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# *Effect of Planting Density on Growth and Yield Productivity of* Hevea brasiliensis *Muell. Arg. Clone PB 235*

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*Clone PB 235 is high yielding and vigorous but highly sensitive to tapping panel dryness and wind damage in Africa. The planting density for panel opening at six years after planting was studied since 1989 in south western Côte d'Ivoire to determine the influence of environmental parameters in reducing the incidence of tapping panel dryness. The study showed that the number of tappable trees was acceptable and had not varied much with the density of planting. There were also no link between density of planting and the occurrence of tapping panel dryness and wind damage. Bole growth and yield were strongly influenced by planting density, yet their interactions were in opposing modes indicating the antagonism of the bole growth yield factors. The optimum planting density was determined at 650 trees/ha. In spite of the high yield noted, the physiological status was in equilibrium indicating the effective tapping system practised. This tapping system resulted in a low rate of panel dryness. These results confirm the influence of age at opening of tapping on bole growth and yield, especially the opening for tapping of clone PB 235 at six years after planting.*

**Key words**: *Hevea brasiliensis*; planting density; bole growth; yield; PB 235; physiological profile; panel dryness

Clone PB 235 of *Hevea brasiliensis* Muell. Arg. is a Malaysian clone which is widely planted in the Asean region. It possesses good agronomic characteristics, strong vigour, very good early flow and high rubber yields[1–3]. However, in Africa, particularly in Côte d'Ivoire, this clone is tapped between 4 and 5 years after planting, according to the present norm *i.e.* the opening for tapping is realised when the trees reaches 50 cm of girth at 1 m from the ground. Under this criterion of exploitation, PB 235 displays several unfavourable secondary characteristics such as susceptibility to wind damage and tapping panel dryness (TPD)[3–7]. These unsatisfactory characteristics inhibit its promotion so much so that since 1993, it has been regressed from Class I to Class II b in Côte d'Ivoire.

Much work has been carried out to refine the conditions of utilisation which can reduce

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the above disadvantages of utilising PB 235 to increase the agronomic potential anticipated by planters. To affect that, the planting density has been studied with clone PB 235 since 1989, to solve this problem of wind damage and to envisage its possible rehabilitation. Furthermore, this study has been conducted to set all opening treatments at six years for consolidation and validation of the new opening criterion[8,9]. It is aimed at determining the planting densities which assure both maximum profitability and high economic exploitation longevity.

The purpose of this study is to examine the results of the 11 years of studies related to panel opening for tapping at six years with effect to the behaviour of clone PB 235 and the effect of wind damage and planting density.

## MATERIAL AND METHODS

### Planting Material

PB 235 is a Asean clone of *Hevea brasiliensis* which was recently introduced in Africa, especially in Cote d'Ivoire. This clone produces large trees and grows vigourously and homogeneous during the period of immaturity growth[5]. It belongs to the fast vegetative growth clone class[8]. Its yield is certainly good but above all it is characterised by an exceptional growth in rubber production[5,2]. However, it is sensitive to tapping panel dryness and wind damage[5,7].

### Methods

*Localisation, statistical design and treatments*. The trial began in 1989 on ferrallitic soil in an experimental site of the Rubber Company of Go (HEVEGO) in south-western Côte d'Ivoire. Ten months old PB 235 was planted in polybags (green buddings) in straight lines, according to Fisher block design with 10 treatments (densities of planting), three replications and covered an area of 24 ha. Nine different densities of planting and a sub-soiling treatment (control) was also carried out as shown below:

- Treatment 1: 510 trees/ha (control)
- Treatment 2: 200 trees/ha
- Treatment 3: 300 trees/ha
- Treatment 4: 400 trees/ha
- Treatment 5: 500 trees/ha
- Treatment 6: 600 trees/ha
- Treatment 7: 700 trees/ha
- Treatment 8: 800 trees/ha
- Treatment 9: 900 trees/ha, and
- Treatment 10: 1000 trees/ha.

### Tapping System

Commencement of tapping for all treatments was at the same time *i.e.* at 6 years and 3 months after planting. Only one tapping system was applied to all treatments: ½ S d/4 6 d/7 ET 2.5% pa 1(1) 3/y. Tapping was for the first two years on *Panel A* (*BO-1*) and 3rd year on *Panel B* (*BO-2*), with the alternative exploitation on both panels (*A* and *B*) from the 4th year[10]. The tapped trees were stimulated 3 times per year, with 1 g mixed paste at 2.5% (v/v) Ethephon. The paste was applied on a 1 cm band, above the tapping cut (renewal panel). The paste constituted of palm oil; Ethrel® was mixed with a commercial product containing the active ingredient Ethephon and 2-chloro-ethyl-phosphonic acid [400 g/kg (40%)]. For preparing the stimulant at 2.5% of active ingredient, a final concentration of Ethrel® at $2.5\% \times 100/40 = 6.25\%$, was necessary. For 1 g of stimulant at 2.5% : $1 \times 6.25/100 = 0.0625$ g of Ethrel® was used. In 1 g of stimulated paste at 2.5% (v/v) of active ingredient (Ethephon), there was 937.5 mg of palm oil and 62.5 mg of Ethrel®.

### Measurements Realised

*Production*. The production was collected by treatment and inspected monthly. The coefficient of transformation (C.T.) (percentage of dry rubber of one given sample of coagulum) permited the calculation of the production expressed in dry rubber for each treatment. This coefficient was calculated with a sample of 6 coagulum. The production measured was expressed in kg per hectare (kg/ha), gram per tree (g/t) and gram per tree per tapping (g/t/t).

*Bole growth*. Annually, the girth (G) of trees was measured at 1.7 m from the ground. The girth increment ($G_i$) was determined by the following relation: $G_i$ (cm/year) = $G_n - G_{n-1}$. Where $G_n$ is the mean girth of trees of the year n and $G_{n-1}$, the mean girth of trees of the year n-1.

*Biometrical and physiological parameters*. Latex was collected by conventional tapping and conserved in ice then transfered to the laboratory within the same hour. This latex was measured, by microdiagnostic latex methodology (MDL)[11], the dry rubber content (DRC), sucrose content, inorganic phosphorus (Pi) and R-SH content.

### Economic Parameters

*Cost of exploitation*. All expenses were recorded, since planting (beginning of trial) until the 5th year of exploitation and evaluated. The cost of labour ($C_L$) was an important expense. The daily labour cost was estimated at USD 265. In the same way, the total cost of plants ($C_{Plants}$) established with the unit cost was estimated at USD 0.4. The stimulant cost ($C_{Stimulation}$) was established, with the ready paste container of 25 kg costing USD 100. The total cost ($C_T$) during the period from planting to the 5th year of tapping was constituted as:

$$C_{Exploitation} = C_{Labour} + C_{Plant} + C_{Stimulation} \quad \ldots 1$$

*Return of exploitation*. The return of exploitation ($R_{Exploitation}$) was obtained from the sale of 5 year cumulative yields at the rate of USD 0.2 per kg of commercial rubber [5 year cumulative yield × 0.6 (D.R.C in south-east rubber growing areas) × USD 0.2].

*Benefit of exploitation*. The benefit of exploitation ($B_{Exploitation}$) was obtained as the difference between return of exploitation and cost of exploitation, expressed as:

$$B_{Exploitation} = R_{Exploitation} - C_{Exploitation} \quad \ldots 2$$

*Statistical analysis*. Statistical analysis covered production and growth data, sucrose content, dry rubber content, diseases, cut length, the percentage of dry trees at the beginning and end of the trial, inorganic phosphorus (Pi) and thiols grouping (R-SH) content at the end of the trial. These analyses were done with the software STATGRAPHICS, SAS PROC-NLIN programme and EXCEL.

## RESULTS

### Population of Living and Tappable Trees

At the opening of tapping (1995), the mean rate of living trees at 94.2% was good and there was no discrimination amongst planting densities (*Table 1*). For tapped trees, the mean rate, during the first year of tapping (April 1996 – March 1997) was reached at 78.8% (*Table 1*). The mean rate varied from 69.5% to 85.6% with the two densities:

- That of densities where the rate of tapped trees per ha was more than 80% ; this related to densities 200, 500, 600, 700, 800 trees/ha and the control.
- That of densities which presented a rate of tapped trees ranging from 69.5% for a density of 1000 trees/ha, 76.3% for a density of 300 trees/ha, 72.6% for planting density of 900 trees/ha and 75% (400 trees/ha).

At the beginning of year 1997–1998, a satisfactory recovery of tappable trees was obtained and its rate reached 90.7% where only the rates of two tapping densities of 900 and 1000 trees/ha were less than 85%.

**Radial Bole Growth**

Immature bole growth, determined by the girth, before 6 years of the untapped trees, varied according to the density of planting (*Table 1*). The densities of planting of 200 to 700 trees/ha and that of control presented, in fact, similar values of girth. The densities of planting ranging from 700 and 1000 trees/ha had trees with the same girth (48%–52%) but significantly inferior to that of the first group. After the first five years of tapping, the girth expressed the influence of the density of planting. Rubber trees planted at very low density, 200 trees/ha, had girth significantly higher to that of the other densities. The girth of rubber trees of densities of planting 300 and 400 trees/ha was comparable but superior to that of the other planting densities except for those of 200 trees/ha. The girth of trees of planting densities 400 trees/ha and 500 trees/ha was comparable but superior to that of densities ranging from 600 trees/ha and 1000 trees/ha. That was the same of the densities 500 and 600 trees. The densities of planting 800, 900 and 1000 trees/ha had similar girth.

These results show the very strong influence of planting density on the bole growth of rubber trees, which was variously expressed during tapping. The mean annual girth increment, over the period of 5 years shows it well (*Table 1*).

**Production**

*Grame per tree per tapping*. Production expressed in gram per tree per tapping (g/t/t) of 1999–2000 and that of period 1995–2000 were most important as the density of planting was lower. This evolution of production (g/t/t) is well described by a hyperbolic function of the density of planting (*Figure 1*). The equation of this function is:

$$g/t/t = 1798 / (1+ \text{density}^{0.56}) \qquad \dots 3$$

*Grame per tree*. The mean production per tree (g/t) during the 5 tapping seasons (*Table 2*) was good in general and varied significantly with the density of planting. The density of 200 trees/ha presented the best value. The production of densities 300 and 400 trees/ha have been of the same level but were significantly superior to that of the other densities of planting. The densities of planting 500, 600 and 700 trees/ha had production higher than that of densities 800, 900 and 1000 trees/ha. These densities have given productions (g/t) the same importance statistically. The cumulative production per tree, expressed in gram, of 5 years tapping, was more important than the density of planting which had been followed. The production (cumulative g/t), and the density of planting can be expressed by the hyperbolic relation (*Figure 2*):

$$g/t \text{ cumulative} = 621.10^3 / (1+ \text{density}^{0.56}) \qquad \dots 4$$

TABLE 1. POPULATION STATE, GIRTH AND ANNUAL MEAN GIRTH INCREMENT BEFORE AND DURING 5 YEARS TAPPING OF CLONE PB 235 ACCORDING TO PLANTING DENSITY

| Treatments | NLT* | RLT (%) | NTT | $RTT_0$ (%) | $RTT_1$ (%) | Girth: 4th year | Girth: 6th year | Girth: 11th year | Mean of increment for the 5th year |
|---|---|---|---|---|---|---|---|---|---|
| Control | 502 | 98.4 | 431 | 84.5 | 92.2 | 37.0 a | 57.4 a** | 66.4 cd | 2.1 |
| 200 trees/ha | 183 | 91.7 | 164 | 82.0 | 95.5 | 29.5 b | 55.0 ab | 79.9 a | 5.7 |
| 300 trees/ha | 281 | 93.7 | 229 | 76.3 | 93.7 | 28.8 b | 54.1 ab | 72.5 b | 4.2 |
| 400 trees/ha | 371 | 92.7 | 300 | 75.0 | 89.3 | 31.4 b | 55.2 ab | 68.7 bc | 3.1 |
| 500 trees/ha | 472 | 94.4 | 428 | 85.6 | 98.2 | 33.7 ab | 54.7 ab | 64.1 cd | 2.2 |
| 600 trees/ha | 567 | 94.5 | 482 | 80.3 | 93.0 | 34.0 ab | 53.5 ab | 62.9 de | 2.0 |
| 700 trees/ha | 659 | 94.2 | 563 | 80.4 | 90.0 | 35.3 a | 52.4 bc | 59.1 ef | 1.5 |
| 800 trees/ha | 748 | 93.5 | 657 | 82.1 | 91.4 | 33.3 ab | 50.1 cd | 57.6 fg | 1.7 |
| 900 trees/ha | 846 | 94.0 | 653 | 72.6 | 83.8 | 33.6 ab | 48.8 cd | 55.2 fg | 1.5 |
| 1000 trees/ha | 944 | 94.4 | 695 | 69.5 | 80.6 | 34.8 ab | 48.1 cd | 53.8 g | 1.3 |
| Mean | – | 94.2 | – | 78.8 | 90.7 | 33.1 | 52.9 | 63.6 | 2.6 |

*The treatments affected by the same letters are not significantly different (Scheffe test at 5%)

**NLT : Number of living trees per ha
RLT : Rate of living trees per ha
NTT : Number of tapped trees per ha
$RTT_0$ : Rate of tapped trees at 6 years per ha
$RTT_1$ : Rate of tapped trees at the 5th tapping season per ha
Girth : Measured at 6 years and after 5 tapping years
Inc : Girth mean increment during 5 tapping years.

**Yield**

The mean yield ($t$ ha$^{-1}$) of 5 tapping years, all densities, was satisfactory (*Table 2*). The yield was under the influence of the density of planting. The production per hectare of densities of planting 500, 600, 700, 800, 900 and 1000 trees/ha were not significantly different, and were higher than that of lower densities of 200 and 300 trees/ha. The yield of densities of planting 600, 500, 400 and 300 trees/ha were statistically of the same importance and were more superior than that of the yield of planting density 200 trees/ha. This last density of planting was significantly less productive among all the densities studied.

The cumulative yield ($t$ ha$^{-1}$), of 5 years of tapping, of various densities, adjusted to mathematic models, showed that Mitscherlich's model well describes the shape of this parameter. Its analytic expression is:

$$t \text{ ha}^{-1} = 11\,547 - 10\,557\,1\,e^{-0.0028 \text{ density}} \quad \ldots 5$$

TABLE 2. MEAN RUBBER PRODUCTION (G/T; KG/HA) FOR THE PLANTING DENSITY OF CLONE PB 235

| Treatments | Mean (g/tree) | Mean Kg/ha |
|---|---|---|
| 510 a/ha (Control) | 4485 cd | 1910 ab |
| 200 a/ha | 6733 a | 1251 c |
| 300 a/ha | 5635 b | 1562 bc |
| 400 a/ha | 5081 bc | 1790 b |
| 500 a/ha | 4363 cd | 2111 ab |
| 600 a/ha | 3870 d | 2175 ab |
| 700 a/ha | 3497 de | 2214 ab |
| 800 a/ha | 3052 e | 2280 ab |
| 900 a/ha | 2940 e | 2276 ab |
| 1000 a/ha | 2933 e | 2566 a* |
| Mean | 4259 | 2014 |

*The treatments affected by the same letters are not significantly different (Scheffe test at 5%)
Note: The mean yield ($t$ ha$^{-1}$) of 5 tapping years, for all densities except where the control is 2.025 *t*.

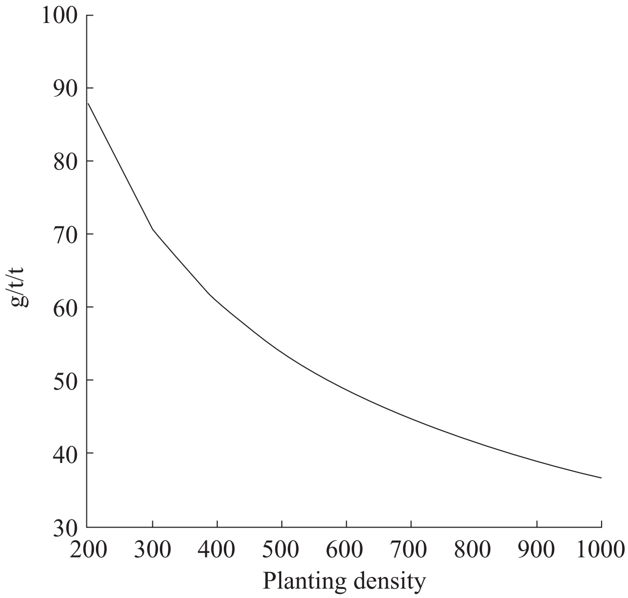


*Figure 1. Production per tree and per tapping (g/t/t) for planting density of clone PB 235.*

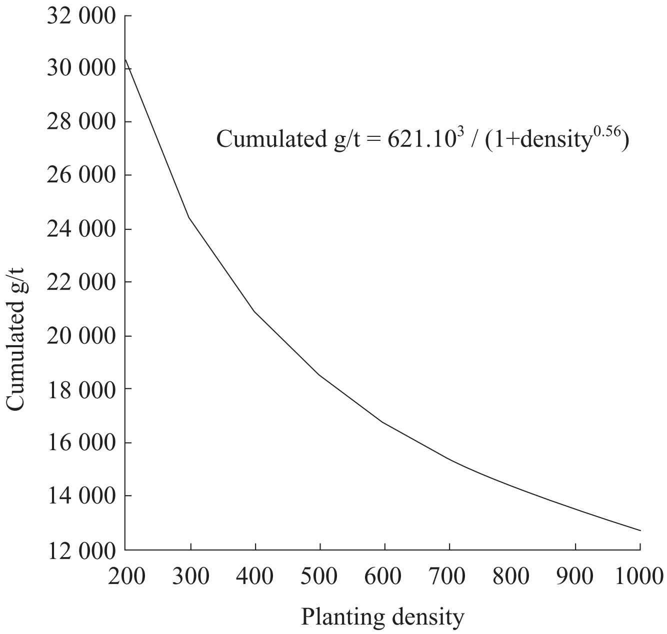


*Figure 2. Relationship between cumulated production per tree (g/t) and planting density of clone PB 235.*

TABLE 3a. TANGENT VALUES OF RUBBER PRODUCTION CURVE FOR PLANTING DENSITY OF CLONE PB 235

| $d_i$ | 200 | 300 | 400 | 500 | **600** | **700** | 800 | 900 | 1000 |
|---|---|---|---|---|---|---|---|---|---|
| tg $\theta d_i = f'(d_i)$ | 16.885 | 12.761 | 9.6447 | 7.289 | **5.509** | **4.164** | 3.147 | 2.378 | 1.798 |
| tg $\theta d_i$ – tg $\theta d_{i+1}$ | 4.124 | 3.117 | 2.355 | 1.780 | **1.345** | **1.017** | 0.769 | 0.586 | 0.580 |

TABLE 3b. TANGENT VALUES OF RUBBER PRODUCTION CURVE BETWEEN DENSITIES 600 AND 700 TREES/HA

| $d_i$ | 600 | 625 | 650 | 675 | 700 |
|---|---|---|---|---|---|
| tg $\theta d_i = f'(d_i)$ | 5.5091 | **5.1367** | **4.7894** | 4.4656 | 4.1637 |
| tg $\theta d_i$ – tg $\theta d_{i+1}$ | 0.3724 | 0.3473 | 0.3138 | 0.3019 | – |

This function of production ($t$ ha$^{-1}$) admits an asymptote $M = 11\ 547\ t$ ha$^{-1}$. It increases with density, contrary to productions g/t.

**Determining the Optimum Technical Density**

Mitscherlich's model of cumulative production per hectare, according to the density of planting, permits us to determine the optimum technical density (O.T.D.).

The production does not always correspond to the planting density. In fact, the production generated, beyond the O.T.D. becomes less and less proportional.

Let $\theta d_i$ be, the angle defined by the tangent at point $d_i$ (densities from 200 to 1000 trees/ha) of the production curve and the horizontal axis (*Figure* 3). The expression tg $\theta d_i$ represents the angular value of the mean production of rubber. This angular difference decreases with the density of planting.

Let tg $\theta d_i$ – tg $d_{i+1}$ be the absolute value of the differential between the tangents of two consecutive angles, and the following is obtained:

$$\text{tg}\ \theta d_i = f'(d_i)\ \text{avec}\ f(d) = 11\ 547 – 10\ 557e^{-0.0028d}\ \text{and}\quad f'(d) = 10\ 557 \times 0.0028\ e^{-0.0028d} \qquad \ldots 6$$

Globally the absolute values of differential (tg $\theta d_i$ – tg $\theta d_{i+1}$) planting densities 600 and 700 are of the same order and slightly different from 1 (*Table 3a*). From this we deduce that the optimum density would be locate between 600 and 700 trees/ha. Moreover, the analysis of *Table 3b* indicates that the values of tangents to 625 and 650 are similar and with a very little difference of 5; contrary to the density of 600 trees/ha whose value is nearly 6 and densities of 675 and 700 trees/ha which correspond to a value of tg = 4. The optimum density is probably between 625 and 650 trees/ha.

**Biochemical Parameters of Latex and Tapping Panel Dryness**

Latex diagnosis was carried out: 1997 in the 2nd tapping year on *Panel A* (*BO-1*); 1998 in the 1st tapping year on *Panel B* (*BO-2*) and in 1999, the 3rd year of tapping but against *Panel A* (*Table 4*). The three sets of latex diagnosis gave the following results:

- The DRC was not different according to planting densities; the rate was satisfactory and in accordance with that of clone PB 235.
- The mean sucrose content was also not different for planting densities and suitable for this clone.
- The Pi was characteristic of clone PB 235 without the control (lower level) and was very slightly variable from one planting density to another.
- The thiol groupings content (RSH) was satisfactory, indicating a good protection of colloidal systems which assure the production.

For tapping panel dryness (*Table 5*) the annual mean rate by treatment was inferior to 5%. It varied little for one density to another density of planting and seemed more pronounced on *Panel A* (*BO-1*) than on *Panel B* (*BO-2*).

**Vegetative Growth and Rubber Production**

The vegetative growth, expressed by the girth of rubber trees, measured at 1.7 m from

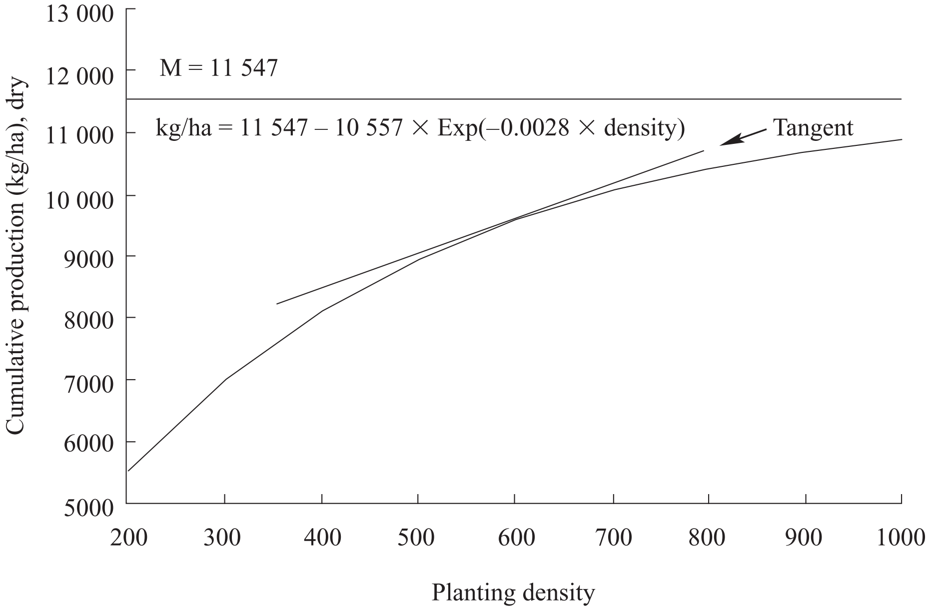


*Figure 3. Mitscherlich realationship between production of rubber and density of planting for clone PB 235 of* Hevea brasiliensis.

TABLE 4. PHYSIOLOGICAL PARAMETERS OF LATEX DIAGNOSIS REALISED FROM 1997 TO 1999 ACCORDING TO PLANTING DENSITY OF *HEVEA BRASILIENSIS* CLONE PB 235

| Planting density | Latex diagnosis (1997) *BO-1* (2nd year of tapping) | | | | Latex diagnosis (1998) *BO-2* (1st year of tapping) | | | | Latex diagnosis (1999) *BO-1* (3rd year of tapping) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DRC | SAC | Pi | R-SH | DRC | SAC | Pi | R-SH | DRC | SAC | Pi | R-SH |
| 510 (Control) | 51.5 | 5.7 | 22.5 | 0.79 | 50.2 | 5.5 | 16.7 | 0.62 | 57.3 | 3.5 | 18.3 | 0.43 |
| 200 | 54.2 | 5.1 | 14.2 | 0.77 | 48.8 | 5.7 | 17.8 | 0.67 | 51.3 | 3.9 | 22.3 | 0.49 |
| 300 | 53.4 | 5.5 | 14.7 | 0.77 | 47.2 | 7.9 | 21.5 | 0.77 | 51.3 | 4.1 | 22.3 | 0.49 |
| 400 | 54.1 | 6.3 | 11.9 | 0.72 | 45.9 | 5.6 | 15.6 | 0.68 | 48.7 | 4.8 | 24.2 | 0.51 |
| 500 | 53.1 | 4.7 | 11.7 | 0.64 | 42.5 | 11.1 | 20.3 | 0.84 | 49.3 | 5.6 | 24.5 | 0.60 |
| 600 | 51.8 | 6.7 | 12.6 | 0.61 | 41.7 | 6.2 | 18.9 | 0.70 | 50.1 | 5.8 | 22.3 | 0.56 |
| 700 | 51.9 | 6.1 | 12.8 | 0.79 | 48.7 | 6.5 | 19.0 | 0.69 | 50.0 | 4.2 | 19.3 | 0.52 |
| 800 | 51.7 | 6.8 | 11.4 | 0.71 | 44.5 | 9.1 | 17.5 | 0.71 | 47.4 | 4.5 | 26.1 | 0.62 |
| 900 | 51.8 | 6.6 | 12.7 | 0.77 | 45.6 | 10.3 | 20.2 | 0.80 | 48.6 | 4.2 | 28.3 | 0.60 |
| 1000 | 53.3 | 7.8 | 9.5 | 0.80 | 45.7 | 8.5 | 18.4 | 0.72 | 51.4 | 4.5 | 21.3 | 0.51 |

D.R.C : Dry Rubber Content (%)
SAC : Saccharose (mM)
Pi : Inorganic phosphorus (mM)
R-SH : Thiols grouping (mM).

ground, before and during the tapping, was strongly correlated with the production of the rubber tree (*Figure 1*) during 5 years. This relation is a non-linear function, poisson model expressed as:

$$g/t/t = 5.10^{-3} \times G^{2.23}$$
[where g/t/t is expressed in (g) and $G$ the girth in (cm)] … 7

**Profitability**

*Benefit and optimum economic density*. All planting densities give a positive difference between return and cost of exploitation (*Table 6*), however only some densities from them were economically justifiable. The level of the benefit according to the planting density leads to envisage a modelling of this relation so as to make a choice, the adjustment of production function to the Mitscherlich's function permits us to obtain an optimum planting density (625 to 650 trees/ha).

The adjustment of (benefit – planting density) relation to a parabolic function, describes well the economic results. The general expression of this function is:

$$B_{\text{Exploitation}} = a \text{ density}^2 + b \text{ density} + c$$
(where $a$, $b$ and $c$ are the constants)
$$B_{\text{Exploitation}} \text{ (USD)} = -3.7310^{-3} \text{ density}^2 + 4.8 \text{ density} + 1170$$

This parabolic function presents a maximum point where the first derivate is null, corresponding to optimum economic density point:

$$B_{\text{Exploitation}} = -7.4610^{-3} \text{ density} + 4.8 = 0$$
$$-7.4610^{-3} \text{ density} = -4.8$$
$$\text{density} = -4.8 / -7.4610^{-3}$$
$$\text{density} = 643 \text{ trees/ha.}$$

DISCUSSION

In relation to the population of rubber trees (tappable and untappable), the slight variation of the population state parameters such as rate of living trees (RLT), rate of tappable trees at the beginning ($RT_0T$) and rate of tapped tress during 5 years of tapping ($RT_1T$) show that the planting density does not influence the number of living and or tappable trees, before and after the first 5 years of tapping. In the case of damage due to wind, a weak impact is noted in the planting densities of 200 trees/ha to 400 trees/ha[12]. At these less densities, wind passage penetration corridor is created which increases speed and makes it capable of causing damages to the trees[13]. The architecture of these trees, notably as the aerial part is more voluminous than the underground part, predisposes it to fall down[14]. The decrease with time of the density of tappable trees could be in part caused by the early tapping[15] of clone PB 235 which in this way, becomes weakened.

The vegetative growth, before and during tapping as contrary to the population state, is very strongly dependent on the planting density. The immature vegetative growth is not closely linked up to the competition observed with vegetable (plant) in the exploitation of environment resources. This is why even 4 years after planting, there is practically no difference of growth due to density. The difference of growth linked up to the density is expressed, from 5 and or 6 years, at the time where the trees present a canopy. This is the scenario of vegetative growth during the first 5 years growth of clone[16] RRII 105. The competition is perceptible at the time of the tapping and is exacerbated with the exploitation intensity[17], probably because of the strong energetic demand of the rubber production[18,19]. This competition is not always compensated for plant vigour, reduced in part by resources less

TABLE 5. TAPPING PANEL DRYNESS RATE FROM MEASUREMENTS REALISED FROM 1997 TO 1999 FOR PLANTING DENSITY OF *HEVEA BRASILIENSIS* CLONE PB 235

| Planting density | Tapping panel dryness (%) | | |
|---|---|---|---|
| | 1997 | 1998 | 1999 |
| 510 (Control) | 1.8 | 1.9 | 0.7 |
| 200 | 6.3 | 0.3 | 2.5 |
| 300 | 4.7 | 0.2 | 3.2 |
| 400 | 3.4 | 0.0 | 1.6 |
| 500 | 2.8 | 0.1 | 2.1 |
| 600 | 4.2 | 0.2 | 2.8 |
| 700 | 4.1 | 0.0 | 1.7 |
| 800 | 2.3 | 0.2 | 1.4 |
| 900 | 4.0 | 0.1 | 2.3 |
| 1000 | 2.2 | 0.1 | 1.4 |

TABLE 6. RETURN OF EXPLOITATION, COST OF EXPLOITATION AND BENEFIT OF EXPLOITATION (USD) FOR PLANTING DENSITY OF *HEVEA BRASILIENSIS* CLONE PB 235

| Planting density (Number of trees/ha) | Return of exploitation (/ha/5 years) | Cost of exploitation (From planting to 5 years of tapping) | Benefit of exploitation |
|---|---|---|---|
| 200 | 2814 | 779 | 2036 |
| 300 | 3516 | 1036 | 2480 |
| 400 | 4027 | 1289 | 2739 |
| 500 | 4750 | 1696 | 3054 |
| 600 | 4893 | 1836 | 3057 |
| 700 | 4981 | 2034 | 2947 |
| 800 | 5131 | 2313 | 2676 |
| 900 | 5121 | 2550 | 2571 |
| 1000 | 5773 | 3256 | 2517 |

and less available, due to competition between trees. This result, already reported by Westgarth and Buttery[14], is very important in as much as it illustrates an almost general situation in rubber growing estates, and is worthy to be taken into account in the management of plantations. Templeton[20] shows that the annual increment of girth is linked up with the initial girth at the opening of tapping of trees. The increments of girth noted in our experiment confirmed that.

Good results have been acquired, concerning tapping age, with an opening of tapping at age of 6 years, in the eco-climatic conditions of south-east and south-west of Côte d'Ivoire and bring the supplementary arguments as for age pertinence, instead of the girth at the opening of tapping[21] especially of clone[9] PB 235. This notion of opening of tapping according to the age finds its interest in the possibility of becoming free conditions of planting diversity and dependence on geographic planting space. The opening of tapping according to the age constitutes probably a criterion, to be able to solve the height/girth measurement problem. This can thus be permited to decide with less uncertainty the opening of tapping because this criterion is applied differently in Asia and in Africa. In Asia, the measurement is done between 1.25" and 1.6" in of stock scion, between about 1.75 m and 2 m from the ground[14,22–28]. In Africa, the measurement is realised at 1 m from the ground. In Africa, particularly in Côte d'Ivoire, the girth value at these different trunk heights is linked to inter- and intra-clonal variability. The relation which governs the girth measured at these height is linear; its general expression is:

$Y = AX$, in which $Y$ and $X$ express the girth at these heights and $A$ is a constant. For clones PB 235 and GT 1, it is respectively:

Girth (1.7 m) = 0.92 girth (1 m)
(r = 0.9983)
Girth (1.7 m) = 0.93 girth (1 m)
(r = 0.9734)

This result corresponds to a time difference between girth at 12 to 18 months from 1 m and 1.7 m (Obouayeba *et al.* 2001; Unpublished). According to Asean tapping criterion, the clone PB 235 would be tapped from 6 years instead of 4 to 5 years in Africa. This result is moreover in accordance with Asia where most of the clones are tapped between 6 and 7 years[1,2,25].

These different investigations indicate that the opening for tapping should be commenced 6 years after planting. The agronomic behaviour of clone PB 235 shows that its adverse characters (tapping panel dryness, damage due to wind, production being less important from 5 years *etc*.) are all the more pronounced where the opening is before 6 years, notably when the tapping starts between 4 and 5 years[8,9].

All the results obtained in the exploitation[1,2,8,9,15] of clone PB 235 permit to conclude that the adverse characters of PB 235 could be corrected by judicious technical itinerary applications. That will be essentially to plant on a deep and movable soil and above all to open for tapping 6 years after planting. This *sine qua non* would be able to improve the cultural behaviour of this clone as:

- An excellent vegetative growth with voluminous girth at panel opening; this will help against wind damage[29].
- A better management of indispensable energy to the general (vegetative growth) and secondary (rubber production) metabolic functionings so as to limit the physiological stress leading to tapping panel dryness.
- Sufficient latex vessel equipment[9] for a high and good rubber production.

## CONCLUSION

The planting density does not influence the living rubber trees. At the immature phase, the planting density had no effect on the bole growth. On the other hand, during exploitation, the bole growth was a function of the planting density. The density of 650 trees/ha is the optimal density of planting. Results of production, bole growth, and tappable rubber tree population are good. They permit to conclude that inhibitory characteristics that are usually showed by clone PB 235 have probably been attenuated because of the tapping achieved at prior to 6 years of age. These results show that the tapping of the PB 235 achieved between 6 and 7 years in Asean is more adapted to its characteristics than the tapping in Africa between 4 and 5 years. This puts into evidence the importance of age over the girth for the opening of tapping of rubber trees. The optimal exploitation of the clone PB 235 requires the follow-up of a judicious technical itinerary.

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