Original Research Article

DETERMINATION OF THE INFLUENCE OF CULTURAL TECHNIQUES "DENSITIES AND OPENING STANDARD″ ON AGROPHYSIOLOGICAL PARAMETERS OF CLONES PB 260, IRCA 111 AND RRIM 703

Abstract

To find out the effect of cultural techniques on agrophysiological parameters, four combinations ‟planting densities (low density or DF at 350 a/ha, normal density or DN at 510 a/ha) and opening standards (opening at 65cm and opening at 50 cm)″ were tested on Hevea brasiliensis clones PB 260, IRCA 111and RRIM 703. This study was conducted for nine years with a split-plot experimental design of two treatments and two subtreatments repeated three times. The different combinations of treatments and subtreatments tested were (DN-50 cm), (DN-65 cm), (DF-50 cm), (DF- 65 cm). The parameters evaluated were the production at bleeding and per hectare, the average annual increase in circumference, the rate of tree losses and the rate of trees with dry notches. Production per tree was significantly higher at 350 a/ha and 65 cm opening (DF-65 cm), while per hectare production was higher at 510 a/ha. The girths of the different clones are stronger at DF and at the 65 cm opening. The rate of tree loss and the rate of trees with dry notch were low at the 510a/ha density and the 65cm opening. The appropriate density and opening standard was "normal density 510 a/ha and opening to circumference 50 cm". The cultivation techniques especially the density and opening standard judiciously applied can participate in the sustainable improvement of rubber productivity of rubber plantations.

Key words: Planting density, opening standards, production, circumferences, losses, dry notch

Introduction

The rubber tree (*Hevea brasiliensis*) is a plant cultivated mainly for its latex, a source of natural rubber. Natural rubber is indispensable in countless industrial applications: gaskets, surgical gloves, rubber, shoes, aircraft tires, etc..., with elasticity and waterproofing properties that make it a raw material that is now irreplaceable in certain uses [1]. The main sector of use of natural rubber is tires with 90% of the world production [2]. Latex comes from the cytoplasm of laticifers cells following the application of tapping on the plant trunk [3-4]. As for bleeding, it consists of incising or cutting at the bark of the tree trunk, where laticifier cells, organized in paracirculatory systems, are localized [5], which results in the flow of latex expelled by turgor pressure [6-8].

Tapping takes into account certain criteria to reduce competition between production and vegetative growth. Indeed, the production of rubber as well as the production of primary biomass depends on a source of hydrocarbon molecules, including sucrose from photosynthesis. The production stability of a tree depends on the balance between these two orientations of the general metabolism. Thus, the opening criterion for establishing the right balance is to open the trees at 6 years of age when the circumference at one meter from the ground reaches 50 cm [9-11].

In the context of improving rubber productivity, genetic selection of rubber trees aims at finding clones with high production potential combined with desirable secondary attributes, such as initial vigor, thick and smooth bark with good laticious coat equipment, good bark turnover, high growth rate after opening, tolerance to major diseases, wind resistance, good resilience to dry notching, good response to stimulation.

Moreover, the improvement of tree productivity can be achieved in another context, which is that of better monitoring of technical itineraries, i.e., through the rigorous practice of cultivation techniques applied to a cultivated plant species [12].

However, the major problem encountered in rubber cultivation, particularly in Côte d'Ivoire, is the failure to follow technical itineraries, linked in part to the lack of knowledge of these techniques by some non-industrial rubber growers [13].

In the majority of village plantations, the technical itineraries are carried out with less rigor and the plantations are confronted with numerous physical and physiological damages such as breakage due to wind, susceptibility to dry notching and to certain diseases. This lack of respect for cultural practices results in lower and lower yields, which in turn leads to an obvious lack of interest in the practice of rubber farming. Taking into account the challenges of the rubber industry, which is to increase Ivorian production, one of the important questions currently posed to research is the improvement of latex production systems. The determination of an optimal plantation density and the determination of an adequate opening circumference contribute to this improvement, without harming the environment [14-15; 11].

Thus, in order to guide the choice, of a suitable tree stand and opening girth, our study aims to determine the effect of different combinations of ‶planting density- opening standards″ on agrophysiological parameters of PB 260, IRCA 111and RRIM 703 clones.

Specifically, this study aims to determine the effect of density and opening standard on:

- tree production;

- average annual increment; and

- Percentage of tree loss;

- susceptibility to dry notching

MATERIALS AND METHODS

1. Plant material

The plant material used in this study consisted of three clones of *Hevea brasiliensis*, mainly belonging to the fast metabolic activity class.

Table I: Different clones

Clones	Crossing	Origin
PB 260	PB 5/51 X PB 49	Malaysia
IRCA 111	PB5/51 X RRIM 605	Côte d’Ivoire
RRIM703	RRIM 500X RRIM600	Malaysia

2. Method

2.1. Experimental protocol

The experimental design was a split-plot of two treatments (normal density (ND) at 510 a/ha, low density (LD) at 350 a/ha and two sub-treatments (65 cm opening, 50 cm opening) with three replications on an average area of 6.88 ha planted at the density corresponding to the treatments studied. The different treatments and sub-treatments (densities and opening standard) are presented in Table II. The different combinations of treatments and sub-treatments formed are in

abbreviations (DN-50 cm), (DN-65 cm), (DF-50 cm), (DF- 65 cm). The experiment was conducted with downward bleeding every four, five and five days with the number of annual stimulation ranging from 6 to 10, depending on the metabolic activity class of the clone (S/2 d4 6d/7 2.5% AND Pa1(1) n/y). The trial lasted nine years on the experimental site of the Société Civile Agricole du Sud-Ouest (SCASO) located in southwestern Côte d'Ivoire.

The experiment was set up at different ages depending on the clone independently of the planting density and the attainment of circumferences at 50 cm and 65 cm (Table III). Data were collected from the first incision (opening) of the bark of the trees at 1.20 m from the ground.

Table II: Treatments and sub-treatments applied to trees for nine years

	Names	Description
Treatments (densities)	Normal Density (DN)	510 trees planted with a spacing of 7 meters between lines and 2.8 m between plants
	Density Low (DF)	350 trees planted with a spacing of 7 meters between lines and 4.1 m between plants
Under-treatments: (Opening standard)	Opening at 50 cm	Opening when the tree circumference reaches 50 cm
	Opening at 65 cm	Opening when the tree circumference reaches 65 cm

Table III: Tree opening age by clone and planting density

Clones	Opening age at 50 cm	Opening age at 65 cm 510 t/ha	Opening age at 65 cm 350 t/ha
PB 260	5 years 9 months	7 years 9 months	7 years 9 months
IRCA 111	4 years 9 months	5 years 9 months	6 years 9 months
RRIM 703	5 years 3 months	7 years 9 months	7 years 3 months

t/ha : tree per hectare

2.2. Measured parameters

2.2.1. Rubber production

Rubber production was recorded per treatment. The coagulum, removed at the next tapping, was collected, weighed monthly (fresh weight, F.W.) using a balance. The processing coefficient (PC), the percentage of dry rubber in a given sample of fresh rubber, was used to calculate the dry rubber production (dry weight, DW).

The conversion of FP to rubber PS was performed for each treatment based on the following relationship:

DW (g) = F.W x PC

Dry rubber production was expressed in kilograms per hectare per year ($kg.ha^{-1}.yr^{-1}$) and grams per tree per tapping ($g.t^{-1}.t^{-1}$).

2.2.2. Isodiametric trunk growth

The trees were selected on the basis of the circumference of the trunk measured at a height of 1 m before bleeding, which is either 50 cm or 65 cm. During bleeding, the circumference was measured at 1.70 m from the ground. All measurements were made with a tape measure. Each year of the experiment, at the end of each physiological cycle, i.e. before the beginning of defoliation (which corresponds to the months of January and February), the circumference of the trunk of each selected tree was measured again at a height of 1.70 m from the ground.

2.2.3 Tree loss rate

For each treatment, the number of dead trees each year as well as the percentage of dead trees (% Dead Trees) was determined by the following relationship:

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

NAV: Number of living trees; N: Total number planted; NAM: Number of dead trees

2.2.4. Visual estimation of the dry notch

The rapid survey method of visual estimation is used to report the appearance and progress of the dry notch [16]. Depending on the state of latex flow for each bled tree, a number between 0 and 6 was assigned by the observer following the bled tree.

The percentage of totally dry trees in each treatment was determined by the following relationship:

$$\text{Dry trees } (\%) = (n_6 + ES) \times N^{-1}$$

n6: Number of trees in class 6; N: Total number of trees; ES: Number of trees with total dry notch.

RESULTS

1.Production

After nine years of experimentation, the yields of all treatments were of a good level (1758 to 2359 $kg.ha^{-1}.yr^{-1}$; Table IV). It was 2359 $kg.ha^{-1}.yr^{-1}$ for the PB 260 clone, 1758 $kg.ha^{-1}.yr^{-1}$ for IRCA 111 and 2167 $kg.ha^{-1}.yr^{-1}$ for RRIM 703. Yields varied by clone. Planting density influenced the yield of the clones except for RRIM 703. The openings did not significantly influence the yield of any clone. However, the combination (DN-50 cm) showed the highest values for all three clones.

At the level of production per tree and bleeding, the combinations "density and opening standard″ influenced the $g.t^{-1}.t^{-1}$ of the clones and gave a good level of tree production. The productions of all treatments reached 87 $g.t^{-1}.t^{-1}$ for PB 260, 72 $g.a^{-1}.s^{-1}$ for IRCA 111 and 82 $g.a^{-1}.s^{-1}$ for RRIM 703. Density of 350 t/ha and opening to 65 cm positively influenced $g.t^{-1}.t^{-1}$. For a density of 350 a/ha and the opening at 65 cm, the production at the tree and at the bleeding is significant. The highest productions in $g.t^{-1}.t^{-1}$ are obtained by the combination (DF-65 cm) with respectively 104, 93, 95 $g.t^{-1}.t^{-1}$ for respectively PB 260, IRCA 111, and RRIM 703.

The comparison of the clones shows that the clone IRCA 111 gives productions expressed in $g.t^{-1}.t^{-1}$ and in $kg.ha^{-1}.yr^{-1}$ low compared to PB 260 and RRIM 703.

Table IV: Average annual dry rubber production as a function of density and opening standard during nine years of downward tapping

Treatments	Under Treatments	Production in kg.ha^{-1}.yr^{-1}			Production g.t^{-1}.t^{-1}		
Density	Opening	PB 260	IRCA 111	RRIM703	PB 260	IRCA 111	RRIM703
	50cm	2503±408 a	1729±325 a	2245±476 a	73±9,2 a	56 ± 8,2 b	66 ±6,7 b
DN: 510 a/ha	65 cm	2023±286 b	1655 ±284 a	2056±217a	85±7,7 a	63 ± 8 b	85 ±14,1 ab
Average DN		2263 ±240 b	1692 ± 37 b	2151 ±95 a	79 ±6 b	60 ±4 b	76 ±10 b
	50 cm	2464±467 a	1728 ±284 a	2178±340 a	86±9,3 ab	75 ±11,5 ab	83±8,1 ab
DF : 350 t/ha	65 cm	2444 ±462 a	1920 ±326 a	2188 ±289a	104 ±5,3 a	93±11,8 a	95±16,7 a
Average DF		2454 ±10 a	1824 ±96 a	2183 ± 5 a	95 ±9 a	84 ±9 a	89 ± 6 a
	Average 50 cm	2484 ±20a	1729 ±10 a	2212 ±34 a	80±7 b	66±10 b	75 ± 9 b
	Average 65 cm	2320 ±271 a	1788 ±133 a	2122 ±66 a	95 ±10 a	78 ±15 a	90 ± 5 a
	Overall average	2359	1758	2167	87	72	82

Within a column Means assigned the same letters are not significantly different (Newman Keuls 5%).

kg.ha^{-1}.yr^{-1}: kilogram per hectare per year ; g.t^{-1}.t^{-1} : gram per tree per bleeding ; t/ha : tree per hectare

2.Radial vegetative growth

Figure 1 shows the effect of the four treatment combinations on the mean vegetative growth of trees in *Hevea brasiliensis* clones PB 260, IRCA 111, and RRIM 703. In the three different clones, the "density - opening standard" combinations significantly influenced the mean annual tree growth.

In clone PB 260, the mean annual girth increment of the (DF - 65 cm; 4 $cm.yr^{-1}$) combination was significantly higher than that of the (DN- 65 cm; 3 $cm.yr^{-1}$) and (DN - 50 cm; 3.2 $cm.yr^{-1}$) treatments, which were lower. The combination (DF-50 cm; 3.4 $cm.yr^{-1}$) gave a mean annual increment of the same order of magnitude as the other three combinations.

For clone IRCA 111, the mean annual girth increments of the combinations (DF-65 cm; 3.8 $cm.yr^{-1}$), (DF-50 cm; 4.1 $cm.yr^{-1}$) were statistically the same and greater than that of the treatment (DN- 65 cm; 2.6 $cm.yr^{-1}$), which was the lowest. The growth of the pattern (DN-50 cm; 3.2 $cm.yr^{-1}$) did not differ from the previous treatments.

The level of vegetative growth of clone RRIM 703 was higher with treatment (DF-50 cm; 3.3 $cm.yr^{-1}$) in contrast to the level of growth obtained in treatments (DN-50 cm; 2.4 $cm.yr^{-1}$) and (DF-65 cm; 2.2 $cm.yr^{-1}$). The combination (DN-65 cm; 2.8 $cm.yr^{-1}$) gave a mean annual increase of the same order of magnitude as the other three combinations.

Overall, mean annual increases in girth were greatest at low density (350 t/ha) and open at 65 cm.

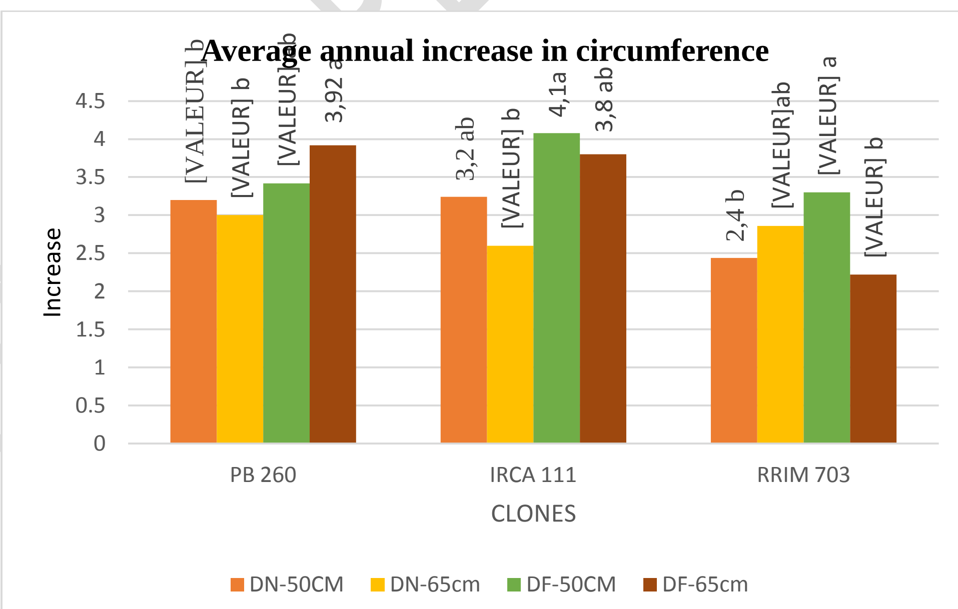

Figure 1: Average annual increase in girth as a function of the density-opening standard combination for nine years

3.Tree loss rate

The number of trees per hectare at the end of the experiment and the percentage of tree loss after the nine years of experimentation are presented in Table V. From these results, it can be observed that losses varied according to the pattern and clone. Losses in the PB 260 clone were homogeneous for all combinations and low compared to the other two clones. In clones IRCA 111 and RRIM 703 the losses recorded are influenced by the treatment. The density of 510 t/ha (DN) caused more losses in IRCA 111 at the 50 cm opening and in RRIM 703 at the 65 cm opening.

Table V: Tree loss rates as a function of density and opening standard for nine years

Treatments	Under Treatments	PB 260		IRCA 111		RRIM 703	
Density	Opening	t/ha	Losses (%)	t/ha	Losses (%)	t/ha	Losses (%)
DN	50cm	453	11,2 a	407	20,2 a	441	13,5 b
	65 cm	431	15,5 a	437	14,3 b	412	19,2 ab
Average DN		442	13a	422	17b	427	16 b
DF	50cm	301	14,0 a	267	23,7 a	285	18,6 ab
	65 cm	311	11,1 a	285	18,6 ab	268	23,4 a
Average DF		306	12 a	276	21 a	277	21 a
	Average 50 cm	377	13 a	337	22 a	363	16 b
	Average 65 cm	371	13 a	361	16 b	340	21 a
	Overall average	374,0	13,0	349,0	19,2	351,5	18,7

Within a column Means assigned the same letters are not significantly different (Newman Keuls 5%)

t/ha : tree per hectare

4.Notch rate

The rate of dry notching generated by the three different clones was significantly influenced by the treatment (Figure 2). Clones PB 260 and RRIM 703 showed more dry trees with the combination (DF-50 cm), while IRCA 111 had more dry notching with the combination (DN-50 cm). The opening circumference at 65 cm in DN (510 a/ha) or DF (350 a/ha) resulted in a lower susceptibility to dry rot in all three clones.

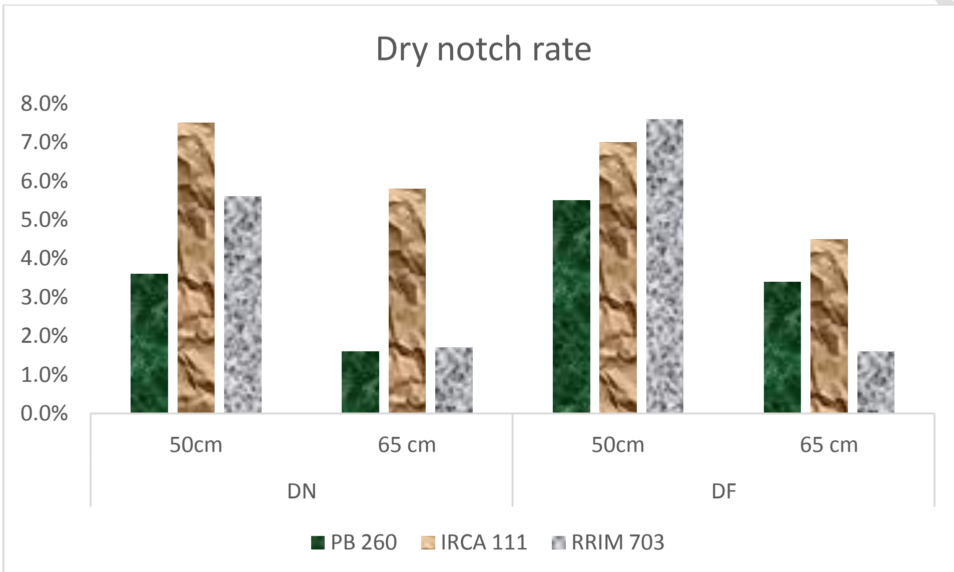

Figure 2: Dry notch rate as a function of ‵density-opening standard″ combination during nine years.

DISCUSSION

The results of tree and tapping production showed that low densities (350 t/ha) and opening to 65 cm favored better tree production compared to normal density (510 t/ha) and opening to 50 cm, regardless of the clone. This probably expresses the fact that the rubber productivity of a tree is positively related to the circumference and to the reduction of competition between trees on the plot. Indeed, the greater the circumference of a tree, the greater the thickness of the bark. The thickness of the bark of the rubber tree trunk is positively related to the formation and growth of the laticifers, which are the vessels containing the latex [9; 11]. These statements corroborate the findings of [6; 17; 11] who established a positive correlation between production and certain structural parameters of the trunk, including the circumference and the total number of laticifer mantles in radial section. Thus, with the opening at 65 cm, the trunk of the trees has probably reached a vigor necessary for a good functioning of the rubber production metabolism. Moreover, relative to the planting density, the 350 t/ha size gives rise to a better expression of the individual production potential of a tree than the 510 t/ha size. This could be explained by sufficient coverage of the trees' energy needs by the resources available on the plot and a good distribution of these resources [11; 18].

Yields in kg. $ha^{-1}.yr^{-1}$ were good regardless of the combination of treatments applied to the trees. They were not affected by opening but were influenced by the number of trees per hectare. The density of 510 t/ha gave the best production per hectare. These results clearly show that there is an increasing gradient of productivity per hectare with planting density as shown by some authors [19]. Moreover, according to the work of [11] and [10], the increase in the number of trees at densities below 625 t/ha leads to an increase in production, which logically explains why trees planted at 510 t/ha produce more per hectare than those at a density of 350 t/ha.

Vegetative growth of trees was stronger or significant at low planting densities of 350 t/ha. Also, the effect of opening varied from clone to clone. These results, like those of many other authors [11; 18], clearly show that there is a decreasing gradient of mean annual girth increase with planting density. Indeed, the greater the spacing between two trees, the less competition there is. And the more resources are available to produce the primary biomass of a tree, the better the vegetative growth under bleeding, hence the good level of radial growth observed in DF (350 t/ha).

Tree losses of clone PB 260 over the years were relatively homogeneous, invariant to the treatments and lower than those of the other clones. The different combinations acted differently on the clones. Overall, the density of 510 t/ha and the open trees at 65 cm recorded less tree loss. This result could be explained by the reduced effect of some tree reduction factors such as wind breakage, susceptibility to dry notch and *Fomes*. Indeed, the density of a plantation can reduce wind damage since wind flow will be low between trees due to the tightness of the row spacing. Also, trees up to 65 cm have an availability of resources conferring a certain vigor that allows them to be resistant to bad weather, diseases and certain physiological disorders such as dry rot. Indeed, our results showed that trees opened at 65 cm showed less dry rot than trees opened at 50 cm.

Conclusion

At the end of the work, which aimed at analyzing the influence of planting density and opening standard on the agrophysiological and sanitary parameters of *Hevea brasiliensis* clones PB 260, IRCA 111 and RRIM 703, in order to optimize the yields of rubber plantations in Côte d'Ivoire, we can retain that the planting density and the opening circumference are important parameters for the establishment and the good management of a rubber tree plantation. The different treatments have influenced the studied parameters. The productions per tree were high with the density of 350 t/ha and the opening at 65 cm (DF- 65 cm) while at the density of 510 t/ha they were more important. Tree girths of the different clones were larger at DF and 65 cm opening. The rate of tree loss and the rate of trees with dry notch were low at 510 t/ha and 65 cm opening.

The density and opening standard was therefore "normal density 510 t/ha and opening to circumference 504/cm". Properly applied cultivation techniques, especially density and opening standard, can contribute to the sustainable improvement of rubber productivity in rubber plantations.

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