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RELATIONSHIP BETWEEN THE TAPPING CUT LENGTH AND THE PARAMETERS OF VEGETATIVE GROWTH AND RUBBER YIELD OF *HEVEA BRASILIENSIS*, CLONES GT 1 AND PB 235 IN SOUTH-EASTERN CÔTE D'IVOIRE

SAMUEL OBOUAYEBA[1,*], ERIC FRANCIS SOUMAHIN[1], KOFFI MATHURIN OKOMA[3], ANGELO EVARISTE BADOU N'GUESSAN[2], RÉGIS LACOTE[4], LACINA FANLÉGUÉ COULIBALY[1,5], AKÉ S.[5]
[1]CNRA, Research Station of Bimbresso, 01 BP 1536 Abidjan 01, Côte d'Ivoire
[2]CNRA, Regional Direction, 01 BP 33 Abidjan 01, Côte d'Ivoire
[3]CNRA, Central Laboratory of biotechnology, 01 BP 1740 Abidjan 01, Côte d'Ivoire
[4]CIRAD, UPR 34, Tree Crop-Based Systems, TA B/34, Montpellier F-34000, France
[5]University of Cocody, UFR Biosciences, Laboratory of Plant Physiology, 22 BP 582 Abidjan 22, Côte d'Ivoire
*Corresponding author. E-mail: obouayebasam@yahoo.fr

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Abstract- The management of the bark of rubber tree over a long period is a major concern for rubber planters in order to cope with problems of early replanting due to limited financial means. One of the efficient solutions to this concern is tapping with less longer tapping cuts. The reduction of the tapping cut length in reverse tapping permits to manage better the tapping panel, to improve the productivity of the tapper and to increase the economical life span of rubber trees. On that respect, a study was conducted during six years in south-eastern Côte d'Ivoire in order to determine the length(s) of tapping cut, in downward tapping, which would provide a suitable solution to the problem of rubber farmers. The influence of the reduction of the tapping cut length on the parameters of yield, radial vegetative growth and physiological profile is evaluated in clones GT 1 and PB 235 of *Hevea brasiliensis*. Half, third, quarter and eighth spiral tapping cuts were compared to each other and to a full spiral cut (control). The reduction of the tapping cuts length induces losses in rubber yield compared with the control which yet are not proportional to the reduction of the tapping cuts length. The yield per centimetre of tapping cut is more important with the short cuts than the long cuts. Very strong correlations were determinate between tapping intensity and rubber yield, tapping intensity and annual mean girth increment and between tapping intensity and physiological parameters (DRC and Pi). The curve tendency equations were also determinate. In terms of rubber yield, the PB 235 fits the reduction of the tapping cut length better than the GT 1. The reduction of tapping cuts length favours a better vegetative radial growth. It does not impair the physiological profile of the trees which show signs of under-exploitation.
Keywords: *Hevea brasiliensis*, tapping, yield, growth, physiological profile, Côte d'Ivoire.

1. Introduction

The yield of natural rubber is a key product, economically important to most tropical developing countries. It is contained in the latex which is an extract of the rubber tree (*Hevea brasiliensis*) through the process of tapping. The natural rubber yield in these tropical countries must address two key concerns, difficult to reconcile, which are an ever-increasing productivity over a longer period of time. The high productivity partakes of the mastery of modern exploitation of rubber plantations and helps meet the ever-increasing global demand of 9.9 million tons for natural rubber in 2008 [1]. When maintaining high productivity on the long term accounts for to the lack of capacity of smallholders for replanting rubber, which technically can be exploited for at least 30 years [2, 3, 4]. The tapping process, which consists in an incision (cut) into the bark, is practiced according to certain rules including the establishment of a slope and a tapping cut. The tapping of the rubber tree can be made through tapping cuts of variable lengths; full spiral (S), the cut is made on the whole circumference of the tree, half spiral (S/2), the cut is made on the half of the circumference, third spiral (S/3) on the third, quarter-spiral (S/4) on the quarter of the circumference of the tree, etc.. In the early days of rubber tree cultivation, tapping was made in downward full spiral [4, 5]. Indeed, the full spiral tapping provides a more significant rubber yield than the tapping in short cuts, especially in half, third, quarter, etc. spirals [6]. However, the full spiral tapping is highly bark-consuming and strongly reduces the exploitation period of the plantation, which rarely exceeds 10 years against 20 in the case of the half spiral tapping. Furthermore, the full spiral tapping girdles more or less the tree and can eventually cause a discomfort in the flowing of the elaborated sap because of the incision of the liber [7, 8]. The circling of the tree by full spiral tapping therefore makes insufficient the supply of laticifers in sucrose and other elements resulting from the photosynthesis and necessary to the biosynthesis of the rubber; since this operation damages almost all the phloem, leaving only a thin strip of bark at less than 1.0 mm from the cambium [4, 5]. This shortage in the supply of laticifers may lead then to a reduction in yield or to the phenomenon of the dry cut [9]. The downward full spiral has been abandoned since 1975 with the advent of products that stimulate the yield of rubber [10, 11] in favor of the downward half spiral and the upward quarter or half spiral [4]. Moreover, the losses in rubber yield related to the reduction in the tapping cut are less than proportional to the length of the tapping cut [3]. The reduction of the tapping cut shows on the contrary more advantages related to the duration of bark management, much longer, and to the costs of tapping labour [12]. In order to be more efficient (high productivity over a long period of time) in the modern management of a rubber plantation, it is necessary and essential to study the impact of the reduction of the tapping cut length on the parameters of rubber yield, radial vegetative growth and physiological profile. This helps to determine the length of tapping cut which are able to make efficient the exploitation of a rubber plantation according to the socioeconomic contingencies of the region. This study has been carried out by the Rubber Tree Program of the CNRA, in the southeast of Côte d'Ivoire. The results of a six-year experimentation of the incidence of the reduction of the tapping cut length on the rubber yield, the radial vegetative growth and the physiological profile of the trees of the clones GT 1 and PB 235 are presented in this paper.

2. Material and methods

2.1. Location of the trials

The experiment have been carried out on the experimental land of the CNRA, at the research station of Bimbresso in Anguédédou, at rubber growing region located in, south-east (4°75'-5°75'N, 3-6°W) of Côte d'Ivoire, over an area of 3.1 hectares for each of the clones. This region is characterized by a sub-equatorial climate with two rainy seasons and two dry seasons. The soils are ferralitic, derived from tertiary sand. The trees have been planted in stumps in 1984 with a density of 510 trees per hectare.

2.2. Plant material

The experiment has been made on *Hevea brasiliensis* clones GT 1 and PB 235. The two clones belong different metabolic classes, according to geneticists and agronomists. As the GT 1 rubber clone is the most widely planted clone in Côte d'Ivoire, we used it as the control clone. GT 1 has a moderate or metabolism clone and the PB 235 has rapid or quick metabolism clone.
The test was set up in April 1990 for the GT 1 (opening to 1.20 m in April 1990) and in July 1990 for the PB 235 (opening to 1.20 m in November 1989). The trees of equal size were selected (52.5 cm ± 2.5 cm at 1 m from the ground).

2.3. Methods

Experimental design

The experimental design used is a "one tree plot design" with 33 trees per treatment and total randomization of all the trees in a plot.

Treatments applied Table 1; [13, 14]

The trees of the different treatments have all been stimulated 6 times per year for the GT 1 and twice per year for the PB 235 during the first two years and 8 times per year for the GT 1 and 4 times per year for the PB 235 from the third year on. The tapping of the trees have been made 12 months over 12 using a tapping knife and the yield was harvested in polybags.

Measurements and data processing

The rubber yield per tree was measured by weighing the cumulative coagulated rubber from each tree every 4 weeks. Total solid content (DRC) was measured from a bulk sample taken in each treatment in order to convert fresh weights into grams of dry rubber per tree. Rubber yield was expressed in grams per tree (g/tree), in grams per tree per tapping (g/tree/tapping) and in grams per tree per tapping and per centimetre of cut length (g/tree/tapping/cm) to avoid any effect of the girth on yield.
In the beginning of the experiment, in April 1990 for the GT 1 and in July 1990 for the PB 235 then once

per year (in January), the measurement of the trees girth is carried out at 1.70 m from the ground.

The latex yield per tree was measured by weighing the cumulative coagulated rubber from each tree every 4 weeks. Total solid content was measured from a bulk sample taken in each treatment in order to convert fresh weights into grams of dry rubber per tree. Latex yield was expressed in grams per tree per tapping and per centimetre of cut length (g/tree/tapping/cm) to avoid any effect of the girth on yield.

The main latex biochemical parameters, i.e. sucrose and inorganic phosphorus contents, were measured tree by tree each year between September and November using methods developed by CIRAD and CNRA [15 ,16 ,17] adapted in 1995 [18]. Sucrose and inorganic phosphorus contents were expressed in millimoles per liter of latex (mmol/l). Sucrose content was measured using the Ashwell anthrone method (1957) [19].

The latex content, in sucrose, in inorganic phosphorus and in reduced thiol groupings, is determined from the clear serum called TCA-serum (trichloroacetic acid), obtained after latex acid coagulation, respectively by the Ashwell anthrone method (1957), The Taussky and Shorr molybdate ammonium method (1953) [20] and the Boyne and Ellman dinitro-dithio-dibenzoic (DTNB) acid method (1972) [21]. The concentrations are stated in mmole per litre of latex (mmol/l).

Once per year, at the end of the experiment (February), the bark consumption measurement is made. The bark consumption in d4 is 1.3 to 1.4 mm per tapping, which is about 11 cm per year (78 tappings) and in d2 it is 1.2 to 1.4 mm per tapping, which is 20 cm per year (156 tappings).

The yield data, the growth and of biochemical parameters data of the latex were statistically analysed using the analysis of variance (ANOVA) method according to the statistics software SPSS. All differences were tested for statistical significance using the Student–Newman–Keuls test with an alpha threshold of 0.05.

3. Results

3.1. Rubber yield

3.1.1. Tree productivity

The yield of clone GT 1 (Table 2) expressed (g/tree), the treatment 2, which tapping was done in half spiral 3 times per fortnight give a yield equivalent to that of the control (treatment 1), the yield of treatment 3, which tapping was done in third spiral, is inferior to that of the control (treatment 1) and to that of treatment 2, which tapping was done in half spiral. The yield of treatment 3 is statistically equivalent to that of treatment 4, which tapping was done in quarter spiral. The yield of treatment 4 is superior to that of treatment 5, which tapping was done in eighth spiral. The yield of treatment 5, statistically identical to that of treatment 4, is significantly inferior to that of the first three treatments. For the tapping which were done 3 times a week, the quarter spiral (treatment 6) and the eighth spiral (treatment 7) gave out identical yields. The quarter spirals, may their tapping be done 3 times per fortnight (treatment 4) or 3 times per week (treatment 6) give out yields of statistically same magnitude. It is the same thing for the eighth spirals (treatments 5 and 7). The third and quarter spirals which tapping were done 3 times per fortnight produce as much as the quarter and eighth spirals which tapping were done 3 times per week.

The yield of clone PB 235 (Table 2) expressed (g/tree), the tapping systems which tapping were done in half and third spirals 3 times per fortnight (treatments 2 and 3) and the tapping system which tapping was done in quarter spiral 3 times a week (treatment 6) give out yields comparable to each other and equivalent to that of the control which tapping was done in full spiral 3 times per fortnight (treatment 1). The quarter and the eighth spirals which tapping were done 3 times per fortnight (respectively treatments 4 and 5) and the eighth spiral which tapping was done 3 times per week (treatment 7) give out yields inferior to those of the control. The quarter spirals have identical yields whatever the tapping frequency is. It is the same thing for the eighth spirals.

Correlation is observed between rubber yield per tree and the intensity of tapping, whatever the clone. The rubber yield per tree (g/tree) is strongly and positively correlated with the intensity of tapping (respectively clones GT 1 and PB 235, $r = 0.926$; $p < 0.003$; Fig. 1; $r = 0.895$; $p < 0.007$; Fig. 2).

3.1.2. Tapping productivity

The yield of clone GT 1 (Table 2) expressed in g/tree/tapping and for the tapping made 3 times per fortnight, the half spiral tapping (treatment 2) produces statistically as much as the control (treatment 1) which tapping was done in full spiral. The yield in g/tree/tapping of these two treatments is significantly superior to that of the other treatments (3, 4 and 5). The third spiral gives out yields superior to those of the quarter and eighth spirals, while the quarter spiral and the eighth spiral

give out statistically identical yields. For the tapping which were done 3 times per week, the quarter and the eighth spiral give out yields of statistically the same order. The quarter spirals give out statistically identical yields whatever the tapping frequency is. It is the same thing for the eighth spiral. The eighth spiral which tapping was done 3 times per fortnight produce as much as the quarter spiral which tapping was done 3 times a week. The third spiral which tapping was done 3 times per fortnight and the quarter spiral which tapping was done 3 times a week give out identical yields.
The yield of clone PB 235 expressed in g/tree/tapping, we notice a decrease in the yield according to the tapping cut length whatever the frequency of tapping. The yield of the control (treatment 1), statistically comparable to that of treatment 2, is significantly superior to that of all the other treatments (treatments 3, 4, 5, 6 and 7). Treatment 3 gives out a yield comparable to that of treatments 2 and 4 and significantly superior to that of treatments 5, 6 and 7. The rubber yields of treatments 4, 5, 6 and 7 are statistically equivalent.
Correlation is observed between rubber yield per tree per tapping and the intensity of tapping, whatever the clone. The rubber yield per tree per tapping (g/tree/tapping) is strongly and positively correlated with the intensity of tapping (respectively clones GT 1 and PB 235, $r = 0.899$; $p < 0.006$; Fig. 3; $r = 0.764$; $p < 0.05$; Fig. 4).

3.1.3. Tapping cut productivity

For the yields of clone GT 1 expressed (g/tree/tapping/cm), the half and third spirals d4 and those of the quarter and eighth spirals d2 are significantly superior to that of the control of which yield is identical to that of the quarter and eighth spirals d4. The rubber yield (g/tree/tapping/cm) reaches its peak at half spiral before decreasing later owing to the reduction of the tapping cut length.
The tapping systems of clone PB 235 having a reduced tapping cut length give out rubber yield (g/tree/tapping/cm) statistically superior to that of the control which tapping was done in full spiral. The rubber yields per tree and per centimetre of tapping cut increase in relation with the reduction of the tapping cut length regardless of the tapping frequency.
Correlation is observed between rubber yield per tree per tapping per cm of tapping cut and the intensity of tapping, only for the clone PB 235. The rubber yield per tree per tapping per cm of tapping cut (g/tree/tapping/cm) is strongly and negatively correlated with the intensity of tapping (clone PB 235, $r = 0.962$; $p < 0.001$; Fig. 5).

3.1.4. Radial vegetative growth

The tapping system 4 (S/4 d4 6d/7) of clone GT 1 (Table 3) gives a girth increment statistically equal to those of the tapping systems 5 (S/8 d4 6d/7) and 7 (S/8 d2 6d/7) and significantly superior to those of the other tapping systems. The tapping systems 5 and 7 growths are statistically identical to each other and to that of the tapping system 3 (S/3 d/4 6d/7) and significantly superior to those of the tapping systems 1 (S d4 6d/7), 2 (S/2 d4 6d/7) and 6 (S/4 d2 6d/7). The girth of tapping system 6 is significantly superior to those of the tapping systems 1 and 2. The annual average girth of the tapping system 2 is significantly superior to that of the control which has the weakest girth.

The tapping systems 4 (S/4 d4 6d/7) and 5 (S/8 d4 6d/7) of clone PB 235 give girths increment statistically identical to each other and significantly superior to those of the other tapping systems. The tapping systems 3 (S/3 d4 6d/7) and 7 (S/8 d2 6d/7) also show girths increment identical to each other and significantly superior to those of the tapping systems 1 (S d4 6d/7), 2 (S/2 d4 6d/7) and 6 (S/4 d2 6d/7). The tapping systems 2 and 6 also show girths increment identical to each other and significantly superior to that of the control, which shows the weakest girth.
Correlation is observed between vegetative growth and the intensity of tapping, whatever the clone. The radial vegetative growth (cm/year) is strongly and negatively correlated with the intensity of tapping (respectively clones GT 1 and PB 235 $r = 0.975$; $p < 0.0001$; Fig. 6; $r = 0.858$; $p < 0.013$; Fig. 7).

3.1.5. Physiological profile

The clone GT 1 dry rubber content (DRC) of the latex, at the beginning of the experiment, is high for all the tapping systems (Table 4). The control significantly shows the weakest content. At the end of the experiment, the dry rubber contents of the different tapping systems, except for those of the tapping systems in half and in third spiral, which tapping were done 3 times per fortnight (treatments 2 and 3), have undergone a decrease. The different contents remain nevertheless high on the whole. The control significantly shows the weakest content.
Correlation is observed between vegetative growth and the intensity of tapping, for the clone GT 1. The

dry rubber content (DRC) is strongly but negatively correlated with the intensity of tapping ($r = 0.807$; $p < 0.028$; Fig. 8).

Sucrose content (Suc) of the latex, at the beginning of the experiment, are average on the whole and conform to those of the clone GT 1. The control shows a sucrose content of the latex identical to those of the tapping systems in half spiral, which tapping were done 3 times per fortnight (2), and in quarter and eighth spiral, which tapping were done 3 times per week (6 and 7) and superior to those of the other tapping systems (3, 4 and 5). At the end of the experiment, it notices an increase in the sucrose contents of the latex of the control and of the tapping system which tapping was done in eighth spiral 3 times per fortnight (5). The sucrose contents of the latex of the other treatments (2, 3, 4, 6 and 7) have undergone a fall. The control and the treatment and 7 show sucrose contents of the latex statistically comparable. It is the same thing for treatments 2, 3, 4 and 6. The treatments 5 and 1 sucrose contents of the latex are statistically comparable and significantly superior to the one of the other treatments. The treatment 7 sucrose content of the latex is statistically comparable to that of the control and also to those of treatments 2, 3 and 4. The sucrose contents of the latex of treatments 2, 3 and 4 are statistically in the same magnitude order as the one of treatment 6.

The inorganic phosphorus content (Pi) of the latex is weak at the beginning of the experiment as well as in the end. At the beginning of the experiment, the control shows the highest content and the treatment in eighth spiral which tapping was done 3 times per fortnight (5) shows the weakest content. In the end of the experimentation, it notices, except for the control, an increase in the Pi contents of the latex which remain weak anyway. The Pi contents of the latex of treatments 1 and 2 are identical and significantly superior to those of the other treatments. It notices, on the whole, a decrease, significant or not, of the Pi contents in relation to the reduction of the tapping cuts length regardless of the tapping frequency.

At the beginning of the experiment, the thiol contents of the latex are weak, exception from that of the tapping system in eighth spiral which tapping was done 3 times per fortnight (treatment 5). The treatment (5) shows the highest content while the control shows, with the treatments 2 and 6, the weakest contents. In the end of experiment, we notice an increase in the thiol contents for all the tapping systems. The thiol contents of the latex remain weak anyway for the farming systems 1, 2, 3 and 6. The treatments 5 and 7 give out statistically the highest contents. The indicator gives out average thiol contents and statistically identical to those of treatments 2, 3 and 6. The thiol contents of the latex of treatments 3 and 4 are statistically comparable.

Correlation is observed between Pi content of latex and the intensity of tapping, for the clone GT 1. The Pi content of latex (mmol l^{-1}) is strongly and positively correlated with the intensity of tapping ($r = 0.803$, $p < 0.030$; Fig. 9).

At the beginning of the experiment, the dry rubber contents of the latex of clone PB 235 are high for all the treatments (Table 5). The control significantly shows the weakest rate. In the en of the experiment, we notice an increase in the dry rubber content of all the treatments. The control gives out statistically the weakest rate and the treatments in half, third, quarter and eighth spiral, which tapping were done three times per fortnight, give out the highest rates.

Correlation is observed between vegetative growth and the intensity of tapping, for the clone PB 235. The dry rubber content (DRC) is strongly but negatively correlated with the intensity of tapping ($r = 0.859$; $p < 0.013$; Fig. 10).

The sucrose contents of the latex are average and conform to those of the PB 235 at the beginning of the experiment as well as in the end. At the beginning of the experiment, the indicator and the quarter spiral which tapping was done 3 times per fortnight (treatment 4) give out statistically the highest sucrose contents of the latex and the eighth spirals give out the weakest contents. In the end of the experimentation, we notice, except for the eighth spiral, a decrease in the sucrose contents of the latex of all the treatments. Apart from treatment 6, which tapping was done in quarter spiral 3 times per week, the treatments having a reduced tapping cut length show sucrose contents identical to that of the control.

Inorganic phosphorus contents (Pi) are, on the whole, weak at the beginning as well as in the end of experiment. At the beginning of experiment, the control significantly gives out the highest content and the eighth spiral which tapping was done three times per fortnight, gives out the weakest content. In the end of the experiment, only the control sows a fall in the Pi content of the latex, which remains the highest anyway. The treatment 5 gives out the weakest content. The Pi content falls down, in a significant way or not, in relation with the reduction of the tapping cut length whatever the tapping frequency is.

Correlation is observed between Pi content of latex and the intensity of tapping, for the clone PB 235. The Pi content of latex (mmol.l-1) is strongly positively correlated with the intensity of tapping ($r = 0.898$, $p < 0.006$; Fig. 11).

The thiol contents of the latex are weak at the beginning as well as in the end of the experimentation. At the beginning of the experiment, the control and the treatments, which tapping were done in half, third and quarter spiral, three times per fortnight, show the highest contents. In the end of the experiment, we notice an increase in the thiol contents of the latex of the different treatments, except from treatment 2, which thiol contents has undergone a decrease. The control content and those of the treatments which tapping were done in third, quarter and eighth spiral, three times per fortnight (treatments 3, 4, 5), are statistically comparable each other and superior to those of the other treatments (2, 6, 7) which contents are also statistically of the same magnitude order.

4. Discussion

Rubber yield

The gaps in rubber yield compared to the control which tapping was done in full spiral caused by the reductions of tapping cut length, regardless of the clone, are due to the fact that the tapping cut length influences the surface of the drained area. In fact, the latex flow depends on the drained area and on the number of lactifers affected by the tapping, that is to say the length and thickness of the incised bark and the width of the bark zone affected by the incision [22, 23]. The number of latex vessels (latex cells or laticifers) severed by a long cut is more important than those severed by a shorter cut. The long cuts have a more extended flow [24] owing to the weak index of coagulation. Nevertheless, the gaps in yield noticed in relation with the reductions of tapping cut length are not proportional to the reductions of tapping cuts length.

For a same tapping frequency, in the GT 1, only the half spiral permits to have a yield statistically identical to that of the control while in the PB 235, it is the half spiral and the third spiral which give out a yield comparable to that of the control. The low yields of rubber caused by the reductions of tapping cut length are less important in the PB 235 that in the GT 1. In other words, the reductions of the tapping cut length have a less significant incidence on the yield in the PB 235 than in the GT 1. This difference in reaction is due to the fact that these clones belong to classes of different metabolic activities, the GT 1 belongs to the intermediate metabolic activity class (moderated) and the PB 235 belongs to the quick metabolic activity class (strong) [17, 25, 26]. The PB 235 has a high intrinsic metabolic activity, therefore a very easy flow of latex and a strong yield of rubber, in the absence of hormonal stimulation. On the contrary, the GT 1 has an average intrinsic metabolic activity, a less easy flow and an average yield.

For the GT 1 and the PB 235 and for a tapping in d4, the less important yield gaps compared with the control lead to the conclusion that it is more profitable to do the tapping in short cut than in long cut. The increase in tapping frequency, from a tapping of three times per fortnight to a tapping one three times per week does not induce any significant profit in the yield. Considering the fact that the increase in the tapping frequency induces a more important consumption of bark, it appears therefore more interesting to do the tapping three times per fortnight than three times per week [12]. Whatever the clone and for a same tapping frequency, it is wiser to do the tapping in reduced cut than in long cut and for a same length of cut, it is more profitable to do the tapping in low frequency than in high frequency.

In the PB 235, the yields per tree, per tapping and per centimetre of tapping cut increase in relation with the reduction of the tapping cut length. The more the cuts are short the more their yields per centimetre of tapping cut are important as shown by [4]. In the GT 1 on the contrary, beyond the half spiral, the rubber yields per tree and per centimetre of tapping cut diminish in relation with the reduction of the tapping cut length yet without falling below the one of the control.

For the GT 1 and the PB 235, the yield per tree and per centimeter of tapping cut of the treatments with reduced tapping cut is superior or equal to those of the control. Nevertheless, in the framework of a reduction of the tapping cut length it is preferable to use the PB 235 instead of the GT 1 in the sense that the first one reacts more in favourably to the reduction of the tapping cut length. This result is probably linked to the fact that the metabolic activity of the clone PB 235 is stronger than that of the GT 1.

Radial vegetative growth

For a same system of stimulation and in comparison with the long cuts, the reductions of the tapping cut length favour a better vegetative growth whatever the clone. This result corroborates those of [8, 27, 28], which showed that the radial vegetative growth is inversely proportional to the rubber yield. The reductions of the tapping cuts length are anyway more in favour of the vegetative growth in the GT 1 than in the PB 235. The reductions of the tapping cut length have therefore a more significant incidence on the vegetative growth in the PB 235 than in the GT1. In response to the reduction in the length of the tapping cut, the PB 235 produces more rubber than the GT 1. This explains the fact that the vegetative growth of the GT 1 is more important than that of the PB 235. Indeed, it is shown that a high rubber yield negatively affects the vegetative growth [8, 26, 29, 30].

On the whole, the reductions of of tapping cut length favour a better radial vegetative growth whatever the clone is (GT 1 or PB 235). Nevertheless, that profitable incidence on the vegetative growth is more significant in the clone GT 1 than in the clone PB 235. This result corroborates the works of several authors who have shown that the tapping induces a depressive effect on the vegetative growth of rubber trees which annual average circumference growth ends up reduced [8, 26, 27, 29, 30, 31]. This depressive effect on the vegetative growth during the tapping is even more marked as the tapping intensity is strong [27, 30]. In fact, the reduced tapping cuts determine farming systems having a weak tapping intensity. Those farming systems having a weak tapping intensity owing to their limited yield of rubber influence the pair vegetative growth - rubber yield to the benefit of the vegetative one. This explains the better vegetative growth shown by the farming systems having reduced tapping cuts length.

Physiological profile
Clone GT 1

At the beginning and in the end of the experimentation, the dry rubber contents of clone GT 1 are good for all the tapping systems. The reductions of the tapping cuts length did not have any negative incidence on the dry rubber contents. The activity of the rubber regeneration metabolism is on the contrary more intense at the level of the reduced cuts than at the one of the full spiral. The sucrose contents are average on the whole for all the farming systems. Compared to the indicator, the reductions of tapping cuts length induce, broadly, a decrease in the sucrose contents. The full spiral is therefore more supplied with sucrose than the short cuts [31]. Concerning the reduced cuts, we notice anyway an increase, significant or not, in the sucrose contents in relation with the reduction of the tapping cut lengths, regardless of the tapping frequency. This can be explained by a phenomenon of sucrose accumulation at the level of the short cuts owing to the weak metabolism process of the latter following a weak latex-bearing activity. The weak yields obtained with the short cuts illustrate well this weakness of the latex-bearing activity. The increase in the tapping frequency, from a tapping of three times per fortnight to a tapping of two times per week, induces a decrease of the sucrose content. This has to do with the fact that at the level of the high tapping frequencies, there is a more important metabolic usage of the sucrose.

Generally speaking, the inorganic phosphorus content diminishes in relation with the reduction of the tapping cut length. The more the cuts are short the more the Pi contents are weak. The intensity of energetic metabolism diminishes in relation with the reduction of the cuts length. This activity is therefore proportional to the length of tapping cut and therefore to the quantity of latex drawn off per tapping. Besides, for the same length of tapping cut, the increase in tapping frequency, from the tapping done three times per fortnight to the tapping done in twice per week, doesn't have any significant effect on inorganic phosphorus content. The intensity of energetic metabolism is therefore not correlated to the tapping frequency but rather to the tapping cut length.

The thiol contents increase with the reduction of tapping cuts length. The colloidal stability of the latex is more preserved with the short cuts than the long cuts. The regeneration metabolism [32, 33] of the rubber is more important at the level of the short cuts than at the one of long cuts, because of the fact that, the thiols which are more numerous at the level of the short cuts, are the activators of the invertase and pyruvate kinase, key enzymes of the glucidic catabolism [34, 35]. The rubber yields should be more important at the level of the short cuts than of the long ones [36, 34]. That is not the case on the respect that at the level of the short cuts, the weak supply in sucrose, one of the yield-limiting factors, and especially the weak Pi contents induce a weak metabolism process of the sugars and therefore a weak yield of rubber by the short cuts [37, 38].

The physiological profiles of the treatments are fairly well balanced on the whole for the clone GT 1. Our results show indeed that for the GT 1, except for the dry content, almost all the other parameters of the physiological profile have undergone a clear-cut improvement during the exploitation (tapping) and according to the farm intensification. These results are moreover in compliance with those of rubber yield and those of vegetative growth. The farm intensification by the increase in tapping frequency, which induces a decrease in the latex sucrose content, is the guarantee of a more important metabolic usage of the sucrose [31] for the rubber yield. This is corroborated by our yield results.

The yields obtained, which are weak on the whole, are partly due to the insufficient activation of the yield metabolism following a weak system of stimulation. This metabolism inactivation is more strong and proportional to the tapping cut reduction. These results are the highlight of an under exploitation of the different treatments.

Clone PB 235

The dry rubber contents are good at the beginning as well as in the end of the experimentation. The highest rate in dry extracts of reduced cuts are not the highlight of a more important biosynthetic activity, otherwise, that would result in a higher yield, but would be due to weaker processes of interplasmalemical water transfers which are produced notably during the tapping of reduced cuts in comparison to those produced during the long cuts [38]. The high dry rubber contents that do not favour the flow of the latex owing to the high viscosity of the latex [39, 40, 38], the highest rates at the level of the short cuts would have induced a shorter latex flow time and could justify the less important yields of reduced cuts.

The sucrose contents are average. The reduction of tapping cuts length has no significant effect on the sucrose contents. It is the same thing for the increase in the tapping frequency. The supply of lactiferous in sucrose and the metabolic usage of the latter seem not to be affected in the PB 235 by the tapping cut length and the tapping frequency.

The inorganic phosphorus contents are weak at the beginning as well as in the end of the experimentation. They are more important with the full spiral than with the reduced cuts. The Pi contents, on the whole, diminish proportionally with the reduction of the tapping cut length whatever the tapping frequency. In eighth spiral, the increase in the tapping frequency has a significant effect on the Pi content, which is not the case in quarter spiral. The intensity of energetic metabolism of the lactiferous [15] decreases then with the reduction of the tapping cut length, increases with the tapping frequency in eighth spiral and remains intact with the increase in the tapping frequency in quarter spiral. This fall in the energetic metabolism intensity would be due to the fact that at the level of the short cuts, the quantity of rubber extracted by the tapping being weak, it provokes a weak regeneration metabolism, and therefore weaker Pi contents.

The thiol contents are very weak. In the PB 235, except for the case of the half spiral, the reduction of the tapping cut length induces a decrease in the thiol contents. The increase in the tapping frequency induces a decrease in the thiol contents. The colloidal stability is therefore more preserved in full spiral than in fraction spiral. At the level of the reduced cuts, the colloidal stability improves with the reduction of the tapping cut length. The increase in tapping frequency impairs the colloidal stability.

In the case of the clone PB 235, except for the sucrose content, almost all the other parameters of the physiological profile have undergone a clear-cut improvement during the tapping. The sucrose content of the latex is anyway conforms to that of the clone PB 235, especially the sucrose content resulting from the six-year experimentation. The sucrose content in the end reflects the level of yield of the obtained rubber, which is weak compared to the usual yields of the PB 235. This result is in compliance with the activation level of the rubber yield metabolism, which depends on the Pi content. The latter of course has increased, along the time, but it far below the usual level of the Pi that expresses a good activation of the PB 235 metabolism. The relative inactivation of laticigenous metabolism undoubtedly has repercussions on the colloidal stability of the latex and therefore the latex cells. In fact, except for treatment 2, which tapping was done in downwards half spiral, three times per fortnight, which latex thiol contents has undergone a decrease during the exploitation, all the other treatments which tapping were done at the frequency d4 have undergone a clear-cut improvement of their latex thiol contents. Despite the improvement in tapping of their latex thiol contents, the level is average and partly explains the inactivation or the less activation of laticigenous metabolism. The trees of the clone PB 235 as well as those of the GT 1 have been in a state of under exploitation owing to an inadequate tapping frequency for the clone PB 235 and to an insufficient stimulation since it was unable to compensate the gap of necessary energy but not brought by the weak tapping frequency.

The strong positive correlation between rubber yield (g/tree and g/tree/tapping) and intensity of tapping, regardless of the clone is in accordance with the principle that the yield is closely linked to the activation of latex cells [3, 8] influenced itself by the intensity of tapping, which is defined by the length of tapping cut and the number of tappings made in a given period (frequency of tapping). This situation suggests taking into account, in the exploitation of these clones or their counterparts of the same class of metabolic activity, the intensity of tapping which seems crucial in the successful exploitation of the clones of *Hevea brasiliensis*.

Our results also show a strong correlation, but negative, between the radial vegetative growth (cm/year) and the intensity of tapping, whatever the clone. It expresses the fact that the higher the intensity of rubber trees tapping is, the weaker the vegetative growth they show is. As the intensity of tapping positively influence the yield, we can understand the negative impact of the intensity of trees tapping on their vegetative growth. Indeed, several authors [29, 41, 42, 43, 44] have shown the existence of an antagonism between rubber yield and vegetative growth. The works of Obouayeba *et al*. [27] and Obouayeba, [30], showed that the competition between rubber yield and vegetative growth could slow down the vegetative growth by at least 24%. This is explained by the very strong demand for energy for the synthesis of the cis-polyisopren that is made to the detriment of the vegetative growth [29]. The intensity of rubber trees tapping indirectly affects the vegetative growth through its effect on the yield which directly affects this parameter.

5. Conclusion

The reduction of tapping cuts length induces, in the GT 1 and the PB 235, by downward tapping on virgin bark of the low panel, less important rubber yields compared to the indicator which tapping was done in full spiral. These yield gaps are nevertheless not proportional to the reductions of the tapping cuts lengths. The rubber yields per centimetre of tapping cut are all the more important since the tapping cuts are short. The clone PB 235, which has a quick metabolism, reacts better, in terms of rubber yield, to a reduction of the tapping cut length than the clone GT 1, which has a moderate (intermediary) metabolism. The yield losses caused by the reductions of tapping cuts length are indeed more important in the GT 1 than in the PB 235.

Moreover, the reductions in the intensities of the tapping system have no negative incidence on the radial vegetative growth of the trees, in the GT 1 as well as in the PB 235. Preferably, it favours a better vegetative growth of the trees.

The reductions of the tapping cuts length induce in the G T1 a weak energetic activation, a good colloidal stability and good dry rubber contents. In the PB 235, they induce a weak energetic activation, a bad colloidal stability, a good supply in sucrose and good dry rubber contents. The physiological profiles of these trees are nevertheless not impaired. They are only the highlight of the trees under exploitation, considering the important dry rubber contents and the weak inorganic phosphorus contents.

The reductions of the tapping cuts length do not affect negatively the yield parameters of the clones GT 1 and PB 235. The tapping panel saving and the important yields per centimetre of tapping cut which the reduced cuts permits to attain must campaign in favour of a promotion of these tapping systems.

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Table 1- Treatments applied

Tapping Intensity (%)		GT 1	PB 235	Description
1. S d4 6d/7 ET 2.5% Pa 1 (1)	100	6−8/y	2−4/y	Full spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
2. S/2 d4 6d/7 ET 2.5% Pa 1 (1)	50	6−8/y	2−4/y	Half spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
3. S/3 d4 6d/7 ET 2.5% Pa 1 (1)	33.3	6−8/y	2−4/y	Third spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest ; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
4. S/4 d4 6d/7 ET 2.5% Pa 1 (1)	25	6−8/y	2−4/y	Quarter spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest ; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
5. S/8 d4 6d/7 ET 2.5% Pa 1 (1)	12.5	6−8/y	2−4/y	Eighth spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest ; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
6. S/4 d2 6d/7 ET 2.5% Pa 1 (1)	50	6−8/y	2−4/y	Quarter spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest ; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.
7. S/8 d2 6d/7 ET 2.5% Pa 1 (1)	25	6−8/y	2−4/y	Eighth spiral cut tapped downward at fourth daily frequency, six days in tapping followed by one day rest ; stimulated with Ethephon of 2.5 % active ingredient with 1 g of stimulant applied on panel on a 1 cm band, 6-8 applications per year for GT 1 and 2-4 applications per year for PB 235.

Table 2- Annual mean yield of rubber (g/tree/tapping, g/tree and g/tree/tapping cm^{-1}) according to tapping system applied to the clones GT 1 and PB 235 during the first six downward tapping years.

Treatments or tapping systems 12m/12 ET2.5% Pa1(1)	Clone GT 1			Clone PB 235		
	g/tree	g/tree /tapping	g/tree/tapping cm^{-1}	g/tree	g/tree /tapping	g/tree/tapping cm^{-1}
1. S d4 6d/7 6/y(6w)-8/y(m)*	3811 a	50 a	0.731d	2630 a	37 a	0.523 f
2. S/2 d4 6d/7 6/y(6w)-8/y(m)	3119 a	40 a	1.001 a	2362 ab	33 ab	0.894 d
3. S/3 d4 6d/7 6/y(6w)-8/y(m)	1890 b	24 b	0.839 c	1769 abc	25 bc	0.983 c
4. S/4 d4 6d/7 6/y(6w)-8/y(m)	1256 bc	16 c	0.733 d	1487 bc	21 cd	1.054 b
5. S/8 d4 6d/7 6/y(6w)-8/y(m)	634 c	8 c	0.723 d	791c	11 d	1.112 a
6. S/4 d2 6d/7 6/y(6w)-8/y(m)	1943 b	19 bc	0.928 b	2001 ab	14 cd	0.744 e
7. S/8 d2 6d/7 6/y(6w)-8/y(m)	1113 bc	10 c	0.912 b	1337 bc	10 d	1.029 b

Mean within columns followed by the same letters are not significantly different according to Newman Keuls test at $p < 0.05$.

* Control

Table 3- Annual mean girth increment (cm) according to tapping system applied to the clones GT 1 and PB 235 during the first six downward tapping years.

Tapping System	GT 1	PB 235
1. S d/4 6d/7	1.2 e	1.8 d
2. S/2 d/4 6d/7	2.9 d	2.1 c
3. S/3 d/4 6d/7	3.8 b	2.4 b
4. S/4 d/4 6d/7	4.2 a	3.0 a
5. S/8 d/4 6d/7	4.0 ab	2.9 a
6. S/4 d/2 6d/7	3.3 c	2.2 c
7. S/8 d/2 6d/7	4.0 ab	2.4 b
Mean	**3.3**	**2.4**

Mean within columns followed by the same letters are not significantly different according to Newman Keuls test at $p < 0.05$.

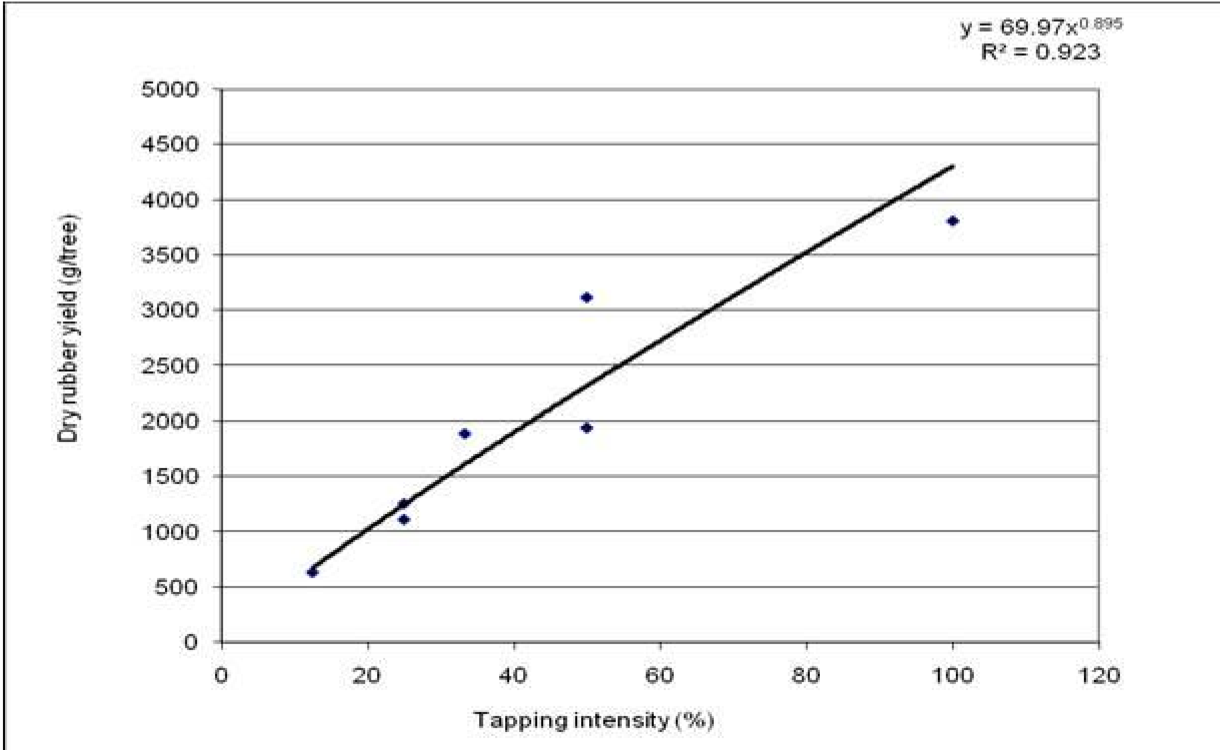

Fig. 1. Relationship between the dry rubber yield (g/tree) and the tapping intensity (%) of 7 tapping systems applied to clone GT 1 over a tapping period of 6 years (df = 6, Pearson correlation, $r = 0.926$, $P < 0.003$).

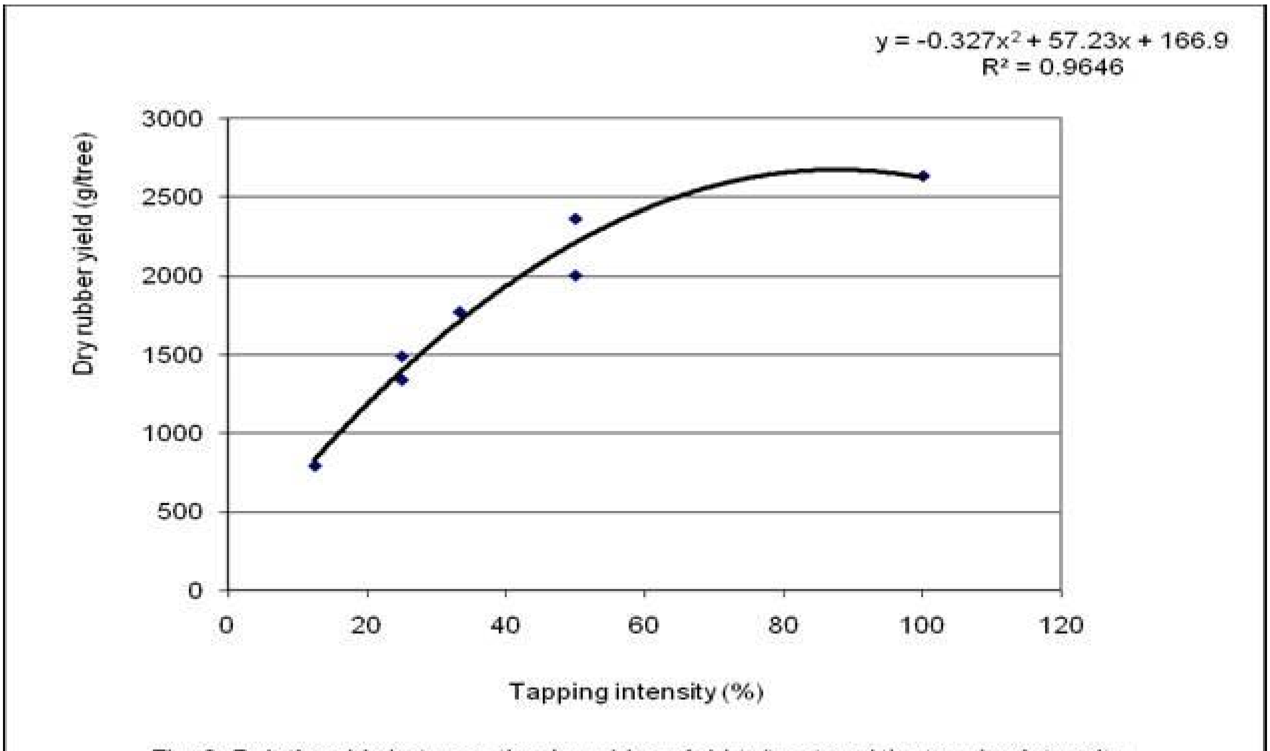

Fig. 2. Relationship between the dry rubber yield (g/tree) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, $r = 0.895$, $P < 0.007$).

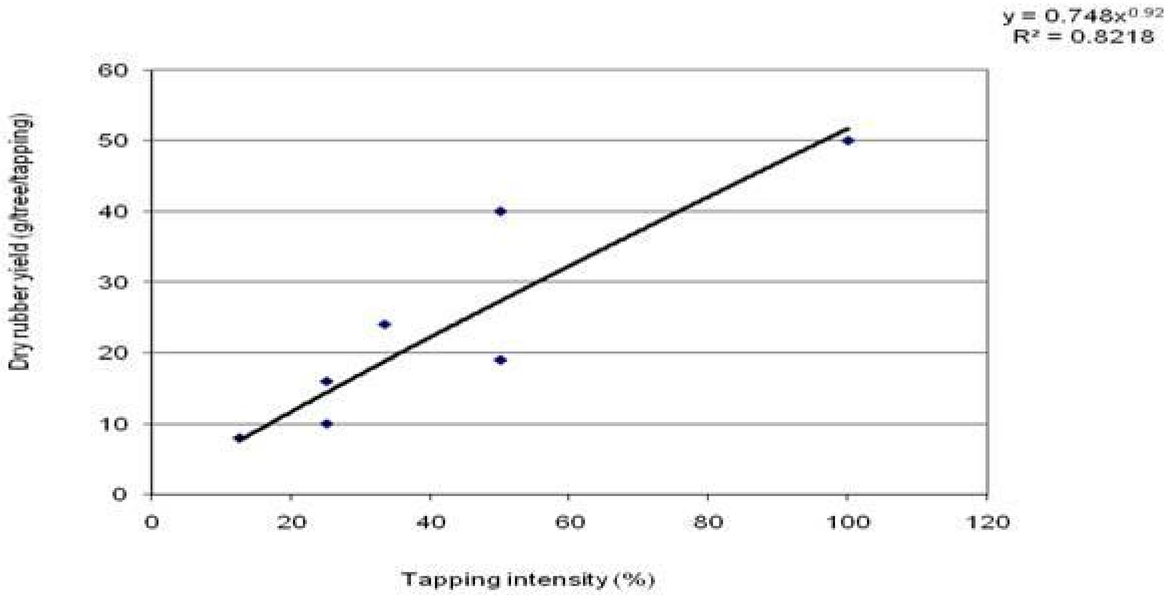

Fig. 3. Relationship between the dry rubber yield (g/tree/tapping) and the tapping intensity (%) of 7 tapping systems applied to clone GT 1 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.899, P < 0.006).

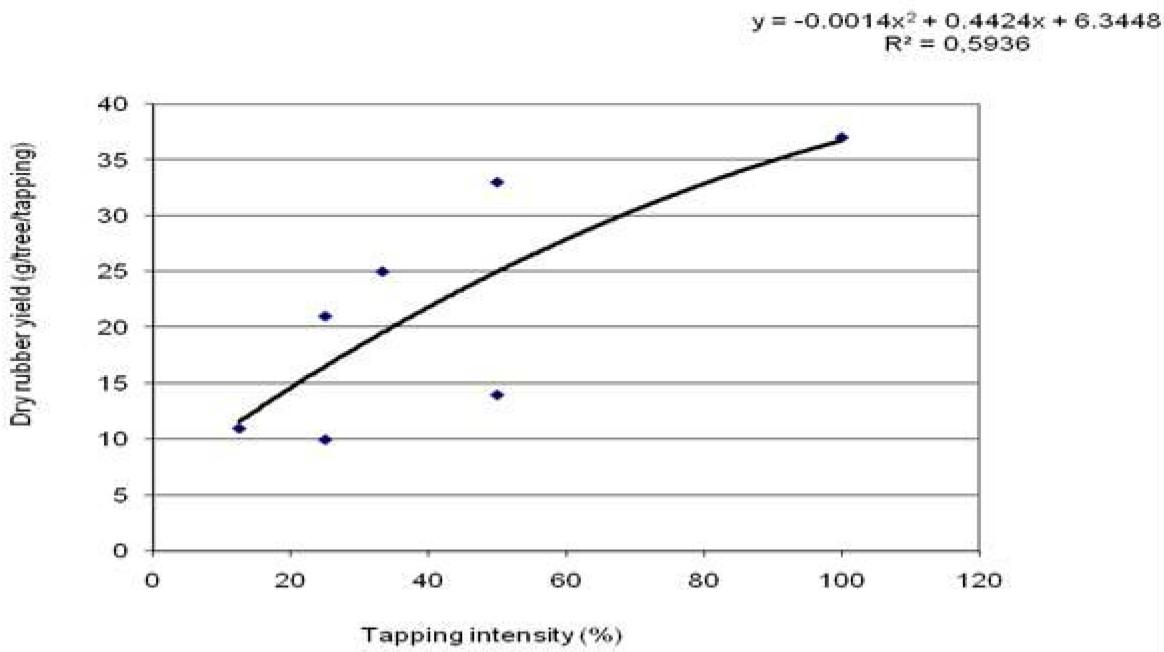

Fig. 4. Relationship between the dry rubber yield (g/tree/tapping) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.764, P < 0.05).

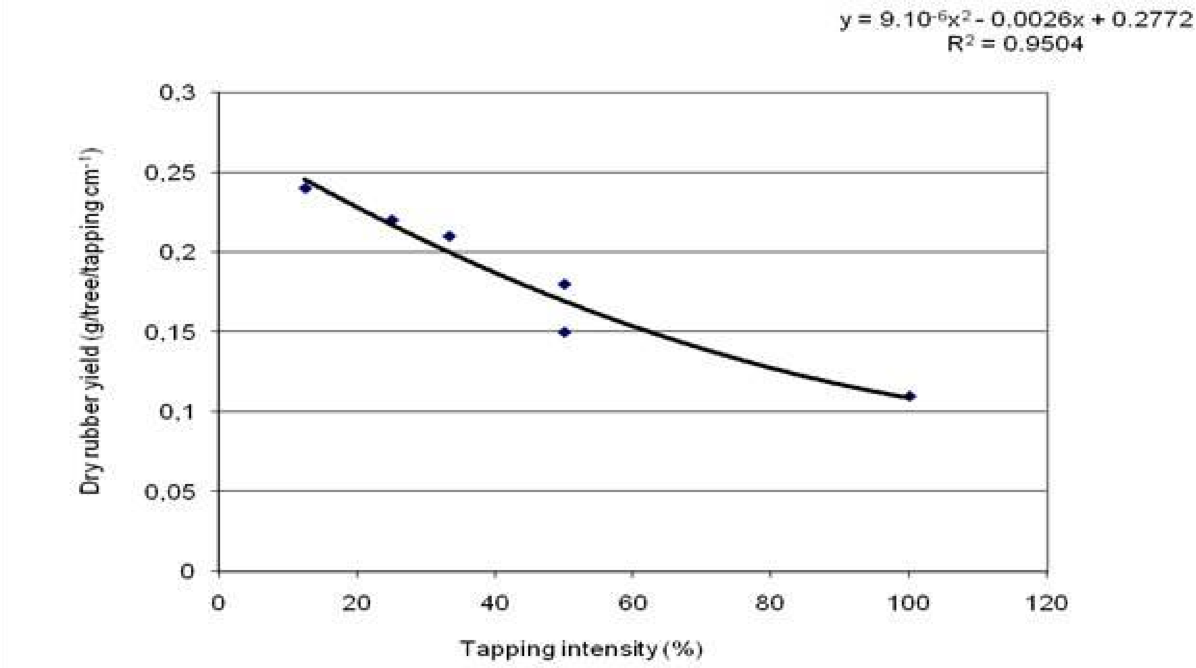

Fig. 5. Relationship between the dry rubber yield (g/tree/tapping cm^{-1}) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.962, $P < 0.001$).

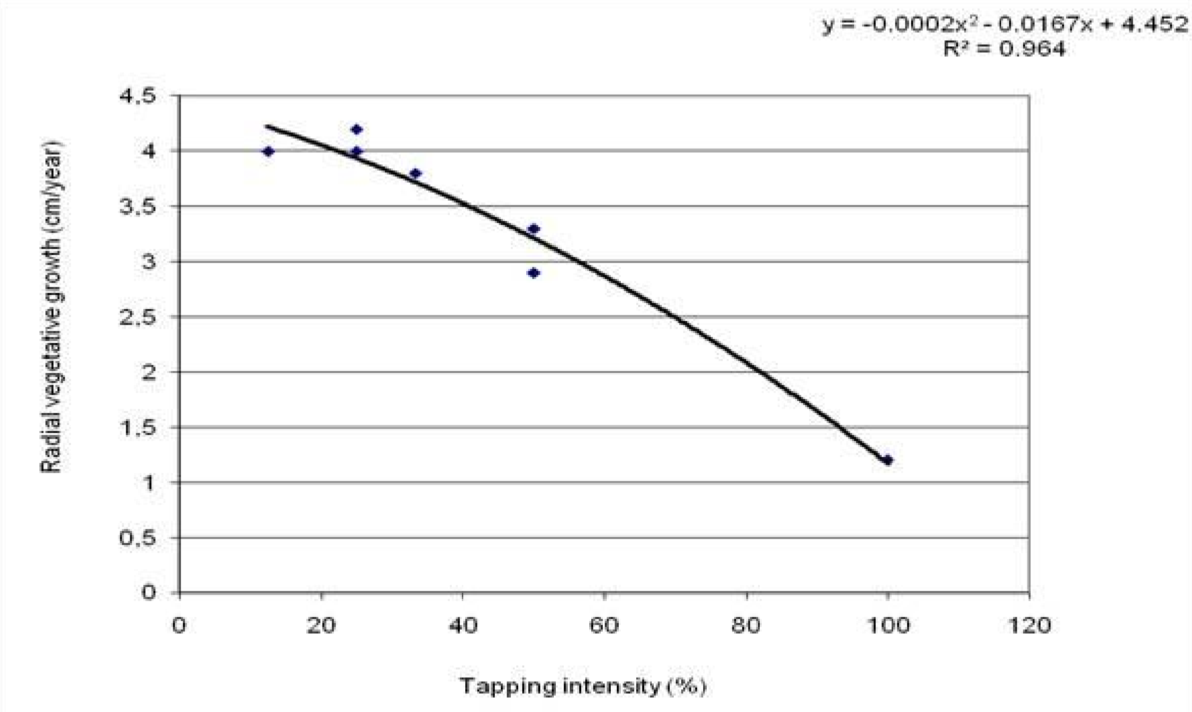

Fig. 6. Relationship between the radial vegetative growth (cm/year) and the tapping intensity (%) of 7 tapping systems applied to clone GT 1 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.975, $P < 0.0001$).

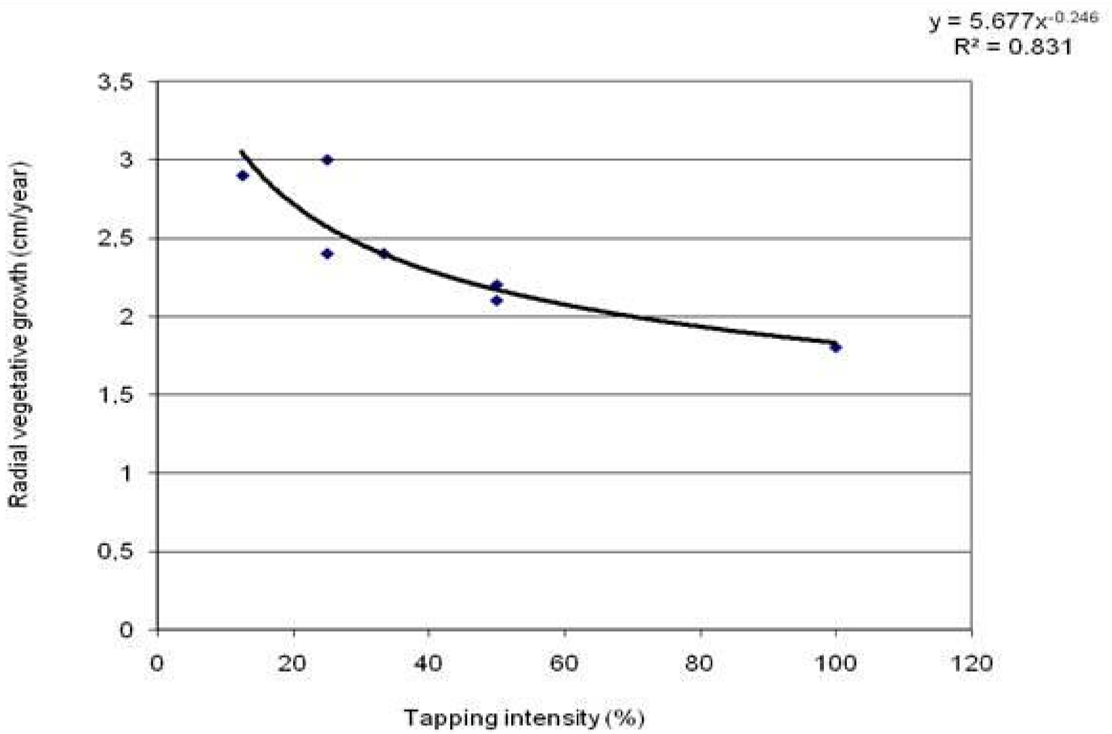

Fig. 7. Relationship between the radial vegetative growth (cm/year) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.858, P < 0.013).

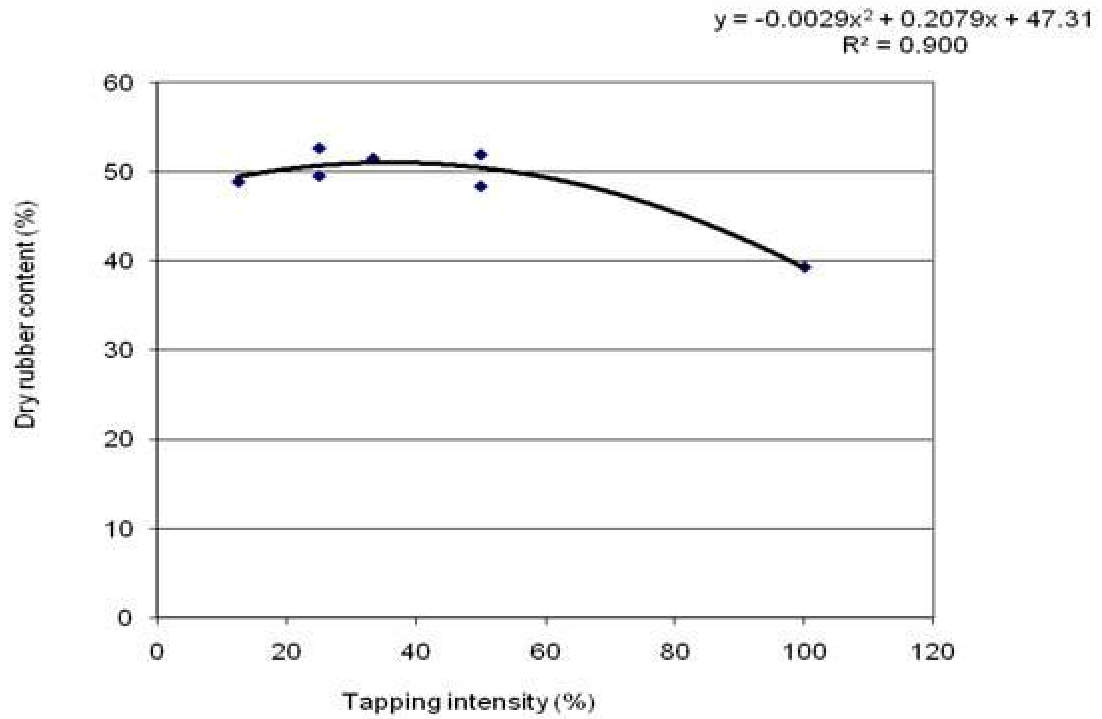

Fig. 8. Relationship between the dry rubber content (%) and the tapping intensity (%) of 7 tapping systems applied to clone GT 1 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.807, P < 0.03).

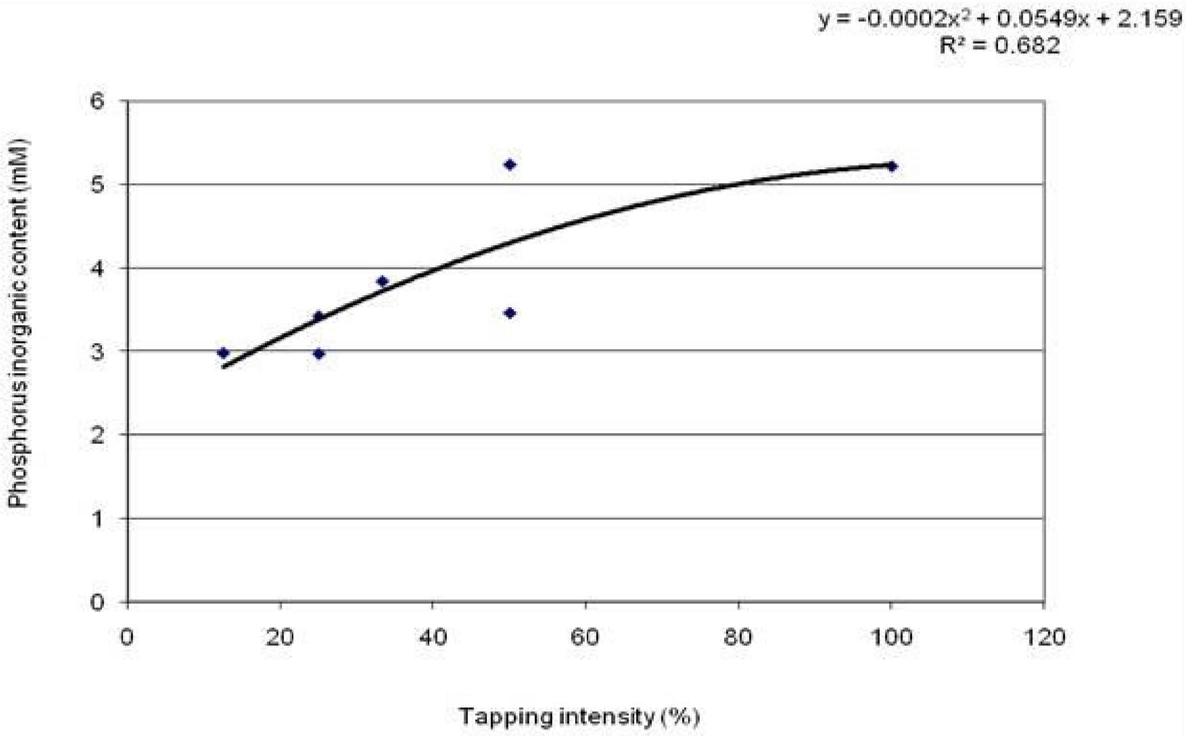

Fig. 9. Relationship between the inorganic phosphorus content (Pi, mmol l^{-1}) and the tapping intensity (%) of 7 tapping systems applied to clone GT 1 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.803, P < 0.03).

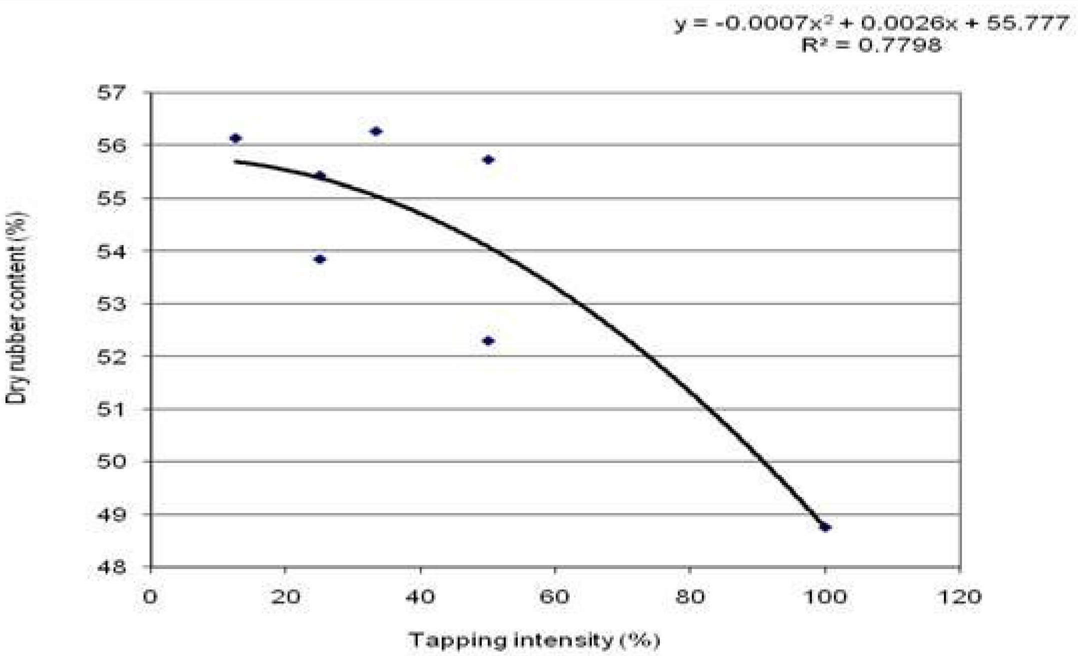

Fig. 10. Relationship between the dry rubber content (%) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.859, P < 0.013).

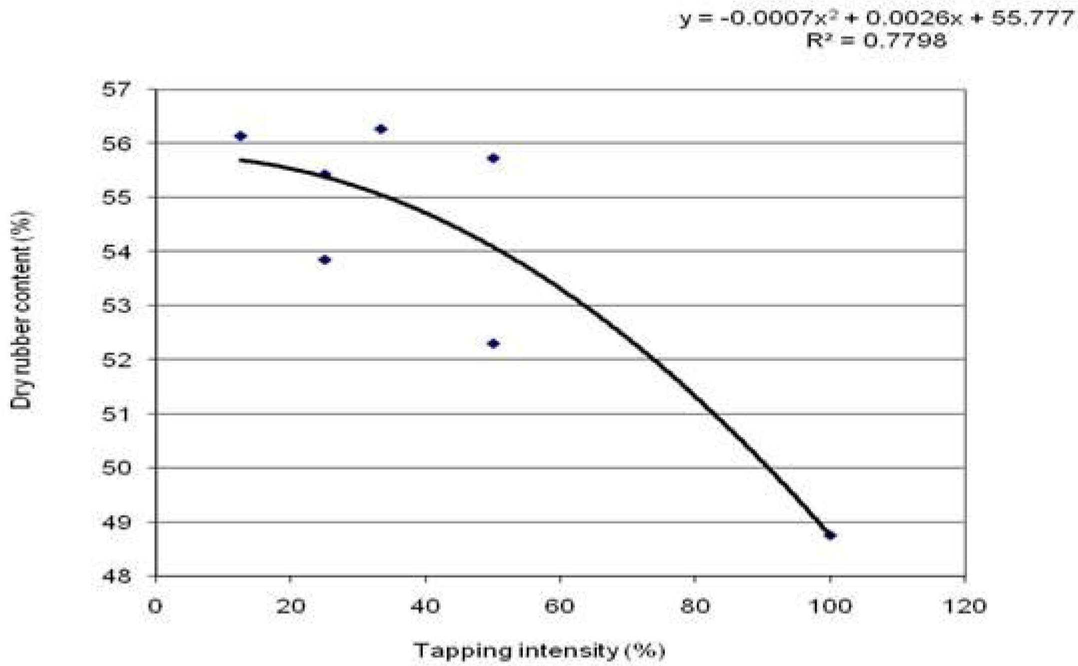

Fig. 10. Relationship between the dry rubber content (%) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.859, P < 0.013).

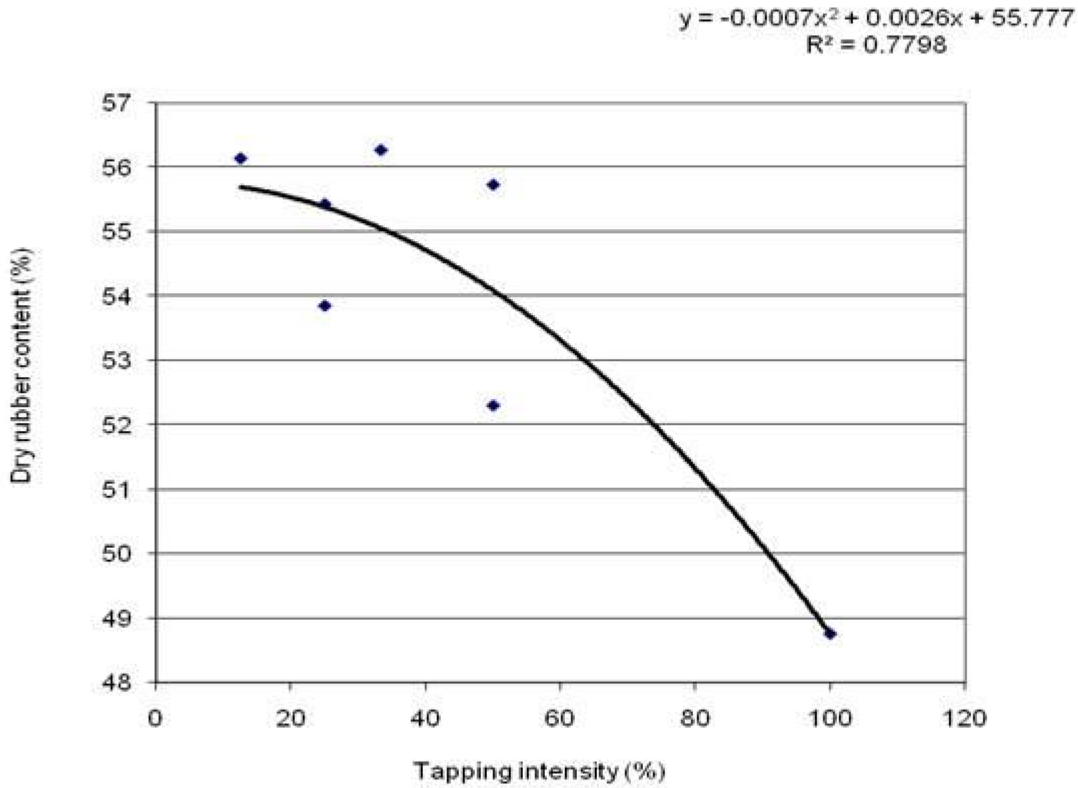
y = -0.0007x² + 0.0026x + 55.777
R² = 0.7798
Dry rubber content (%)
57
56
55
54
53
52
51
50
49
48
0
20
40
60
80
100
120
Tapping intensity (%)

Fig. 10. Relationship between the dry rubber content (%) and the tapping intensity (%) of 7 tapping systems applied to clone PB 235 over a tapping period of 6 years (df = 6, Pearson correlation, r = 0.859, P < 0.013).