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Evolution of the Rate of Live and Tapped Trees of *Hevea brasiliensis* Clones, Muell. Arg. the First 15 Years of Plantation Establishment

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The density of tapped rubber trees in a plantation is a determining parameter of its productivity. It is related to the number of trees planted per hectare, the evolution of which can be influenced by several factors that act on the trees from the year of establishment to the time of tapping. To this end, a study to determine the evolution of the rate of live trees and tapped trees of eight rubber clones during the first fifteen years of establishment was carried out in southwestern Côte d'Ivoire. At opening, rubber trees planted at 510 trees/ha (7 m x 2.80 m) were bled in a descending half-spiral at different tapping and stimulation frequencies. The experimental design was a Fisher block design with 6 treatments (d2, d3/4y, d4/4y, d4/8y, d5/8y, d6/10y) and 3 replications. The results

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revealed that the rate of live trees and tapped trees was not influenced by either clone or latex harvesting treatment. The rate of live trees decreased progressively from the immature phase of the plantation (94.71 ± 1.34%) to the end of the downward tapping (91.55 ± 0.67%). The rate of tapped trees increases from the time of planting (69.51 ± 8.03%), over the years (92.00 ± 1.39%) until it equals the rate of live trees (92.00 ± 1.08%) before gradually decreasing to 88 ± 3.78%. It should be noted that the factors influencing the evolution of the rates of live and taped trees caused less damage to the rubber trees. And this influence is not dependent on clone, metabolic activity class and latex harvesting system.

Keywords: Density of trees; live trees; tapped trees; immature period; Hevea brasiliensis.

1. INTRODUCTION

The cultivation of rubber trees (*Hevea brasiliensis*, Euphorbiaceae), which originated two centuries ago in the Amazon basin, nowadays in Brazil, has become the object of an important economic activity throughout the world, since it generates enormous revenues [1,2]. The rubber tree is the main source of natural rubber used in various fields, especially in tires [3,4]. Tires made from natural rubber, especially rubber trees, are more resistant to tearing than those made from synthetic rubber [5,6]. Planting density is the number of trees planted on a given area. In rubber cultivation, this planting density is variable. Taking into account the challenges of the rubber industry, one of the important questions currently posed to research is the intensification of latex production systems. The optimization of planting systems and densities is one of the solutions for this intensification, which is without destructive effects on the environment [7,8]. The results of experiments on planting systems and densities have been reported by some authors such as Rodrigo et al, [9] and Obouayeba et al, [10]. Indeed, high planting densities, often inducing strong competition linked to the distance between trees, can lead to a reduction in biomass production and consequently in yield [11,10]. On the other hand, optimal planting densities can contribute to an increase in productivity [12,7], especially in rubber plantations [13,10,8]. Several factors (wind breakage, latex harvesting systems, dry notch syndrome...) can influence the evolution of the number of living trees. In a rubber plantation, not all trees reach maturity at the same time, due to replacements. According to studies by Obouayeba et al [14], maturity is reached at 6 years with a minimum circumference of 50 cm, measured at one meter from the ground. The attainment of this maturity is specific to each group of clones, relative to the radial vegetative growth class. As a result, the number of living and tapped trees in a plantation varies over time between the first five years of tapping. This phenomenon of the evolution of rubber trees over time raises concerns for a good exploitation and especially for a good forecast of the harvest. Thus, in the framework of this study, the first step is to evaluate the evolution of the number of living trees over time according to different latex harvesting systems applied to them and the second step is to study the relationship between the number of living trees and the number of tapped trees.

1.1 Study Site

The various trials were conducted in the experimental and production plantations of HEVEGO (Société Hévéicole du Gô), now SCASO (Société Civile Agricole du Sud-Ouest) located in the southwest of Côte d'Ivoire. This region is characterized by a rainfall that varies between 1200 and 1800 mm per year, and an annual insolation of 1500 hours. The average temperature is 25°C with seasonal variations of low amplitude. The hottest months are February, March and April (28.5 to 29°C) and the coolest months August and September (25.6°C on average) [15]. The soil is ferralitic, derived from migmatites and schists, clayey-sandy, poor in exchangeable bases, with a gravelly horizon and lateritic armour. The climate of this region is humid subtropical with four seasons clearly differentiated by their rainfall: two dry seasons and two rainy seasons. The relative humidity is 90%.

2. MATERIALS AND METHODS

2.1 Plant Material

The plant material consists of several clones of the three different classes of metabolic activity recorded in the tables below.

Table 1. Main characteristics of the slow-metabolizing clones studied [16]

Clones	Origins	Characteristics
PB 217	*Prang Besar* (PB), in Malaysia; Female parent PB 5/51 and male parent PB 6/9	- carbohydrate reserve and content of thiol groups thiol groups; - Low inorganic phosphorus content; - Vigorous; - Constant progression of average production in the first three years the first three years; - Not very sensitive to dry rot; - Resistant to wind.
PR 107	*Proefstation voor 107*, in Malaysia; Early clone	- High carbohydrate reserve and thiol group content thiol groups; - Low inorganic phosphorus content; - Less vigorous and more productive than the clone GT 1, during the first 5 years of tapping; - Very productive after 6 to 10 years of tapping; - Very good resistance to wind breakage; - High rubber productivity and low sensitivity to high rubber productivity and low susceptibility to dry notching.

Table 2. Principales caractéristiques des clones à métabolisme modéré étudiés [16]

Clones	Origins	Characteristics
BPM 24	*Balai Penelitian Perkebunan Medan* (BPM), in Malaysia; Genetic cross: GT 1 x AVROS 1734	- Presence of thin bark with some latex exudations on the trunk; - Good rubber production from the opening; - Abundant, round and clear seed production. clear.
GT 1	*Gondang Tapen* (GT), Java in Indonesia; Early clone	- Sugar and inorganic phosphorus content Intrinsically moderate; - Physiological characteristics all favourable to rubber for rubber production; - Production per tree is not very high but, largely compensated by its good homogeneity; - Not very sensitive to dry notching and resistant to resistant to breakage due to wind.
RRIC 100	*Rubber Research Institute of Ceylan* (RRIC), in Sri Lanka ; Genetic cross: RRIC 52 x PB 86	- Physiological profile limited by a low level of thiols (RSH); - Vigorous at the immature stage with moderate height moderate height, large round leaflets and very large very large seeds; - Good ground cover when young, but poor ground cover when mature poor ground cover as an adult; - Rubber productivity equal or superior to GT 1. equal to that of GT 1.

Table 3. Principales caractéristiques des clones à métabolisme rapide étudiés [16]

Clones	Origins	Characteristics
IRCA 18	Institut de Recherche de Caoutchouc (IRCA), in Côte d'Ivoire; Genetic cross: PB5/51 x RRIM605	- Low sucrose reserves within the latex; - Risks of physiological imbalance in case of over-stimulation; - Very fast production increase and a relatively late defoliation relatively late; - High production potential. High production potential. very dense before tapping, but reduced in size at reduced in size at maturity; - Sensitive to dry notching and wind breakage wind breakage.
PB 235	*Prang Besar* (PB), in Malaysia; Genetic crossing: PB 5/51 X PB S/78	- High content of inorganic phosphorus (Pi); - Low content of sucrose and thiol compounds thiols; - Strong and homogeneous vegetative growth before the tapping; - Resistant to leaf diseases; - Susceptible to dry rot and wind breakage wind breakage.
PB 260	*Prang Besar*(PB), in Malaysia; Genetic crossing: PB 5/51 x PB 49	- High inorganic phosphorus content; - Relatively low content of sucrose and thiol groups; - Sensitive to dry rot and moderately resistant to windburn.

2.2 Methods

2.2.1 Experimental design and treatments

The experimental design of this study was a Fisher block design consisting of 6 treatments and 3 replications. The starting year of the trials varied according to the clones. However, the experiments ended in 2005 for all clones. The numbers of living and tapping trees were obtained after counting the trees in the different plots. For the number of tapped trees, trees having reached 50 cm in circumference were taken into account. Tapping was carried out using a knife or a tapping gouge. It was carried out by descending on a low panel. The tapping was carried out every two, three, four, five and six days out of seven with Sunday as a rest day for tapping. Trees were stimulated on the tapping panel, on a 1 cm wide strip, at a rate of 1 g of stimulation product per tree [17]. The stimulation product used was obtained by mixing Ethrel and palm oil. Ethrel is the trade name of Ethphon (2-chloroethyl phosphonic acid) which is the active ingredient (a.m.). 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 paste used in the experiments of this study had a concentration of 2.5% of Ethrel. The treatments carried out were the following:

- d2: Tapping every second day, six working days out of seven; Sunday is a rest day for tapping;
- d3/ 4y: Tapping every third day, six working days a week; stimulation with 2.5% concentrated ethephon, 4 times a year;
- d4/ 4y: Tapping every four days, four days and five days, six working days a week; stimulation with 2.5% concentrated ethephon, 4 times a year;
- d4/ 8y: Tapping every fourth, fourth and fifth day, six working days a week; stimulated with 2.5% E-bephon concentrate, 8 times a year;
- d5/8y: Tapping every five days, six working days out of seven; stimulated with 2.5% concentrated Ezephon, 8 times a year;
- d6/10y: Tapping every six days, six working days out of seven; stimulation with 2.5% E-bephon concentrate, 10 times a year.

2.2.2 Measured parameters

2.2.2.1Stand

For each treatment, the rate of living trees (% Living Trees) was determined by the following relationship:

$$(\%)\ TAV = (N - NAM) \times 100 \times N^{-1}$$

TAV: Rate of living trees; N: total number of trees; NAM: number of dead trees

2.3 Statistical Analysis

The present study is essentially comparative (comparison of treatments, live tree rate and tapped tree rate). The raw data collected from the trial were first tabulated and then classified into homogeneous groups (by clone and by treatment), and then converted into international system units.

Data entry and preliminary calculations were performed on Excel 2016 software. Hypothesis testing was carried out using Xlstat 2016 software, especially those related to the comparison of several means (ANOVA).

3. RESULTS

3.1 Immature Stand of Rubber Clones

Results on the average live and taped tree rates from the year of planting to the first year of latex harvest are presented in Table 4. Overall, these results show that the average rate for all clones during the immaturity period is about 95 ± 0.94%. This corresponds to an average tree loss of about 5%. This means an average annual tree loss of between 0.83 and 1% of the planted rubber tree stand. They also indicate a progressive and regular decrease in the number of living trees, all clones combined, from the year of planting to the first year of latex harvesting, i.e. during the immature period.

3.2 Mature Stand of Rubber Clones

The results for the average tapping rates from the year of planting to the end of the latex harvest are presented in Table 5.

Overall, the results show that the average rate for all clones combined during the maturity period, i.e. during the nine years of latex harvesting, is 88 ± 3.78%. This corresponds to an average tree loss of about 7% during the nine years of latex harvesting and 12% during the 15 years of plantation establishment. This means an average annual loss of trees during tapping of about 0.78% and during the 15 years of cultivation of 0.80% of the planted rubber tree stand.

Table 4. Evolution of tree rates during the immature period

Clone	PB 260	IRCA 18	GT 1	RRIC 100	PB 217	PB 235	PR 107	IRCA 18
Rate of trees	TAV	TAV	TAV	TAV	TAV	TAV	TAV	TAV
Rate of trees at planting	100	100	100	100	100	100	100	100
Rate of trees at maturity	93	95	98	95	95	95	93	95

TAV : Living Tree Rate

Table 5. Rate of living trees for all clones and treatments

	Average	
Period	**TAS**	**TAV**
End of the immature period, beginning of the mature period (tapping of the rubber trees)	69 ± 8,03	95 ± 0,94
At the peak	92 ± 1,39	92 ± 1,08
After 9 years of downward tapping	88 ± 3 ,5	88 ± 3,78
average	83 ± 9,33	91,66 ± 2,44

TAV: Rate of Living Trees; TAS: Rate of tapped Trees

Table 6. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone PB 260

	d2		**d3/ 4y**		**d4/ 4y**		**d4/ 8y**		**d5/ 8y**		**d6/ 10y**		**Average**	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1997	95	81	95	78	91	66	92	70	93	71	92	70	**93**	**72**
1998	95	87	94	87	91	81	92	82	92	82	92	79	93	83
1999	94	93	94	94	91	89	92	91	92	92	91	91	92	92
2000	93	93	94	94	90	88	92	91	92	92	91	91	**92**	**91**
2001	93	92	94	93	89	88	91	90	92	92	91	91	92	91
2002	92	91	94	93	88	88	91	89	92	91	90	90	91	91
2003	92	91	94	93	88	88	89	89	91	91	90	90	91	90
2004	91	90	93	93	88	87	89	89	91	91	89	89	90	90
2005	91	90	93	93	87	87	89	89	91	91	89	89	**90**	**90**
moyenne	94	91	94	92	90	86	92	88	93	89	92	88	92	89

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation.

3.3 Stands during the 15 Years of Plantation Establishment

The average rate of live trees, all clones combined (Table 5), during the 15 years of plantation establishment is 91.66 ± 2.44%. This indicates an overall loss of about 8.34%, or an annual loss of 0.56% of rubber trees.

The loss of living trees during the 15 years of plantation establishment is approximately equal for all clones, showing its independence from the clones planted.

3.4 Evolution of the Rate of Tapped Trees in Relation to the Rate of Living Trees in Mature Period

3.4.1 Evolution of the rate of tapped trees in relation to the rate of living trees in the PB 260, IRCA 18 and PB 235 clones during the mature period

The results of the effect of tapping frequency on the evolution of the rate of live trees and tapped trees of clones PB 260, IRCA 18 and PB 235 are recorded in Tables 6, 7 and 8. These results show an increase in the rate of tapped trees from the first year of latex harvesting (TAS (%) = 72, 60, 81) to a peak in the third or fourth year of latex harvesting (TAS_{Peakc}(%) = 92; 93 Table 5) and then a slight decrease over the years until it equals the rate of live trees (TAV (%) = 92; 93) for all clones. Moreover, unlike the rate of live trees, which constantly decreases over the years of latex harvesting, the rate of tapped trees increases until it equals the rate of live trees before decreasing. In the first year of latex harvesting, the difference between the live tree rate and the tapped tree rate is significant for all treatments. Furthermore, regardless of the treatment, after reaching the peak, the rates of live trees and tapped trees are essentially identical and evolve in the same way over the years of latex harvesting. Moreover, regardless of the treatment, the rate of live and taped trees is at a good level (between 80 and 90%) as long as it is greater than or equal to 75% after 9 years of latex harvest.

3.4.2 Evolution of the rate of tapped trees in relation to the rate of live trees in the GT 1, RRIC 100 and BPM 24 clones in the mature period

The results on the effect of tapping frequency on the evolution of the rate of live trees and tapped These results show an increase in the rate of tapped trees from the first year of latex harvesting to a peak (TAS (%) = 97, 91, 93) after 5 years (GT 1), 3 years (RRIC 100) and 4 years (BPM 24) of latex harvesting and then a small and steady decrease over the years until the rate of live trees (TAV (%) = 97, 91, 93) is equal. In the first year of latex harvesting, the difference between the rate of live trees and the rate of tapped trees is high for all treatments combined. In fact, as the years of latex harvesting progress, unlike the rate of live trees which decreases continuously, the rate of tapped trees increases until it almost equals the rate of live trees before decreasing for all treatments. Moreover, after reaching the peak, the rates of live trees and tapped trees are more or less identical and evolve in the same way over the years of latex harvesting, and are of a very good level (around 90%), since they are higher than 85% after 9 years of latex harvesting.

3.4.3 Evolution of the rate of tapped trees in relation to the rate of live trees of clones PB 217 and PR 107 in the mature period

The results of the effect of tapping frequency on the evolution of the rate of live trees and tapped trees of clone PB 217 recorded in Tables 12 and 13 reveal an increase in the rate of tapped trees from the first year of tapping until reaching a peak after 4 years (PB 217) and 5 years (PR 107) of latex harvesting (TAS (%) = 93; 89). Indeed, after reaching the peak, the rate of live trees and tapped trees evolve in the same direction regardless of the treatment during the years of latex harvest. Moreover, the difference between the rates of live and taped trees is high for all treatments in the first year of latex harvest. Furthermore, regardless of treatment, the rate of live and taped trees is good as long as it is above 85% after 9 years of latex harvesting.

4. DISCUSSION

4.1 Stand in Immature Period of the Clones

Plantation density according to Compagnon [18] is defined as the number of trees planted per hectare. It is one of the important parameters that condition the level of production and/or productivity and the economic results. It is also the most important parameter that determines the level of competition affecting tree growth and yield [19]. The rates of live trees and tapped

Table 7. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone IRCA 18

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1994	95	67	95	58	97	57	95	64	93	58	93	54	**95**	**60**
1995	94	84	95	86	97	88	95	90	93	85	93	85	95	86
1996	93	87	95	91	97	95	94	93	93	93	92	91	94	92
1997	92	92	94	93	96	96	93	93	92	92	90	90	93	93
1998	91	91	93	93	95	95	92	92	92	92	90	90	**92**	**92**
1999	90	90	92	92	95	95	91	91	91	91	90	89	92	92
2000	90	90	92	92	95	95	91	90	90	90	89	89	91	91
2001	89	89	91	91	95	95	90	90	90	90	89	89	91	91
2002	88	88	91	91	95	95	90	90	90	90	89	88	91	90
2003	88	88	91	91	95	95	90	90	89	89	89	88	90	90
2004	86	86	91	91	95	95	89	89	89	89	88	88	90	90
2005	85	85	90	90	94	94	89	89	87	87	86	86	**89**	**89**
moyenne	90	87	92	88	96	91	92	88	91	87	90	86	92	88

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation.

Table 8. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone PB 235

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1995	92	82	95	85	98	85	95	76	97	81	95	79	**95**	**81**
1996	95	85	94	81	97	86	95	85	94	82	93	88	95	85
1997	95	92	93	90	96	92	95	93	94	90	93	91	94	91
1998	93	93	91	91	93	92	94	94	93	92	91	91	**93**	**92**
1999	93	88	89	89	93	89	94	90	92	90	90	90	92	89
2000	86	80	82	82	89	83	87	81	88	84	87	82	87	82
2001	80	80	78	78	76	76	73	73	83	83	79	79	78	78
2002	80	80	78	78	75	75	73	73	83	83	78	78	78	78
2003	79	79	78	78	75	75	73	73	82	82	78	78	77	77
2004	78	78	77	77	75	75	72	72	81	81	77	77	77	77
2005	78	78	77	77	74	74	71	71	80	80	75	75	**76**	**76**
moyenne	86	83	85	82	85	82	84	80	88	84	85	83	86	82

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

Table 9. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone GT 1

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1995	99	79	97	86	97	82	98	82	97	81	98	78	**97**	**81**
1996	98	91	96	92	97	92	97	92	96	92	98	95	97	92
1997	98	94	96	93	97	93	97	93	96	93	98	95	97	93
1998	98	96	96	94	97	94	97	95	96	94	98	96	97	95
1999	98	98	96	96	96	96	96	96	96	96	98	98	**97**	**97**
2000	98	98	95	95	96	96	96	96	96	96	98	98	97	97
2001	98	98	95	95	96	96	96	96	96	96	98	98	96	96
2002	98	98	95	95	96	96	95	95	96	96	97	97	96	96
2003	98	98	94	94	96	96	95	95	96	96	97	97	96	96
2004	98	98	94	94	96	96	94	94	96	96	97	97	96	96
2005	98	98	94	94	96	96	94	94	96	96	97	97	**96**	**96**
moyenne	98	95	96	94	97	94	96	94	96	94	98	95	97	95

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

Table 10. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone RRIC 100

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1995	96	64	94	58	93	69	94	63	97	55	95	69	**95**	**63**
1996	95	82	93	84	93	82	93	83	97	84	94	86	94	84
1997	95	92	93	92	92	91	92	91	97	93	94	89	94	91
1998	91	91	91	91	91	91	91	91	95	95	89	89	**91**	**91**
1999	91	91	91	91	89	89	91	91	95	95	88	88	91	91
2000	91	90	90	90	89	89	90	90	94	93	86	86	90	90
2001	90	90	89	89	89	89	90	90	94	93	85	85	89	89
2002	90	90	89	89	89	89	89	89	94	93	85	84	89	89
2003	90	90	89	89	87	87	88	88	93	93	84	84	89	89
2004	89	89	89	89	87	87	88	88	93	93	83	83	88	88
2005	89	89	89	89	86	86	87	87	93	93	83	83	**88**	**88**
moyenne	91	87	91	86	90	86	90	86	95	89	88	84	91	87

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

Table 11. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone BPM 24

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1997	95	64	96	55	94	60	96	64	93	53	95	58	**95**	**59**
1998	94	79	96	72	94	73	95	82	93	75	95	75	94	76
1999	93	92	95	94	93	90	95	94	92	91	94	94	94	92
2000	93	93	95	95	93	93	94	93	92	92	94	94	**93**	**93**
2001	93	92	94	94	92	91	93	92	92	91	93	93	93	92
2002	93	93	94	94	92	91	92	91	91	91	92	92	92	92
2003	92	92	92	92	91	90	90	89	90	90	91	91	91	91
2004	90	90	91	91	90	90	90	89	90	90	91	91	90	90
2005	89	89	91	91	89	89	90	89	90	90	91	91	**90**	**90**
moyenne	92	87	94	86	92	85	93	87	91	85	93	86	93	86

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

Table 12. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone PB 217

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1996	96	60	97	57	96	63	93	63	96	57	93	64	**95**	**61**
1997	95	82	96	79	95	82	92	83	95	79	91	82	94	81
1998	94	87	95	87	95	91	91	86	94	85	91	86	94	87
1999	94	93	95	95	95	94	91	90	94	94	91	91	**93**	**93**
2000	87	87	95	94	92	91	87	87	89	89	85	85	89	89
2001	86	85	95	94	92	90	87	86	88	88	84	84	89	88
2002	85	84	94	94	90	90	87	86	88	87	83	83	88	87
2003	84	84	94	94	90	90	87	86	88	87	82	82	87	87
2004	83	83	94	94	90	90	86	86	88	87	81	81	87	87
2005	82	82	93	93	89	89	86	86	87	87	80	80	**86**	**86**
moyenne	89	83	95	88	92	87	89	84	91	84	86	82	90	85

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

Table 13. Effect of tapping frequencies on the evolution of the rate of live trees and tapped trees of clone PR 107

	d2		d3/ 4y		d4/ 4y		d4/ 8y		d5/ 8y		d6/ 10y		Average	
Years	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV (%)**	**TAS (%)**	**TAV**	**TAS**
1999	93	71	96	76	90	70	94	74	90	68	94	73	**93**	**72**
2000	93	80	96	83	90	79	94	80	90	76	94	79	93	79
2001	92	80	96	87	90	80	94	82	90	78	93	81	93	81
2002	92	89	96	89	90	81	94	85	89	82	93	85	92	85
2003	92	89	96	93	90	87	94	89	89	86	93	89	92	89
2004	92	91	96	93	90	87	94	89	89	86	93	89	92	89
2005	92	91	96	94	90	87	94	89	89	86	93	89	**92**	**89**
moyenne	92	84	96	88	90	82	94	84	89	80	93	84	92	84

TAV: Live Tree Rate; TAS: tapped Tree Rate; d2: tapping three times a week; d3: tapping twice a week; d4: tapping three times every 14 days; d5: tapping 6 times every 35 days; d6: tapping once a week, n y: number of annual stimulation

trees from the year of planting to the first year of latex harvesting in this study showed a progressive decrease overall, expressing the low and regular loss of live trees and tapped trees for all clones. Except for the PB 235 clone, which lost nearly a quarter of its trees in nine years of latex harvesting, this decrease varied very little according to clone. The decrease in the rate of living trees could be explained by the effect of several factors influencing plantation density, such as wind breakage and root rot caused by the genus *Fomes*, uprooting, etc. The rate of decline observed in our study is a low 8.34% over fifteen years of plantation establishment. This expresses a regular annual loss of about 0.56%. In fact, according to Pathiratna and Edirisinghe [12], under the economic conditions generally encountered in rubber-producing countries, and with the most widely planted and known clones, it is assumed that the density at planting should be between 500 and 550 trees per hectare to reach 400 and 450 trees at tapping, i.e. 100 trees lost. However, the projection of our results gives a loss of tapped trees estimated between 60 and 66 trees, after nine years of latex harvesting. These results are good because they reflect the manifestation of a lesser environmental impact and destructive cultivation practices on the rubber tree stand. These results are significantly better than those reported by Pathiratna and Edirisinghe [12], and especially Tran [20], who reported an annual rubber tree loss of about 1%.

4.1.1 Evolution of the rate of tapped trees compared to the rate of living trees in mature period

Regarding the effect of the operating system on the evolution of the rate of living trees and tapped trees of the different clones studied, the results indicated an increase in the rate of tapped trees of the first year of latex harvest until reaching a peak between 3 and 5 years and then decreased slightly over the years until equalling the rate of live trees. And also a steady decrease in the rate of living trees. This decrease would be due first to factors such as breakage due to wind, white root rot (*Fomes*) and then, to a lesser extent, to the latex harvesting system applied to trees. These results corroborate those of some authors such as Compagnon, [18] and Démange et al., [21] who have shown in their work that the number of trees in place decreases regularly over time for a variety of reasons (root rot, wind damage that can lead to uprooting, breakage or serious damage to the trunk, and the gradual appearance of dry trees due to dry notching, i.e., no longer giving rubber when tapped). This contributes to a considerable decrease in the number of productive trees in a stand. As for the rate of tapped trees, it increases until it equals the rate of living trees because in the first year of latex harvesting, not all trees reach the 50 cm circumference required for tapping. Over the years of latex harvesting, trees reaching their minimum circumference to be bled are added to the previous ones, and so on, until all the living trees are tapped. Thus, the rate of tapped trees is cumulative, which would explain its increase. However, after all the trees have reached their minimum circumference to be bled, there is a progressive and regular decrease in the rate of tapped trees. These results can be explained firstly by the effect of latex harvesting systems which can cause a dry notch which is a stop in the flow of latex, and secondly by uprooting due to root rot caused by the genus *Fomes,* or to breakage due to wind. Given that in most cases by the fifteenth year of plantation establishment, the rates of tapped and live trees are equal or nearly so, this means that tapping has not adversely affected the trees, and thus the low rate of wastage trees, which is almost of the same magnitude, can in no way be attributed to any latex harvesting system. Overall and individually, tapping and/or the harvesting system did not affect the rate of tapped trees and thus the rate of living trees.

5. CONCLUSION

The present study on the evolution of the rate of live trees and tapped trees of the rubber clones during the 15 years of establishment has shown that the rate of live trees decreases progressively and regularly from the year of establishment of the plantation. This same study also showed that the rate of tapped trees increases over the years until it equals the rate of living trees between 3 and 5 years of latex harvesting before gradually decreasing. The results of this study show that the evolution of the rate of living and tapping trees is not a function of the metabolic activity class or the latex harvesting system. It should be noted that several factors mentioned above influence the evolution of the live and taped tree rates during the first fifteen years of establishment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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