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Full Length Research Paper

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

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The cultivation of *Hevea brasiliensis*, which is the main source of natural rubber, is facing a problem of scarcity and/or high cost of skilled labour. One of the means to remedy this constraint is to reduce the intensity of tapping. This work aims at studying tapping systems of low intensity tapping but highly stimulated (S/4 d3 6d/7 8-10/y(m) and S/2 d6 6d/7 8-10/y(m)) which enable to reduce the need for tappers by 10 and 50% compared to a standard or traditional tapping system (S/2 d3 6d/7 4/y(3m), the control), in clone PR 107 of *Hevea brasiliensis* in south-eastern Côte d'Ivoire. This study was carried out on the basis of agronomic, physiological and economic criteria. The results of 21 years of exploitation have shown that reducing the frequency of tapping is not compensated, in terms of yield, by high stimulations. However, the reduction of the length of tapping cut is compensated, in terms of yield, by hormonal stimulation. Low intensity tapping systems do not adversely affect the growth and physiological profile of trees. They reduce the rate of tapping panel dryness. All tapping systems are profitable. The best low intensity tapping systems (S/4 d3 6d/7 10/y(m) and S/2 d6 6d/7 10/y(m)) may constitute an alternative to the standard or traditional tapping system so as to reduce the need for tappers and thus, make up for a deficit and/or a high cost of tapping labour.

Key words: *Hevea brasiliensis* clone PR 107, low intensity tapping systems, stimulation, yield, growth, tapping panel dryness, labour, profit margin, Côte d'Ivoire.

INTRODUCTION

Rubber cultivation is experiencing a surge in productivity thanks to the genetic selection and harvesting techniques. However, it still remains heavily labour-dependent and labour-consuming. This is a serious handicap for that crop, since the tapping labour, which is in charge of harvesting rubber yield is rare and/or expensive (Shahabudin, 1994).

The competitiveness of rubber cultivation and especially the monthly income maintenance for rubber farmers of non-industrial rubber area (smallholders) are an inescapable fact for the development of that crop. To achieve this, the management of rubber plantations by directing standard and traditional tapping systems (more labour-consuming) towards low intensity tapping systems (less labour-consuming) is inevitable. These tapping systems should enable to reduce the tapping work and therefore, the need for tappers on one hand, and on the other hand to compensate for downsizing of labour by an additional increase in tapping work productivity.

Therefore, the implementation of low intensity tapping

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systems implies, compared to standard tapping systems, a reduction in the intensity of tapping (reduction of tapping frequency and/or tapping cut length). This reduction in tapping intensity must be at least partially compensated by an increase in the intensity of hormonal stimulation (Compagnon 1986; Vijayakumar et al., 2001; Soumahin, 2003; Soumahin et al., 2009; Obouayeba et al., 2006).

This experiment is part of the prospect of reduction in the need for tappers in order to make up for shortages and/or high cost of tapping labour. It is about the study of low intensity tapping systems (S/2 d6 6d/7 8-10/y(m) and S/4 d3 6d/7 8-10/y(m)) compared to a standard or traditional tapping system (S/2 d3 6d/7 4/y(3m)) used as reference, in clone PR 107, in south-eastern Côte d'Ivoire. It is a comparative study to be conducted on the basis of rubber yield, vegetative radial growth, physiological profile and sensitivity to tapping panel dryness. An economic analysis underlies the agronomic and physiological study so as to set the profitability of these tapping systems.

MATERIALS AND METHODS

Plant materials

The experiment focused on the clone PR 107 of *Hevea brasiliensis,* stump planted in 1962. The trees, which started to be tapped in 1969 at 1.20 m from the ground, were exploited in downward full spiral, twice a week (S d3 6d/7) until July 1975. The experiment began in August 1976 after a year of exploitation in downward half-spiral, twice a week (S/2 d3 6d/7) and was completed in 1997. The PR 107 is a clone with slow metabolic activity (Chan and Chuah, 1983; Eschbach et al., 1984; Jacob et al., 1995). Its immature growth (prior to tapping) is slow (Obouayeba et al., 2000) as well as during tapping. The PR 107 is among the clones which are relatively more resistant to breakage due to wind; it is famous for keeping a large stand of tappable trees over time. It is less sensitive to tapping panel dryness. This clone shows strong features of slow starter, that is to say, a slow rise in yield with a good level of yield in the old plantations (Chan and Chuah, 1983).

Methods

Study site

The experiment was carried out at Centre National de Recherche Agronomique (Station de Recherche de Bimbresso) in the south east of Côte d'Ivoire (5°19'N latitude, 4°09'E longitude). This region is characterized by a subequatorial climate with two rainy seasons and two dry seasons. The soils are ferralitic derived from tertiary sand (Keli et al., 1992).

Statistical equipment

The statistical equipment was set in completely randomized blocks with 5 treatments and 4 repetitions spread over 20 elementary plots of approximately 400 trees. The lines were spaced 6 m apart and the locations 2.35 m apart. The elementary plots occupied each an area of 0.17 ha, that is 3.42 ha for the trial. The average density was 400 trees per hectare. All trees showing any anomaly (breakage due to wind, tapping panel dryness, black stripes, *Fomes lignosus* attacks, etc), were eliminated retroactively since the beginning of the experiment.

Treatments or tapping systems

The experiment was conducted in three stages, depending on the tapping panel (up or down) the nature of the exploited bark (virgin, first or second regeneration) and the orientation of the tapping (down or ascending). They are:

(I) 1st stage: downward tapping on 1st regeneration bark of the low panel;
(II) 2nd stage: upward or reverse tapping on virgin bark of the high panel;
(III) 3rd stage: downward tapping on 2nd regeneration bark of the low panel.

For each stage, 5 tapping systems were tested (Tables 1 and 2). The tapping systems notation used was one of the International Notation for Latex Production Technology (Vijayakumar et al., 2009). According to Vijayakumar et al. (2009) the tapping systems 2, 3, 4 and 5 presented 50% of reducing tapping intensity in comparison with tapping system 1. With the tapping systems 2 and 3 and the tapping systems 4 and 5, the number of tappers required can be reduced, respectively, by up to 50 and 10%.

Tapping

The tapping was realized with tapping knives; the tapping is done every month. The quality of tapping was monthly inspected. The consumption of bark admitted for each tapping was about 1.5 mm (downward and upward tapping). The production (latex) was collected into polybags or latex-cups.

Stimulation

The stimulant product was the concentrated Ethrel Stimulatex which content 480 $g.l^{-1}$ of active ingredient (2-chloroethylphosphonic acid or Ethephon). The density of product was 1.2, so, its contents 400 $g.kg^{-1}$ (40%) of active ingredient. The Ethrel was mixed with palm oil at final concentration of 5 and 10% of active ingredient (Ethephon). So, the quantity of Ethrel applied per tree was 0.25 g, that is, to say:

(I) 2 g of stimulant on half spiral cut tapping with 5% of active ingredient;
(II) 1 g of stimulant on quarter spiral cut tapping with. Brush was used for applying the stimulant according to two methods;
(III) Below the tapping cut (downward tapping) or above the tapping cut (upward tapping), on 2 cm band of scraped bark (Ba);
(IV) On the tapping cut, on 1 cm band scraped bark and on band of 1 cm of renewal panel (BaPa).

Data collection

Rubber production: A production check on each tree was made every 4 weeks. A sample of the rubber yielded was used to determine the coefficient of transformation of each treatment, which permits determination of the weight in dry rubber. The production was expressed in kilogram per hectare ($kg.ha^{-1}$), gram per tree ($g.t^{-1}$) and in gram per tree per tapping ($g.t^{-1}.t^{-1}$).

Radial vegetative growth: Radial growth was measured at the beginning of the experiment in August 1976, and thereafter, once per year (in January). Tree circumference was measured at 1.90 m above the ground. The girth increment (Gi) was determined by the following relation:

Table 1. Treatments (tapping systems) of first and 3rd period (1976-1984 and 1990-1997).

Treatment code	Description
S/2 d3 6d/7 ET5% Ba2(2) 4/y(3m)	Half spiral cut tapped downward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 5% active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut, 4 applications per year at interval of 3 months between applications.
S/2 d6 6d/7 ET5% BaPa2(2) 8/y(m)	Half spiral cut tapped downward at sixth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 5% active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 8 applications per year, applied at monthly interval.
S/2 d6 6d/7 ET5% BaPa2(2) 10/y(m)	Half spiral cut tapped downward at sixth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 5% active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.
S/4 d3 6d/7 ET 10% BaPa1(2) 8/y(m)	Quarter spiral cut tapped downward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10% active ingredient with 1 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 8 applications per year, applied at monthly interval.
S/4 d3 6d/7 ET10% BaPa1(2) 10/y(m)	Quarter spiral cut tapped downward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10% active ingredient with 1 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.

Table 2. Treatments (tapping systems) of 2nd period (1984-1990).

Treatment code	Description
S/2U d3 6d/7 ET5% Ba2(2) 4/y(3m)	Half spiral cut tapped upward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 5 % active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut, 4 applications per year at interval of 3 months between applications.
S/2U d6 6d/7 ET5% BaPa2(2) 10/y(m)	Half spiral cut tapped upward at sixth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10 % active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.
S/2U d6 6d/7 ET5% BaPa2(2) 10/y(m)	Half spiral cut tapped upward at sixth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10 % active ingredient with 2 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.
S/4U d3 6d/7 ET10% BaPa1(2) 10/y(m)	Quarter spiral cut tapped upward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10 % active ingredient with 1 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.
S/4U d3 6d/7 ET10% BaPa1(2) 10/y(m)	Quarter spiral cut tapped upward at third daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 10 % active ingredient with 1 g of stimulant applied on 2 cm band on scraped bark below the tapping cut and on panel, 10 applications per year, applied at monthly interval.

Table 3. Annual mean rubber (kg.ha-1, g.t-1, g.t-1.t-1) of clone PR 107 of *Hevea brasiliensis* under low intensities tapping systems with different intensities of stimulation using Ethephon during 21 years.

Tapping systems	$kg.ha^{-1}$	$g.t^{-1}$	$g.t^{-1}.t^{-1}$
1	2 609^{a}	6 035^{a}	61^{b}
2	2 014^{c}	5 277^{a}	106^{a}
3	2 224b^{c}	5 323^{a}	107^{a}
4	2 416a^{b}	5 940^{a}	59^{b}
5	2 612^{a}	5 986^{a}	60^{b}

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

Table 4. Annual average girth increment of clone PR 107 of *Hevea brasiliensis* under low intensities tapping systems with different intensities of stimulation using Ethephon during 21 years.

Tapping systems	Annual average girth increment ($cm.year^{-1}$)
1	1.0^{b}
2	1.2^{a}
3	1.1^{ab}
4	1.2^{ab}
5	1.1^{ab}

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

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

Where, Gn is the mean girth of trees of the year n and Gn-1, the mean girth of trees of the year n-1.

Latex analysis: A latex microdiagnosis was carried out once per year between Augusts - January taking into account the dry rubber rate and the sucrose, inorganic phosphorus and thiol contents. To determine the dry rate (%), a latex sample was weighed before and after drying in oven at 80ºC for 24 h. The sucrose, the inorganic phosphorus and the 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 (1957) anthrone method, the Taussky and Shorr (1953) molybdate ammonium method and the Boyne and Ellman (1972) acid dinitro-dithio-dibenzoic (DTNB) method. The results were stated in mmole per litre of latex (mM).

Visual estimation of the tapping panel dryness: On certain trees, during tapping, the flow of latex is abnormally weak or even nonexistent; a more or less important part of the cut does not produce latex. This is called symptom of tapping panel dryness. The tapping panel dryness quick measurement method by visual estimation enables to report on the progress of the "disease". On that respect, the trees tapped were rated from 0 - 6 in proportion to the progress of the disease according to the code below:

(I) 0 : healthy cut, normal flow all along the tapping cut
(II) 6: completely dry cut.

Economic analysis: For each tapping system, the profit margin (P.M) was calculated and stated in US $ as follow:

P.M = O.I – O.C.; with O.I. = Y x S.P.R. and O.C. = M.C + S.C.

Where, O.I is Operating Income; O.C is Operating Cost; Y is Yield in kg of ex-farm rubber/hectare; S.P.R is Ex-farm Selling Price per kg of rubber; M.C is Manpower Cost; S.C is Stimulation Cost. NB: Exfarm kg of rubber = kg of dry rubber / 60%.

Statistical analysis

The rubber production, plant growth and the latex analysis data were subjected to analysis of variance using statistics softwares Statgraphics and Excel. The level of significance of the differences between averages was estimated by the Newman-Keuls test at a limit of 5%.

RESULTS

Influence of low intensity tapping systems on the yield of dry rubber

At the end of the 21 years of exploitation, the annual average yields of dry rubber expressed in $kg.ha^{-1}$ of tapping systems 4 and 5, having a reduced cut length, statistically identical to each other, were not different from that of the standard tapping system (control, Table 3). Tapping systems 2 and 3, having a low tapping frequency, with annual average yields statistically equivalent, were less productive than the standard tapping system. The yield of tapping system 2 was significantly lower than that of the control and tapping systems 4 and 5. Tapping system 3 has produced as much as tapping system 4.

The annual average yields expressed in $g.t^{-1}$ of all tapping systems were of the same order of magnitude (Table 3).The yields expressed in $g.t^{-1}.t^{-1}$, of weekly tapping systems (treatments 2 and 3), statistically comparable to one another, were significantly higher than those of the other tapping systems (treatments 1, 4 and 5; Table 3).

Influence of low intensity tapping systems on the radial vegetative growth of trees

At the end of the experiment, the annual average girth increments of low intensity tapping systems, all having the same order of magnitude, did not differ from the standard tapping system, except the annual average increase in girth of system 2 (Table 4). The annual average girth increment of the latter tapping system was significantly higher than that of the standard tapping system.

Influence of low intensity tapping systems on the physiological status of trees

At the beginning of the experiment, the rate of dry rubber and sucrose content of the latex of the different tapping

Table 5. Physiological status of clone PR 107 of *H. brasiliensis* under low intensities tapping systems with different intensities of stimulation using Ethephon during 21 years.

Tapping systems	DRC (%)		Sucrose (mM)		P i (mM)		R–SH (mM)	
	Start	End	Start	End	Start	End	Start	End
1	41.0	49.3	10.2	10.9	26.9	16.2	0.91 a	0.61 a
2	44.0	49.6	9.7	8.7	18.8	15.5	0.74 b	0.47 b
3	40.6	50.0	9.6	10.6	23.8	15.4	0.92 a	0.51 ab
4	44.0	49.5	9.9	12.1	20.3	16.9	0.84 a	0.63 a
5	42.2	48.6	9.1	12.9	25.7	17.2	1.03 a	0.64 a

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

Table 6. Tapping panel dryness of clone PR 107 of *H. brasiliensis* under low intensities tapping systems with different intensities of stimulation using Ethephon during 21 years.

Tapping	Dry cut (%)		Dry trees (%)	
Systems	Start	End	Start	End
1	15.5	22.5	3.3	5.8
2	15.3	20.5	3.2	4.9
3	11.6	17.1	2.6	3.7
4	14.1	9.8	1.6	4.5
5	13.3	9.1	3.7	3.6

the different tapping systems were statistically identical (Table 5). The Pi and thiol contents of the latex of the different tapping systems were statistically of the same order of magnitude, except the thiol content of the latex of tapping system 2 which was lower than those of the other tapping systems. An increase in the rate of dry rubber and sucrose content of the latex was observed at the end of the experiment. Tapping system 2, which experienced a decrease in sucrose content of the latex, was an exception. No difference was observed at the end of the experiment between the different rates of dry rubber and sucrose and Pi contents of the latex of the different tapping systems tested. Only the thiol content of tapping system 2, statistically identical to that of tapping system 3, was lower than those of the other tapping systems (treatments 1, 3, 4 and 5).

Influence of low intensity tapping systems on the sensitivity to tapping panel dryness

During the experiment, an increase in the rate of dry trees was observed in the different tapping systems, except in tapping system 5, which experienced a slight decrease in those rates (Table 6). The rates of dry trees have increased by three quarters in the standard tapping system, by half in the low intensity tapping systems and by triple in tapping system 4. Generally speaking, the rates of dry trees have increased little in so far as being less than 3% at the beginning of the experiment; they did not reach 5% at the end. Regarding to the rates of dry cut, an increase in half-spiral tapping systems and a decrease in quarter-spiral tapping systems were observed. In each case, the increase or decrease in the rates of dry cut occurred almost by half. During the experiment, the average rate of dry cut in all tapping systems combined, ranged between 14 and 16%.

Profitability of low intensity tapping systems

Operating cost

With a labour cost of US $ 4 /day, minimum cost including all expenses for labour, the standard tapping system had the highest operating cost per hectare, in the same order of magnitude as that of tapping system 5, in quarter-spiral (Table 7). The lowest operating costs were those of half-spiral tapping systems, tapped weekly (treatments 2 and 3). The latter systems, including tapping system 2, have indeed led to a reduction of almost half of operating costs compared to the standard tapping system.

Operating income

With a purchase price of US $ 0.4 /kg for the rubber at the farm gate, which is the average purchase price over the last 15 years, tapping system 5 and the standard one,

Table 7. Annual profitability per hectare of clone PR 107 of *Hevea brasiliensis* under low intensities tapping systems with different intensities of stimulation using Ethephon during 21 years.

Tapping systems	Operating cost/ha/year (US $)	Operating income/ha/year (US $)	Operating gross margin/ha/year during the study (US $)
1	231	1 239	1 008
2	113	956	844
3	126	1 056	930
4	207	1 148	941
5	224	1 241	1 017

NB: Price of commercial rubber = 0.29 US $/kg of ex-farm rubber; cost of labour = 2.86 US $/day.

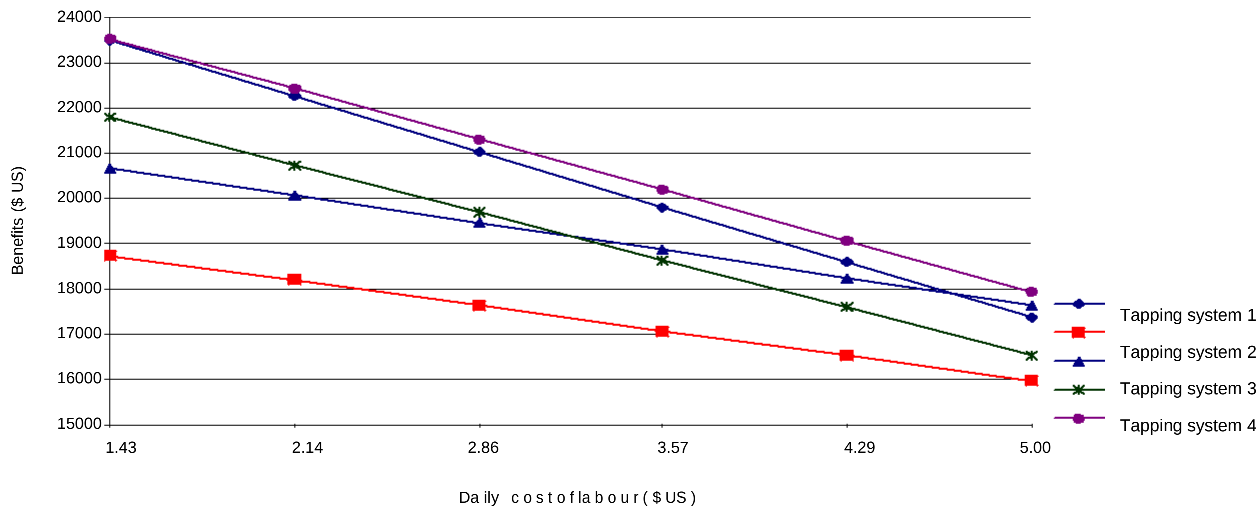

Figure 1. Evolution of tapping systems benefits for cost of rubber at 0.29 US $/kg.

the most productive, had the highest income (Table 7). The least productive ones, weekly tapping systems (treatments 2 and 3), had the lowest revenue.

Operating gross margins

With a purchase price of US $ 0.4 /kg for the rubber at the farm gate and a daily labour cost of U.S. $ 4, the gross margins of the different tapping systems are all positive (Table 7). Tapping systems 1 and 5 had the highest gross margins. Up to a daily labour cost of U.S. $ 7.5, tapping system 5, with a reduced tapping cut length, had the most significant gross margin (Figure 1). When the daily labour cost exceeds U.S. $ 7.5, tapping system 3, having a low tapping frequency, becomes more profitable than the standard tapping system.

DISCUSSION

The reduction of the tapping cut length was compensated, in terms of annual average yield, by the high stimulation while the reduction of the tapping frequency, with the same amount of stimulation, has led to annual average losses of 23 - 15 % in yield compared to the annual average yield of the standard or traditional tapping system. In terms of yield, it is thus, more profitable to reduce the length of the cut instead of the intensity of tapping, in the context of a reduction in tapping intensity compensated by high stimulations (Langlois, 1969; Vijayakumar et al., 2003).

Compared to the standard tapping system, the best annual average girth increments were those of low intensity tapping systems (Langlois, 1969; Vijayakumar et al., 2003). On the whole exploitation, the reduction of tapping frequency was less detrimental to growth than the reduction of tapping cut length. The most productive tapping systems were those that led to the lowest girth increments, which corroborates the works of Obouayeba and Boa (1993); Gohet (1996).

The analysis of physiological parameters showed that all tapping systems presented physiological profiles almost comparable in the beginning and at the end of exploitation. However, the quarter-spirals presented the most balanced and activated physiological profiles, especially at the end of exploitation (Paardekooper et al., 1975; Eschbach, 1986 ; Dian et al., 1997), followed by the standard tapping system. These physiological profiles were characterized by a high protection of the integrity of lutoids, sufficient energy availability, a better glucidic supply and an active isoprenic biosynthesis, corroborated by the good level of yield obtained. The half-spirals tapped weekly showed the less activated physiological profiles, especially at the end of exploitation. Indeed, the glucidic supply, the energy availability as well as the protection of the integrity of lutoids of the half-spirals tapped weekly were very low.

This indicates a slowdown of the metabolism of regeneration, due to large extensions of time between two consecutive tappings (Dian et al., 1997) and not to over-exploitation in so far as the sucrose content was not limiting and the isoprenic biosynthesis very activated, illustrated by high levels of dry content (Dian et al., 1997). This metabolic slowdown causes a limitation of the biochemical energy involved in the supply of sugar in latex vessels (Lacrotte, 1991; Obouayeba et al., 1996). This situation leads to think that the activation of the metabolism of regeneration only by the increase in hormonal stimulation was not sufficient to achieve the optimal level of half-spirals tapped weekly (Dian et al., 1997; Soumahin et al., 2009). The analysis of physiological profiles reveals however that, no tapping system has shown signs of physiological fatigue all along the experiment (Thomas et al., 2003; Xiaodi et al., 2003; Hashim, 1988). On the contrary, the physiological profiles indicated an under-exploitation of trees (Eschbach and Banchi, 1985; Eschbach, 1986). In order to have a good yield and a better physiological balance of trees, it is preferable to reduce the length of tapping cut rather than the frequency of tapping, which confirms that the latex-producing metabolism of the producing tissue in the clone PR 107 is slow (Jacob et al., 1988).

The low intensity tapping systems led to the lowest sensitivity to tapping panel dryness compared to the standard tapping system, as already shown by certain authors (Eschbach and Banchi, 1985; Sivakumaran and Hashim, 1985; Hashim, 1988; Rajagopal et al., 2003; Thomas et al., 2003; Obouayeba et al., 2008, 2009; Soumahin et al., 2009). The quarter-spirals in spite of being more productive, were less sensitive to tapping panel dryness, compared to the half-spirals tapped weekly. This result is very interesting since it does not corroborate the works of Gener and Du Plessix (1971); Chan and Chuah (1983) which indicate that the flow time of latex, that is, they yield the more as long as the tapping cut itself is long. From the foregoing, it is preferable to reduce the length of tapping cut rather than the frequency of tapping.

For annual average yields of rubber equivalent to those of the standard tapping system, the quarter-spirals had the advantage of leading to a better vegetative growth, a better physiological profile and a low sensitivity to tapping panel dryness. The half-spirals tapped weekly, despite annual average losses of 15 and 23 % in yield of rubber, have enabled , compared to the traditional tapping system, a better growth of trees and a low sensitivity to tapping panel dryness unlike quarter-spirals, have led to a slowdown in the metabolism of regeneration of latex, therefore of rubber. At both agronomic and physiological levels, it is preferable in the context of a reduction in the intensity of tapping compensated by high stimulations, to reduce the length of tapping cut rather than the frequency of tapping because of the best compromise that it offers between rubber yield, radial vegetative growth, physiological profile and tapping panel dryness. Tapping system 5 (S/4 d3 6d/7 10/y(m)), the best of quarter-spirals and tapping system 5 (S/2 d3 6d/7 10/y(m)), the best of half-spirals tapped weekly, are the best alternatives to the standard tapping system in the context of a reduction in the intensity of tapping.

The economic analysis of the results of rubber yield has shown that, for a selling price of US $ 0.4 per kg for the rubber and a daily labour cost between U.S. $ 4 and 9, all the tapping systems tested are strictly profitable (Xiaodi et al., 2003; Vijayakumar et al., 2003 ; Soumahin et al., 2009). The saving of labour made by low intensity tapping systems (10% for quarter-spirals tapped twice a week and 50% for half-spirals tapped once a week) enables therefore, to compensate for the increase in stimulation costs as well as losses in yield caused by the reduction in the intensity of tapping (Soumahin et al., 2009). In addition to that, tapping systems 3 and 5 showed a better profitability compared to the traditional tapping system (Eschbach and Banchi, 1985), in a context of overbid and shortage of labour. They are therefore, the best alternative to the traditional tapping system to make up for the shortage and/or high cost of tapping labour (Hashim, 1988; Obouayeba et al., 2002; Jacob et al., 1995).

Conclusion

This study, conducted on the clone PR 107, has enabled us to show that it is possible to reduce the need for tappers and, therefore, to make up for the shortage and/or the high cost of tapping labour, by the adoption of low tapping frequency or short tapping cut length systems and its highly stimulated. Indeed, the strong stimulations helped compensate, in terms of rubber yield, partly or totally, the reduction by 10 - 50% in tapping intensities while maintaining a better vegetative and health state and a good physiological balance of trees, particularly in tapping systems of reduced cut length.

However, it is important to note that the stimulations were not sufficient, particularly concerning low frequency tapping systems, to allow the clone PR 107 to reach its rubber yield potential. Indeed, during the experiment, no sign of degradation of physiological profiles linked to over stimulation appeared. On the contrary, tapping systems of short cut length showed balanced and activated physiological profiles overall, and low frequency tapping systems showed less activated physiological profiles. This indicates that low intensity tapping systems, notably low tapping frequency tapping systems, can be more stimulated in order to increase their yield without major impact on the physiological balance of trees. This would increase the ability to compensate, in terms of rubber yield, the reduction in tapping frequency.

The most interesting low intensity tapping systems at the agronomic, physiological and economical levels are the best alternatives to the standard tapping system ((S/2 d3 6d/7 4/y(3m)) in order to solve the problem studied namely the shortage and/or high cost of labour. They are:

(i) Tapping system S/4 d3 6d/7 10/y(m), with reduced cut length. This tapping system enables to reduce by 10 % the need for tappers,

(ii) Tapping system S/2 d6 6d/7 10/y(m), with reduced tapping frequency. This tapping system enables to reduce by 50 % the need for tappers.

The decision to use S/4 d3 or S/2 d6 depends on the over-riding severity of tapper scarcity. Thus, S/4 d3 is suitable for slight and S/2 d6 for acute tapper scarcity.

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