Original Research Article

EFFECT OF EARLY UPWARD TAPPING ON RUBBER PRODUCTIVITY OF CLONE PB 260 OF THE HIGH METABOLIC ACTIVITY CLASS

Abstract

In order to evaluate the effect of early upward tapping on rubber productivity of rubber trees and to determine its proportion relative to downward tapping, a study was conducted at SAPH Divo on the PB 260 clone of the fast metabolic activity class. The experimental set-up was a Fisher block with seven treatments and three replications. Tapping was carried out in d3 with 6 stimulations. Three upward tapping times at 6, 7 and 8 years, each coupled with two concentrations of the stimulating paste 2.5 and 5% of Ethephon and a downwardly tapped control stimulated with 5% of Ethephon were tested. The data collected were for rubber production, isodiametric growth, tapping panel dryness susceptibility and tree physiological profile. The results showed that the different treatments tapped in upward at 6, 7 and 8 years of age significantly improved the productivity of the PB 260 clone relative to the control by downward for nine years. All treatments combined, rubber productivity (4723 $kg.ha^{-1}.yr^{-1}$) and radial vegetative growth (3.8 $cm.yr^{-1}$) were good. The gain in rubber productivity of the early upward tapping compared to the downward tapping was 42%. The tapping panel dryness rate was low at 2.6% and the physiological profile of the trees was well balanced. Our results suggest that PB 260, and therefore metabolically active clones, can be tapped in early upward tapping, especially at 6 years of age.

Key words: early, productivity, tapping, upward

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1. INTRODUCTION

Hevea brasiliensis Muell Arg. (Euphorbiaceae) is a tropical plant species cultivated for its latex. The latex contains 90% of natural rubber particles which can be processed to become various products such as (gaskets, surgical gloves, rubber, foot wear, vehicle tires, airplane tires, etc.). The exploitation of rubber trees can last more than thirty years [1, 2]. In Côte d'Ivoire, the latex harvesting is carried out in two distinct phases. The first phase consists of alternately exploiting the two low panels (BO) in downward tapping for nine years [3]. This phase is followed by the second phase, which consists of exploiting the high panel (HO) in quarter spiral for four years [4]. At the end of this first series of four years of upward tapping, which ends in the 13th year of tapping of the rubber tree, a second series of downward tapping (14th and 15th years) is carried out. This is followed by the second series of four years of upward tapping completing the tapping on virgin bark. Then Trees are harvested from regenerated bark up to 30 years old.

This current tapping panel management scheme [4] in the African rubber region is effective since these two phases are characterized by an increasing gradient of rubber productivity [4, 5]. Despite this increasing productivity, non-industrial rubber farmers (smallholding farmers) expect more. the smallholder farmer’s environment is characterized by, among other weaknesses, a very high consumption of bark [5], which further complicates the management of their bark capital, according to the tapping panel management scheme of Gohet *et al* [4]. A harvesting system with high return on investment in a short period is likely more preferable [3]. This aspiration may be met by adjusting the downward tapping duration. In particular, by shortening it and replacing the time saving on the downward tapping with upward tapping, which is at least 25% more productive than that of downward tapping [5]. However, the proportion of this improvement on rubber productivity is still unknown, especially in relation to latex harvesting technology and clone metabolism. According to previous studies, latex harvesting technologies giving high rubber production induce Tapping Panel Dryness (TPD) and reduce radial vegetative growth and alter the physiological status [6-7].

The PB 260 clone is one of the most planted clones in Côte d'Ivoire. It is characterized by a risk of physiological imbalance in case of overexploitation and sensitivity to tapping panel dryness. This clone was chosen to better assess the possible effect of overexploitation due to upward tapping treatments applied to the trees.

Thus, our study aims to evaluate the productivity of rubber trees and to determine the proportion of productivity difference of early upward tapping compared to downward tapping in a high metabolic activity clone (PB 260) during four years of latex harvesting. The study also investigated the effect of early upward tapping on the rubber productivity, radial vegetative growth, TPD occurrence, and the latex physiological profile. This work contributes to the improvement of the productivity of the producers by upward tapping.

2. MATERIAL AND METHODS

2.1. Material

2.1.1. Study site

The experiment was conducted in the rubber plots of the Société Africaine de Plantation d'Hévéa (SAPH). The plots are located in Divo, East-central of Côte d'Ivoire, 5°49'N and 5°22'W. The Department of Divo is one of the country's moderately watered regions, with an average annual rainfall average annual rainfall of between 1200 and 1600 mm, an annual maximum temperature around 35°C and a minimum of 20°C. The climate is of equatorial type of transitional type, which combines two rainy seasons with two dry seasons [8].

2.1.2 Plant material

Clone PB 260, a high metabolic activity clone, was used in this study. It is one of the most cultivated clones in Côte d'Ivoire due to its high productivity. This clone originated from Malaysia and is a genetic cross of PB 5/51 × PB 49 [9]. The trees were planted in a straight line (7m x 2.8m) planting space with a density of 510 trees per hectare.

2.2. Methods

2.2.1. Experimental setup

The experiment was designed according to a Fisher block design, consisted of 7 treatments with three replications; 25 trees were used per elementary plot. The plots were open-tapped when 50% of the selected trees had a circumference ≥50 cm at 1 m above the ground.

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2.2.2. Treatments

The upward tapping system was started in October 2012 at 1.25 m above the ground on panel A (HO-1). The upward tapping system was conducted in the 6^{th}, 7^{th}, and 8^{th} year after downward tapping on panels A (BO-1) and B (BO-2) (Table I). The tapping system was combined with the thephon concentration i.e. 2.5% or 5.0%. A downward tapping system with 5.0% of ethephon stimulation was used as a control.

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Table I: treatments applied to clone PB 260 in October 2012

N°	Treatments	abbreviations	Designation
1	S/4 U d3 6d/7 ET 5% Pa 1(1) 6/Y **(6th year)** :	(6th year, 5%ET)	Quarter-spiral upward tapping at 6 years of age every three days, six working days out of seven; stimulated with 5% concentrated ethephon at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations performed per year
2	S/4 U d3 6d/7 ET 2.5% Pa 1(1) 6/Y **(6th year)** :	(6th year, 2.5%ET)	Quarter-spiral upward tapping at 6 years of age every three days, six working days out of seven; stimulated with 2.5% ethephon concentrate at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations performed per year
3	S/4 U d3 6d/7 ET 5% Pa 1(1) 6/Y **(7th year)** :	(7th year, 5%ET)	Quarter-spiral upward tapping at 7 years of age every three days, six working days out of seven; stimulated with 5% concentrated ethephon at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations performed per year
4	S/4 U d3 6d/7 ET 2.5% Pa 1(1) 6/Y **(7th year)** :	(7th year, 2.5%ET)	Quarter-spiral upward tapping at 7 years of age every three days, six working days out of seven; stimulated with 2.5% ethephon concentrate at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations performed per year
5	S/4 U d3 6d/7 ET 5% Pa 1(1) 6/Y **(8th year)** :	(8th year, 5%ET)	Quarter-spiral upward tapping at 8 years of age every three days, six working days out of seven; stimulated with 5% ethephon concentrate at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations per year
6	S/4 U d3 6d/7 ET 2.5% Pa 1(1) 6/Y **(8th year)** :	(8th year, 2.5%ET)	Quarter-spiral upward tapping at 8 years of age every three days, six working days out of seven; stimulated with 2.5% ethephon concentrate at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations performed per year
7	S/2 d3 6d/7 ET 2.5% Pa 1(1) 6/Y (**control**):	(10th year, 5%ET, control)	Downward half-spiral tapping every three days, six working days out of seven; stimulated with ethephon concentrated at 5% at a rate of 1 g of stimulant on a 1 cm wide strip; 6 stimulations are practiced per year

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2.2.3. Trial conduct and data collection

- **Production data**

Rubber production data were collected from tapped trees in the elemental plots. The collection lasted for four years, alternating annually between tapping panels A (HO-1), B (HO-2), C (HO-3) and D (HO-4). Rubber production in form of cup lump from each treatment was weighed every 4 weeks. Samples of fresh rubber were collected for each treatment to determine the Coefficient of Transformation (CT), which is the percentage of dry matter in a given rubber sample, which was used to calculate the production of dry rubber expressed in grams per tree per tapping (g t^{-1} t^{-1}) and in kilograms per hectare per year (kg ha^{-1} y^{-1}).

- **Radial vegetative growth**

The circumference of the trunk was measured at 1.70 m above the ground at the beginning of the experiment and repeated once a year in December. The average annual increase in circumference was determined by the following equation:

$$Gi\ (cm\ year^{-1}) = Gn - G_{n-1}. \quad (1)$$

Where **Gn** is the mean girth of trees in the year n and $\mathbf{G_{n-1}}$, the mean girth of trees in the year n-1.

- **Tapping panel dryness**

The quick measurement method of tapping panel dryness was done by visual assessment. The trees were scored on a 0- 6 scale based on the progress of tapping panel dryness (TPD). The meaning of the grades is as follows:

- 0, healthy tapping notch,

- 1, Tapping Panel Dryness on 1 - 20% of its length (10% on average),

- 2, Tapping Panel Dryness 21 - 40% of its length (average 30%),

- 3, Tapping Panel Dryness 41-60% of its length (average 50%),

- 4, Tapping Panel Dryness 61-80% of its length (average 70%),

- 5, Tapping Panel Dryness for 81-99% of its length (average 90%),

- 6, Tapping Panel Dryness completely dry.

The percentage of trees completely dry (TPD) was determined by the following relation:

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$$TPD\ (\%) = (n6 + DT) \times N^{-1}$$

With: **n6**: Number of trees affected by the dry notch class noted 6, totally dry trees whose tapping continues; **N**: Total number of trees; **ES**: Number of trees with total TPD whose tapping is stopped.

- **Physiological parameters**

Latex was collected for the realization of the latex micro diagnosis (LMD) in view of the physiological state of the trees studied through the dry extract rate (Ex.S) of the latex and the contents of sucrose (Sac), inorganic phosphorus (Pi) and thiol group of the latex. The dry extract content was determined according to the method described by Eschbach *et al*. [10], while the methods of Ashwel [11], Taussky and Shorr [12], Boyne, and Ellman [13] were used to determine the sucrose, inorganic phosphorus, and thiol group contents of latex, respectively. The MDL data were analysed based on the reference values established by Jacob *et al.* [14]. The results were expressed in millimoles per litre of latex (mmol l^{-1}) from the coefficients of the calibration ranges.

- **Statistical Analysis**

The collected data were processed using XL-STAT statistical software version 7. 1 (Addinsoft). An analysis of variance was performed to determine the level of significance. The difference between the means was estimated by the NEWMAN-KEULS test at a threshold of 5%.

3. RESULTS

3.1. Rubber production

The average annual production for the upward tapping was 111.0 g t^{-1} t^{-1}, all treatments combined (Table II). It varied significantly according to the treatment (84 to 130 g t^{-1} t^{-1}). The production of treatments 1 (6th year, ET5%;126 g t^{-1} t^{-1}), 2 (6th year, ET2.5%; 126 g t^{-1} t^{-1}) and 3 (7th year, ET5%;130 g t^{-1} t^{-1}) are statistically identical to each other and were significantly higher than those of the downward tapping control (10th year, ET5%; 84 g t^{-1} t^{-1}) and treatments 5 (8th year, ET5%; 90 g t^{-1} t^{-1}) and 6 (8th year, ET2.5%; 86 g t^{-1} t^{-1}).

Similarly, the average annual rubber yield expressed in kg.ha^{-1}.yr^{-1} for all treatments combined, under early upward tapping, was 4612 kg.ha^{-1}.yr^{-1}. It was influenced by the treatment and ranged from 3566 to 5239 kg.ha^{-1}.yr^{-1}. Treatments 1 (6 years, ET5%; 5488 kg.ha^{-1}.yr^{-1}), 2 (6 years, ET2.5%; 5373 kg.ha^{-1}.yr^{-1}) and 3 (7 years, ET5%; 5354 kg.ha^{-1}.yr^{-1}) had statistically identical and

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higher yields than the other treatments. However, those of treatments 5 (8 years, ET5%; 3916 $kg.ha^{-1}.yr^{-1}$), 6 (8 years; ET2.5%; 3665 $kg.ha^{-1}.yr^{-1}$) and the control (10 years, ET5%; 3335 $kg.ha^{-1}.yr^{-1}$) were significantly lower by the same amount. The concentration of the stimulating paste did not significantly influence rubber production. The overall average productivity gains for all tapped treatments, in early upward, was 42% higher than that of the control. In general, the production was of a good level and the rubber trees were more productive in the 6- and 7-year-old tapped designs with gains of more than 50%.

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Table II: Average dry rubber production of clone PB260, subjected to early upward tapping.

N°	Treatments	Average rubber production			
		g.t^{-1}.t^{-1}	**Gain (%)**	**kg.ha^{-1}.yr^{-1}**	**Gain (%)**
1	S/4U d3 6d/7 ET5% Pa1(1) 6/y (6 years)	126 ± 15,5 a	50	5488 ± 64,3 a	65
2	S/4U d3 6d/7 ET2.5% Pa1(1) 6/y (6 years)	126 ± 27,4 a	50	5373 ± 11,4 a	61
3	S/4U d3 6d/7 ET5% Pa1(1) 6/y (7 years)	130 ± 14,7 a	55	5354 ± 58,9 a	61
4	S/4U d3 6d/7 ET2.5% Pa1(1) 6/y (7 years)	108 ± 19,6 ab	29	4540± 82,3 ab	36
5	S/4U d3 6d/7 ET5% Pa1(1) 6/y (8 years)	90 ± 7,3 b	7	3916 ± 28,6 b	17
6	S/4U d3 6d/7 ET2.5% Pa1(1) 6/y (8 years)	86 ± 7,0 b	2	3665 ± 30,0 b	10
7	S/2 d3 6d/7 ET5% Pa1(1) 6/y (Control)	84 ± 6,8 b	0	3335 ± 27,9 b	0
	Overall average (early upward tapping times)	**111 ± 17,6**	33	**4723 ± 73,3**	42

Within a column, the means assigned the same letters are not significantly different (Newman keuls 5%).

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3.2. Radial vegetative growth

The average annual increase in circumference presented in Figure 1 shows that the delay in upward tapping had a significant effect on the radial vegetative growth of the trees with an overall average of 3.8 $cm.year^{-1}$. The average annual increments are globally of a good level with a variation ranging from 3.5 to 4.4 $cm.year^{-1}$. The highest average annual increase in girth was obtained with treatment 5 (8 years, 2.5% ET; 4.4 $cm.year^{-1}$) tapped in upward at 8 years with a concentration of 2.5% Ethephon. In addition, for the same year of upward tapping, the average annual increase in girth of trees that received a stimulating paste with a concentration of 2.5% Ethephon was greater than those that received 5% of Ethephon.

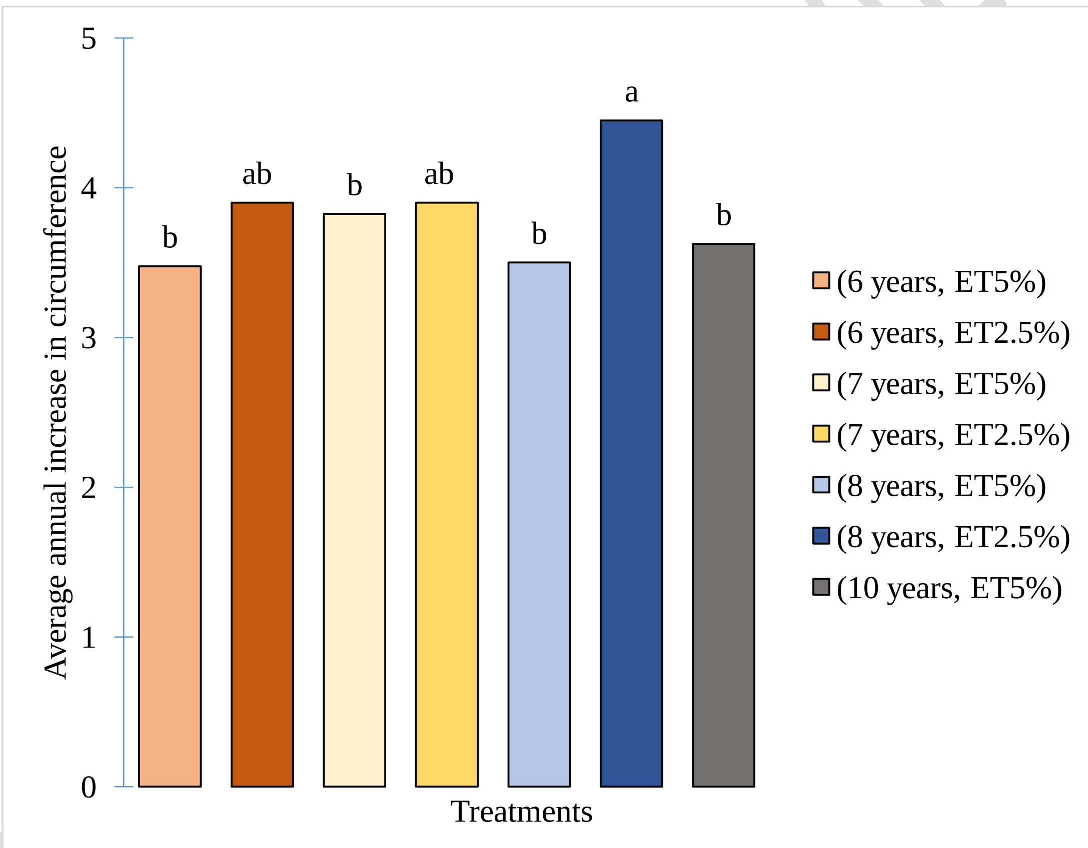

Figure 1: Average annual girth increase during four years of upward tapping of clone PB 260

3.3. Tapping Panel Dryness

The rate of tapping panel dryness for all treatments is presented in Figure 2. The annual average tapping panel dryness rate for all treatments was 2.6%. This rate was low and significantly influenced by treatment. Treatments 1 (6 years, ET5%; 0%), 2 (6 years, ET2.5%; 0%) and 6 (8 years, ET2.5%; 0.3%) yielded nearly zero annual mean rates. The rate of dry trees in the control treatment (10 years, ET5%; 7.75%) was significantly greater than in the other treatments. For the same year of upward tapping, at 6, 7, or 8 years, the designs that received the 5% Ethephon yielded more trees with dry notches.

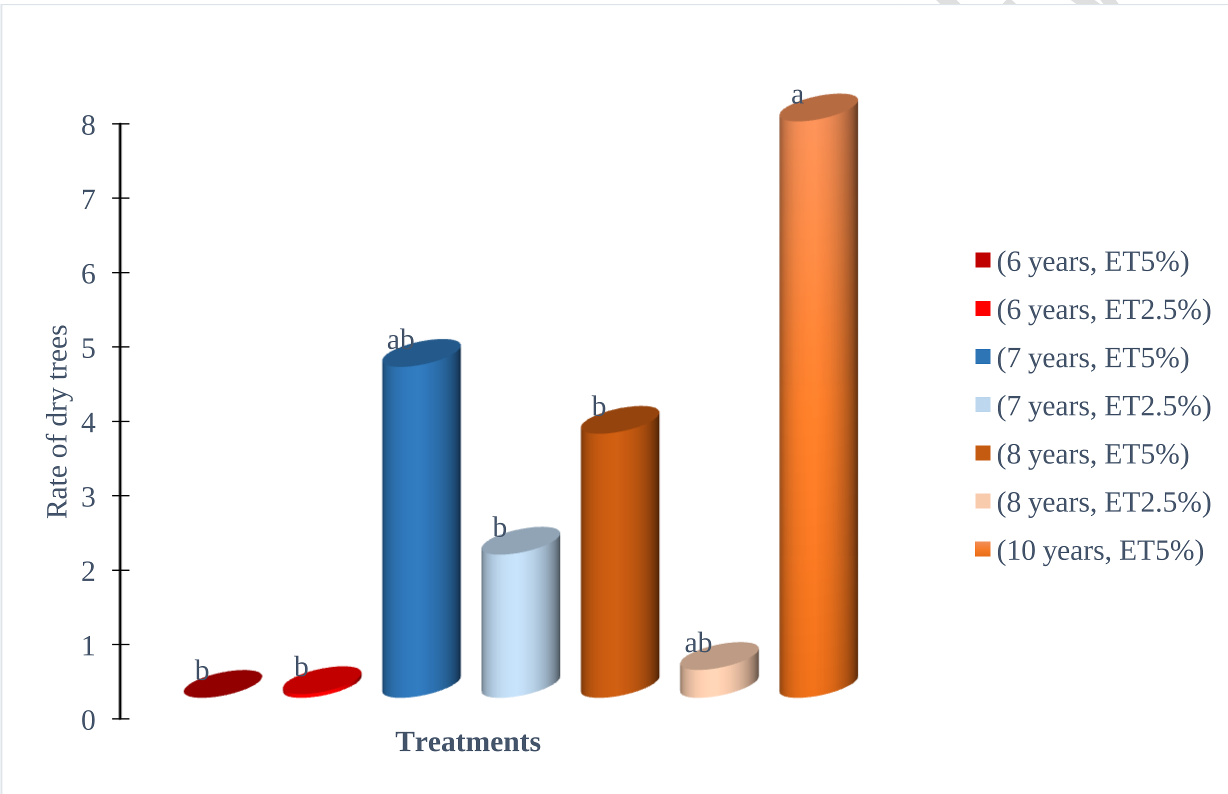

Figure 2: Average annual rate of trees with tapping panel dryness during four years of upward tapping

3.4. Physiological profile

The analysis of the dry extract rate shows that both at the beginning and at the end of the experiment, all the trees had very high latex dry extract rates (> 43, reference value; Table III). The average annual rate for all treatments combined was 46.6% at the beginning and 59.1% at the end of the experiment. At the beginning of the experiment, the dry rubber content varied statistically according to the treatment and fluctuated from 43 to 54.2%. The dry rubber content of treatments 3 (7 years, ET5%; 54%) and 4 (7 years, ET2.5%; 50%) was significantly higher than that of treatments 2 (6 years, ET5%; 45%), 5 (8 years, ET5%; 44%), 6 (8 years, ET2.5%; 43%) and 7 (control, 10 years ET5%; 43%). At the end of the trial, the rates all increased to an overall average of 59% and the different treatments had no significant effect on the dry extract rate.

At the beginning of the experiment, the average annual sucrose content of the latex, all treatments combined, was very low (2.4 $mmol.l^{-1}$) and did not vary relative to the treatment. At the end of the trial, there was an increase in content reaching 7.7 $mmol.l^{-1}$, which is an average content and consistent with that of an active metabolism clone. At the beginning of the trial, the averages per treatment were all the same, while at the end of the experiment the sucrose contents of the latex were influenced by the time of upward tapping. They increased, whatever the treatment. The highest contents were obtained from treatments 2 (6 years, ET2.5%; 9.8 $mmol.l^{-1}$) and 5 (8 years, ET5%; 10.4 $mmol.l^{-1}$) and the lowest from treatments 7 (10 years, ET5%; 5.2 $mmol.l^{-1}$) and 1 (6 years, ET5%; 5.1 $mmol.l^{-1}$).

The mean annual inorganic phosphorus content of the latex was average at the beginning and high at the end of the trial, with means for all treatments combined of 15.5 $mmol.l^{-1}$ and 24.3 $mmol.l^{-1}$ respectively. The Pi content of the latex of the different treatments was statistically different according to the treatment at the beginning and at the end of the trial. At the beginning of the trial, the Pi content of the latex of the control, tapped in reverse at 10 years (18 $mmol.l^{-1}$) and of treatments 5 (8 years, ET5%; 19 $mmol.l^{-1}$) and 6 (8 years, ET2.5%; 23.6 $mmol.l^{-1}$) were significantly equivalent and higher than those of the other treatments while that of treatment 2 (6 years, ET5%; 6.3 $mmol.l^{-1}$) was significantly lower. At the end of the trial, the contents were mostly high with contents ranging from 18.8 to 31.5 $mmol.l^{-1}$, giving significantly higher and identical values between them, obtained in treatments 1, 2, 3, 4 and 7.

The content of thiol compounds in the latex of all treatments is very low at the beginning of the trial (0.5 $mmol.l^{-1}$) and then becomes high at the end (0.8 $mmol.l^{-1}$) of the trial. All treatments, regardless of the period, gave statistically different levels. However, the trees opened at six years of age had the highest levels of SH-R at the beginning and at the end of the trial.

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Table III: Physiological parameters of latex from trees tapped in upward during four years

N°	Treatments	DRC (%)		Suc (mmol.l^{-1})		Pi (mmol.l^{-1})		R-SH (mmol.l^{-1})	
		Begin	End	Begin	End	Begin	End	Begin	End
1	S/4 U d3 6d/7 ET5% Pa 1(1) 6/y (6 years)	47 ±3,0 ab	58 ±2,6 a	2,4 ± 1,2 a	5,1 ± 1,1 b	6,3 ± 2,3 c	31,5 ± 6,2 a	0,76 ±0,6a	1,35 ± 0,2 a
2	S/4 U d3 6d/7 ET2.5% Pa 1(1) 6/y (6 years)	45 ±3,3b	59 ± 2,8 a	2,8 ± 1,9 a	9,8 ± 3,2 a	14,1 ± 3,8 b	28 ± 6,01 a	0,56 ± 0,2 ab	0,95 ± 0,2 a
3	S/4 U d3 6d/7 ET5% Pa 1(1) 6/y (7 years)	54±4,2 a	56 ± 2,7a	2,8 ± 1,8 a	7,3 ±2,6 ab	15,3 ± 4,1 b	21,8 ± 3,2 ab	0,52 ± 0,6 ab	0,64 ± 0,2 ab
4	S/4 U d3 6d/7 ET2.5% Pa 1(1) 6/y (7 years)	50 ±3,7 a	60 ± 2,6a	3,6 ± 2,1 a	8,3 ± 2,8 ab	13 ± 3,2 b	22,9 ± 3,4 ab	0,63 ± 0,8 ab	0,64 ± 0,2 ab
5	S/4 U d3 6d/7 ET5% Pa 1(1) 6/y (8 years)	44 ±3,5b	62 ± 2,7a	1,6 ± 1,2 a	10,4 ± 3,7a	19 ± 4,2 ab	19,8 ± 4,3 b	0,54 ± 0,3ab	0,66 ± 0,2 ab
6	S/4 U d3 6d/7 ET2.5% Pa 1(1) 6/y (8 years)	43 ±3,05b	59 ± 2,5a	1,9 ± 1,4 a	8 ±2,6 ab	23,6 ± 3,7 a	18,8 ± 4,1 b	0,59 ± 0,2 ab	0,59 ± 0,2 b
7	S/2 d3 6d/7 ET5% Pa 1(1) 6/y (Control, 10 years)	43 ±3,01 b	60 ±2,3 a	1,5 ± 0,7 a	5,2± 1,1 b	18 ± 4,1 a	27 ± 5,9 a	0,31 ± 0,2 b	0,66 ± 0,2 ab
	General averages	**47 ±3,3 a**	**59 ±2,2 a**	**2,5±1,2b**	**8,1±3,1a**	**15,2±3,8 b**	**26,9±3,4 a**	**0,6±0 ,1 a**	**0,8±0,32 a**

In the same column, the means assigned the same letters are not significantly different (Newman keuls 5%)

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4. DISCUSSION

The study of the effect of early upward tapping on the agrophysiological parameters of clone PB 260, during four years of upward tapping, shows that the average tree and tapping productivity (107.00 $g.t^{-1}.t^{-1}$) and kilogram per hectare (4450 $kg.ha^{-1}.yr^{-1}$) of the different treatments are good. This productivity at the tree and at the tapping is largely superior to the average productivity (between 65 and 80 $g.t^{-1}.t^{-1}$) in downward and upward tapping obtained from the works of [10-14]. Moreover, the yield obtained is higher than the national average annual yield of 1700 $kg.ha^{-1}.yr^{-1}$, which is among the best in the world [15-16]. These results show that early upward tapping positively affects tree production, and despite the reduction in cut length from half spiral in downward tapping to quarter spiral in upward tapping, upward tapping is significantly more productive. This result is contrary to the findings of [10] analysing the effect of reducing the length of the TPD on the productivity of the rubber tree. According to this work, short notches are less metabolically active than long notches. However, this result further confirms the fact that a properly exploited short notch, good tapping frequency and good concentration of stimulating paste, is at least as productive as a long notch [14]. These results also indicate an increased availability of photoassimilates at the top panel in contrast to the bottom panel. Furthermore, they confirm the conclusions of the work of many authors who have shown that upward tapping produces 25% more than downward tapping [19-20]. The productivity of more than 50 % of that of the control of rubber trees tapped at 6 and 7 years of age shows that from the sixth year of harvesting, the rubber trees have the necessary energy to withstand upward tapping. This result confirms the work of Obouuayeba *et al.* [3] and Moro *et al.* [19], which asserted that upward tapping in the sixth year is more productive than tapping in the tenth year. The increase in productivity of rubber trees that received the 5 % Etéphon stimulating paste could be explained by the fact that stimulation not only prolongs the duration of latex flow but also promotes the regeneration of latex exported after tapping, by activating the metabolism of the laticifers up to a certain limit [20].

Despite the good production level of the PB 260 clone, the average annual increase in trunk circumference of the trees is also of a good level [15, 16]. This result reflects the fact that the photosynthates necessary for latex production (secondary metabolism) within the laticifers [16],

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and for primary biomass production are consequently available to feed these two metabolisms equally within the tree [22-26]. It also indicates a low impact of rubber production on tree trunk thickness growth [27]. In this respect, the highest intra-lactose availability could be the one for which the antagonism between growth and production is the lowest [28]. This confirms once again an increased and especially non-limiting intracellular sucrose availability at the PB 260 clone level, regardless of the early upward tapping delay [28, 29]. Furthermore, early upward tapping trees (6 years, 7 years, 8 years) expressed relatively less sensitivity to tapping panel dryness than the downward tapping control. This result shows that early upward tapping is a practice that elicits less physiological disorder leading to the onset and exacerbation of dry notch. This statement is similar to and corroborates numerous studies [29, 18, 20, 15] conducted under upward tapping. The occurrence and evolution of tapping panel dryness is not a limiting factor in improving the productivity of a rubber plantation under upward tapping, especially early tapping [29, 3]. The higher rate obtained by downward tapping trees indicates that the applied half-spiral causes an overexploited state in the trees well before upward tapping. These assertions are supported by the findings of studies by Krishnakumar and Jacob [29] on the effect of changing the panel of a tree with tapping panel dryness in rubber trees. This work indicated that once a tree is affected by this disorder, it will likely develop on other panels as well.

In terms of physiological parameters, the latex dry extract rate (>43 % , reference value) reflects a high activity of the latex and therefore rubber regeneration metabolism, and the rubber factory, which is the laticifier cell, has been running or functioning with a good yield [28]. This high activity is the same regardless of the time of upward tapping. This justifies a good regeneration of the latex exported in upward tapping, because the dry extracts, the dry matter of the latex, reflect the efficiency of isoprenic syntheses within the laticifere cells as highlighted by Jacob et al. [27].

The sucrose content was very low at the beginning and average at the end of the experiment. In view of the high Pi content of the latex, this low sucrose content, which is characteristic of metabolically active clones, is probably due to a high utilization of sucrose in the rubber production mechanism. These results corroborate those obtained from the previous works [29, 28]. The increase in content at the end of the trial shows that the trees still have a good supply of photosynthates, this is probably ensured by the flow of elaborated sap and the hydrocarbon stock located in the drained area [24].

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Inorganic phosphorus in the latex can be considered as an indicator of the energy intensity of the metabolism of the laticifer cells [25]. Its average and high level expressed by the different treatments is due to the fact that the PB 260 clone of the fast metabolic activity class, like all other clones of this metabolic class, is known to have high inorganic phosphorus contents in the latex [16, 28]. This is one of the characteristics of clones of this class, and is also a good indication that the availability of metabolic energy in the laticifers is not a limiting factor in production [16]. This explains the good rubber productivity of this clone in this study regardless of the latex harvesting technology.

Thiol groups are a major parameter of latex diagnosis [26], as they determine the physiological state of the laticifers of the bled trees. In our trial, they were low at the beginning, and at a good level after four years of experimentation. This low level at the beginning is not the result of a weak protection, but rather of the low sugar content, another limiting factor [2-18]. Indeed, the regeneration of the thiol group also requires energy in the form of ATP and therefore also depends on a part of the sugar available in situ, since it is the origin of the molecular carbon [25, 28]. The increase in R-SH content at the end of the trial reflects good protection by these molecules at the laticifers on the one hand and strong metabolic activation due to the latex harvesting technologies applied on the other hand [2-18].

5. Conclusion

At the end of this study, which aimed to evaluate the effect of early upward tapping on the agrophysiological and sanitary parameters of clone PB 260, we can conclude that early upward tapping does not negatively affect the productivity of the trees of this clone, quite the contrary. Productivity was very good overall, but that of the trees tapped in reverse at less than 10 years of age was higher than that of the downward bled trees, with a rate of 42%. In addition, the radial vegetative growth was satisfactory, the tapping panel dryness rate negligible and the physiological profile balanced. From these results, we can conclude that upward tapping can be started as early as the sixth year without risk of negatively affecting the physiological condition of trees of clone PB 260.

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