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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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...
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 tapped 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 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 (P<sub>i</sub>);                         |
|          |                                              | - 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 fifth day, 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

2.2.2.1 Stand

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

\[ (\%) \text{ TAV} = (N - NAM) \times 100 \times N^{-1} \]

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 tapped 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 | 99 | 95 | 95 | 93 | 93 | 95 |

*TAV*: Living Tree Rate

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

| Period                                                      | Average   |
|-------------------------------------------------------------|-----------|
| End of the immature period, beginning of the mature period  | 69 ± 8,03 |
| At the peak                                                 | 92 ± 1,39 |
| After 9 years of downward tapping                           | 88 ± 3,5  |
| average                                                    | 83 ± 9,33 |

*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

| Years   | d2     | d3/4y  | d4/4y  | d4/8y  | d5/8y  | d6/10y | Average |
|---------|--------|--------|--------|--------|--------|--------|---------|
|         | TAV (%)| TAS (%)| TAV (%)| TAS (%)| TAV (%)| TAS (%)|         |
| 1997    | 95     | 81     | 95     | 78     | 95     | 77     | 96      |
| 1998    | 95     | 87     | 94     | 87     | 91     | 89     | 91      |
| 1999    | 94     | 93     | 94     | 94     | 91     | 99     | 93      |
| 2000    | 93     | 93     | 94     | 94     | 90     | 91     | 93      |
| 2001    | 93     | 92     | 94     | 93     | 89     | 91     | 92      |
| 2002    | 92     | 91     | 94     | 93     | 88     | 91     | 91      |
| 2003    | 92     | 91     | 94     | 93     | 88     | 89     | 91      |
| 2004    | 91     | 90     | 93     | 93     | 88     | 89     | 91      |
| 2005    | 91     | 90     | 93     | 93     | 87     | 89     | 91      |
| moyenne | 94     | 91     | 94     | 92     | 90     | 86     | 91      |

*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 (TASpeakl (%) = 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 rate of live trees and the rate of tapped trees 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 treatment, the rate of live and tapped 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 harvesting.

3.4.2 Evolution of the rate of tapped trees in relation to the rate of live trees of the GT 1, RRIC 100 and BPM 24 clones 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 tapped trees is high for all treatments in the first year of latex harvest. Furthermore, regardless of treatment, the rate of live and tapped 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

| Years | d2  | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|-----|-------|-------|-------|-------|--------|---------|
|       | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | Average |
| 1994  | 95  | 67    | 95    | 65    | 95    | 64    | 93      | 56      | 93      | 56      | 93      | 54      | 93      | 60      |
| 1995  | 94  | 84    | 95    | 86    | 97    | 88    | 95      | 90      | 93      | 85      | 93      | 85      | 92      | 89      |
| 1996  | 93  | 87    | 95    | 91    | 97    | 95    | 94      | 93      | 93      | 92      | 92      | 90      | 90      | 90      |
| 1997  | 92  | 92    | 94    | 93    | 96    | 96    | 93      | 93      | 92      | 92      | 90      | 90      | 93      | 93      |
| 1998  | 91  | 91    | 93    | 95    | 95    | 92    | 91      | 91      | 91      | 90      | 89      | 89      | 91      | 91      |
| 1999  | 90  | 90    | 92    | 92    | 95    | 95    | 91      | 90      | 90      | 89      | 89      | 89      | 91      | 91      |
| 2000  | 90  | 92    | 92    | 92    | 95    | 95    | 91      | 90      | 90      | 89      | 89      | 89      | 91      | 91      |
| 2001  | 89  | 89    | 91    | 91    | 95    | 95    | 90      | 90      | 90      | 89      | 89      | 89      | 91      | 90      |
| 2002  | 88  | 88    | 91    | 91    | 95    | 95    | 90      | 90      | 90      | 89      | 89      | 89      | 90      | 90      |
| 2003  | 88  | 88    | 91    | 91    | 95    | 95    | 90      | 90      | 90      | 89      | 89      | 89      | 89      | 90      |
| 2004  | 86  | 86    | 91    | 91    | 95    | 95    | 89      | 89      | 89      | 88      | 88      | 88      | 90      | 90      |
| 2005  | 85  | 85    | 90    | 90    | 94    | 94    | 89      | 89      | 87      | 87      | 86      | 86      | 89      | 89      |
| moyenne | 90 | 87    | 92    | 92    | 96    | 96    | 91      | 92      | 88      | 91      | 91      | 91      | 93      | 93      |

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

| Years | d2  | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|-----|-------|-------|-------|-------|--------|---------|
|       | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | Average |
| 1995  | 92  | 82    | 95    | 85    | 98    | 85    | 95      | 76      | 97      | 81      | 95      | 79      | 90      | 81      |
| 1996  | 95  | 83    | 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      | 79      | 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      | 75      | 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.
| Years | d2 | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|----|-------|-------|-------|-------|--------|---------|
|       | 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 | 96 | 95 | 95 | 96 | 96 | 96 | 96 | 96 | 98 | 98 | 97 | 97 |
| 2001  | 98 | 98 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 96 | 98 | 98 | 96 | 96 |
| 2002  | 98 | 98 | 95 | 95 | 95 | 96 | 96 | 95 | 95 | 96 | 96 | 97 | 97 | 96 |
| 2003  | 98 | 98 | 94 | 94 | 96 | 96 | 95 | 95 | 95 | 96 | 97 | 96 | 96 | 96 |
| 2004  | 98 | 98 | 94 | 94 | 96 | 96 | 94 | 94 | 96 | 96 | 97 | 96 | 97 | 96 |
| 2005  | 98 | 98 | 94 | 94 | 96 | 96 | 94 | 94 | 96 | 96 | 97 | 97 | 97 | 96 |
| moyenne | 98 | 95 | 96 | 95 | 97 | 97 | 96 | 96 | 96 | 96 | 97 | 96 | 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

| Years | d2 | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|----|-------|-------|-------|-------|--------|---------|
|       | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS (%) | TAV (%) | TAS |
| 1995  | 96 | 64 | 94 | 58 | 93 | 89 | 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 | 92 | 91 | 91 | 97 | 93 | 94 | 89 | 94 | 91 |
| 1998  | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 95 | 95 | 95 | 89 | 89 | 91 |
| 1999  | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 91 | 95 | 95 | 95 | 88 | 88 | 91 |
| 2000  | 91 | 90 | 90 | 90 | 90 | 90 | 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 | 85 | 89 | 89 |
| 2003  | 90 | 90 | 89 | 89 | 87 | 87 | 87 | 88 | 88 | 93 | 93 | 84 | 84 | 89 | 89 |
| 2004  | 89 | 89 | 89 | 87 | 87 | 88 | 88 | 88 | 93 | 93 | 83 | 83 | 88 | 88 |
| 2005  | 89 | 89 | 89 | 86 | 86 | 87 | 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

| Years | d2  | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|-----|-------|-------|-------|-------|--------|---------|
|       | TAV (%) | TAS (%) | 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    | 93    | 93    | 93    | 94    | 93    | 92    | 92    | 94    | 94    | 93    | 93    |        |
| 2001  | 93  | 92    | 94    | 94    | 92    | 91    | 93    | 92    | 91    | 91    | 92    | 92    | 92    | 92    |        |
| 2002  | 93  | 93    | 94    | 94    | 92    | 91    | 92    | 91    | 91    | 91    | 91    | 91    | 91    | 91    |        |
| 2003  | 92  | 92    | 92    | 92    | 91    | 90    | 90    | 89    | 90    | 90    | 90    | 90    | 90    | 90    |        |
| 2004  | 90  | 90    | 91    | 91    | 91    | 90    | 90    | 89    | 90    | 90    | 90    | 90    | 90    | 90    |        |
| 2005  | 89  | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    | 89    |        |
| 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

| Years | d2  | d3/4y | d4/4y | d4/8y | d5/8y | d6/10y | Average |
|-------|-----|-------|-------|-------|-------|--------|---------|
|       | 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    | 91    | 91    | 93    | 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    | 87    | 86    | 88    | 87    | 87    | 82    | 82    | 87    | 87    |        |
| 2004  | 83  | 83    | 94    | 94    | 90    | 86    | 86    | 88    | 87    | 81    | 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 (%) |
| 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    | 92    | 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, environmental impact or class of the latex harvesting system. It should be noted that several factors mentioned above influence the evolution of the live and tapped tree rates during the first fifteen years of establishment.

COMPETING INTERESTS

Authors have declared that no competing interests exist.
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