCA 130; from June 1989 to October 1994 for the clone IRCA 18; from June 1990 to April 1995 for the clone PB 235 and from May 1997 to April 2005 for the clone PB 260.

2.3 Treatments

The trees were opened at height of 1.20 m (panel BO-1). The tapping systems imposed and the intensity of tapping are shown in Table 1.

2.4 Tapping

Two tappers were employed with repetitions. A and B assigned to tapper 1, and repetitions C and D to tapper 2. Average consumption of bark (perpendicular to the tapping cut) were:

- d2: 1.0 to 1.3 mm/tapping, 156 tapping per years (156 to 203 mm/y)
- d3: 1.3 to 1.5 mm/tapping, 104 tapping per years (135 to 156 mm/y)
- d4: 1.5 to 1.8 mm/tapping, 78 tapping per years (117 to 140 mm/y)
- d5: 1.7 to 2.0 mm/tapping, 65 tapping per years (110 to 130 mm/y)
- d6: 1.8 to 2.0 mm/tapping, 52 tapping per years (93 to 104 mm/y)

2.5 Stimulation

The trees were stimulated on panel and tapping cut with 1 g per tree of homogenized paste containing Ethephon at 2.5% of active ingredient. The product used was ELS 50 Double Red diluted by an equal amount of water (1 weight of ELS 50 + 1 weight water).

2.6 Measurement of Parameters Studied

2.6.1 Production

Rubber production of each treatment was weighed every 4 weeks using a scale. Samples of fresh rubber were collected for each treatment to determine the coefficient of transformation (CT) which was used to calculate the production of dry rubber expressed in grams per tree per tapping ($g.t^{-1}.t^{-1}$); in grams per tree per year ($g.t^{-1}.y^{-1}$) and in kilograms per hectare per year ($kg.ha^{-1}.y^{-1}$).

2.6.2 Radial vegetative growth

The circumferences of trees were measured annually in November (opening of trees in November 1993) for the clone IRCA 111; August (opening trees in August 1998) for the clone IRCA 130; October (opening trees in October 1994) for the clone IRCA 18; April (opening trees in April 1995) for the clone PB 235 and May (opening of trees in May 1997) for the clone PB 260. The measurements were made at the height of 1.70 m above the ground using a measuring tape.

2.6.3 Rates of tapping panel dryness

The percentage of tapping panel dryness was determined visually. This rate was obtained by taking into account of percentage of dry trees.

Table 1. Treatments applied in tapping downward to clones IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260 during nine years of experimentation in southwestern Cote d'Ivoire

N°	Treatments	TI (%)	Description
1	S/2 d2 6d/7, nil stimulation	100	Half spiral cut tapped at alternate daily frequency, six days in tapping followed by one day rest, not stimulated
2	S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	67	Half spiral cut tapped at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 4 applications per year.
3	S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	50	Half spiral cut tapped at fourth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 4 applications per year.
4	S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	50	Half spiral cut tapped at fourth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 8 applications per year.
5	S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	40	Half spiral cut tapped at fifth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 8 applications per year.
6	S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	33	Half spiral cut tapped at sixth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5% active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 10 applications per year.

TI: Tapping Intensity [18,19]

2.7 Statistical Analysis

An analysis of variance of the data including the rubber yield, vegetative radial growth, latex micro diagnostic and tapping panel dryness was done with the SAS statistical software[16] and the Student-Newman-Keuls test, at P < 0.05.

3. RESULTS

3.1 Rubber Production of Clones to Active or Fast Metabolism IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260

Rubber production per tree and per tapping of clone IRCA 18 varied significantly depending on the latex harvesting system (Table 2). Production to tapping of the tapping frequency (d2) is significantly lower than that of all other tapping frequencies. That of the weekly frequency of tapping (d6) is statistically higher than the production of all other tapping frequencies. The production is even stronger that tapping frequency is reduced comparatively to the control. For a same tapping frequency (d4), the increase in annual stimulations from 4 to 8 results in a relative increase in production (treatment 3: d4-4/y, treatment 4: d4-8/y). On other hand, rubber production of this clone, expressed in $g.t^{-1}.y^{-1}$, varied significantly according to tapping frequency. Overall, this rubber production is lower as the frequency of tapping is reduced comparatively to the control (Table 2). Trees of treatment 1 (d2-nil stimulation) gave a rubber production statistically identical to that of the patterns 2 (d3-4/y), 3 (d4-4/y) and 4 (d4-8/y) and significantly higher than that of the patterns 5 (d5-8/y) and 6 (d6-10/y). In d4, the most stimulated trees (treatment 4, 8/y) have a relatively larger output than the less stimulated (treatment 3, 4/y). The average annual yield of rubber expressed in $kg.ha^{-1}.y^{-1}$ varied significantly depending on the latex harvesting technology. The rubber yield is lower as latex harvesting technology is low intensity relative to the control (treatment 2; Table 2). Treatment 2 (d3-4/y) shows the production statistically the most important, but identical to the treatments 1 (d2-nil stimulation), 3 (d4-4/y) and 4 (d4-8/y) and significantly higher than those of the patterns 5 and 6 (d5 and d6 respectively). The annual stimulations passage from 4 to 8 in d4 causes a relative increase in production (Treatments 3 and 4).

Rubber production per tree and per tapping of clone IRCA 111 is significantly different from one treatment to another (Table 3). Production to tapping of tapping frequency (d2) is significantly lower than that of all other tapping frequencies. That of the weekly frequency of tapping (d6) is statistically greater than the production of all other tapping frequencies. The production is even stronger that tapping frequency is reduced comparatively to the control. For a same frequency of tapping (d4), the increase in annual stimulations, from 4 to 8, entrains a relatively smaller production (Treatment 3: d4-4/y, Treatment 4: d4-8/y). Moreover, rubber productions of clone IRCA 111, expressed in $g.t^{-1}.y^{-1}$, varied significantly according to tapping frequency. These productions of rubber decrease with the reduction of the frequency of tapping (Table 3). Trees of treatment 1 (d2-nil stimulation) gave rubber productions statistically identical to those patterns 2 (d3-4/y) and 3 (d4-4/y) and significantly higher than those of the patterns 4 (d4-8/y), 5 (d5-8/y) and 6 (d6-10/y). In d4, the most stimulated trees (Treatment 4, 8/y) have less important products as less stimulation (Treatment 3, 4/y). The average annual yield of rubber expressed in $kg.ha^{-1}.y^{-1}$ varied significantly depending on the frequency of tapping. Rubber productions decrease with the reduction of the tapping frequency (Table 3). Treatment 2 (d3-4/y) shows the production statistically the most important, but identical to the treatments 1 (d2-*nil stimulation*), 3 (d4-4/y) and 4 (d4-8/y) and significantly higher than those of the patterns 5 and 6 (d5 and d6 respectively). The passage from 4 to 8 annual stimulations in d4 causes a relative lower rubber production (treatments 3 and 4).

The dry rubber productions of clone IRCA 130 expressed in $g.t^{-1}.t^{-1}$ increase with the reduction of tapping frequency (Table 4). Production to tapping of tapping frequency (d2) is significantly lower than that of all other tapping frequencies. That of the weekly frequency of tapping (d6) is statistically higher than the production of all other tapping frequencies. The dry rubber productions generated by the six treatments are significantly different from one, another. For a same frequency of tapping (d4), the increase in stimulation causes relatively less rubber production (Treatment 3: d4-4/y and Treatment 4: d4-8/y). Moreover, rubber productions expressed in $g.t^{-1}.y^{-1}$ varied significantly according to tapping frequency. The productions of rubber decrease with the reduction of the frequency of tapping (Table 4). The production of dry rubber treatment 3 (d4-4/y) was significantly higher than that of treatments 5 (d5-8/y) and 6 (d6-10/y) and statistically identical to those of the patterns 1 (d2-nil stimulation), 2 (d3-4/y) and 4 (d4-8/y). The patterns 5 and 6 have the productions statistically identical between them and to those of treatments 1, 2 and 4.

Increasing the number of stimulations in d4 causes a relative smaller rubber production (Treatments 3 and 4). The average annual yield of rubber of clone IRCA 130, expressed in $kg.ha^{-1}.y^{-1}$, varied significantly depending on the frequency of tapping. The annual yield of rubber treatment 3 (d4-4/y) is significantly higher than those of treatments 1, 2, 4, 5 and 6 (Table 4) that are statistically identical between them. The productions of treatments 1 (d2-*nil stimulation*), 2 (d3-4/y), 4 (d4-8/y), 5 (d5-8/y) and 6 (d6-10/y) are all statistically identical.

The rubber productions per tree and per tapping of clone PB 235 are significantly different according to tapping frequency (Treatment 5). Production of treatment 6 (d6) is statistically higher than those of all other tapping

Table 2. Annual mean of dry rubber production expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ in tapping downward of clone IRCA 18 during nine years in southwestern Côte d'Ivoire

	Dry rubber production		
Treatments	**$g.t^{-1}.t^{-1}$**	**$g.t^{-1}.y^{-1}$**	**$kg.ha^{-1}.y^{-1}$**
S/2 d2 6d/7 nil stimulation	35 ± 8e	5734 ± 850ab	2594 ± 401ab
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	54 ± 12d	5903 ± 737a	2730 ± 337a
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	68 ± 16c	5475 ± 757bc	2629 ± 355ab
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	72 ± 17cb	5735 ± 741ab	2638 ± 314ab
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	80 ± 20b	5316 ± 726c	2433 ± 313c
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	96 ± 28a	4973 ± 826d	2252 ± 342d
Mean	**68 ± 18**	**5394 ± 325**	**2546 ± 174**

a, b, c, d, e : Mean productions followed by same letters in each column are not significantly different (test of student-Newman-Keuls at 5%)

Table 3. Annual mean of dry rubber production expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{1}.y^{-1}$ in tapping downward of clone IRCA 111 during nine years in southwestern Côte d'Ivoire

	Dry rubber production		
Treatments	**$g.t^{-1}.t^{-1}$**	**$g.t^{-1}.y^{-1}$**	**$kg.ha^{-1}.y^{-1}$**
S/2 d2 6d/7 nil stimulation	38 ± 9f	5720 ± 1770a	2142 ± 389ab
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	54 ± 10e	5459 ± 1515ab	2184 ± 1160a
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	72 ± 16c	5403 ± 1511ab	2062 ± 1245ab
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	67 ± 12d	5079 ± 1300bc	2027 ± 1220ab
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	78 ± 15b	4897 ± 1375c	1994 ± 1317b
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	91 ± 17a	4530 ± 1349d	1816 ± 1566c
Mean	**67 ± 19**	**5182 ± 479**	**2038 ± 130**

a, b, c, d, e, f : Mean productions followed by same letters in each column are not significantly different (test of student-Newman-Keuls at 5%)

Table 4. Annual mean of dry rubber production expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ in tapping downward of clone IRCA 130 during nine years in southwestern Côte d'Ivoire

	Dry rubber production		
Treatments	**$g.t^{-1}.t^{-1}$**	**$g.t^{-1}.y^{-1}$**	**$kg.ha^{-1}.y^{-1}$**
S/2 d2 6d/7 nil stimulation	36 ± 7f	4978 ± 1505 ab	2296 ±734b
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	53 ± 13e	5087 ± 1460ab	2357 ±802b
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	74 ± 18c	5407 ± 1630a	2532 ± 866a
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	69 ± 15d	5056 ± 1327ab	2334 ± 683b
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	81 ± 18b	4936 ± 1311b	2280 ± 696b
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	98 ± 19a	4733 ± 1103b	2230 ± 686b
Mean	**69 ± 22**	**5033 ± 222**	**2338 ± 105**

a, b, c, d, e, f : Mean productions followed by same letters in each column are not significantly different (test of student-Newman-Keuls at 5%)

frequencies. The production of treatment 1 (d2) is significantly lower. The most tapped trees of this clone PB 235 have the lowest production of rubber in $g.t^{-1}.t^{-1}$ and vice versa (Table 5). Increasing the stimulation frequency has no significant impact on its production when the tapping is done every 4 days (Treatments 3 and 4). The production of rubber of clone PB 235, in $g.t^{-1}.y^{-1}$, of latex harvesting technologies d2 nil stimulation (Treatment 1), d3-4/y (Treatment 2), d4-4/y (Treatment 3), d4-8/y (Treatment 4) and d5-8/y (Treatment 5) are identical and statistically superior to that of pattern d6-10/y (Treatment 6, Table 5). At the same tapping frequency (d4), increasing the number of annual stimulations of 4/y to 8/y has no impact on production. Just like at the same stimulation regime (8/y, treatments 4 and 5), the reduction of tapping intensity (d4 to d5) does not affect dry rubber production. The average annual yield of rubber expressed in $kg.ha^{-1}.y^{-1}$varied significantly as a function of the frequency of tapping. The least stimulated trees but most tapped, namely those of treatments 1 and 2 (d2 nil stimulation, d3-4/y) are productions statistically equivalent (Table 5). These values are significantly higher than those of treatments 3, 4, 5 and 6 (d4-4/y; d4-8/y; d5-8/y and d6-10/y). The lowest yield was obtained with the treatment d6-10/y whose trees are the least tapped. For the same latex harvesting frequency (d4), the increase of the stimulation frequency from 4 to 8/y does not affect the rubber yield.

The rubber productions per tree and per tapping of clone PB 260 are significantly different according to tapping frequency. The production of treatment 6 (d6) is statistically higher than those of all other tapping frequencies. Production of treatment 1 (d2) is significantly lower. The most tapped trees have the lowest production of rubber in $g.t^{-1}.t^{-1}$ and vice versa (Table 6). Increasing the stimulation frequency has no significant impact on the production of clone PB 260 when the tapping is done every 4 days (Treatments 3 and 4). Production of its dry rubber expressed in $g.t^{-1}.y^{-1}$ of latex harvesting technologies d2 nil stimulation (Treatment 1), d3-4/y (treatment 2), d4-4/y (Treatment 3), d4-8/y (Treatment 4) and d5-8/y (treatment 5) are identical and statistically superior to that of the pattern d6-10/y (Treatment 6, Table 6).

At the same tapping frequency (d4), increasing the number of annual stimulations from 4 to 8/y has no impact on production. As in identical stimulation regime (8/y), the reduction of the tapping intensity (d4 to d5) does not affect dry rubber production. The average annual yield of dry rubber expressed in $kg.ha^{-1}.y^{-1}$ varied significantly depending on the frequency of tapping. The least stimulated trees but most tapped, namely those of treatments 1 and 2 (d2-nil stimulation, d3-4/y) are productions statistically equivalent (Table 6). These values are significantly higher than those of treatments 3, 4, 5 and 6 (d4-4/y; d4-8/y; d5 and d6). The lowest yield of clone PB 260 is obtained with the treatment d6-10/y whose trees are the least tapped. For the same latex harvesting frequency (d4), the increase of the stimulation frequency of 4 to 8/y does not affect its rubber yield.

The average production of dry rubber per tree and per tapping, whatever the clone and the latex harvesting technology, reached 67 g. The average production of dry rubber of clone PB 235 expressed in $g.t^{-1}.t^{-1}$ is 59. It is significantly lower. Then follow those of clones IRCA 18, IRCA111 and IRCA 130 that, whatever the system or the latex harvesting technology applied, are statistically identical, with respective average yields of 67, 68 and 69 $g.t^{-1}.t^{-1}$. Finally, the clone PB 260 with 73 $g.t^{-1}.t^{-1}$ gives a rubber production per tree and per tapping superior to those of all the other clones PB 235, IRCA 18, IRCA 111 and IRCA 130 (cf. Table 6).

Table 5. Annual mean of dry rubber production expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ in tapping downward of clone PB 235 during nine years in southwestern Côte d'Ivoire

	Dry rubber production		
Treatments	**$g.t^{-1}.t^{-1}$**	**$g.t^{-1}.y^{-1}$**	**$kg.ha^{-1}.y^{-1}$**
S/2 d2 6d/7 nil stimulation	32 ± 5e	4781 ± 788a	2061 ± 378a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	47 ± 8d	4785 ± 872a	2029 ± 358a
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	60 ± 10c	4534 ± 733ab	1929 ± 255b
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	60 ± 8c	4541 ± 672ab	1910 ± 299b
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	70 ± 10b	4389 ± 708b	1907 ± 311b
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	84 ± 16a	4075 ± 760c	1756 ± 331c
Mean	**59 ± 17**	**4518 ± 266**	**1931 ± 97**

a, b, c, d, e, f : Mean productions followed by same letters in each column are not significantly different (test of student-Newman-Keuls at 5%)

Table 6. Annual mean of dry rubber production expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ in tapping downward of clone PB 260 during nine years in southwestern Côte d'Ivoire

	Dry rubber production		
Treatments	**$g.t^{-1}.t^{-1}$**	**$g.t^{-1}.y^{-1}$**	**$kg.ha^{-1}.y^{-1}$**
S/2 d2 6d/7 *nil stimulation*	39 ± 8e	5963 ± 1225a	2829 ± 627a
S/2 d3 6d/7 ET2.5% Pa1(1) 4/y	**60** ± **13d**	**6011** ± 1223**a**	**2821** ± 643**a**
S/2 d4 6d/7 ET2.5% Pa1(1) 4/y	79 ± 19c	5959 ± 1496a	2555 ± 711b
S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	80 ± 18c	6039 ± 1365a	2715 ± 684ab
S/2 d5 6d/7 ET2.5% Pa1(1) 8/y	92 ± 24b	5790 ± 1530a	2636 ± 769ab
S/2 d6 6d/7 ET2.5% Pa1(1) 10/y	102 ± 29a	5150 ± 1486b	2310 ± 726c
Mean	**75 ± 23**	**5819 ± 339**	**2644 ± 195**

a, b, c, d, e, f : Mean productions followed by same letters in each column are not significantly different (test of student-Newman-Keuls at 5%)

The average annual yield of dry rubber expressed in $kg.ha^{-1}.y^{-1}$, whatever the clone and the latex harvest technology, is 2299 $kg.ha^{-1}.y^{-1}$. According the five clones in experimentation (IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260), the clone PB 260 is the most productive regardless of the system or the latex harvesting technology adopted (cf. Table 6) with a production average of 2562 $kg.ha^{-1}.y^{-1}$ then, follow the clones IRCA 18, IRCA 130, IRCA 111 and PB 235 with respectively 2506, 2338, 2038 and 1931 $kg.ha^{-1}.y^{-1}$.

3.2 Radial Vegetative Growth of the Clones to Active or Fast Metabolism IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260

3.2.1 Clone IRCA 18

The mean circumference of the trees (immature and mature phases, in cut tapped downward) every latex harvesting technologies combined is 73.5 cm (Table 7). It varies significantly from the latex harvesting technology to another. Latex harvesting technology, one tapped every two (2) days without stimulation of rubber production, presented the greatest circumference (75.90 cm) which is statistically of the same order of magnitude as that of the tapping every six days stimulated 10 times (74.10 cm). The girth of the trees of this treatment (treatment 2) is statistically equivalent to that of all the other latex harvesting technologies. The girth of the trees of the latter is statistically of the same order of magnitude.

3.2.2 Clone IRCA 111

The average circumference of trees clone IRCA 111 (immature and mature phases, in tapping downward) all the latex harvesting technologies combined is 78.4 cm. The trees of treatment 1 (d2-nil stimulation), non-stimulated, have the largest circumference (81.9 cm; Table 7), statistically the same as treatment 3 (d4-4/y; 78.0 cm) and 6 (d6-10/y; 79.0 cm) and superior to those of treatment 2 (d3-4/y), 4 (d4-8/y) and 5 (d5-8/y). Trees of treatments 2 (d3-4/y; 77.6 cm), 4 (d4-8/y; 76.6 cm) and 5 (d5-8/y; 77.5 cm) have the lowest circumferences. These circumferences are however the same order of magnitude as those of the treatments 3 and 6. All the trees stimulated treatments have of circumferences statistically equivalents and lower than non-stimulated trees, treatment 1.

3.2.3 Clone IRCA 130

The mean circumference of the trees (immature and mature phases, in cut tapped downward) every latex harvesting technologies combined is 74.8 cm (Table 7). Trees of treatment 1 (non-stimulated) presented the largest circumference (77.8 cm). This circumference is statistically superior to that of rubber all other latex harvesting technologies. The circumferences of trees of other latex harvesting technologies are statistically equivalents.

The average circumference of trees of clone PB 235 (immature and mature phases, in tapping downward) all latex harvesting technologies combined is 79.7 cm. It varies significantly from the latex harvesting technology to another. Latex harvesting technology, one tapped every two (2) days without stimulation of rubber production has the greatest circumference (82.8 cm) that is statistically similar to that of the tapping all the three days stimulated 4 times (80.3 cm). The circumference of this treatment (treatment 2) is statistically of the same size as that of all the other treatments. The mean values of circumference of trees of these treatments are statistically identical.

3.2.4 Clone PB 260

The average circumference of trees (immature and mature phases, in cut tapped downward) all latex harvesting technologies combined is 72.7 cm. Treatment 1, the trees are not stimulated, has the highest circumference (76.1 cm). The circumferences of the trees of the treatments 2 (d3-4/y; 71.2 cm), 3 (d4-4/y; 72.6 cm), 4 (d4-8/y; 71.8 cm), 5 (d5-8/y; 72.2 cm) and 6 (d6-10/y; 72.3 cm) are statistically equal and smaller than those of non-stimulated trees (Treatment 1; Table 8).

On the whole, the average circumference of tree of clones IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260 (immature and mature phases, in tapping downward) regardless of latex harvesting technology and the clone is 75.8 cm. Latex harvesting technology, tapped every two (2) days non-stimulated with 78.7 cm has the most statistically significant circumference. The circumferences of all other latex harvesting technologies are statistically similar. Relatively to the clones, the clone PB 235 with 79.7 cm presents statistically the circumferences greatest. However, it is statistically identical to that of clone IRCA 111 whose circumference is also significantly superior to that of all the other clones. The clone IRCA 130 with 74.8 cm below the first two, however circumference is statistically similar to that of clone IRCA 18. The clone PB 260 has the lowest circumference although it is statistically equivalent to that of clone IRCA 18.

3.3 Rates of Tapping Panel Dryness in Percentage of Clones to Active or Fast Metabolism IRCA 18, IRCA 111, IRCA 130 PB 235 and PB 260

3.3.1 Clone IRCA 18

The average rate of tapping panel dryness all technologies reached 4.5% (Table 8). This rate is moderate and shows an effect of the latex harvesting technology, including an effect of the latex harvesting intensity. Indeed, the treatment, tapped every two days, non-stimulated, 100% of latex harvesting intensity, has the highest rate (13.7%), when the treatment, tapping all the six days of latex harvesting intensity 33%, with 0.6% gives the lowest rate of tapping panel dryness.

3.3.2 Clone IRCA 111

The average rate of tapping panel dryness all technologies reached 11.8% (Table 8). This rate is higher because it exceeds 10 % and is generally show an effect of the latex harvesting technology, including an effect of the latex harvesting intensity. The trees of pattern 1, tapped the most, present the highest rates of the tapping panel dryness (22.4%) while those of latex harvesting technology 3 gave the lower rate of tapping panel dryness (8.3%). Relatively to the trees tapped at the same frequency d4 (treatments 3 and 4), the rate of trees suffering from this anomaly is higher with increasing number of stimulations, respectively d4-4/y, 8.3% and d4-8 /y, 10.6%. For the same level of stimulation (treatment 2 : d3-4/y and treatment 3 : d4-4/y follows of treatment 4 : d4-8/y and treatment 5 : d5-8/y), the rate of tapping panel dryness is higher among the rubber trees tapped to high frequency (d3-4/y, 11.1% and d4-4/y, 8.3%; d4-8/y, 10.6% and d5-8/y, 8.6%).

3.3.3 Clone IRCA 130

The average rate all technologies combined is 13.8% (Table 8). This rate is higher because it exceeds 10% and shows, except the treatment 2, tapped every 3 days at a rate higher than the first treatment, an effect of latex harvesting technology, in particular an effect latex harvesting intensity. The rate of tapping panel dryness generally increases, in fact, with the intensity of latex harvesting (d6 (TI 33%) 5.5%, d5 (TI 40%) 10.2%, d4 (TI 50 %) 13.0%, d2 (TI 100%) 18.6%). The latex harvesting technology that drives the largest rate of tapping panel dryness of the six treatments is the pattern 1 (d2-nil stimulation) whose trees are the most tapped (2.8 %) while the trees of treatment 6 (d6-12/y) have the lowest rate (1.3%). The increase stimulation in d4 (from 4 to 8/y) results in a rate higher to tapping panel dryness (Treatment 3; 10.1% and Treatment 4; 16.0%). By cons, for the same level of stimulation (Treatment 2 : d3-4/y and Treatment 3 : d4-4/y follows of Treatment 4 : d4-8/y and Treatment 5 : d5-8/y), the rate of tapping panel dryness is higher among the rubber trees tapped to high frequency (d3-4/y, 22.5% and d4-4/y, 10.1%; d4-8/y, 16.0% and d5-8/y, 10.2%).

3.3.4 Clone PB 235

The average rate of tapping panel dryness all technologies is 8.2% (Table 8). This rate is mean because it is lower than 10% and shows a fluctuation depending on the treatment, giving sawtooth evolution. The latex harvesting technology results the largest rate of tapping panel dryness of the six treatments is the

Table 7. Mean values of circumference of tree trunks (cm.y^{-1}) in tapping downward of treatments during nine years in southwestern Côte d'Ivoire

Treatments	Circumference of tree trunks (cm.y^{-1})					
	IRCA 111	**PB 260**	**IRCA 18**	**PB 235**	**IRCA 130**	**Mean**
S/2 d2 6d/7 nil stimulation	81.9 a	76.1 a	75.9 a	82.8 a	77.8 a	**78.66 ± 3,0**
S/2 d3 6d/7 ET2.5%Pa1(1) 4/y (T)	77.6 b	71.2 b	75.9 b	80.3 ab	74.5 b	**74.86 ± 3, 5**
S/2 d4 6d/7 ET2.5%Pa1(1) 4/y	78 ab	72.6 b	72.3 b	79.8 b	75.8 b	**75.08 ± 3,2**
S/2 d4 6d/7 ET2.5%Pa1(1) 8/y	76.6 b	71.8 b	73 b	78.6 b	72.7 b	**74,34 ± 2,8**
S/2 d5 6d/7 ET2.5%Pa1(1) 8/y	77.5 b	72.2 b	72.8 b	77.9 b	74.2 b	**74.32 ± 2.9**
S/2 d6 6d/7 ET2.5%Pa1(1) 10/y	79 ab	72.3 b	74.1 ab	78.5 b	73.7 b	**74.98 ± 3.2**
Mean	**78.43 a**	**72.7c**	**73.5bc**	**79.65a**	**74.78b**	**75.81**

pattern 1 (d2-nil stimulation) whose trees are most tapped (14.2%), while the trees of treatment 5 (d5-10/y) have the lowest rate (5.5%). The increase stimulation in d4 (from 4 to 8/y) has no impact on the rate of tapping panel dryness (Treatment 3; 6.4% and Treatment 4; 7.5%). By cons, for the same level of stimulation (Treatment 4: d4-8/y and Treatment 5: d5-8/y), the rate of tapping panel dryness is higher for rubber tapped to high frequency (d4-8/y, 7.3% and d5-8/y, 5.5%).

3.3.5 Clone PB 260

The average rate of tapping panel dryness all technologies combined is 2.9% (Table 8). This rate is low because it is significantly lower than 5% and showed, except the treatment 6, tapped every six days at a rate higher than the treatment 5, an effect of latex harvesting technology, including an intensity effect of latex harvesting. Overall, the rate of tapping panel dryness increases, in fact, with the intensity of latex harvesting (d5 (TI 40%) 1.1%, d4 (TI 50%) 3.6 %, d3 (TI 67%) 5.4%, d2 (IT 100%) 9.4%). The latex harvesting technology results the largest rate of tapping panel dryness of the six treatments is the pattern 1 (d2-nil stimulation) whose trees are most tapped (9.4%), while the trees of treatment 5 (d5-10/y) have the lowest rate (1.1%). The increase stimulation in d4 (from 4 to 8/y) has no effect on the rate of tapping panel dryness (Treatment 3; 3.6% and Treatment 4; 3.5%). By cons, for the same level of stimulation (Treatment 2: d3-4/y and Treatment 3 : d4-4/y follows of Treatment 4 : d4-8/y and Treatment 5 : d5-8/y), the rate of tapping panel dryness is higher for rubber tapped to high frequency (d3-4/y, 5.4% and d4-4/y, 3.6% ; d4-8/y, 3.5% and d5-8/y, 1.1%).

Table 8. Mean rates of tapping panel dryness (%) of trees of clones IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260, in tapping downward, as a function of treatments during nine years in southwestern Côte d'Ivoire

Treatments	Rates of tapping panel dryness (%)					
	IRCA 111	**PB 260**	**IRCA 18**	**PB 235**	**IRCA 130**	**Mean**
S/2 d2 6d/7 nil stimulation	22.4	9.4	13.7	14.2	18.6	**15.7**
S/2 d3 6d/7 ET2.5 % Pa1(1) 4/y (T)	11.1	5.4	4.5	6.4	22.5	**10.0**
S/2 d4 6d/7 ET2.5 % Pa1(1) 4/y	8.3	3.6	2.2	7.5	10.1	**6.3**
S/2 d4 6d/7 ET2.5 % Pa1(1) 8/y	10.6	3.5	3.8	7.3	16.0	**8.2**
S/2 d5 6d/7 ET2.5 % Pa1(1) 8/y	8.6	1.1	2.3	5.5	10.2	**5.5**
S/2 d6 6d/7 ET2.5 % Pa1(1) 10/y	10.0	2.3	0.6	8.2	5.5	**5.3**
Mean	**11.8**	**4.2**	**4.5**	**8.2**	**13.8**	**8.50±3.96**

On the whole, the average rate of tapping panel dryness of clones IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260 (in downward tapping), regardless the latex harvesting technology and the clone, is 8.50%. This rate is not excessive very average and it seems good to say generally acceptable as clones of this metabolic class are deemed sensitive to the tapping panel dryness. It is generally closely related to the latex harvesting technology, in particular to the tapping intensity and increases with this parameter. The treatment 1 with 100% of tapping intensity expresses the highest rate (15.7%) followed by the second treatment (TI 67%), which presents 9.9%, when treatment 6 (TI 33%) recorded the lowest rate 5.5%. Relatively to the clones, it is apparent that the clones IRCA 111 (11.8%) and IRCA 130 (13.8%) expressed a level of sensitivity to tapping panel dryness higher to other clones. Then, there are in descending order the clones PB 235 (8.2%), IRCA 18 (4.5%) and PB 260 (4.2%).

4. DISCUSSION

Dry rubber production per tree and per tapping increases with the reduction of tapping intensity. This production increase is explained by the extension of time (days) between two consecutive tapping [20]. Indeed, over the period between two consecutive tapping is long, the more production to the tree and per tapping is significant as [12,21] have already shown.

Rubber productions expressed in $g.t^{-1}.y^{-1}$ and in $kg.ha^{-1}.y^{-1}$ decrease with the reduction of the tapping frequency. This result is conform to that of [13] which states that more rubber is tapped more his production increases. The laticigene function of tree is thereby stimulated. Indeed, tapping itself stimulates the production of latex [9,21]. This is the phenomenon of the response to tapping [20].

The trees non-stimulated have the greatest circumference. This indicates that the application of the stimulant on the bark does not promote radial vegetative growth of trees. This application, according [22] is harmful to the bark of the tree. However, the negative effect of the hormonal stimulation of vegetative growth is mitigated by reducing the tapping intensity. Therefore the trees of treatment S/2 d6 6d/7 ET 2.5% Pa1(1) 10/y also have a radial vegetative growth statistically equal to that of non-stimulated rubber trees. The hormonal stimulation is a determining factor in the vegetative growth of trees of clones in this class, as indeed for the same annual number of stimulations regardless tapping frequency, the circumferences of trees remains statistically identical.

The least tapped trees generate the lowest rates of tapping panel dryness. This result shows that the reduction of tapping frequency leads to low expression of the sensitivity to tapping panel dryness. This result illustrates that over a latex harvesting system is productive, it is the cause of increased of rates of tapping panel dryness. Consequently, the least tapped systems are less activated and thus less productive, so it is easy to explain the low impact on sensitivity to tapping panel dryness. The high rate of tapping panel dryness displayed by the most production systems is probably due to an exacerbation of metabolism activation (over-tapping and/or over-stimulation) driving an important runaway productive process giving a consequent production of rubber and leading to the top physiological fatigue behind the rising rates of tapping panel dryness [9,23]. This phenomenon is most pronounced with the clones to active metabolism as they inherently have more energy powering the productive metabolism than the clones of other two metabolisms. This is corroborated by the work of [9,24-35].

The rates of tapping panel dryness are low with the latex harvesting technologies S/2 d5 6d/7 ET2.5% Pa1(1) 8/y and S/2 d6 6d/7 ET2.5 % Pa1(1) 10/y regardless the clone. These technologies are among those best suited to latex harvesting of rubber trees of clones of the class to active metabolism because it generates good rubber production, but drastically reduce the rate of tapping panel dryness.

Overall the results show that regardless of the treatment the production are very good and well above the Ivorian national average is one of the best in the world (≤1800 $kg.ha^{-1}.y^{-1}$). These averages of productions may even reach 2562 $kg.ha^{-1}.y^{-1}$. The clone PB 260 is the most productive of the five (5) clones. It is true that it has the lowest radial vegetative growth but this clone is by far the most powerful of all because in addition to its large rubber production potential, our results indicate it has the lowest rate of tapping panel dryness. The relative poorer of radial vegetative growth is due to the fact that the correlation between production and vegetative growth is still negative [36-38]. This signifies that more rubber is tapped and produces a significant quantity of rubber, under the tree grow. Indeed, the photosynthetic assimilates and energy are allocated to secondary metabolism causing rubber production at primary metabolism feeding vegetative growth, including radial [23,36-38].

The rates of tapping panel dryness are higher among the rubber of clones IRCA 130, IRCA 111 than those of clones IRCA 18 and PB 260. This high sensitivity to tapping panel dryness added relatively to the smaller dry rubber production of clone IRCA 111 makes it less efficient on the agronomical level that the clones IRCA 130 and PB 260.

The latex harvesting technology S/2 d2 nil stimulation certainly give strong stimulation of dry rubber production, however, this system has the drawback of being bark consumer and can be a source of depletion of the tree.

In addition, the clones to active metabolism cannot be operated to the latex harvesting technology S/2 d4 6d/7 ET2.5% Pa1(1) 8/y as it leads to increased sensitivity to tapping panel dryness and causes a depression in the vegetative growth. Consequently, in a context of labor tapper hand of availability, the following latex harvesting technologies can be recommended for use of clones of the class to active metabolism:

- S/2 d3 6d/7 ET2.5% Pa1(1) 4/y in the case of the normal operation of planting.
- S/2 d4 6d/7 ET2.5% Pa1(1) 4/y in the case of shortage of labor tapper 25%.
- S/2 d5 6d/7 ET2.5% Pa1(1) 8/y in the case of a severe shortage of labor tapper 33 %.
- S/2 d6 6d/7 ET2.5% Pa1(1) 10/y in the case of a severe shortage of labor tapper 50%.

5. CONCLUSION

After nine years of experimentation on the clones IRCA 18, IRCA 111, IRCA 130, PB 235 and PB 260 of the class to active metabolism, we accept that these clones are very productive. They are performing in intense tapping frequencies. In parallel with the above, better productions were also obtained with the reduced of tapping frequencies combined with a consequent stimulation regime. Regardless the clone; the annual average production generated per tree per tapping increases with the reduction of the tapping intensity. This promotes the exploitation of clones to active metabolism in tapping frequencies reduced.

In addition, the vegetative growth is greatest with non-stimulated trees and this regardless of the clone. The consequence of this observation is that it is more appropriate to use a low stimulation system regarding the clones in this class.

The rates of tapping panel dryness are relatively low than usual for the clones of that class. The highest rates of tapping panel dryness were observed with the non-stimulated trees and tapped at the highest frequency (d2 6d/7) and those operated in the pattern S/2 d4 6d/7 ET2.5 % Pa1(1) 8/y. Both latex harvesting technologies are strongly discouraged for the exploitation of clones of the class to active metabolism. For the reasons against, the treatments S/2 d3 6d/7 % ET2.5 Pa1(1) 4/y; S/2 d4 6d/7% ET2.5 Pa1(1) 4/y; S/2 d5 6d/7 % ET2.5 Pa1(1) 8/y and S/2 d6 6d/7% ET2.5 Pa1(1) 10/y are best suited to harvest the latex of these clones. The last two treatments of low tapping intensity, allowing an economy in tapping manpowers respective from 40 to 50%, strongly contribute to the efficient management of the availability tappers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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