



Influence of age and girth at opening on rubber yield, biochemical and tapping panel dryness parameters of *Hevea brasiliensis* in determining tapping norms

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Abstract

The incidence of several girths or tapping start period on the parameters of rubber yield, the physiological profile and the sensitivity to tapping panel dryness of *Hevea brasiliensis* have been studied for a decade in southeastern rubber growing area of Côte d'Ivoire. The study was conducted from so called early (tapping start at 40, 45 cm girth) and/or late (opening at 55, 60 and 65 cm girth) tapping applied to clones GT 1, PB 217 and PB 235. This study shows that starting tapping clone GT 1 at 40 cm girth and clones PB 217 and PB 235 at 50 cm are the best treatments in terms of rubber yield, physiological parameters and tapping panel dryness. These girths at the opening were reached at approximately 6 years after planting, regardless of the clone. The satisfactory results recorded demonstrate the preponderance of the notion of "opening age" over that of circumference of tapping start. Thus, the age of 6 years after planting seems to be the best period to start tapping rubber trees, because it is a good benchmark of physiological maturity in *Hevea brasiliensis*. Despite this precedence of the age over the girth, the different results indicate the need to use both criteria to take into account a delay in the growth and especially a difference in the vegetative growth of the clones planted.

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Introduction

The tapping of rubber tree creates a significant antagonism between the vegetative growth of the tree, characterized by the production of wood biomass mainly due to the primary metabolism, and rubber yield which requires large amounts of energy and photosynthates (Le Bras, 1953; Templeton, 1969; Wycherley, 1976 b) demonstrated by several authors (Templeton, 1969 ; Narayanan and Ho, 1973; Wycherley, 1976; Sethuraj, 1981; Raghavendra, 1991; Gohet *et al.*, 1996; Obouayeba *et al.*, 2000; Obouayeba *et al.*, 2002). A good balance between the annual average increase in girth and rubber yield is obtained when the tapping (Templeton, 1969) is less likely to affect the production of primary biomass (vegetative growth) as shown by Raghavendra, 1991. This will ensure a proper physiological functioning of trees. The girth of trees at the opening is decisive in this context and the low increase in girth during tapping is an indicator of low vegetative growth and physiological immaturity of rubber trees (Compagnon, 1986; Obouayeba *et al.*, 2002). However, the good vegetative growth is the outward sign of a good balance between the physiological profile and the good health of rubber trees, a *sine qua non* for high productivity during the economic life of trees (Gohet *et al.*, 1996). Among the components of systems of latex harvesting ensuring a better balance between the primary metabolism of vegetative growth and the secondary one of rubber yield, girth and/or time of opening up are extremely important (Gohet *et al.*, 1996; Obouayeba, 2005). The girth at the opening up was right from the beginning the only empirical criterion to start tapping the rubber trees (Compagnon, 1986). It consists in tapping the rubber trees when their girth measured at 1 m above the ground reaches 50 cm. Similarly, the tapping period should enable to take into account the concept, overshadowed by the empirical criterion, of growth retardation and especially growth difference observed among the clones planted (Compagnon (1986); Obouayeba *et al.*, 2000). Recent studies (Obouayeba *et al.*, 2000; Obouayeba *et al.*, 2002; Obouayeba *et al.*, 2005)

have shown the importance of using both criteria despite the precedence of the notion of age (time) of rubber trees opening up. This study aims at analyzing and determining the effect of the girth and/or the time of opening, on the biochemical parameters of latex and those of rubber yield and tapping panel dryness of three *Hevea brasiliensis* clones PB 235, GT 1 and PB 217, in rubber growing area in south-eastern Côte d'Ivoire.

Materials and methods

Location of trials

The study was conducted in rubber growing region located in south-eastern (4°75'-5°75'N, 3-6°W) of Côte d'Ivoire. This region is characterized by the bimodal rainfall regime, with two rainy seasons and the average annual rainfall reaches 1600 mm. The soil is acidic ($4 < \text{pH} \leq 5$) ferralitic, deep, very desaturated on tertiary sand in the south-eastern.

Plant materials

Origin, physiological and yield characteristics

The three clones GT 1, PB 217 and PB 235 which were used in different works conducted in this study were all from south-east Asia. They were clones of *Hevea brasiliensis* Muell.-ARG., having the following characteristics:

Sucrose content of latex, main source for the biosynthesis of rubber, was low (PB 235), middle (GT 1) or high (PB 217). This characteristic is probably the basis of the ability of these clones to bear more or less hormonal stimulation of yield; the clone PB 235 bear lesser stimulation than the others. Similarly, the clone GT 1 bear lesser stimulation than the two others belonging to the same group.

Rubber yield, in the early years of tapping, the clone GT 1 was the least productive, respectively followed by the PB 217 and clone PB 235.

Characteristics of growth, physiological profile and sensitivity to tapping panel dryness

The plant materials used are clones GT1, PB 217 and PB 235 of *Hevea brasiliensis*. The selected clones are widely used in the rubber sector, but previous work showed that the biological activity of their latex system is different (Eschbach *et al.*, 1984; Jacob *et al.*, 1985; Prévot *et al.*, 1986; Commère *et al.*, 1988; Gohet *et al.*, 1991; Jacob *et al.*, 1995 d; Gohet *et al.*, 1996). The functioning typology of their latex system was the following: the clone PB 235 had a fast metabolic activity, the clone GT 1 showed a moderate or intermediate metabolic activity and the clone PB 217 had a slow metabolic activity. Similarly, the vegetative growth of clones PB 235, GT 1 and PB 217 was respectively fast, moderate and slow (Obouayeba *et al.*, 2000a). Sensitivity to tapping panel dryness was low for clone PB 217, moderate for GT 1, high for clone PB 235.

Selection of trees, experimental designs and Treatments

The trials for determining latex harvesting systems were carried out using two types of experimental designs. The treatments were subject only to the traditional system of harvesting latex (S/2 d4 6d/7 and a 2.5% Pa1(1)2/Y).

One tree plot design

The experiment was conducted using the setting where one tree represented a repetition and it focused on three clones of *Hevea brasiliensis*, PB 235, PB 217 and GT 1, planted at a density of 510 trees / ha: 7 m x 2.80 m. The averages girths of trees were between 39.50 and 39.97 cm, with a coefficient of variation (CV) comprised between 2 and 4 %. The trials area was approximately 3.12 ha where the trees being experimented were selected after eliminating the ones on border and close to sources of *Fomes lignosus*. The experiment with the clone PB 235 had five treatments (five girths at opening, 40, 45, 50, 55 and 60 cm). The one carried out on clone PB 217 studied four treatments (opening at 50, 55, 60 and 65 cm girth). The two tests on clone GT 1 studied four treatments (opening at 40, 45, 50, 60 cm girth) and five treatments (opening at 30, 35,

40, 45, 50 cm girth), that is, 132 to 198 (respectively 6 x 33; 4 x 33; 5 x 33; 6 x 33) trees per experiment.

Completely randomized blocks design (CRBD)

The clone PB 235 was used in two trials located in Bimbresso (southeast). The rubber trees were planted at a density of 510 trees / ha: 7 m x 2.80 m. Their average girths were between 49 and 51 cm, the coefficient of variation was around 5 %. The trees affected or not, close to sources of *Fomes lignosus*, were not selected for experimentation. Three and ten treatments were studied in Fisher blocks with 4 repetitions. Each repetition had 95 trees, that is, 1,140 trees for the trial.

Studied parameters

Rubber yield

The yield was recorded tree by tree (one tree plot design) or repetition by repetition (blocks design), at the rate of one yield check every four weeks, that is, every six tapping, the yield was collected in the field in a coagulated state. This coagulation occurs naturally in polyethylene bag or polybag.

The cumulative yield of six tappings was thus obtained at each yield check. After unbagging, the coagula were weighed individually. We determined, then for each tree the weight of fresh matter produced (FMW). A coefficient of transformation (CT) enabled to determine, from the weight of fresh coagulum (FMW), the weight of dry matter (DMW) produced in the form rubber by each tree of the trial over the six tappings concerned. During yield check, a sample was taken from each treatment of each trial. This sample, which coefficient of transformation (CT) we wanted to determine, was weighed before creping (FMTW = fresh matter total weight) and after creping (CFMTW = creped fresh matter total weight).

The creping consisted in eliminating a great part of the water contained in the coagulum by passing it through two metallic rollers (creping machine) rotating in opposite directions. The coagulum was then smashed and removed from the creping machine in the form of a flat sheet, much easier to

dry than the coagulum in its initial state. Only a fraction of that creped coagulum was dried in an oven (80 °C, 24 hrs).

The weight of that fraction was determined before drying (CFMW = creped fresh matter weight) and after drying (CDMW = creped dry matter weight). The coefficient of transformation was then defined by the formula:

$$CT = (CFMW / CDMW) \times (CFMTW / FMTW) \quad (1)$$

The conversion of fresh matter weight (FMW) into dry rubber weight (DMW) was carried out for each tree of each treatment by multiplying FMW by CT:

$$DMW = CT \times FMW \quad (2)$$

When calculating the average or cumulative yield, only the trees that were still being tapped at the end of the experiment were taken into account: dry trees no longer producing latex, as well as broken or uprooted ones, were retroactively removed from the test since the beginning of the trial, in order to avoid any bias regarding the relationship growing - yield. The yield was initially expressed in g of dry rubber per tree per tapping ($\text{g.t}^{-1}.\text{t}^{-1}$) and kg of dry rubber per tree per year ($\text{kg.t}^{-1}.\text{y}^{-1}$).

Tapping panel dryness

During tapping, the flow of latex on some trees was sometimes abnormally low or even nonexistent, a part or the whole of the tapping cut was non productive in that case, which characterizes the tapping panel dryness syndrome.

The quick survey method of tapping panel dryness by visual estimation provided a simple way to account for the incidence of the syndrome and to quantify as a percentage of total length of tapping panel dryness (TLTPD %) (Data sheet CIRAD, 1993). The observer who carried out the survey followed the tapper and gave progressively a rate from 0-6 to each tree tapped :

0: healthy cut or latex productive cut

1: dry cut from 1 to 20 % of its length (10 % on average)

2: dry cut from 21 to 40 % of its length (30 % on average)

3: dry cut from 41 to 60 % of its length (50 % on average)

4: dry cut from 61 to 80 % of its length (70 % on average)

5: dry cut from 81 to 99 % of its length (90 % on average)

6: completely dry cut.

Each time a tree showed at least a portion of dry cut (*a priori* trees rated from 1 to 6), the observer checked with a punch that the depth of the cut was correct, that is to say latex vessels were actually cut during the tapping.

For a given plot, the total length of tapping panel dryness (TLTPD) was calculated (Data sheet Anonymous 2, 1993) using the formula:

$$TLTPD = 0.1 n_1 + 0.3 n_2 + 0.5 n_3 + 0.7 n_4 + 0.9 n_5 + n_6 \quad (3)$$

Where n_i is equal to the total number of trees rated *i*.

The coefficients of this linear combination represent the average percentages of tapping panel dryness of each class of disease.

Physiological parameters

The rubber tree has undergone during the year a period of high metabolic activity (March-December) and another one of very low activity from January to February (hibernation). Thus we defined the physiological campaign as the beginning and the end of the period of normal metabolic activity. From September to December each year, a physiological analysis of the latex (latex diagnosis) was performed on 10 trees of each treatment. The period specified above is considered ideal to the extent that latex physiological parameters showed little progress during that period (stable window). Moreover, since each physiological campaign began in March-April, the analysis of latex in September-December enabled to assess accurately, six months earlier, the effect of the latex harvesting system implemented in early campaign. Thus we determined:

the dry content, which is the percentage of dry matter of latex produced (DRC,%)

- the sucrose content in latex (Suc mM)
- the inorganic phosphorus content in latex (Pi, mM)
- the thiol content in the latex (R-SH, mM).

Latex was collected by normal tapping. It was harvested between the 5th and 35th minute after tapping start. The first five minutes of flow were in fact discarded because they contained latex rich in broken and contaminated luteoids (various debris, bacteria, fungi etc.) (Pakianathan *et al.*, 1966; Ribaillier, 1972)

Statistical analysis

Data concerning the rubber yield, physiological parameters (biochemical) and the sensitivity to tapping panel dryness of rubber trees undergoing tapping were subject to a one-way analysis of variance (ANOVA). The statistical analyses were performed at a p-value $\alpha = 5\%$, using the Scheffe test, which allows to take into account, for the analysis of variance, many missing values. The statistical software used for these analyses was STATGRAPHICS®.

Results

Rubber yield

Case of clones GT 1, PB 217 and PB 235 tapped according to girth (at various ages) in the Southeast
Rubber yield in grams per tree and per tapping (g/t/t)

The yield expressed in g/t/t varied depending on the girth at opening. In the clone GT 1 (1984-1994) the opening at 50 cm girth had a yield in g/t/t statistically comparable to that of the opening at 45 cm and higher than those of the openings at 40, 35 and 30 cm (Table 1).

For the period from 1992 to 1999, the yield (g/t/t) of the openings at 40, 45 and 50 cm, of the same size, was statistically lower than the opening at 60 cm (Table 2).

The yield (g/t/t) of the opening at 50 cm, of PB 217, was significantly lower than those recorded at 55, 60 and 65 cm girth (Table 3).

Concerning clone PB 235, the values of g/t/t of the openings at 40 and 45 cm, comparable to each other, were statistically lower than those of openings superior or equal to 50 cm (Table 4).

The yields (g/t/t) of the openings at 50 and 60 cm girth, not different, were significantly lower than that of the opening at 70 cm (Table 5).

Moreover, the rubber yield expressed in g/t/t was also subject to clonal influence. The yield (g/t/t) of clone PB 217 was in fact higher than that of PB 235 which value was higher than that of clone GT 1. This result is consistent with the level of yield of these clones.

Yield in grams per tree per year (g/t/y)

Concerning clone GT 1, the cumulative yield, g/t/y from 1984 to 1994 (Table 1) was significantly lower especially as the girth at opening was smaller. The cumulative yields (g/t/y) of the openings at 50, 45 and 40 cm girth, statistically comparable, were in fact higher than those of the openings at 35 and 30 cm girth. These last two girths at opening had cumulative yields of the same order of magnitude.

From 1992 to 1999, the cumulative yield, g/t/y (Table 2) of the treatment undergoing tapping at 40 cm girth, was significantly higher than that of the ones undergoing tapping at 50 and 60 cm girth.

In the case of clone PB 217, the cumulative yield (g/t/y; Table 3) reached a good level and did not vary according to the girth at tapping start. Indeed, this yield was the same regardless of the girth at tapping opening.

Concerning clone PB 235, the cumulative yield (g/t/y; Table 4) was average regarding the performance of this clone. It varied according to the girth at tapping start. Indeed, the cumulative yield of the ones undergoing tapping at 40, 45, 50 and 55 cm girth were the same size but higher than that of the pattern tapped at 60 cm girth.

Yield (land productivity) in kg/ha

The average yield expressed in kg/ha of clone PB 235 of 1999 (Table 5) slightly exceeded a ton. It varied according to the girth at opening. The one

undergoing tapping at 70 cm (at 9 years 10 months) gave a yield significantly higher than the ones which tapping started at 50 and 60 cm girth (respectively 7 years 10 months and 5 years 10 months). These last two periods gave yields of the same size.

Under cumulative yield over the period from 1992 to 1999 (Table 5) there is a reversal of the tendency indicated above. Indeed, the cumulative yield of the tapping which started at 50 cm girth was significantly higher than the ones which started at 60 and 70 cm. The cumulative yield of the tapping

which started at 60 cm girth was statistically higher than the yield of the one which started at 70 cm (Table 5).

Parameters of physiological profile

Case of clones GT 1, PB 217 and PB 235 started to be tapped according to girth (at various ages) in the Southeast

Table 1. Rubber yield (g/t/t, g/t/y cumulative) of clone GT 1 from 1984 to 1994.

Treatments	Rubber yield between 1984 and 1994	
	g/t/t	g/t/year
	Average	Cumulative
Opening at 30 cm girth or at 3 years 5 months	23.1 d	24903 b
Opening at 35 cm girth or at 3 years 10 months	25.3 cd	26061 b
Opening at 40 cm girth or at 4 years 4 months	29.2 bc	28500 a
Opening at 45 cm girth or at 4 years 9 months	31.7 ab	29705 a
Opening at 50 cm girth or at 5 years 9 months	33.9 a	29829 a

a, b, c: Treatments assigned with the same letter were not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7, that is, 78 tappings/year.

Table 2. Rubber yield (g/t/t, g/t/y cumulative) of clone GT 1 from 1992 to 1999.

Treatments	Rubber yield between 1992 and 1999	
	g/t/t	g/t/year
	Average	Cumulative
Opening at 40 cm girth or at 6 years	39.6 b	21087 a
Opening at 45 cm girth or at 6 years 10 months	42.7 b	19647 ab
Opening at 50 cm girth or at 7 years 9 months	41.0 b	15906 c
Opening at 60 cm girth or at 9 years 10 months	49.7 a	11583 d

a, b, c : Treatments assigned with the same letter were not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7, that is, 78 tappings/year.

Dry rubber content

The clone GT 1 regardless of the period, 1984-1994 or 1992-1999, presented a average level of dry rubber content at opening in compliance with standards. It has improved somewhat over tappings

concerning certain treatments (Fig. 1 (a and b)). The dry content did not vary significantly from one treatment to another whatever the period of tapping.

Table 3. Rubber yield (g/t/t, g/t/y cumulative) of clone PB 217 from 1988 to 1999

Treatments	Dry rubber yield between 1988 and 1999	
	g/t/t	g/t/year
	Average	Cumulative
Opening at 50 cm girth or at 6 years 10 months	69.7 c	58794
Opening at 55 cm girth or at 7 years 4 months	78.2 b	62376
Opening at 60 cm girth or at 8 years 3 months	84.2 a	62666
Opening at 65 cm girth or at 8 years 10 months	88.8 a	61290

a, b, c : Treatments assigned with the same letter are not significantly different (Sheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7, that is, 78 tappings/year.

Table 4. Rubber yield (g/t/t, g/t/y cumulative) of clone PB 235 from 1991 to 1999

Treatments	Dry rubber yield between 1991 and 1999	
	g/t/t	g/t/year
	Average	Cumulative
Opening at 40 cm girth or at 4 years 11 months	40.0 b	24500 a
Opening at 45 cm girth or at 5 years 3 months	42.1 b	24505 a
Opening at 50 cm girth or at 6 years 3 months	50.8 a	25607 a
Opening at 55 cm girth or at 7 years	54.0 a	23992 ab
Opening at 60 cm girth or at 7 years 6 months	53.8 a	21958 b

a, b, c : Treatments assigned with the same letter are not significantly different (Sheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7, that is, 78 tappings/year.

Table 5. Rubber yield (g/t/t, g/t/y cumulative, kg/ha average and cumulative) of clone PB 235 of 1992 to 1999

Treatments	Dry rubber yield between 1992 and 1999			
	g/t/t	g/t/year	kg/ha	kg/ha
	Average	Cumulative	Average	Cumulative
Opening at 50 cm girth or at 5 years 10 months	43.9 b	23700 a	970.8 b	8854 a
Opening at 60 cm girth or at 7 years 10 months	46.4 b	18090 b	910.7 b	5538 b
Opening at 70 cm girth or at 9 years 10 months	55.3 a	12931 c	1214.1a	3598 c

a, b, c: Treatments assigned with the same letter are not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7, that is, 78 tappings/year.

Table 6. Sensitivity to tapping panel dryness expressed by the Length of Diseased Cut and dry trees of clone GT 1 of *Hevea brasiliensis* from 1984 to 1994

Treatments	Tapping Panel Dryness (%)			
	LDC		Dry trees	
	Start	end	Start	End
Opening at 30 cm girth or at 3 years 5 months	0.3 b	26.6 a	0.0	1.4 d
Opening at 35 cm girth or at 3 years 10 months	0.0 c	25.1 a	0.0	8.9 a
Opening at 40 cm girth or at 4 years 4 months	2.4 a	19.5 b	0.0	5.6 b
Opening at 45 cm girth or at 4 years 9 months	0.3 b	17.7 b	0.0	3.4 c
Opening at 50 cm girth or at 5 years 9 months	-	14.1 c	0.0	3.2 c

a, b, c, d: Treatments assigned with the same letter are not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7 that is 78 tappings/year.

Table 7. Sensitivity to tapping panel dryness expressed by the rates of Length of Diseased Cut and dry trees of clone GT 1 of *Hevea brasiliensis* from 1992 to 1999.

Treatments	Tapping panel dryness (%)			
	LDC		Dry trees	
	Start	End	Start	End
Opening at 40 cm girth or at 6 years	0.0 b	6.1 b	0.0	0.0 c
Opening at 45 cm girth or at 6 years 10 months	0.3 a	0.3 c	0.0	0.0 c
Opening at 50 cm girth or at 7 years 9 months	0.0 b	10.0 a	0.0	9.1 a
Opening at 60 cm girth or at 9 years 10 months	0.0 b	5.6 b	0.0	3.2 b

a, b, c, d: Treatments assigned with the same letter are not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7 that is 78 tappings/year.

Table 8. Sensitivity to tapping panel dryness expressed by the rate of Length of Diseased Cut and dry trees of clone PB 217 of *Hevea brasiliensis*, from 1988 to 1999.

Treatments	Tapping panel dryness (%)			
	LDC		Dry trees	
	Start	End	Start	End
Opening at 50 cm girth or at 6 years 10 months	0.9 a	0.0 c	0.0	0.0 c
Opening at 55 cm girth or at 7 years 4 months	0.3 b	10.0 ab	0.0	3.2 b
Opening at 60 cm girth or at 8 years 3 months	0.0 b	11.9 a	0.0	6.5 a
Opening at 65 cm girth or at 8 years 10 months	-	8.3 b	-	6.7 a

a, b, c, d: Treatments assigned with the same letter are not significantly different (Scheffe test at 5%).

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7 that is 78 tappings/year.

Table 9. Sensitivity to tapping panel dryness expressed by the rate of Length of Diseased Cut (LDC) and dry trees of clone PB 235 of *Hevea brasiliensis* from 1991 to 1999

Treatments	Tapping Panel Dryness (%)			
	LDC		Dry trees	
	Start	End	Start	End
Opening at 40 cm girth or at 4 years 11 months	1,2	5.0	0.0	0.0
Opening at 45 cm girth or at 5 years 3 months	0.6	8.8	0.0	3.1
Opening at 50 cm girth or at 6 years 3 months	0.6	10.3	0.0	0.0
Opening at 55 cm girth or at 7 years	-	6.9	0.0	3.1
Opening at 60 cm girth or at 7 years 6 months	-	6.4	0.0	0.0

Treatments are tapped at the same frequency i.e. S/2 d4 6d/7 that is 78 tapplings/year.

Table 10. Sensitivity to tapping panel dryness expressed by the rate of Length of Diseased Cut and dry trees of clone PB 235 of *Hevea brasiliensis*, from 1992 to 1999

Treatments	Tapping Panel Dryness (%)			
	LDC		Dry trees	
	Start	End	Start	End
Opening at 50 cm girth or at 5 years 10 months	1.25 b	12.38a	0.3 b	6.88 a
Opening at 60 cm girth or at 7 years 10 months	1.38 b	10.18a	0.5 b	6.95 a
Opening at 70 cm girth or at 9 years 10 months	5.45 a	12.18a	3.3 a	4.50 b

a, b, c, d :Treatments assigned with the same letter are not significantly different (Scheffe test at 5%). Treatments are tapped at the same frequency i.e. S/2 d4 6d/7 that is 78 tapplings/year.

Sucrose content

The sucrose content of clone GT 1 was also high and in compliance with standards, it did not vary according to the girth at opening. Except for the control, non-tapped (Fig. 1b), which value decreased at the end of trial, all the other treatments had higher final sucrose content (Fig. 1a and b).

Inorganic phosphorus

Except the case of the control which presented very low values, the contents of the other patterns were high (Fig. 1a and b). The final contents, on the whole, have increased compared to the initial values (1992-1999; Fig. 1b) unlike for the period from 1984 to 1994 (Fig. 1a). The final Pi content was consistent with that of GT 1.

Thiol groups

A general decrease in contents of clone GT 1 was observed compared to the values of early opening (Fig. 1a and b). This decrease could not be systematically attributed to early opening especially as it was also observed in the absolute control non-tapped (Fig. 1b). The thiol groups content was consistent with that of the clone. It showed changes related to treatments but which did not globally discriminate the controls opened at 6 years.

Dry rubber content

The dry content at opening of clone PB 217 has increased and has been higher especially as the tapping start occurred at larger girths. At the end of the experiment, the dry content enabled to identify

two treatment groups (Fig. 2). The first one concerned the openings at 50 and 55 cm which had statistically identical dry contents. These rates were

higher than the ones of the second group, openings at 60 and 65 cm, which showed contents of equal size.

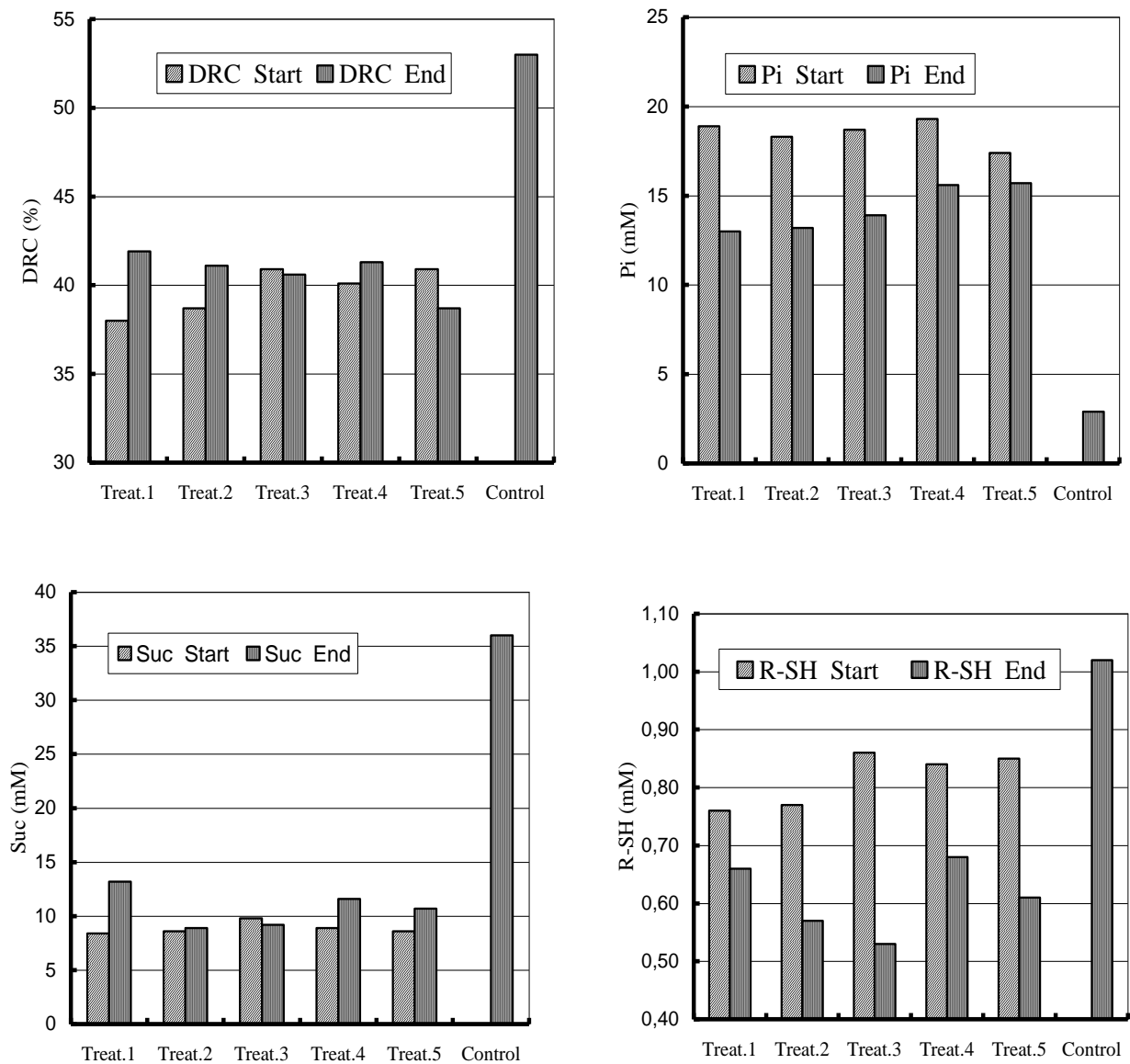


Fig. 1a. Parameters of physiological profile of clone GT 1 of *Hevea brasiliensis* according to girth at the opening (1984 - 1994)

Treat. 1 : opening at 30 cm of girth

Treat. 2 : opening at 35 cm of girth

Treat. 3 : opening at 40 cm of girth

Treat. 4 : opening at 45 cm of girth

Treat. 5 : opening at 50 cm of girth

Control : untapped

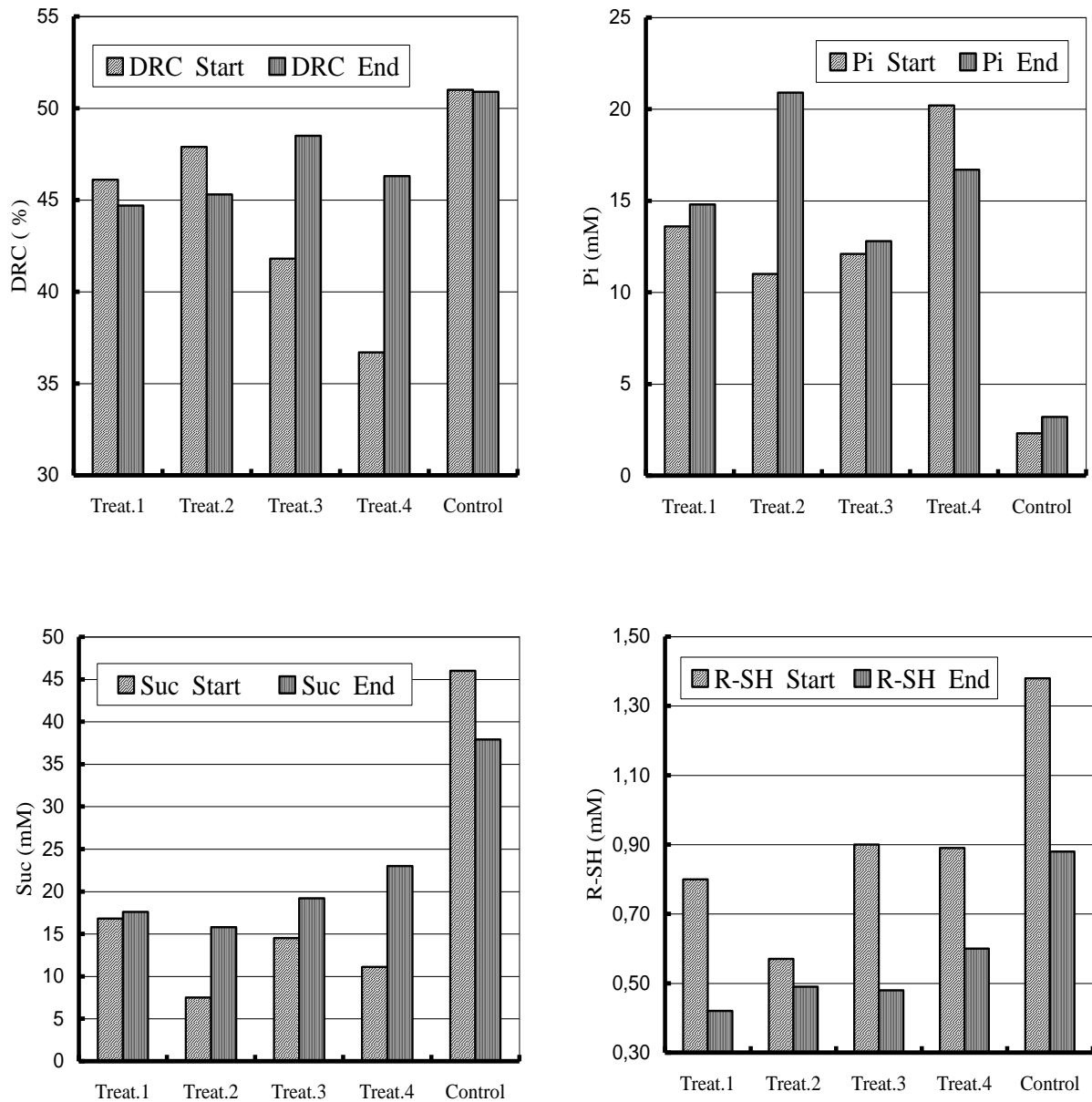


Fig. 1b. Parameters of physiological profile of clone GT 1 of *Hevea brasiliensis* according to girth at the opening (1992 - 1999)

- Treat. 1 : opening at 40 cm of girth
- Treat. 2 : opening at 45 cm of girth
- Treat. 3 : opening at 50 cm of girth
- Treat. 4 : opening at 60 cm of girth
- Control : untapped

Sucrose content

The sucrose content of PB 217 was a high, except for treatment 2, opening at 55 cm girth, which content was significantly lower than that of the other contents, which had values of equal size (Fig. 2).

Inorganic phosphorus content

The openings up at 50, 55 and 60 cm girth had statistically less different values but lower than that of the opening at 65 cm. The overall level was appropriate and consistent with the characteristics of clone PB 217(Fig. 2).

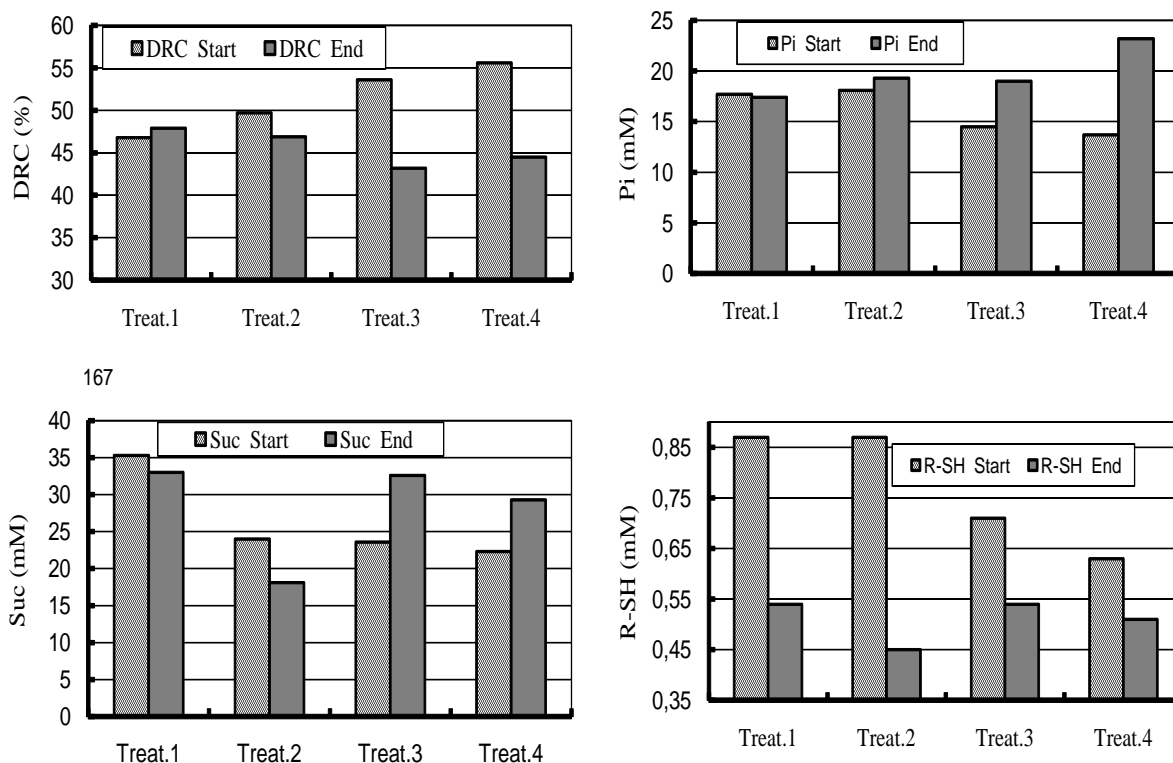


Fig. 2. Parameters of physiological profile of clone PB 217 of *Hevea brasiliensis* according to girth at the opening (1988 -1999)

Treat. 1 : opening at 50 cm of girth

Treat. 2 : opening at 55 cm of girth

Treat. 3 : opening at 60 cm of girth

Treat. 4 : opening at 65 cm of girth

Thiol groups' content

The thiol groups content did not distinguish the openings at 50, 60 and 65 cm which values of the same size were higher than that of the opening at 55 cm girth (Fig. 2).

Dry rubber content

The dry rubber content average of clone PB 235, all periods put together, was average to high (Fig. 3a and b). It has changed a little according to the girth at opening, except for the control, non-tapped. The average of dry rubber content has increased significantly over time. The activity of rubber biosynthesis has not been discriminatory to the treatments but was clearly improved at the end of experiment.

Sucrose content

The sucrose content of the different openings, except for those of treatments 2 and 5, was low (Fig.

3 a). Concerning Figure 3 b, the sucrose content was compliant with the annual standards and yield of the treatments. The contents of the first two treatments were comparable and higher than those of the last one (Fig. 3 a). However, on the whole, compared to the initial values, it has increased and has been consistent with that of PB 235 (Fig. 3 a and b).

Inorganic phosphorus (Pi) content

The Pi content (Fig. 3 a and b) has varied over time and according to the girth at opening. Only the earliest opening showed a lower final content. The Pi content has increased over time (Fig. 3 b). All periods put together, the Pi content was consistent with the characteristics of clone PB 235 undergoing tapping.

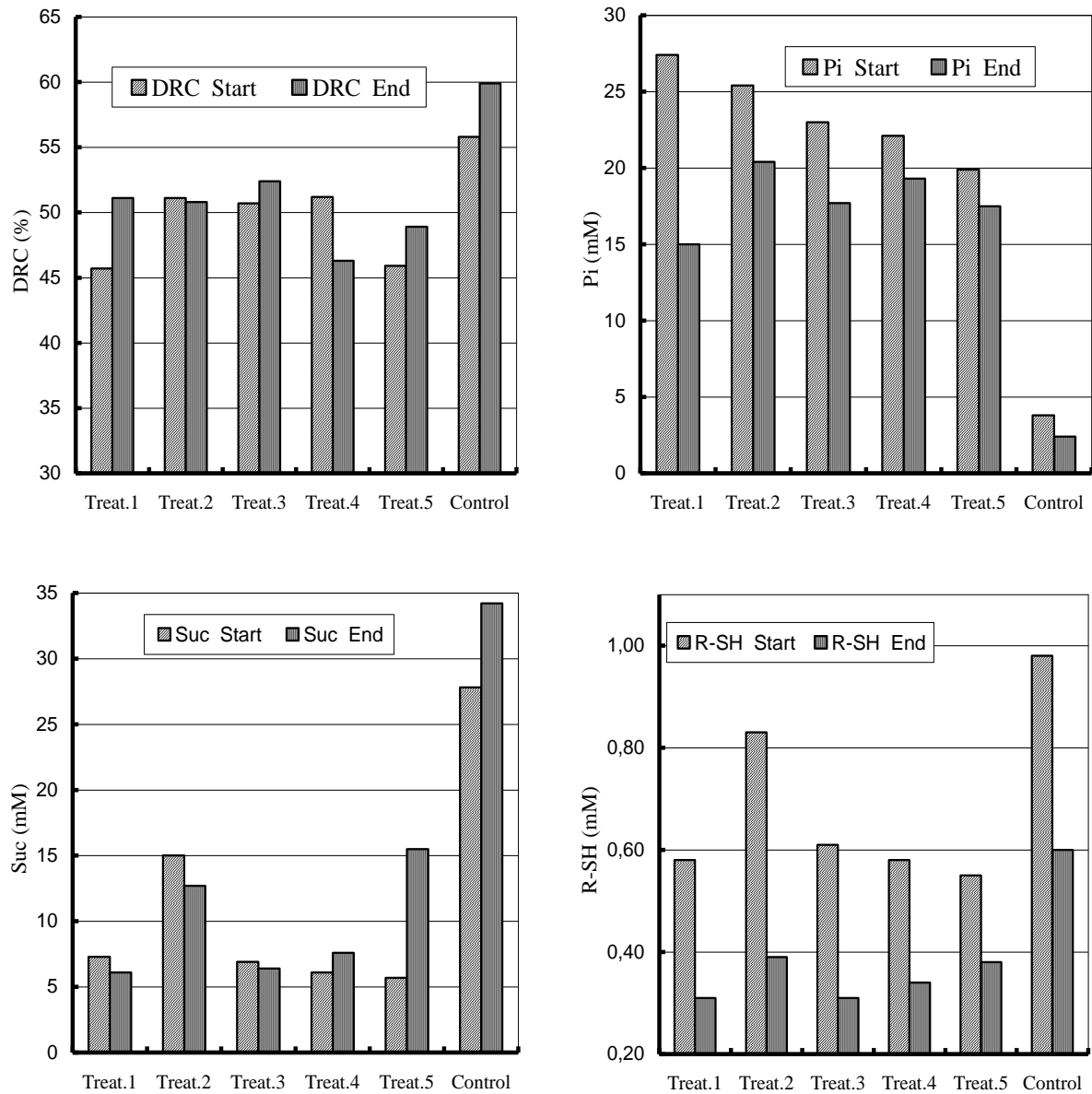


Fig. 3a. Parameters of physiological profile of clone PB 235 of *Hevea brasiliensis* according to girth at the opening (1991 - 1999)

- Treat. 1 : opening at 40 cm of girth
- Treat. 2 : opening at 45 cm of girth
- Treat. 3 : opening at 50 cm of girth
- Treat. 4 : opening at 55 cm of girth
- Treat. 5 : opening at 60 cm of girth
- Control : untapped

Thiol groups (R-SH)

The thiol groups' content (R-SH), whatever the period was generally low and consistent with that of clone PB 235 (Fig. 3 a and b). It has undergone a fall over time. However, all the girths at the opening, regardless of the period, were statistically

comparable with respect to their thiol content (Fig. 3 a and b).

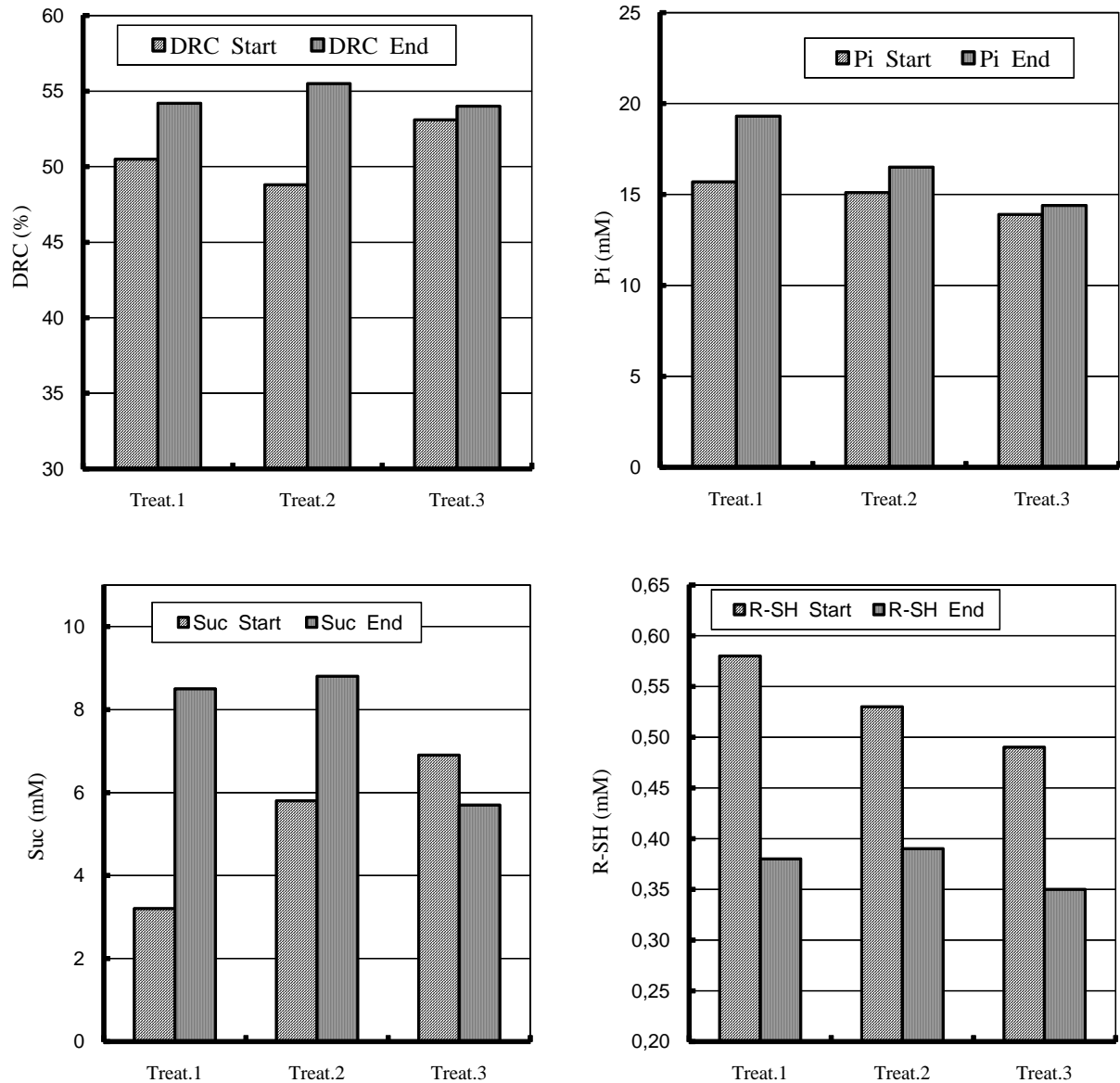


Fig. 3b. Parameters of physiological profile of clone PB 235 of *Hevea brasiliensis* according to girth at the opening (1992 - 1999)

Treat. 1 : opening at 50 cm of girth

Treat. 2 : opening at 60 cm of girth

Treat. 3 : opening at 70 cm of girth

Sensitivity to tapping panel dryness

Case of clones GT 1, PB 217 and PB 235 started to be tapped according to girth (at various ages) in the Southeast.

The clone GT 1, in general, showed from 1984 to 1994 (Table 6) a significant increase of tapping panel dryness compared to initial levels of Length of

Dry Cut (LDC) and dry trees. This increase was important especially as the tapping was early. From 1992 to 1999, the different treatments (Table 7) showed little overall sensitivity to tapping panel dryness. The treatment tapped at 50 cm, relative control, was the most sensitive, while the one which was opened up at 45 cm expressed less sensitivity. This result of tapping panel dryness has on the

whole been consistent with the sensitivity level of clone GT 1.

Concerning clone PB 217, only the opening at 50 cm girth has shown no sensitivity to tapping panel dryness (Table 8). The other treatments have all shown, at various stages, sensitivity to tapping panel dryness yet, it was equally significant.

Concerning PB 235, the sensitivity to tapping panel dryness (1991-1999, Table 9) has increased with tapping, especially regarding the Length of Diseased Cut (LDC). It varied according to the girth at opening.

The relative control (opening at 50 cm) showed the highest sensitivity. Concerning the rate of dry trees, only the openings at 45 and 55 cm provided dry trees but the rate was appropriate and consistent with the sensitivity of clone PB 235.

Concerning the period 1992-1999 (Table 10) an evolution and final state of the same magnitude of LDC were noticed. In the case of dry trees, the first two treatments were statistically similar as compared to evolution as well as the end of the trial. They showed a rate of dry trees higher than that of the last treatment.

Discussion

The works on the dynamics of vegetative growth of *Hevea brasiliensis* and the formation of structural organs, such as bark and latex vessels, have helped to highlight the criterion of tapping age in view of determining standards for tapping start or opening (Obouayeba *et al.*, 2000; Obouayeba *et al.*, 2002; Obouayeba, 2005). The age of 6 years after planting is ideal for a sustainable exploitation from a tapping start based on agro-pedo-climatic and intrinsic characteristics of the plant. The age criterion selected shall be evaluated in comparison with the criterion in force in relation to key agronomic parameters that are rubber yield, vegetative growth under tapping, physiological profile and sensitivity to tapping panel dryness. The purpose of rubber tree tapping is, in fact, to yield rubber steadily,

without significant damage to trees, a state which is reflected by a good growth under tapping.

To that extent, this study has evaluated the effect of rubber trees tapping at different girths and/or tapping start period on rubber yield, physiological profile and sensitivity to tapping panel dryness of trees. Our results have shown, all experiments combined, that early tapping reduced *vice versa* rubber yield and the annual average increase in girth during tapping. These results also highlight the fact that the competition *vegetative growth-rubber yield* is important especially as the tapping is early. These results are in accordance with those of many authors (Templeton, 1969, Wycherley, 1976, Anonymous 2, 1987, Anonymous 3, 1988, Anonymous 4, 1989, Obouayeba *et al.*, 2002, Obouayeba, 2005). However, these results have indicated that when the tapping is performed at the age of 6 years after planting, the functioning of the couple *vegetative growth-rubber yield* is good (Obouayeba *et al.*, 1996 b and Premakumari *et al.*, 1996). The good balance observed, all experiments combined, between the components of the couple *vegetative growth-rubber yield*, explains this situation well. The low sensitivity to tapping panel dryness shown the trees reinforces this thesis which is also corroborated by a good balance of the physiological profile, with no signs of physiological fatigue (Jacob *et al.*, 1994; Obouayeba *et al.*, 1996 b).

Furthermore, our results on the behaviour of rubber trees tapped at different girths and/or tapping start period, all experiments combined, also confirm our findings on radial vegetative growth and the dynamics of bark and latex vessel coats formation (Obouayeba *et al.*, 2000; Obouayeba *et al.*, 2002; Obouayeba, 2005). Indeed, the experiments we conducted have showed that the best compromise, concerning the different girths at the opening, compared to the competition *vegetative growth-rubber yield*, is obtained for openings at 40 and 50 cm on clone GT 1 and 50 cm on clones PB 217 and PB 235. The periods or corresponding ages, in

relation to planting, ranged from 5 years 9 months and 6 years 10 months, all clones combined. These results have shown that six years after planting, the behaviour of *Hevea brasiliensis* at rubber yield, at radial vegetative growth, at physiological profile and sensitivity to tapping panel dryness, was not dependent on the girth at opening, all experiments combined.

Moreover, as the trees of all these openings have presented physiological profiles fairly well balanced, corroborated by a low sensitivity to tapping panel dryness, we can then conclude that 6 years after planting, the *Hevea brasiliensis* has actually reached an latex harvesting maturity which reflects a physiological maturity.

Conclusion

The experiments relating to the impact of several girths or tapping start period on the agronomic performance of some clones of *Hevea brasiliensis* show that the tapping start at 40 and 50 cm girth for clones GT 1, PB 217 and PB 235 are the best treatments in terms of rubber yield, radial vegetative growth under tapping, physiological profile and sensitivity to tapping panel dryness. The different periods corresponding to those tapping start girths have enabled to notice that they were reached about six years after planting, regardless of the vegetative growth class of the clone. Considering the growth retardation, by at least a year, suffered by clones GT 1 and PB 235, the preponderance of the notion of opening age over opening girth can be admitted. Similarly, the age of 6 years after planting seems to be the best tapping start period of rubber trees, because it is invariable for the three classes of vegetative growth of the clones studied and can be a strong marker of physiological maturity in *Hevea brasiliensis*.

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