Original Research Article

Influence of downward tapping delay on agronomic parameters of upward tapping rubber trees

Abstract

The nine-year period of downward tapping prior to upward tapping is often considered too long and irrelevant. Thus, a study was carried out to determine the minimum time needed for downward tapping for which the agronomic parameters (rubber production, vegetative growth) of the rubber trees could best be expressed in upward tapping. Clones with slow (PB 217 and IRCA 41), moderate (GT 1) and fast (PB 260 and IRCA 18) metabolisms were used as plant material in the experiments carried out in Gagnoa, Bettié, Daoukro, San Pedro and Divo. The rubber trees were tapped in a half-spiral downward direction at different times followed by quarter-spiral upward or upward tapping. The experimental design was a Fisher block design with 9 treatments and 4 replications. The results showed that upward tapping preceded by downward tapping for 5 and/or 6 years was the best regardless of the metabolic activity class of the clone. Rubber production expressed in $kg.ha^{-1}$. year-1 [Slow (5y-2675 ± 79) (6y-2488 ± 59) (T9y-2238 ± 45); Moderate ((5y-5417 ± 127) (6y-5094 ± 141) (T9y-3993 ± 58); Fast (5y-5210 ± 239) (6y-4733 ± 500) (T9y-3723 ± 245)] resulting from these upward tappings increased with an increasing gradient of clone metabolism without, however, detrimental to vegetative growth ($cm.\ yr^{-1}$) [Slow (5 yr-3.90 ± 1.27) (6 yr-4.05 ± 1.48) (T9 yr-3.40 ± 1.13); Moderate ((5 yr-3.02 ± 0.25) (6 yr-2.80 ± 0.05) (T9 yr-2.39 ± 0.02); Fast (5 yr-4.27 ± 0.42) (6 yr-3.97 ± 0.28) (T9 yr-3.60 ± 0.05)]. These results show that upward tapping in year 6 is more advantageous than tapping in year 10.

Keywords: Hevea brasiliensis; PB 217, IRCA 41, GT 1, PB 260 and IRCA 18; rubber production; vegetative growth; Ivory Coast

Introduction

The rubber tree, botanical name Hevea brasiliensis, is a perennial plant cultivated for its latex, which is the main source of commercially exploited natural rubber [1]. **(**It is indispensable in the industrial field.Indeed, rubber from the rubber tree is used in the manufacture of gaskets, surgical gloves, rubber, shoes, etc., with properties of elasticity and impermeability that make it an irreplaceable material in certain uses today [2]. In the framework of modern and efficient management of a rubber plantation, two latex harvesting systems (downward tapping and upward tapping) are applied in a distinct and complementary manner. This is done in such a way that the classical downward tapping of the low tapping panel (BO) is immediately followed, and/or alternated, by upward or upward tapping of the high tapping panel (HO) [3]. The current trend is to improve the rubber productivity of the rubber tree in order to increase income. This improvement in productivity inevitably involves optimal exploitation of the tree, which consists of upward tapping, which is clearly more productive in terms of rubber [4-5].However, it is known that the high rubber production of the tree weakens it in the short, medium and long term. The performance of upward tapping in terms of rubber productivity has been proven [4-6-7].However, the influence of the low panel, tapped downwards, on the high panel, tapped upwards (inverted) is very rarely mentioned [8]. This is all the more true since upward tapping can be carried out early and/or late [9]. The period of downward tapping preceding upward tapping could play a determining role in achieving the objective of sustainably improving the rubber productivity of the plantation.Numerous studies, including those of [8], have shown this without, however, quantifying a superiority in rubber productivity of upward tapping over downward tapping. On the other hand, the study by [7]indicated that upward tapping, at the beginning of downward tapping, gave a rubber productivity statistically comparable to that of downward tapping.In contrast, early upward tapping preceded by four years of downward tapping is more productive than downward tapping [9]**.** Based on this result, it was important to determine, from an agronomic point of view, the nature and importance of the influence of upward tapping on reverse tapping. Specifically, the effect of the period of downward tapping prior to upward tapping on the production and vegetative growth of upward tapping should be assessed.

Study site

This study, which highlights the influence of downward tapping on the productivity of upward tapping of rubber clones, was conducted in Côte d'Ivoire. The rubber growing area of Côte d'Ivoire is composed of the mountainous western forest zone and the southern part. The various trials were conducted on experimental plots in five localities (Gagnoa, Bettié, San Pedro, Divo and Daoukro)**(Figure 1)**. The different characteristics of these localities are recorded in the table below**(Table 1)**.

Table 1: Characteristics of the study localities

Locality	Geographical coordinates	Vegetation	Soil	Precipitation (mm/year)	Temperature (°C)	Insolation (Hours/year)	Relative humidity (%)
Divo	5°50'N, 5°21'O	Cleared forest Mesophilic	Highly desaturated ferralite, gravelly	1400 - 1600	25	1900 - 2000	85
Bettié	6°04'N, 3°23'O	Dense humid forest semi-deciduous	Highly desaturated ferralite, gravelly	1400 - 1600	26	1900 - 2000	80
Daoukro	7°15'N, 3°52'O	grassy savannah to the west and degraded forest to the east, north and south.	Highly desaturated ferralite, gravelly	1200 - 1400	26	1900 - 2000	80
Gagnoa	6°08'N, 5°56'O	Dense humid forest semi-deciduous	Low desaturated ferrallitic, gravelly	1400 -1600	28	1900 - 2000	80

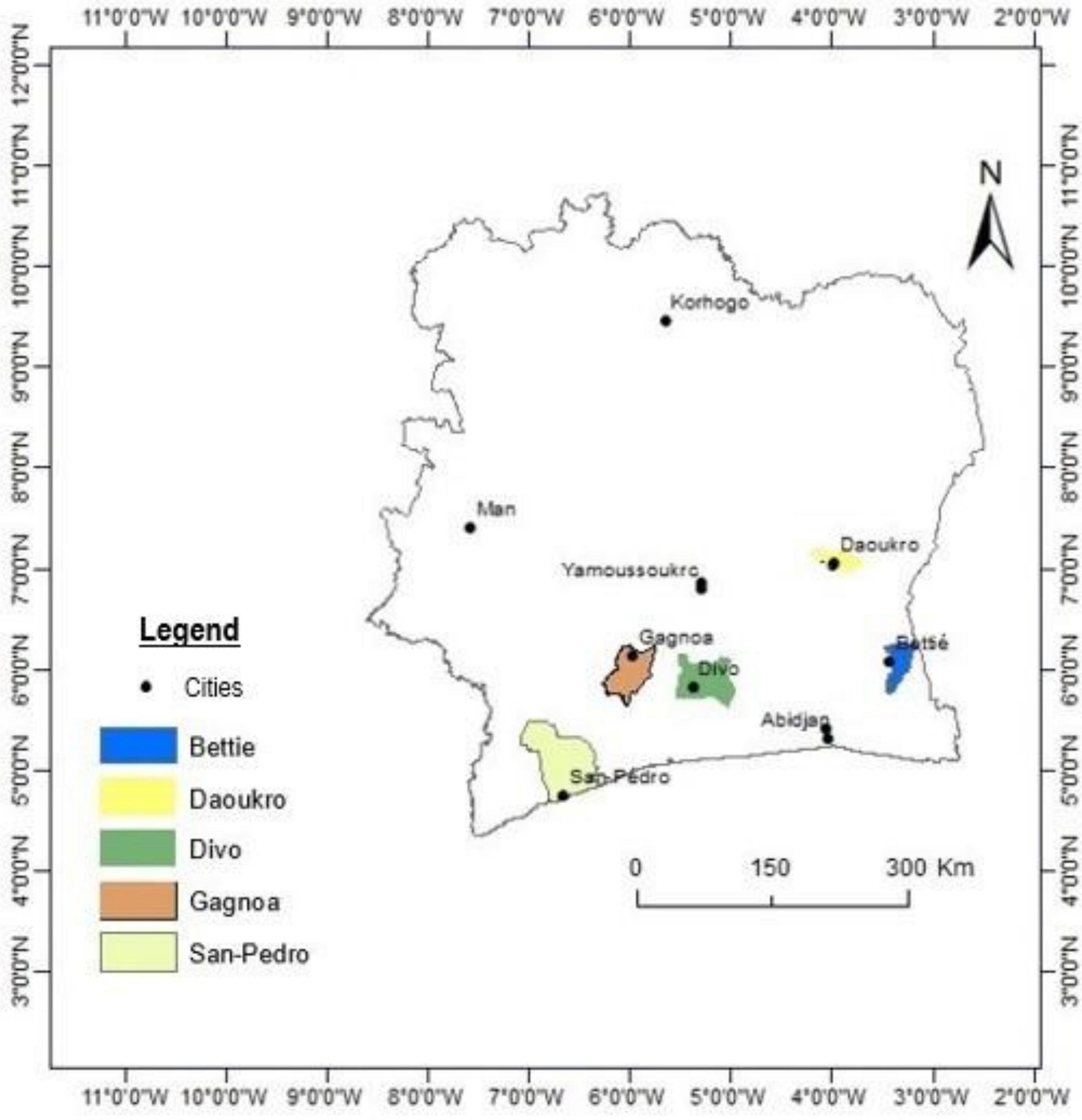

Figure 1: Map of Côte d'Ivoire showing the study localities

1. MATERIALS AND METHODS

1.1 Plant material

The plant material consists of the rubber clones GT 1, IRCA 18, IRCA 41, PB 217 and PB 260**(Table 2)**.

Table 2: Characteristics of the clones studied

Clones	Origin	Metabolic activity class	particularity	Stimulation regime
PB 217	Prang besar (PB), in Malaysia; female parent PB 5/51 and male parent PB 6/9	Slow metabolism; high carbohydrate reserve and thiol group content; low inorganic phosphorus content	Vigorous but very heterogeneous; latex flow difficult; steady increase in average production in the first three years; not very susceptible to dry rot; wind resistant	Intense Stimulation
IRCA 41	Institut de Recherche sur le Caoutchouc (IRCA), in Côte d'Ivoire; genetic cross: PB 5/51 and GT 1	Slow metabolism; high sugar reserves; low inorganic phosphorus content	Vigorous; very strong increase in production from the fifth year	Intense Stimulation
GT 1	Gondang Tapen (GT), Java, Indonesia	Moderate metabolism; moderate sugar and inorganic phosphorus content; all physiological characteristics favourable to rubber production	Production per tree is not very high, but this is largely compensated by its good homogeneity; not very susceptible to dry rot and resistant to wind breakage	Moderate stimulation
PB 260	Prang besar (PB), in Malaysia; genetic cross: PB5/51 and PB 49	Active metabolism; high inorganic phosphorus content; relatively low sucrose and thiol group content	Sensitive to dry notching and moderately resistant to gales	Moderate stimulation
IRCA 18	Institut de Recherche sur le Caoutchouc (IRCA), in Côte d'Ivoire; genetic cross: PB 5/51 and RRIM 605	Active metabolism; low sucrose reserves within the latex; risk of physiological imbalance in case of over-stimulation	Very rapid onset and relatively late defoliation; high production potential; susceptible to wind breakage	Moderate stimulation

1.2 Methods

1.2.1. Data collection

1.2.1.1. Selection of plots

The experiment was conducted in a non-industrial rubber farm environment over a period of eight years (October 2006 to October 2014). Two plots were selected on each of these sites. The elementary plots consisted of 20 trees. At the start of this study, the trees were in their 5th year of downward tapping on panel B. In each of the two plots per site, trees were selected on the basis of :

- the homogeneity of their circumference (≥ 55 cm), after elimination of border trees;

- the homogeneity of their unstimulated production (field weight) determined previously with 2 to 3 coagulums corresponding to the number of taps;

- the homogeneity of the downward bleeding history over the last 5 years;

- of the year of opening or of the tapping made at a height of 1.40 m from the ground, for upward tapping patterns according to the established protocol.

1.2.1.2. Experimental design

The Fisher block experimental design consisted of 9 treatments with 4 replications. Each elementary plot consisted of 20 rubber trees**(Figure 2)**.

A	B	C	D	E	F	G	H	I
B	C	D	E	F	G	H	I	A
C	D	E	F	G	H	I	A	B
D	E	F	G	H	I	A	B	C
E	F	G	H	I	A	B	C	D
F	G	H	I	A	B	C	D	E
G	H	I	A	B	C	D	E	F
H	I	A	B	C	D	E	F	G
I	A	B	C	D	E	F	G	H

Figure 2: Experimental design

1.2.2. Treatments

The trial started in the 6th year (year 6) of tapping (season 2006-2007) and ended in the 13th year (year 13) of latex harvest (season 2013-2014), i.e. 8 years.A total of 9 treatments (A, B, C, D, E, F, G, H and I: the control) were established. The latex from the tapping was collected in a plastic cup using a tapping knife or gouge.Downward tapping was done in a half spiral and upward tapping in a quarter spiral. Tapping was carried out every three days, six days a week. Sunday was the day of rest for tapping. They were carried out 12 months out of 12.The coagulum, removed at the next tapping, was collected, weighed monthly (fresh weight, F.W.) and stored. The trees were stimulated on the tapping panel, in a 1 cm wide strip, at a rate of 1 g of stimulation product per tree [10]. The stimulant used was obtained by mixing Ethrel and palm oil. Ethrel is the commercial name for the active ingredient (a.i.) Etephon (2-chloroethyl phosphonic acid). Ethrel contains 480 g/l of active ingredient. The density of Ethrel at 480 g/l is 1.2; this gives 400 g/kg of active ingredient, or 40%.The stimulating sprays used in the experiments of this study have concentrations of 2.5 and 5% of Ethephon respectively in downward tapping and/or upward tapping. The stimulation frequencies used varied from 6 to 13 per year (6-13/y) depending on the treatment. The growth in trunk thickness of the rubber trees was measured with a tape measure.

The treatments are as follows:

A: Upward tapping at 6 years (downward tapping to 5 years), stimulated at 5%.

B: Upward tapping at 6 years (downward tapping to 5 years), stimulated at 2.5%.

C: Upward tapping at 7 years (downward tapping up to 6 years), stimulated at 5 %

D: Upward tapping at 7 years (downward tapping up to 6 years), stimulated at 2.5%

E: Upward tapping at 8 years (downward tapping up to 7 years), stimulated at 5

F: Upward tapping at 8 years (downward tapping to 7 years), stimulated at 2.5

G: Upward tapping at 9 years (downward tapping up to 8 years), stimulated at 5

H: Upward tapping at 9 years (downward tapping up to 8 years), stimulated at 2.5

I: Control, classic upward tapping at 10 years (downward tapping up to 9 years), 5% (current panel tapping scheme)

1.2.3. Measurements carried out on agronomic parameters

1.2.3.1. Rubber production

Rubber production was recorded per treatment. The processing coefficient (PC), the percentage of dry rubber in a given sample of fresh rubber, was used to calculate the dry rubber production (dry weight, DW) for each pattern. It was calculated from one coagulum sample per treatment. Each sample was weighed (fresh weight), creped, oven dried at 80°C for 24 hours and reweighed (creped dry weight). The P.C. is defined by the following formula:

$$\mathbf{P.C = D.W \times (F.W)^{-1} \times 100}$$

1.2.3.2. Radial vegetative growth

The growth in thickness of the rubber tree trunk was assessed by measuring the circumference at 1.70 m above the ground, using a tape measure. Measurements were taken at the beginning of the experiment and then at the end of each physiological cycle just before the onset of natural defoliation (January to February), which coincides with very weak growth of the rubber trees. The average annual increase in girth was determined by the following relationship:

Accrn= Circn- Circn-1

Accrn: average annual increase in circumference ;

Circn: Circumference of trees in the current season;

Circn-1: circumference of trees from the previous season.

1.2.4. Statistical analysis

The statistical analyses were performed with the XLSTAT-Pro 7.5 statistical software. The analysis of variance with one classification criterion, followed by a comparison of means by the Student-Newman-Keuls test and the Scheffe test, were performed on the mean values of production and radial vegetative growth at the 5% threshold.

2- RESULTS

2.1. Clones with low or slow metabolism

2.1.1. Dry rubber production per hectare of slow metabolism clones IRCA 41 and PB 217

Overall, downward tapping had a significant effect on the average annual upward tapped rubber production of the slow metabolism clones (IRCA 41 and PB 217) **(Table 3).**The average annual rubber production generated by treatments A [upward tapping at 6 years and stimulated with 5% Ethephon concentrate (2695 ± 79 kg.ha-1.yr^{-1})] and B [upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate (2655 ± 35 kg.ha-1.yr^{-1})], with rubber production gains of 20 and 19%, respectively, compared to the control, were the highest.These productions are not statistically different from those of treatments C to G, which varied from 2473 ± 27 to 2516 ± 36 kg.ha-1.yr^{-1}. Conversely, the average annual production generated by treatment I (control) is the lowest (2238 ± 45 kg.ha-1.yr^{-1}) but is not different from that expressed by treatment H (upward tapping at 9 years of age and stimulated with 2.5% Ethephon concentrate) which is 2386 ± 110 kg.ha-1.yr^{-1}**(Table 3).**

In the IRCA 41 clone, treatments A and B also recorded the highest average annual rubber production, 2752 and 2680 kg.ha-1.yr^{-1}respectively. Similarly, Treatment I [control (conventional upward tapping at 10 years)] had the lowest average annual production (2270 kg.ha-1.yr^{-1}). The other treatments from C to H had statistically identical mean annual production, fluctuating between 2542 and 2464 kg.ha-1.yr^{-1}.

For clone PB 217, the average annual rubber production from upward tapping, ranging from 2206 to 2639 kg.ha-1.yr^{-1}, also discriminated between treatments **(Table 3).** Treatments A and B expressed the highest average annual production, respectively 2639 and 2630 kg.ha-1.yr^{-1}. Also, treatment I [control (classic upward tapping at 10 years)] had the lowest average annual production (2206 kg.ha-1.yr^{-1}).The other treatments, with the exception of H (upward tapping at 9 years and stimulated with 2.5% Ethephon concentrate) with an average annual production of 2464 kg.ha-1.yr^{-1}, presented average annual productions that were not statistically different from those expressed by treatments A and B.

Table 3. Dry rubber production of slow-metabolizing clones

	Dry rubber production (kg.ha-1.yr^{-1}**)**			
Treatments	**IRCA 41**	**PB 217**	**Averages**	**Gain %**
A	2 752 a	2 639 a	**2695 ± 79 a**	20
B	2 680 a	2 630 a	**2655 ± 35 a**	19
C	2 517 b	2 460 ab	**2488 ± 40 ab**	11
D	2 531 b	2 447 ab	**2489 ± 59 ab**	11
E	2 542 b	2 491 ab	**2516 ± 36 ab**	12
F	2 454 b	2 493 ab	**2473 ± 27 abc**	10
G	2 527 b	2 434 ab	**2480 ± 65 ab**	11
H	2 464 b	2 308 b	**2386 ± 110 bc**	7
I	2 270 c	2 206 c	**2238 ± 45 c**	0

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

2.1.2. Radial vegetative trunk growth of trees of the slow-metabolizing clones IRCA 41 and PB 217

Overall, the analysis of **Table 4** shows that the period of upward tapping did not significantly influence the mean annual increases in upward tapped trunk circumference of the trees of the slow-metabolism clones (IRCA 41 and PB 217) despite the fact that they fluctuated between 3.25 and 4.05 cm.yr^{-1}.However, for clone IRCA 41, treatments A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate) and B (upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate) showed the highest mean annual trunk increments of 4.8 cm.yr^{-1} and 5.1 cm.yr-1 respectively.This is not the case for the other treatments where the mean annual tree trunk increments fluctuated between 3.9 and 4.4 cm.yr^{-1} and are statistically the lowest and identical.As for clone PB 217, the average annual trunk growth of trees from clone PB 217 from treatment C (upward tapping at 7 years of age and stimulated with 5% Ethephon concentrate) is the highest (2.2 cm.yr^{-1}) and the only one to be statistically higher than that of treatment I (control), which is 1.8 cm.yr^{-1}.However, this value expressed by treatment C is statistically identical to those recorded by treatments A, B and D, which are of the order of 2.0 cm.yr^{-1}. The other treatments from E to H showed the lowest and statistically identical mean annual tree trunk increments, fluctuating between 1.5 and 1.6 cm.yr^{-1}.

Table 4. Trunk circumference growth of slow-metabolizing clone trees

	Circumference increase (cm.yr^{-1})		
Treatments	**IRCA 41**	**PB 217**	**Moyennes**
A	4,8 a	2,0 ab	**3,90 ± 1,27 a**
B	5,1 a	2,0 ab	**4,05 ± 1,48 a**
C	4,4 b	2,2 a	**3,30 ± 1,55 a**
D	4,4 b	2,0 ab	**3,70 ± 0,98 a**
E	4,1 b	1,5 c	**2,80 ± 1,83 a**
F	3,9 b	1,6 c	**3,25 ± 0,91 a**
G	4,2 b	1,6 c	**3,40 ± 1,13 a**
H	4,0 b	1,5 c	**3,25 ± 1,06 a**
I	4,0 b	1,8 b	**3,40 ± 0,84 a**

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

2.2 Moderate metabolism clones

2.2.1. Dry rubber production of the moderate metabolism clone GT 1

Analysis of **Table 5** reveals that treatment A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate) stands out from the other treatments by having the highest average annual rubber production (5461 ± 16 kg.ha-1.yr^{-1}), with a 37% gain in production over the control.However, this production is not statistically different from treatments B (5373 ± 127 kg.ha-1.yr^{-1}), C (5220 ± 28 kg.ha-1.yr^{-1}), D (4967 ± 141 kg.ha-1.yr^{-1}), E (4780 ± 231 kg.ha-1.yr^{-1}) and F (4683 ± 387 kg.ha-1.yr^{-1}).On the other hand, treatment I (control) had the lowest average annual rubber production (3993 ± 58 kg.ha-1.yr^{-1}), but this was not statistically different from treatments E (4780 ± 231 kg.ha-1.yr^{-1}), F (4683 ± 387 kg.ha-1.yr^{-1}), G (4570 ± 345 kg.ha-1.yr^{-1}) and H (4373 ± 301 kg.ha-1.yr^{-1}).

Table 5. Dry rubber production of the moderate metabolism clone GT 1

Treatments	Dry rubber production (kg.ha-1.yr^{-1})	Gain (%)
A	5461 ± 16 a	37
B	5373 ± 127 ab	34
C	5220 ± 28 abc	30
D	4967 ± 141 abc	24
E	4780 ± 231 abcd	20
F	4683 ± 387 abcd	17
G	4570 ± 345 bcd	14
H	4373 ± 301 cd	9
I	3993 ± 58 d	0

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

2.2.2. Radial vegetative trunk growth of trees of the moderately metabolically active clone GT 1

Analysis of **Table 6** indicates that treatments A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate), B (upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate) and F (upward tapping at 8 years and stimulated with 2.5% Ethephon concentrate) differ from the other treatments in having the highest mean annual trunk increments.These mean annual tree trunk increments ranging from 3.00 to 3.03 cm.yr^{-1}are not statistically different from those generated by treatments C (2.83 ± 0.01 cm.yr^{-1}), D (2.76 ± 0.08 cm.yr^{-1}) and E (2.82 ± 0.07 cm.yr^{-1}), which are statistically identical. On the other hand, treatment I [control (conventional upward tapping at 10 years)] showed the lowest mean annual trunk increment (2.39 ± 0.02 cm.yr^{-1}).This is statistically identical to those presented by treatments G (upward tapping at 9 years and stimulated with 5% Ethephon concentrate) and H (upward tapping at 9 years and stimulated with 2.5% Ethephon concentrate), which are respectively 2.46 ± 0.09 cm.yr^{-1}and 2.50 ± 0.03 cm.yr^{-1}.

Table 6. Vegetative trunk growth of trees of the moderate metabolism clone GT 1

Treatments	**Circumference increase** (cm.yr^{-1})
A	3,03 ± 0,25 a
B	3,01 ± 0,17 a
C	2,83 ± 0,01 ab
D	2,76 ± 0,08 ab
E	2,82 ± 0,07 ab
F	3,00 ± 0,15 a
G	2,46 ± 0,09 b
H	2,50 ± 0,03 b
J	2,39 ± 0,02 b

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

2.3 "Fast" or active metabolism clones

2.3.1. Dry rubber production of 'fast' metabolising clones IRCA 18 and PB 260

Overall, the analysis in **Table 7** reveals that the period of downward tapping had a significant effect on the average annual rubber production from upward tapping of the fast metabolising clones (IRCA 18 and PB 260). The average annual rubber production shown by treatment A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate), with a production gain of 41% compared to the control, is the highest (2695 ± 79 kg.ha-1.yr^{-1}).This is not statistically different from those generated by treatments B to G, with statistically identical production ranging from 4088 ± 277 to 5158 ± 234 kg.ha-1.yr^{-1}. Conversely, the average annual production recorded by treatment I (control (classic upward tapping at 10 years)) is the lowest (3723 ± 29 kg.ha-1.yr^{-1}) but is not different from those expressed by treatments C to H, despite the fact that these varied from 3967 ± 212 to 4951 ± 351 kg.ha-1.yr^{-1}**(Table 7).**Particularly for the IRCA 18 clone, the average annual rubber production expressed by treatment A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate) is also the highest (5408 kg.ha-1.yr^{-1}), without however being different from those generated by treatments B (upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate (5324 kg.ha-1.yr^{-1}) and C (upward tapping at 7 years and stimulated with 5% Ethephon concentrate (5200 kg.ha-1.yr^{-1})) which are statistically identical.Similarly, Treatment I [control (conventional upward tapping at 10 years)] had the lowest average annual rubber production (3744 kg.ha-1.yr^{-1}). This was not statistically different from treatments F (upward tapping at 8 years and stimulated with 2.5% Ethephon concentrate), G (upward tapping at 9 years and stimulated with 5% Ethephon concentrate) and H (upward tapping at 9 years and stimulated with 2.5% Ethephon concentrate), which had yields ranging from 4118 to 4368 kg.ha-1.yr^{-1}**(Table 7).**

Particularly in the PB 260 clone, treatments A (upward tapping at 6 years and stimulated with Ethephon 5% concentrate), B (upward tapping at 6 years and stimulated with Ethephon 2.5% concentrate) and C (upward tapping at 7 years and stimulated with Ethephon 5% concentrate) recorded the highest average annual yields of 5,117, 4,992 and 4,703 kg.ha-1.yr^{-1}respectively.Treatment I [control (conventional upward tapping at 10 years)] had the lowest average annual production (3702 kg.ha-1.yr^{-1}). The other treatments from D to H had mean annual rubber yields ranging from 3817 and 4129 kg.ha-1.yr^{-1}. These are both statistically identical to each other and to all treatments.

Table 7. Dry rubber production of fast metabolizing clones

	Dry rubber production (kg.ha-1.yr^{-1}**)**			
Treatments	**PB 260**	**IRCA 18**	**Averages**	**Gain %**
A	5117 a	5408 a	**5262 ± 205 a**	41
B	4992 a	5324 ab	**5158 ± 234 ab**	38
C	4703 a	5200 ab	**4951 ± 351 abc**	33
D	4120 ab	4908 b	**4514 ± 557 abc**	21
E	4129 ab	4701 b	**4415 ± 404 abc**	18
F	3990 ab	4368 bc	**4179 ± 267 abc**	12
G	3892 ab	4284 bc	**4088 ± 277 abc**	10
H	3817 ab	4118 bc	**3967 ± 212 bc**	6
I	3702 b	3744 c	**3723 ± 29 c**	0

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

2.3.2. Radial vegetative growth of the trunk of trees of the 'fast' metabolising clones PB 260 and IRCA 18

Overall, treatment A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate) produced the greatest average annual increase in tree trunk circumference (4.55 ± 0.21 cm.yr^{-1}). This is statistically identical to the other treatments, except for the control (classic upward tapping at 10 years), which is the smallest (3.60 ± 0.00 cm.yr^{-1}).However, individually, the analysis of the results in **Table 8** shows that, irrespective of the fast metabolizing clone (IRCA 18 and PB 260), the period of downward tapping had no significant effect on the radial vegetative growth of upward tapped trees.

Table 8. Trunk girth increase of trees of fast metabolizing clones

	Circumference increase (cm.yr^{-1})		
Treatments	**PB 260**	**IRCA 18**	**Averages**
A	3,7 a	4,3 a	**4,00 ± 0,42 ab**
B	4,4 a	4,7 a	**4,55 ± 0,21 a**
C	3,8 a	4,2 a	**4,00 ± 0,28 ab**
D	3,8 a	4,1 a	**3,95 ± 0,21 ab**
E	3,5 a	3,9 a	**3,70 ± 0,28 ab**
F	3,8 a	3,8 a	**3,80 ± 0,00 ab**
G	3,8 a	3,5 a	**3,65 ± 0,21 ab**
H	3,9 a	3,8 a	**3,85 ± 0,07 ab**
I	3,6 a	3,6 a	**3,60 ± 0,00 b**

Mean values with the same letter are not significantly different (Newman-Keuls and Scheffe 5% test)

3. DISCUSSION

The best results in annual rubber production, regardless of metabolic activity class, were obtained with treatments A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate), B (upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate) and C (upward tapping at 7 years and stimulated with 5% Ethephon concentrate), which had relatively shorter downward tapping periods.The results obtained in the present study show that the performance of upward tapping is linked to the previous tapping, which is downward tapping. These results also indicate that a minimum period in years of downward tapping is necessary to make upward tapping efficient.This delay, regardless of the metabolic activity classes, is five (5) years of downward tapping, as far as the results of the present investigation are concerned. This is supported by the work of [2] and [3] who showed that at the 5th year of latex harvesting the trees of the GT 1 clone in the unstimulated rubber production regime have a level of production statistically equivalent to that of the other stimulated trees.This could mean that by the 5th year of latex harvesting, the laticifier cells of the rubber tree are able to sufficiently activate the latex biosynthesis process without requiring exogenous hormonal stimulation.

In addition, the high yields of treatments A (upward tapping at 6 years and stimulated with 5% Ethephon concentrate) and B (upward tapping at 6 years and stimulated with 2.5% Ethephon concentrate) highlight two cases. Firstly, the opening height in the management of the rubber reserves of the drained area and secondly, the activating effect of the metabolism by tapping and hormonal stimulation, as shown by [11] and [12].This illustrates that the overall activation of the tapped tree occurs after five (5) years of down tapping. Thus, tapping downwards for five years is sufficient to have a positive effect on upward tapping rubber production. This fact meets exactly the expectations of the producers who are looking for a quick and significant return on their investment.So, based on the results of the present investigation, there is no need to wait until the tenth year of latex harvesting to switch from downward tapping to upward tapping, which is significantly more productive [8].

The percentage gains in rubber production in this study increased in treatments A (upward tapping at six years after five years of downward tapping) according to the metabolic activity class: 20% for slow, 37% for moderate and 41% for fast.Indeed, these results could be related to the intrinsic energy of the clones in each metabolic activity class. These results corroborate those of [13-14] who showed that rubber production evolves positively along an increasing gradient of the metabolic activity class of the rubber clone.In terms of mean annual girth increment of rubber trees, trees tapped for 5 and 6 years expressed the best values irrespective of clone and metabolic activity class. The control trees, tapped in upward tapping at 10 years (downward tapping for 9 years), showed the lowest average annual growth rates of rubber tree trunk circumference.This shows, in the context of this study, that the shorter the period of downward tapping of the trees, the greater the average annual increases in tree circumference. This is a good indication that downward tapping periods of 5 and/or 6 years are not detrimental to the radial vegetative growth of the rubber tree trunk.These circumference increase results reinforce the strong presumption that upward tapping at 10 years was late rather than normal. This presumption, which became almost a certainty with the work of [15] and [7], is now a proven fact following this latest study.Better still, they show that upward tapping at 6 years (or downward tapping can now be practised for five (5) years, and that upward tapping can be envisaged from the 6th year onwards) is indeed the best timeframe for upward tapping of rubber trees, whatever the clone and the class of metabolic activity. Since the average annual increase in circumference of upward tapped rubber trunks at 6 years (treatment A) is significantly higher than those of the other treatments, including the control.Although the results of the present study are in contradiction with those of [16] who showed an antagonism between production and vegetative growth of rubber trees, it should be noted that upward tapping at 6 years after a 5-year downward tapping is not detrimental to vegetative growth.

CONCLUSION

The present study on the influence of upward tapping on the agronomic parameters of upward tapped rubber trees reveals that the upward tappings performed after 5 and/or 6 years of upward tapping are the best. Rubber yields from these best upward tappings increase with the increasing gradient of the metabolic activity class of the rubber clone.Furthermore, the antagonism between production and vegetative growth is reduced when early upward tapping is practised in the 5th and/or 6th year of tapping. Therefore, the results of the present investigation indicate that it is more advantageous to tap the upward tapping in the 6th year than to wait until the 10th year of latex harvest to switch from downward tapping to upward tapping, which is much more productive.

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