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Latex harvesting technologies adapted to clones PB 217 and PR 107 of *Hevea brasiliensis* Muell. Arg. of the slow metabolism class and to the socio-economic context of Côte d'Ivoire

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Abstract

The modern management of rubber cultivation requires latex harvesting technologies which meet both high productivity and availability of tappers. To cope with that, a study was conducted for nine years in southwestern Côte d'Ivoire with clones of *Hevea brasiliensis* PB 217 and PR 107. Six latex harvesting technologies, S/2 d2 6d/7 nil stimulation ; S/2 d3 6d/7 ET2.5% Pa1(1) 8/y ; S/2 d4 6d/7 ET2.5% Pa1(1) 8/y ; S/2 d4 6d/7 ET2.5% Pa1(1) 12/y ; S/2 d5 6d/7 ET2.5% Pa1(1) 15/y ; S/2 d6 6d/7 ET2.5% Pa1(1) 18/y. During experimentation, the radial growth of trees was very good and yield per tree per tapping ($g.t^{-1}.t^{-1}$) increases with the reduction of tapping frequency. For the same tapping frequency, the increase in the number of annual stimulation leads to a gain in dry rubber yield per tree, per year and per hectare. Sensitivity to tapping panel dryness is low whatever the clone and the pattern. Technologies with high intensities of latex harvesting value better the rubber yield potentials of clones PB 217 and PR 107. They are more efficient when they are tapped once every three days, six working days over seven and stimulated eight times per year (S/2 d3 6d/7 ET2.5% Pa1(1) 8/y). These results confirm the belonging of PB 217 and PR 107 to the class of clones which have a slow metabolism. However, in a context of scarcity of tapping labour, two patterns can be selected: S/2 d4 6d/7 ET2.5% Pa1(1) 12/y and S/2 d5 6d/7 ET2.5% Pa1(1) 15/y.

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Introduction

Hevea brasiliensis, Muell.-Arg is a plant valued for its high rubber performance which is actually one of the main sources of yield of natural rubber (Compagnon, 1986). However, one of the major difficulties arising in its exploitation is to define for each metabolic class the technology (ies) of latex harvesting that would give best yields without compromising the vegetative growth, the physiological and health condition of the plant because some latex harvesting technologies once valued for their performance may in the long run be harmful to the plant growth.

Previous studies certainly have shown that the improvement of rubber yield from the rubber tree went through an intensification of latex harvesting, which consists either in increasing the tapping frequency or to raise the level of stimulation (Obouayeba *et al.,* 1996a; Obouayeba *et al.,* 1996 b Jacob *et al.,* 1988). Obouayeba and Boa (1993) However, more recent works on clones of the slow metabolism class, especially clones PB 217 (Soumahin *et al.,* 2009) and PR 107 (Soumahin *et al.,* 2010) have shown that the reduction of the tapping frequency is a better alternative to traditional tapping systems in a context of shortage of tapping labour. Reductions in the intensity of tapping have the advantage of generating a better rubber yield while favouring a good vegetative growth and a low rate of tapping panel dryness (Soumahin *et al.,* 2010). In a context of expensiveness or scarcity of tapping labour, the tendency is to reduce the tapping frequency (Soumahin, 2010; Vijayakumar *et al.,* 2003, Rajagopal *et al.,* 2003) because it helps to solve the problem of availability of tappers. In such a situation, the choice of a latex harvesting technology remains an important issue.

This study focused particularly on the clones of the slow metabolism class. It aims at determining one or some latex harvesting technology (ies) adapted to clones PB 217 and PR 107 which have a slow metabolism, popularized in Côte d'Ivoire.

Material and methods

Plant material

The plant material consists of clones PR 107 (Rubber Proefstation voor 107) and PB 217 (Prang Besar 217) which have a slow metabolism.

The first plantation of clone PR 107 was established in Côte d'Ivoire in 1959. During the first five year of tapping, PR 107 is less vigorous and more productive than the clone GT 1 but very productive after 6-10 years of tapping (Chapuset, 2001). It is appreciated for its resistance to breakage due to wind, its high productivity, for its low sensitivity to tapping panel dryness (Chapuset, 2001) and its good response to hormonal stimulation (Soumahin, 2010, Obouayeba *et al.,* 2005, 2000, Gohet, 1996, Compagnon, 1986).

Clone PB 217 was planted for the first time in Côte d'Ivoire in 1972. This clone has a growth identical to that of clone GT 1 (Soumahin, 2010, Obouayeba, 2005, Obouayeba *et al.,* 2000). PB 217 is a vigorous clone but susceptible to leaf disease that is caused by *Colletotrichum gloeosporioides*. The flow of its latex is difficult. Its latex is rich in thiol contents and has significant carbohydrate reserves, which predispose clone PB 217 to a good response to hormonal stimulation.

Methods

Study site

The study site is located in southwestern Côte d'Ivoire, coordinates 4°45' N, 6° 38' W. This area is covered by rainforest. The soils are ferralitic, highly desatured and characterized by an abundance of exchangeable bases. In this region, soils are sandy clay (texture) with gravely layers (Brou, 2005, Perraud, 1971, Roose and Cherroux, 1966). The annual average rainfall is 1800-2000 mm with mean annual temperatures ranging between 28.5 and 29 °C (Eldin, 1971).

Experimental design

The experimental design is a randomized complete block. Each elementary plot consists of 100 trees. The test covers an average area of 4.7 ha. This trial was set up on the research station of Gô in southwestern Côte d'Ivoire. The experiments began in May 1996 at the opening of the trees at 1.20 m above the ground and were completed in April 2004 for clone PB 217 and from May 1999 to April 2007 for the clone PR 107. The selected trees showed average circumferences from 49.5 to 50 cm for clone PB 217 and from 50 to 51 cm for clone PR 107. Treatments recorded in Table 1 were applied.

Latex harvesting technologies

Tapping system

The tapping system adopted for all the six treatments was half spiral cut tapped downward. The tapping frequencies performed (Table 1) were alternate daily frequency (S/2 d2); third daily frequency (S/2 d3); fourth daily frequency (S/2 d4); fifth daily frequency (S/2 d5) and sixth daily frequency (S/2 d6). Sunday is a day of rest.

Stimulation

All selected trees were stimulated on tapping panel with Ethephon. 1 g of stimulant applied on 1 cm band. The stimulant was obtained by mixing Ethrel with palm oil. The Ethrel contains 2.5 % active ingredient which is chloro-2-ethyl phosphonic or Ethephon (ET2.5 % Pa1(1)).

Frequencies of stimulation used as treatments were zero stimulation per year (0/y); 8 stimulations per year (8/y); 12 stimulations per year (12/y); 15 stimulations per year (15/y) and 18 stimulations per year (18/y).

Measurements of parameters realised

Production

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

Radial vegetative growth

Trees circumferences were measured in May of each year for the clone PB 217 and in June for the clone PR 107. The measurements were made at the height of 1.70 m above the ground using a measuring tape.

Tapping panel dryness

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

Measurement of biochemical parameters

Theses parameters concerned dry rubber content (DRC), inorganic phosphorus (Pi), Sucrose (SUC) and reduced thiols groupings (RSH). Dry rubber content was determined from 1 ml of fresh latex collected per treatment. This volume was weighed before and after spending 24 hours in an oven at 80 °C.

The contents of sucrose, inorganic phosphorus and reduced thiol groupings were measured on the clear serum called TCA-serum (Trichloroacetic acid that is obtained after latex acid coagulation) respectively by the Ashwell anthrone method (1957), the Taussky and Shorr molybdate ammonium method (1953) and the Boyne and Ellman dinitro2-2'-dithio5-5'-dibenzoic acid (DTNB) method (1972).

The results were expressed in millimoles (mM).

Statistical analysis

The analysis of variance of dry rubber production and the circumferences of tree were performed with the software XLSTAT-Pro 6.1.9. The test of Student-Newman-Keuls and Scheffe were used to distinguish groups at 5 %.

Results

Annual average dry rubber yield in $g.t^{-1}.t.^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ of clone PB 217

Dry rubber yield in $g.t^{-1}.t.^{-1}$

The dry rubber yield per tree and per tapping oscillated between 28 and 75 g. (Table 2). All the average yields of dry rubber in $g.t^{-1}.t.^{-1}$ were significantly different regardless of the latex harvesting technology. The yield increased with the reduction of the intensity of latex harvesting. It was noted that the more the tapping frequency was low, the higher the yield was. The trees tapped in d6 6d/7 and stimulated 18 times per year (18/y) treatment 6 had a yield in $g.t^{-1}.t.^{-1}$ significantly higher than the other treatments. The lowest yields per tapping were obtained with non-stimulated trees (S/2 d2 6d/7 nil stimulation). Under the same tapping frequency, the increase in the intensity of stimulation causes a significant gain in yield.

Dry rubber yield in $g.t^{-1}.y^{-1}$

The average annual yields of dry rubber in $g.t^{-1}.y^{-1}$ vary from 3911 to 4832 (Table 2). The annual yield per tree ($g.t^{-1}.y^{-1}$) of dry rubber was significantly higher in trees exploited according to the pattern S/2 d4 6d/7 ET2.5 % Pa1(1) 12/y than in other treatments. This value was statistically equivalent to that of the trees of the control (pattern 2). The lowest yields were recorded with the trees of treatment 6. Under the same tapping frequency (patterns 3 and 4), the increase in the number of annual stimulations caused a significant increase in dry rubber yield. For the same stimulation regime (treatments 2 and 3), the intensification of latex harvesting caused a gain in rubber yield.

Dry rubber yield in $kg.ha^{-1}.y^{-1}$

Dry rubber yields varied from 1615 to 2129 $kg.ha^{-1}.y^{-1}$ (Table 2).

The yield per hectare ($kg.ha^{-1}.y^{-1}$) of treatment S/2 d3 6d/7 ET2.5% Pa1(1) 8/y was statistically higher than those of the other patterns but remained statistically equal to that of the trees which latex harvesting technology was S/2 d4 6d/7ET2.5% Pa1(1) 12/y. The lowest yield was obtained with less tapped trees (pattern 6). Dry rubber yield increased with the intensity of latex harvesting if it was associated with a substantial stimulation regime.

Table 1. Treatments applied on clones PB 217 and PR 107 during 9 years of experimentation in southwestern Côte d'Ivoire.

N°	Treatments	TI (%)	Description
1	**S/2 d2 6d/7, *nil stimulation***	100	Half spiral cut tapped at alternate daily frequency ,six day in tapping followed by one day rest, not stimulated
2	**S/2 d3 6d/7 ET2.5% Pa1(1) 8/y**	67	Half spiral cut tapped at third 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, 8 applications per year.
3	**S/2 d4 6d/7 ET2.5% Pa1(1) 8/y**	50	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, 8 applications per year.
4	**S/2 d4 6d/7 ET2.5% Pa1(1) 12/y**	50	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, 12 applications per year.
5	**S/2 d5 6d/7 ET2.5% Pa1(1) 15/y**	40	Half spiral cut tapped at fifth 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, 15 applications per year.
6	**S/2 d6 6d/7 ET2.5% Pa1(1) 18/y**	33	Half spiral cut tapped at sixth 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.

TI: Tapping Intensity

Table 2. Annual mean dry rubber yield of clone PB 217 of *Hevea brasiliensis* expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ during nine years in southwestern Côte d'Ivoire

Dry rubber yield				
Treatments	TI (%)	$g.t^{-1}.t^{-1}$	$g.t^{-1}.y^{-1}$	$kg.ha^{-1}.y^{-1}$
1. S/2 d2 6d/7, *nil stimulation*	100	28 f	4386 bc	1864 c
2. S/2 d3 6d/7 ET2.5% Pa1(1) 8/y (T)	67	46 e	4697 ab	2129 a
3. S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	50	55 d	4106 cd	1896 bc
4. S/2 d4 6d/7 ET2.5% Pa1(1) 12/y	50	62 c	4832 a	2044 ab
5. S/2 d5 6d/7 ET2.5% Pa1(1) 15/y	40	69 b	4377 bc	1899 bc
6. S/2 d6 6d/7 ET2.5% Pa1(1) 18/y	33	75 a	3911 d	1615 d
Mean		56	4385	1908

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

TI: Tapping Intensity

Table 3. Annual mean dry rubber yield of clone PR 107of *Hevea brasiliensis* expressed in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ during nine years in southwestern Côte d'Ivoire

Dry rubber yield				
Treatments	TI (%)	$g.t^{-1}.t^{-1}$	$g.t^{-1}.y^{-1}$	$kg.ha^{-1}.y^{-1}$
1. S/2 d2 6d/7, *nil stimulation*	100	18 e	2784 d	1233 d
2. S/2 d3 6d/7 ET2.5% Pa1(1) 8/y (T)	67	46 d	4589 a	2083 a
3. S/2 d4 6d/7 ET2.5% Pa1(1) 8/y	50	50 c	3818 bc	1636 bc
4. S/2 d4 6d/7 ET2.5% Pa1(1) 12/y	50	54 c	4085 b	1792 b
5. S/2 d5 6d/7 ET2.5% Pa1(1) 15/y	40	62 b	3895 bc	1650 bc
6. S/2 d6 6d/7 ET2.5% Pa1(1) 18/y	33	72 a	3632 c	1594 c
Mean		51	3801	1665

TI: Tapping Intensity

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

Average annual dry rubber yield in $g.t^{-1}.t^{-1}$, $g.t^{-1}.y^{-1}$ and in $kg.ha^{-1}.y^{-1}$ of clone PR 107

Dry rubber yield in $g.t^{-1}.t^{-1}$

The dry rubber yield per tree and per tapping varied from 18 to 72 g (Table 3). The yield of trees less frequently tapped (treatment 6) was significantly higher than that of the other treatments. The yield increases with the reduction of tapping frequency. It appeared that the more the tapping frequency was low the higher the yield was. Under the same tapping frequency (d4 6d/7) the increase in the frequency of stimulation did not cause a significant gain in yield.

Dry rubber yield in $g.t^{-1}.y^{-1}$

The average annual yields of dry rubber range between 2000 and 4000 $g.t^{-1}.y^{-1}$ (Table 3) with an overall average of 3801 $g.t^{-1}.y^{-1}$.

The control showed the highest yield. We noted a decrease in yield with the reduction of the tapping frequency. There was no significant difference between the yields of trees tapped every 4, 5 and 6 days. Under the same tapping frequency (d4), the increase in the number of stimulations did not cause significant gain in yield.

Table 4. Evolution of latex biochemical parameters of clone PB 217 of *Hevea brasiliensis* under different latex harvesting technologies during nine years of downward tapping in southwestern Côte d'Ivoire.

	Biochemical parameters							
	DRC (%)		SUC (mM)		Pi (mM)		RSH (mM)	
Treatments	Begin	End	Begin	End	Begin	End	Begin	End
1. d2 - 0/y	45.2 c	43.7 d	21.2 a	29 a	21.6 a	26.0 a	0.80 a	0.85 a
2. d3 - 8/y	48.4 bc	50.5 c	14.4 b	16.5 bc	24.3 a	26.1 a	0.65 b	0.66 b
3. d4 - 8/y	50.7 ab	55.0 ab	13.2 b	14.2bcd	21.8 a	22.9 a	0.63 b	0.54 b
4. d4 - 12/y	51.4 ab	54.2 b	13.1 b	17.3 b	22.2 a	27.9 a	0.61 b	0.55 b
5. d5 - 15/y	52.2 ab	54.2 b	9.9 b	11.7 cd	22.0 a	20.8 a	0.62 b	0.55 b
6. d6 - 18/y	53.7 a	56.4 a	11.2 b	9.4 d	21.1 a	26.2 a	0.60 b	0.53 b
Mean	50.26	52.33	13.83	16.35	22.61	24.98	0.65	0.66

*Treatments are fully described in table 1.

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

Table 5. Evolution of latex biochemical parameters of clone PR 107 of *Hevea brasiliensis* under different latex harvesting technologies during nine years of downward tapping in southwestern Côte d'Ivoire

Biochemical parameters								
	DRC (%)		SUC (mM)		Pi (mM)		RSH (mM)	
Treatments	Begin	End	Begin	End	Begin	End	Begin	End
1. d2 - 0/y	49.0 a	52.2 b	14.2 a	8.8 a	27.1 a	21.4 c	0.78 a	0.65 a
2. d3 - 8/y	48.3 a	53.3 ab	9.8 a	8.3 a	26.0 a	25.1abc	0.74 a	0.64 a
3. d4 - 8/y	50.4 a	54.4 a	14.8 a	7.2 ab	25.0 a	22.3 bc	0.70 a	0.68 a
4. d4 - 12/y	50.6 a	55.0 a	12.5 a	7.2 ab	23.9 a	23.6abc	0.69 a	0.60 a
5. d5 - 15/y	51.5 a	55.1 a	11.4 a	6.8 ab	23.0 a	27.3 a	0.68 a	0.65 a
6. d6 - 18/y	50.6 a	54.6 a	9.6 a	5.4 b	22.6 a	25.8 ab	0.67 a	0.71 a
Mean	50.06	54.1	12.05	6.95	24.6	24.25	0.71	0.65

*Treatments are fully described in table 1.

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

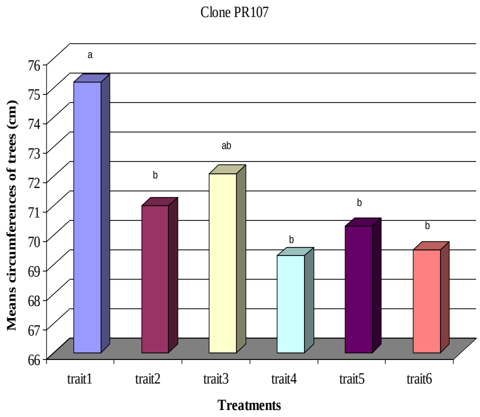

Fig.1. Means circumferences (cm) of trees of clone PR 107 during nine years of experimentation in southwestern Côte d'Ivoire.

Trait 1: S/2 d2, *nil stimulation*

Trait 2: S/2 d3 6d/7 ET2.5% Pa1(1) 8/y

Trait 3: S/2 d4 6d/7 ET2.5% Pa1(1) 8/y

Trait 4: S/2 d4 6d/7 ET2.5% Pa1(1) 12/y

Trait 5: S/2 d5 6d/7 ET2.5% Pa1(1) 15/y

Trait 6: S/2 d6 6d/7 ET2.5% Pa1(1) 18/y

Trait: Treatment

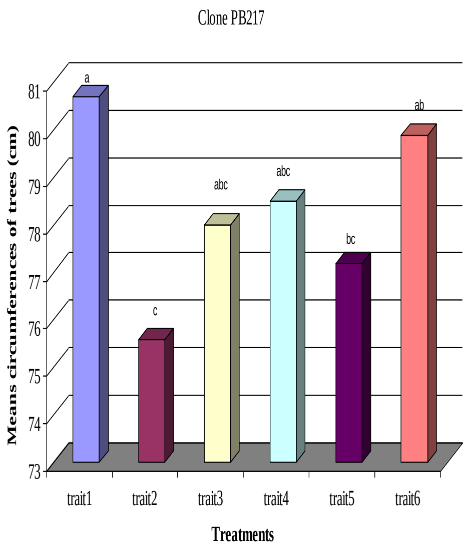

Fig. 2. Means circumferences (cm) of trees of clone PB 217 during nine years of experimentation in southwestern Côte d'Ivoire.

a, b, c : Means followed by same letters are not significantly different (test of Scheffe at 5%).

Trait1: S/2 d2, *nil stimulation*

Trait2: S/2 d3 6d/7 ET2.5% Pa1(1) 8/y

Trait3: S/2 d4 6d/7 ET2.5% Pa1(1) 8/y

Trait4: S/2 d4 6d/7 ET2.5% Pa1(1) 12/y

Trait5: S/2 d5 6d/7 ET2.5% Pa1(1) 15/y

Trait6: S/2 d6 6d/7 ET2.5% Pa1(1) 18/y

Trait: Treatment

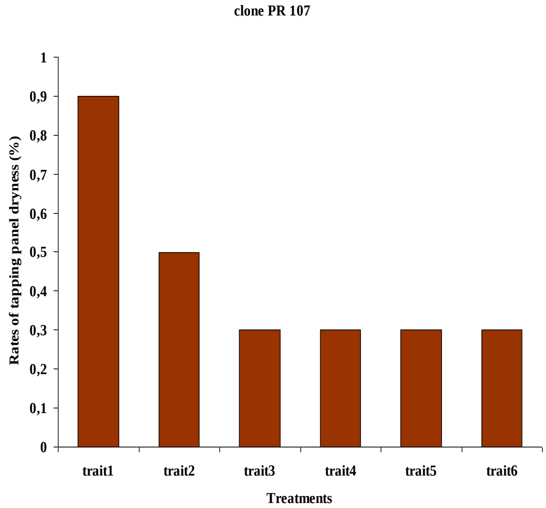

Fig.3. Rates of tapping panel dryness of trees of clone PR 107 of *Hevea brasiliensis* during nine years of experimentation in southwestern Côte d'Ivoire.

	TI (percentage)
Trait1:S/2d2,*nilstimulation*	100
Trait2:S/2d3 6d/7 ET2.5% Pa1(1) 8/y	67
Trait3:S/2d4 6d/7 ET2.5% Pa1(1) 8/y	50
Trait4:S/2d4 6d/7 ET2.5% Pa1(1) 12/y	50
Trait5:S/2d5 6d/7 ET2.5% Pa1(1) 15/y	40
Trait6:S/2d6 6d/7 ET2.5% Pa1(1) 18/y	33

TI:Tappingintensity

Dry rubber yield in kg.ha^{-1}.y^{-1}

The yields varied from 1233 to 2083 kg.ha^{-1}.y^{-1} (Table 3).

The dry rubber yield in kg.ha^{-1}.y^{-1} of trees tapped at the d3 frequency was significantly higher than that of trees of the treatments tapped at frequencies d2, d4, d5 and d6.

Treatment 3 (d4 6d/7-8/y) had a yield statistically identical to that of pattern 5 (d5 6d/7-15/y). The trees of treatment 1 (d2-nil stimulation) gave the lowest yield unlike those of clone PB 217 where the lowest yield was obtained with the less tapped trees of treatment 6. In the treatments under a stimulated regime, we noted a non significant decrease in the rubber yield with the reduction of the tapping frequency notably in d4, d5 and d6. Under an equivalent stimulation regime, the yield increased with the intensity of latex harvesting.

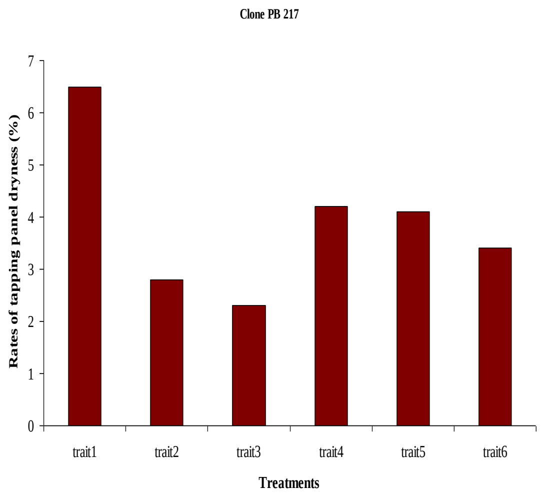

Fig. 4. Rates of tapping panel dryness of trees of clone PB 217 of *Hevea brasiliensis* during nine years of experimentation in southwestern Côte d'Ivoire

	TI (percentage)
Trait1:S/2d2,*nilstimulation*	100
Trait2:S/ d3 6d/7 ET2.5% Pa1(1) 8/y	67
Trait3:S/2d4 6d/7 ET2.5% Pa1(1) 8/y	50
Trait4:S/2d4 6d/7 ET2.5% Pa1(1) 12/y	50
Trait5:S/2d5 6d/7 ET2.5% Pa1(1) 15/y	40
Trait6:S/2d6 6d/7 ET2.5% Pa1(1) 18/y	33

TI : Tapping Intensity

Radial vegetative growth of trees in (cm) in nine years of experimentation

Clone PR 107

The girths varied a little, that is, from 69 to 75 cm (Fig. 1). All the stimulated trees had statistically the same girths, whatever the pattern. The non-stimulated rubber trees showed the most important girths. These values were statistically equivalent to those of trees harvested according the latex harvesting technology S/2 d4 6d/7 ET2.5% Pa1(1) 8/y.

Under the same tapping frequency (d4), the increase of the level of stimulation caused a reduction in the vegetative growth.

Clone PB 217

The girths of trees, all treatments combined, oscillated between 75 and 81 cm (Fig. 2). The radial growth of non-stimulated trees (treatment 1) was statistically equal to that of the trees of patterns 3 (d4-8/y); 4 (d4-12/y) and 6 (d6-18/y). The rubber trees tapped at the same frequency (treatments 3 (d4-8/y) and 4 (d4-12/y)) had statistically the same girth. The trees tapped at the frequency d3 (treatment 2) showed the lowest girths but they were statistically identical to those of the trees of treatments 3, 4 and 5. The radial vegetative growth of clone PB 217 was more sensitive to an increase in the intensity of latex harvesting than an increase in the stimulation regime.

Sensitivity to tapping panel dryness (%)

Clone PR 107

The results indicated that the rates of tapping panel dryness were extremely low (less than 1%) regardless of the treatment (Fig. 3). The most frequently tapped trees (d2 and d3) showed the highest rates of tapping panel dryness (treatments 1 and 2). For the trees subject to latex harvesting technologies 3 (d4-8/y) and 4 (d4-12/y), the increase in the number of stimulations had no effect on the sensitivity to tapping panel dryness.

The sensitivity to tapping panel dryness increased with the intensity of latex harvesting.

Clone PB 217

The rates of tapping panel dryness were relatively low (less than 10%) regardless of the treatment (Fig. 4). The trees tapped at the frequency d2 and non stimulated (treatment.1) generated the highest rate of tapping panel dryness with 6.5%, while those of treatment 3 (d4-8/y) showed the lowest rate (2.3 %). The rubber trees exploited used according to patterns 4 (d4-12/y) and 5 (d5-15/y) had identical rates of tapping panel dryness even if they are different through the system of latex harvesting.

Under the same level of stimulation, the sensitivity to tapping panel dryness of clone PB 217 increased with the intensity of latex harvesting. While under the same tapping frequency, we noted that the sensitivity to tapping panel dryness increased with the intensity of hormonal stimulation.

Biochemical characteristics of the latex of clones PB 217 and PR 107

Clone PB 217

The results of the latex micro diagnosis (LMD) carried out on clone PB 217 and presented in Table 4 indicate a satisfactory dry rubber content (> 35 mM, reference value) for all the treatments. These results show a general increase in the dry rubber content of the latex at the end of the experimentation for all the treatments except the one of treatment 1 where a decrease of the percentage of dry matter was observed. The highest rates of dry rubber content were obtained with low tapping frequency harvesting technologies (treatments 4, 5 and 6) while the trees tapped more frequently (treatments 1 and 2) showed the lowest rate of dry rubber content.

The sucrose content (Table 4) increased after the experimentation for all the treatments except the one of pattern 6, which has decreased. The sucrose content of the most frequently tapped trees (treatment 1) was statistically the most important. The sucrose content of patterns 2, 3 and 4 statistically identical were superior to that of pattern 6. The lowest content was obtained with the less frequently tapped and most stimulated trees (treatment 6) which content was statistically the same importance as that of treatment 5.

The results (Table 4) show an increase in the inorganic phosphorus content (Pi) of the latex of the trees of patterns 1, 2, 3, 4 and 6 at the end of the experimentation. However, a decrease in the Pi content of the latex was observed with treatment 5.
After this period, the inorganic phosphorus contents were similar regardless of the treatment.

At the end of the experimental period, the concentration in thiol groups (Table 4) increased with the most frequently tapped trees (patterns 1 and 2) while with the less frequently tapped trees (treatments 3, 4, 4, 5 and 6) the same content decreased. The trees of pattern 1 gave a thiol group content, which was significantly higher than the RSH contents of the latex of the trees of treatments 2, 3, 4, 5 and 6.

Clone PR 107

Table 5, which shows the biochemical parameters, indicates that the dry rubber content increased at the end of the experimental period and regardless of the treatment. However, there was no significant difference between the dry rubber content of the latex of the most frequently tapped trees, treatments 1 and 2. These contents remained statistically superior to those of the latex of the less frequently tapped trees, patterns 3, 4, 5 and 6. For these less tapped trees (patterns 3, 4, 5 and 5), the dry rubber contents were significantly equivalent.

Regarding the sucrose content (Table 5) of the latex, it has decreased for all the treatments at the end of the experimentation. We noted, however, sucrose contents of the latex statistically of the same importance for the most frequently tapped trees according to the latex harvesting technologies S/2 d2, nil stimulation and S/2 d3 6d/7 ET2.5% Pa1(1) 8/y. These contents were also significantly superior to that of the latex of the less tapped and most stimulated trees of pattern 6. However, the sucrose contents of the latex of the trees of treatments 1, 2, 3, 4 and 5 were statistically equivalent. The trees of patterns 3, 4, 5 and 6 tapped at reduced frequencies had sucrose contents statistically identical.

The inorganic phosphorus content (Table 5) has undergone a slight decrease at the end of the experimentation for all treatments, except that of the trees of patterns 5 and 6 which concentrations have undergone an increase. The lowest Pi content was observed in the latex of the trees of treatment 1. This concentration was statistically identical to that of the trees of patterns 2, 3 and 4. The highest content was obtained from the latex of the trees under the latex harvesting technology S/2 d5 6d/7 ET2.5% Pa1(1) 15/y and this concentration was statistically the same as that of patterns 2; 4 and 6.

The thiol group contents (Table 5) of the latex for all the treatments at the end of the experimental period underwent a slight reduction except for treatment 6. There was, however, no significant difference between the RSH contents of the latex of the different treatments.

Discussion

Annual average yield of dry rubber

The annual average yield of dry rubber of clones PB 217 and PR 107 reached 1791 $kg.ha^{-1}.y^{-1}$ and ranged from 1561 to 2107 $kg.ha^{-1}.y^{-1}$. These results indicate that these clones are productive and interesting as they are superior to the national yield (1700 $kg.ha^{-1}.y^{-1}$) which is one of the best in the world.

The yield per tree and per tapping ($g.t^{-1}.t^{-1}$) increased with the reduction of the tapping frequency. The lower the tapping frequency is, the more important is the yield. This means that the longer the time between two consecutive tappings is, the greater the amount of rubber collected will be. This result indicated by several authors (Soumahin, 2010, Obouayeba *et al.,* 1996, Obouayeba and Boa, 1993; Bouychou, 1962) results from the fact that the practice of tapping makes the tree regenerate the latex harvested. The importance of the energy expended to regenerate that latex is much greater especially as the volume to be regenerated is high and *vice versa*.

The annual average dry rubber yield in $g.t^{-1}.y^{-1}$ and $kg.ha^{-1}.y^{-1}$ of the trees not stimulated and tapped at the highest frequency (d2) as well as that of the rubber trees tapped at the lowest intensity (d6) and stimulated at the highest frequency (18/y) were statistically identical. This result indicates that the losses caused by the reduction of the intensity of tapping are offset by an increase in the number of annual stimulations (Soumahin, 2010, Vijayakumar *et al.,* 2003, Said *et al.,* 1998, Hashim, 1988). However, when the trees are tapped at the same frequency, the increase in the number of annual stimulations leads to a gain in dry rubber yield per tree and per hectare. Our results on rubber yield show that the clones of the slow metabolism class support more an increase in the number of annual stimulations (Obouayeba *et al.,* 2009; Obouayeba *et al.,* 1996) and are efficient in latex harvesting strong technologies. These characteristics concerning the rubber yield showed by these two clones come from their metabolic functioning mode. Indeed, these clones have inherently low metabolic energy (Gohet, 1996) which does not enable to activate sufficiently the metabolism of rubber production. To improve significantly the production there must be exogenous energy (Gohet, 1996, Lacrotte, 1991) which is provided by stimulating products. This situation is indeed illustrated by significantly greater yields of rubber with all the stimulated patterns compared to the non stimulated treatment. However, these results show that the clones of the slow metabolism class are more efficient only when they are tapped at a high or moderate frequency added to a strong stimulation.

The non stimulated trees although tapped at the highest frequency (d2 6d/7) showed the largest girths. However, their dry rubber yield remained the lowest. We had better understand this situation especially as during the period of immaturity in the rubber tree (juvenile tree); the energy is almost assigned to the production of primary biomass that is to say the vegetative growth (Obouayeba, 2005, Gohet *et al.,* 1996, Wycherley, 1976). It is during the tapping implementation that a competition between the primary metabolism and the secondary metabolism appears for the photosynthetic assimilates and energy (Gohet, 1996, Obouayeba and Boa, 1993; Wycherley, 1976, Templeton, 1969). It appears from previous studies (Webster and Paardekooper, 1989) that 2.25 to obtain the same mass in secondary rubber biomass must multiply the energy required to produce a given amount of primary biomass. This explains partly why the competition for assimilates is unfavourable for vegetative growth. The highest annual average dry rubber yield were obtained with three latex harvesting technologies which are respectively in order of size S/2 d3 6d/7ET2.5% Pa1(1) 8/y; S/2 d4 6d/7ET2.5% Pa1(1) 12/y and S/2 d5 6d/7ET2.5% Pa1(1) 15/y.

Radial vegetative growth of the trees

All the stimulated trees had vegetative radial growth significantly equivalent regardless of the treatment and the clone. These girths, however, remained statistically inferior to those of non stimulated rubber trees. This means that the stimulated trees are more rubber productive than the non stimulated ones (confirmed by our results relating to the yield); as the correlation growth-yield is always negative (Obouayeba, 2005, Gohet, 1996).

The trees of latex harvesting technologies S/2 d3 6d/7ET2.5% Pa1(1) 8/y; S/2 d4 6d/7 ET2.5% Pa1(1) 12/y and S/2 d5 6d/7 ET2.5% Pa1(1) 15/y which gave the highest dry rubber yield, showed however the lowest growth, in accordance with the works of several authors (Gohet,1996, Obouayeba and Boa 1993, Wycherley, 1976,Templeton, 1969).

This is explained by the fact that the activation of the latex producing function by hormonal stimulation causes an increase in energy requirements and also in assimilates (mineral, organic elements and enzymes) necessary for the synthesis of the constituents of latex. Face to these increased needs, the plant is forced to use its reserves. The immediate consequence of this action is the reduction of vegetative growth (Obouayeba, 2005, Gohet, 1996, Wycherley, 1975, Templeton, 1969, Bouychou, 1962). Our results on yield and vegetative growth express the fact that the more the tree produces rubber, the less it grows.

Sensitivity to tapping panel dryness

The rates of tapping panel dryness were low whatever the treatment and the clone. These results are in accordance with those of previous studies carried out on these clones (Obouayeba, 2005, Gohet, 1996) and confirm their belonging to the clones of the slow metabolism class. The rubber trees of this class can easily withstand an increase in the frequency of stimulation without risk of saturation latex producing functions (Gohet, 1996) which would result in an increase in the rate of tapping panel dryness.

Sensitivity to tapping panel dryness increases however with the intensity of latex harvesting. The general analysis of the influence of latex harvesting technologies on rubber yield, sensitivity to tapping panel dryness and radial vegetative growth of trees enables to conclude that the clones with slow metabolism are more efficient in high intensity latex harvesting. The pattern S/2 d3 6d/7 ET2.5% Pa1(1) 8/y accordingly responds best to this requirement, it can therefore be recommended. However, given the expensiveness and scarcity of tapping labour, the following latex harvesting technologies, S/2 d4 6d/7 ET2.5% Pa1(1) 12/y, and S/2 d5 6d/7 ET2.5% Pa1(1) 15/y can better adapt to their exploitation under these conditions and thus contribute to face the problem of availability and cost of tapping labour.

Physiological profile

The dry rubber content increased at the end of the experiment whatever the clone and the treatment. This increase is more expressive with the reduction in the intensity of latex harvesting which indicates a high activity of latex regeneration of the trees (Soumahin *et al.,* 2009, Gohet, 1996, Lacrotte, 1991) tapped with reduced tapping frequency latex harvesting technologies: S/2 d5 6d/7ET2.5% Pa1(1) 15/y and S/2 d6 6d/7ET2.5% Pa1(1) 18/y.

The sucrose content increased with the intensity of latex harvesting. The lowest contents were obtained with the latex harvesting technology S/2 d6 6d/7 ET2.5% Pa1(1) 18/y regardless of the clone. This is best understood especially as the intensification of ethylene stimulation results in a decrease in the sucrose content of the latex (Gohet, 1996). Indeed, the stimulation by the use of ethylene activates the production metabolism by an exaltation of the whole process leading to an increased use of certain substances such as sucrose that is carried thanks to an ATPase proton pump (Lacrotte, 1991).

These results also indicate an increase in the inorganic phosphorus content (Pi) at the end of the experimental period, which reflects a good metabolic activity of the latex producing system (Jacob *et al.*, 1988).

The Pi content of the latex had a satisfactory level regardless of the clone. The latex harvesting technologies S/2 d3 6d/7 ET2.5% Pa1(1) 8/y; S/2 d4 6d/7 ET2.5% Pa1(1) 12/y and S/2 d6 6d/ 7 ET2.5% Pa1(1) 18/y are not marked out for this parameter.

The average content in thiol groups of the latex regardless the clone varied from 0.65 to 0.71 mM. These values are above the average and reflect a good availability of the enzymes involved in the isoprene biosynthesis and a good colloidal stability of the latex. The reduction of the intensity of latex harvesting has no effect on the concentration in thiol groups.

The latex harvesting technologies S/2 d3 6d/7 ET2.5% Pa1(1) 8/y; S/2 d4 6d/7 ET2.5% Pa1(1) 12/y and S/2 d6 6d/7 Pa1(1) ET2.5% 18/y have presented the best physiological profile because the physiological parameters are more balanced.

At the end of the nine years of harvesting latex in downward half spiral of clones PB 217 and PR 107 of the slow metabolism class, it appears that:

- The yield per tree per tapping ($g.t^{-1}.t^{-1}$) increases with the reduction in the tapping frequency.
- When the trees are tapped at the same frequency notably in d4, the increase in the number of annual stimulations leads to a gain in dry rubber yield per tree and per year as well as per hectare and per year.
- Whatever the treatments and clones, the trees have kept a good potential for vegetative growth during the experiment. All the stimulated rubber trees growth were statistically the same order of magnitude whatever the treatment and the clone. However, these growths were statistically lower than those of non stimulated rubber trees.
- The sensitivity to tapping panel dryness is low regardless of the treatment and the clone.
- Whatever the treatment, there is a good availability of the enzymes involved in the isoprene biosynthesis, a satisfactory level of Pi content and an increase the sucrose content with the intensity of latex harvesting.

In the context of the Ivorian rubber cultivation and the scarcity of tapping labour, three latex harvesting technologies due to the best compromise between vegetative growth, rubber yield, physiological profile and sensitivity to tapping panel dryness that they offer can then be recommended for the rational harvesting of the latex of the clones of the slow metabolism class:

- ► S/2 d3 6d/7 ET2.5% Pa1(1) 8/y, in the case of good availability of tapping labour.
- ► S/2 d4 6d/7ET2.5% Pa1(1) 12/y, in the case of medium shortage of tapping labour.
- ► S/2 d5 6d/7 ET2.5% Pa1(1) 15/y, in the case of severe shortage of tapping labour.

The choice of one of the three systems is based on the socio-economic context of the period.

References

Ashwell G. 1957. Colorimetric analysis of sugar. Methods Enzymology.**3**, 73-105.

Bouychou JG ,1962. La saignée de l'hévéa. Manuel du planteur d'hévéa, 50P

Boyne AF, Ellman GL. 1972. A methodology for analysis of tissue sulphydryl components. Annals of Biochemistry **46**, 639-653.

Brou YT. 2005. Climat, mutations socio-économiques et paysages en Côte d'Ivoire. Mémoire de synthèse des activités scientifiques présenté en vue de l'obtention de l'habilitation à diriger des recherches. Université des Sciences et Technologies de Lille, 213p.

Chapuset T. 2001. Description des clones étudiés à grande échelle ; Rapport CNRA-HEVEA n°01/01 – A- Mai 2001. 36p.

Compagnon P. 1986. Principes de la conduite de l'exploitation .In : Le caoutchouc naturel, Coste R. ed. GP. Maisonneuve et Larose, Paris, 237-265.

Eldin M. 1971. Le climat. In : Le milieu Naturel de la Côte d'Ivoire. Mémoires ORSTOM **50**, 77-108.

Gohet E, Chantuma P, Lacote R, Obouayeba S, Dian K,Clement-Demange A, Dadan K, Eschbach JM. 2003**.** Latex clonal typology of *Hevea brasiliensis* : Physiological modelling of yield Potential and clonal response to ethephon stimulation. Proceedings. of IRRDB International workshop on exploitation technology, Rubber Research Institute of India ,199-217.

Gohet E. 1996. La production de latex par *Hevea brasiliensis*. Relation avec la croissance. Influences de différents facteurs : Origine clonale, stimulation hormonale, réserves hydrocarbonnés. Thèse de Doctorat d'université, Université Montpellier II, Sciences et Techniques du Languedoc, France, 343p.

Hashim IB 1988**.** Low intensity tapping systems and stimulation pratices affecting responses in *Hevea brasiliensis* (Muell. Arg).PhD in agronomy, University of Pertanian, Malaysia, 358p.

Jacob JL, Serres E, Prévôt JC, Lacrotte R, Clement-Vidal A, Eschbach JM, d'Auzac J. 1988**.** Mise au point du diagnostic latex. Agritrop **12**, 97-118.

Lacrotte R. 1991. Etude des relations entre la teneur en sucres du latex et la production. Approche des mécanismes du chargement en saccharose des laticifères d'*Hevea brasiliensis* Müell. Arg. Thèse de Doctorat d'université, Université Montpellier II, Sciences et Techniques du Languedoc, France, 266p.

Obouayeba S. 1991 . Cultures vivrières intercalaires des jeunes hévéas en milieu villageois du Sud-est de la Côte d'Ivoire. Systèmes Agricoles en Afrique, Vol I, n°2, 21-32.

Obouayeba S, Boa D. 1993**.** Fréquence et repos annuel de saignée d'*Hevea brasiliensis*, clone PB235 dans le sud-est de la Côte d'Ivoire. Cahiers Agricultures **2**, 387-393.

Obouayeba S, Boa D, Keli ZJ. 1996a**.** Adéquation entre quantité de pâte stimulante et production de caoutchouc d'*Hevea brasiliensis* dans le sud-est de la Côte d'Ivoire. Tropicultura **14,** (2), 54-58.

Obouayeba S, Boa D, Jacob JL. 1996b**.** Les performances du clone d'hévéa PB217 en Côte d'Ivoire. Plantations, Recherche, Développement, **3**(5), 346-353.

Obouayeba S, Soumahin EF, Dobo M, Lacote R, Gabla O, Doumbia A. 2009**.** Agronomic performance of the clone IRCA111 of *Hevea brasiliensis* under different frequencies of tapping and stimulation in South-West Côte d'Ivoire, Journal of Rubber Research **12,** (2), 93-102

Obouayeba S. 2005. Contribution à la détermination de la maturité physiologique de l'écorce pour la mise en saignée d'*Hevea brasiliensis* Müell. Arg. (Euphorbiaceae) : normes d'ouverture. Thèse de doctorat d'université, Université de Cocody, Abidjan,
Côte d'Ivoire, 223p.

Obouayeba S, Boa D, Dian K, Ouattara N, Keli ZJ. 2000**.** Dynamics of vegetative growth of *Hevea brasiliensis* in determining tapping norms. Journal of rubber research **3**(1) 53-62

Perraud A. 1971. Les sols. In : Le milieu Naturel de la Côte d'Ivoire. Memoires ORSTOM **50,** 269-390.

Rajagopal R, Vijayakumar KR, Thomas KU, Karunaichamy K. 2003. Yield response of *Hevea brasiliensis* (clone PB217) to low frequency tapping. Proceedings of the international workshop on Exploitation technology, India 127-139

Roose E, Cherroux M. 1966**.** Les sols du bassin sédimentaire de Côte d'Ivoire. Cahier ORSTOM, Série Pédologie **5** (2), 51-91.

Said MAM, Sivakumaran S, Eujof Z, Atan S, 1998. Once-a-week conventional tapping system (1/2S d/6) with ethephon stimulation for young mature rubber. Proceedings of Seminar on low intensity tapping Systems (LITS), Sungei Buloh, Malaysia, Malaysia. 17-41.

Soumahin EF. 2010. Optimisation des systèmes d'exploitation en hévéaculture par la réduction des intensités de saignées. Thèse de doctorat d'université, Université de Cocody, Abidjan, Côte d'Ivoire, 189p.

Soumahin EF, Obouayeba S, Anno AP. 2009**.** Low frequency with hormonal stimulation on *Hevea brasiliensis* clone PB 217 reduces tapping manpower requirement, Journal of Animal And Plant Science ,Vol II, Issue **3**, 109-117

Soumahin EF, Obouayeba S, Dick KE, Dogbo DO, Anno AP. 2010**.** Low intensity tapping systems applied to clone PR 107 of *Hevea brasiliensis* (Muell. Arg.): Results of 21 years of exploitation in South-eastern Côte d'Ivoire, African Journal of Plant Science Vol. IV(5),145-153

Taussky HH, Shorr E. 1953**.** A micro colorimetric method for the determination of inorganic phosphorus. Journal of Biology and Chemistry **202**, 675-685.

Templeton JK. 1969. Partition of assimilates. Journal of Rubber Research, Institute of Malaysia**, 21**, 259-273.

Vijayakumar KR, Thomas KU, Rajagopal R, Karunaichamy K. 2003**.** Response of *Hevea* clone to low frequency tapping. Proceedings of the international workshop on Exploitation technology, India, 17-42

Webster CC, Paardekooper EC. 1989**.** The botany of the rubber tree. In Webster c. C. et Baulkill W. J. (eds) Rubber, 57-84.

Wycherley PR. 1976. Tapping and partition. Journal of Rubber Research. Institute of Malaysia, **24** (4) 169-194.