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Agronomical and Physiological Performances of the IRCA 41 *Hevea Brasiliensis* Clone in South-East of Côte d'Ivoire

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Abstract – **Tapping panel dryness (TPD), characterized by latex out-flow stoppage after tapping, affect latex production in rubber tree, *Hevea brasiliensis*. To evaluate the sensitivity to this syndrome, 13 clones with good agronomic values were subjected to agronomic and physiological practices. This survey was conducted under production conditions using various Ethéphon stimulation frequencies during five years. Analyses of variance and comparisons of averages were achieved from the lengths of sick panel (LSP) collected during the first five years of latex production. Results showed that the syndrome of TPD is under the influence of a genetic, physiological and hormonal determinism. The clone PB 217 confirmed its adherence to the class of low sensitivity to TPD. It was the same as the clone GT 1 for the class of moderate sensitivity and the clone PB 235 for the class of high sensitivity. The different variations of the stimulation frequency, of the duration of rubber production and the combination of the two factors, have influenced the sensitivity to TPD of the twelve clones except the clone IRCA 41 that remained steady in the class of very low sensitivity. This clone thus has good agronomic and physiological skills. The clone IRCA 41 deserves to be promoted and popularized by preference in the non-industrial sector to increase the rubber production in Côte d'Ivoire.**

Keywords – **Rubber tree *Hevea brasiliensis*, Stimulation frequency, Duration of rubber production, Sensitivity to tapping panel dryness, Clone, Côte d'Ivoire.**

I. INTRODUCTION

The Ivorian development plan is considering 600,000 tons of dry rubber by 2025. To achieve this, rubber growers can increase the planted area and/or increase the productivity of their plantation [23].The non-industrial sector is characterized by low productivity (< 1200 kg/ha;[3]), despite the implementation of various options to improve the level of rubber production. In fact, latex harvest technology in rubber tree requires special conditions and practices that are not respected in the non-industrial sector where there is a high tendency to using various latex harvest techniques. Indeed, in rubber tree, unlike other species that produce fruits, seeds, roots or tubers, etc., latex production results from the practice of tapping.

The tapping consists in making an incision or a slash, so-called panel tapping in the bark of the trunk of rubber tree which causes the out-flow of latex [18]-[45]-[29].The tapping of trees in a plantation permits to produce natural rubber [44]. But, this production cannot be modulated to users' needs, in the sense that the tapping, alone, cannot permit to valorize the rubber production potentialities of all cultivated clones groups, because of their different metabolic activities [21]-[23].

Thus, systematically, to the tapping system, is added the hormonal stimulation of rubber production through a policy or strategy of hormonal stimulation of rubber production [16]-[31]-[41]. Hormonal stimulation of rubber production in rubber tree involves applying a stimulating product on the tapping panel[14]-[25]-[28]. The fluently used stimulating products have the 2-chloro-ethyl-phosphonic acid or Ethephon for their active substance, which generates ethylene in lacticifers: specialized cells generating the latex. The presence of ethylene in the tissues permits to prolong the duration of latex out-flow and to get a more important rubber-yielding. However, all clones do not have the same reaction to this stimulation.

Thus, clones with active or fast metabolism have a pretty good reaction to hormonal stimulation, those with moderate metabolism give a good reaction to hormonal stimulation and finally the slow metabolism clones have a very good reaction to stimulation [42]-[46]-[13]. This practice developed itself considerably after the discovery of the important stimulating power of Ethephon; growth regulator releasing ethylene *in situ* [1]-[10]. Recently, [40] showed that the ethylene stimulation with Ethephon significantly modifies sugar balance between the supply and demand in the bark producing latex, while increasing metabolic activation [8]. Other works [41]-[43]-[46] have shown that the use of hormonal stimulation, notably the application of Ethephon, increases the production of latex (rubber) while allowing reduce the needs for tappers, the tapping frequency or even the intensity of the latex harvest technology.

Taking into account of all these considerations associated with hormonal stimulation in the management of a rubber plantation is essential to reach an optimum level of rubber production of the trees without causing damage to them [26]. In Africa and particularly in Côte d'Ivoire, the vast majority of rubber growers have some control of the tapping systems (tapping frequency and length of the tapping panel). On the other hand, the stimulation system of the production is very little controlled. Indeed, in practice, an abusive use of hormonal stimulation to expect an indefinite increase in rubber production is observed. However, the excessive application of the stimulation can cause, in the long term,

the stoppage of the latex out-flow of the trees and to drag a fall of rubber production [32]-[33]-[35]. This phenomenon, which leads eventually to a complete stoppage of latex production in the tree is called tapping panel dryness (TPD) syndrome [15]-[22]. It causes losses in the latex production from 15 to 20 % [11]-[39], which is a loss of profit for rubber growers. TPD is therefore a major concern for rubber cultivation in Côte d'Ivoire. Several studies to explain this phenomenon have shown that it is not due to a pathogenic agent [38]-[24].

Recent investigations on the cause of this syndrome indicate that it is a physiological dysfunction [12]-[19]whose causes remain unknown, however. Recent studies have shown that some clones are more sensitive to TPD than others [34]. The development of TPD is also influenced by physiological and hormonal factors such as the duration of rubber production and the stimulation frequency [6]-[34]. To identify the rubber clones with high level of agronomic and physiological performances that show little sensitivity to TPD, this study of the sensitivity of clones to TPD has been led. It was carried out on the nearly totality of the rubber clones currently planted in Côte d'Ivoire.

II. Material and Methods

A. Study site

The works of this study were performed in experimental plantations of the CNRA-Bimbresso research station located in Anguédédou in south-eastern Côte d'Ivoire (4°75'-5°75'N, 3-6°W). This region is characterized by a bimodal rainfall with two rainy seasons and two dry seasons and the annual average rainfall of 1,600 mm. The soil is acid ($4 < pH \leq 5$) ferralitic, deep and highly desaturated on the tertiary sand. This region is part of the traditional area of rubber cultivation in Côte d'Ivoire.

B. Plant material

This study was performed with 13 clones of *Hevea brasiliensis* (AF 261, PB 235 AVROS 2037 GT 1, PB 217, PB 260, 100 RRIC, IRCA 230, IRCA 130, PB 254, IRCA 209, RRIM 712, and IRCA 41). These clones represent the majority of clones currently planted in Côte d'Ivoire. They come from experimental plantations of the CNRA-Bimbresso research station situated in Anguédédou located in south-eastern Côte d'Ivoire.

C. Experimental design

Each of the 13 clones was planted at a density of 510 trees/ha (7 x 2.80 m) and made the subject of experimentation. The experiment was repeated three times. All clones have been tapped seven years after planting. All trees were half spiral down tapped in all four working days (S/2 d4 6d/7), with a rest day on Sunday. The experiment focused on the first five years of latex production. The experimental design used is the single tree design "One Tree Plot Design", a tree being a repetition. Test border trees were not taken into account. The trees of each clone were divided into eight treatments. Each treatment included 33 trees and corresponds to an annual stimulation frequency to Ethephon (ET 2.5%) applied to trees either, eight stimulation frequencies. The Ethephon is the active ingredient of the stimulating product marketed as Ethrel. These treatments are: 0; 2; 4; 6; 8; 10; 13 and 26 stimulations per year.

D. Data collection

A visual record of dry panel (RDP) was performed per month on all test trees according to the method of [47]. The RDP is a visual appreciation of the latex out-flow after tapping in trees in rubber production. It allows to determine the real length of panel that doesn't produce anymore latex in a tree or length of sick panel (LSP). During the RDP, all trees which have a normal latex out-flow on the whole length of the panel after tapping, were considered as "healthy" trees and scored zero (0). The others were considered as trees affected by tapping panel dryness (TPD) and were noted from 1 to 6 according to the length of latex non-producing panel. Thus, the following classes of percentage of latex non-producing panel were constituted:

- 1 - 20 %, noted 1, trees affected by very low level of TPD;
- 21- 40 % noted 2, trees affected by low level of TPD;
- 41 – 60 %, noted 3, trees affected by medium level of TPD;
- 61 – 80 %, noted 4, trees affected by relatively high level of TPD;
- 81 – 99 %, noted 5, trees affected by high level of TPD ;
- 100 %, noted 6, trees affected by total TPD or dry trees.

The raw data of RDP for the first five years of latex production of the clones were collected.

E Data analysis

The RDP raw data permitted to determine the length of sick panel (LSP) by treatment of each clone according to the following equation [2]: LEM = (0,1 n1 + 0,3 n2 + 0,5 n3 + 0,7 n4 + 0,9 n5 + 1 n6) / N. In this equation, N is the number of trees per treatment; the coefficients (0,1; 0,3; 0,5; 0,7; 0,9 and 1) correspond to the averages of the percentage classes of latex non-producing panel length; and the numbers n1, n2, n3, n4, n5 and n6 represent the numbers of trees observed per class of percentage of latex non-producing panel length.

The analysis of variance of the LSP of clones, measured during the first five years of rubber production all stimulation frequencies included, was carried out to study the effect of the genetic factor on the sensitivity of rubber clones to TPD. LSP being proportions and not following a normal distribution, they were transformed into Arc-Sin Square Root of LSP (ASINLSP) to make the distribution normal and to stabilize the variances in order to make the analysis possible [9]. Duncan statistical test alpha risk of 5 % was used with SAS version 8.2 software for the comparison of LSP averages and the constitution of groups of clones, duration of rubber production and stimulation frequency. The model of the analysis was the additive model: $Xijk = \mu + ai + bj + ck + \Sigma ijk$ with μ = LSP experimental average; a = effect of the clone; b = effect of the year; c = effect of the treatment; i = number of clones; j = number of years; k = number of treatments and Σijk = interaction between the factors.

For the study of physiological and hormonal factors, determined by the duration of rubber production and the

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stimulation frequency, the same analyzes were conducted on the one hand, to establish the relation between Ethephon (ET 2.5%) stimulation class and the sensitivity of the clones to TPD and secondly to establish the relation between the duration of rubber production and the sensitivity of clones to TPD. In the case of the stimulation, the highest stimulation frequency in each class of stimulation frequencies was chosen and variations of the sick panel lengths in the 13 rubber clones were analyzed. For the duration of rubber production, classes of stimulation frequency were replaced by duration of rubber production.

III. Results

3.1 Genetic effect (Clone)

The lengths of sick panel (LSP), measured in 13 rubber clones during the first five years of rubber production irrespectively of the stimulation frequency, varied from 0.37 to 4.38 % (Table 1).

Table 1.Classificationof13rubberclonescomparedtoaverages of sick panel lengths measured during five years of rubber production, all stimulation frequencies to Ethephon (ET2.5 %) confused

Clones	ASIN LSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of group of clones
IRCA 41	0.06	0.37	C1	0.37	-
PB 217	0.17	0.95	C2	1.36	3.33
AF 261	0.17	1.41			
RRIM 712	0.18	1.73			
AVROS 2037	0.22	1.88	C3	2.20	5.02
IRCA 130	0.22	2.18			
IRCA 209	0.24	2.49			
GT 1	0.24	2.25			
PB 254	0.27	2.77	C4	2.86	2.11
IRCA 230	0.27	2.83			
RRIC 100	0.28	2.98			
PB 260	0.36	4.26	C5	4.32	3.82
PB 235	0.38	4.38			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

Analysis of variance of these data showed a very highly significant "clone" effect (Table 2). Comparison of LSP averages permitted to classify clones into five distinct groups C1, C2, C3, C4 and C5 according to the sensitivity to TPD (Table 1). These groups showed low coefficients of variation. The C1 group included only the IRCA 41 clone which presented the lowest rate of TPD. The TPD rates were low among clones of the C2 group (PB 217, AF 261, RRIM 712), moderate in clones of the C3 group (AVROS 2037, IRCA 130, IRCA 209 and GT 1) and high among clones of the C4 group (PB 254, IRCA 230 and RRIC 100). In PB 260 and PB 235 clones constituting the C5 group, very high TPD rates were observed.

Table 2.Analysis of variance table of sick panel lengths of13rubberclonesin rubber production during five years, all stimulation frequencies to Ethephon (ET2.5 %) confused

Source of variation	Degree of freedom	Sum of square deviations	Mean squares	F value	Signification Pr > F
Clone	12	3.208	0.267	7.572	< 0.0001 ***
Residual	457	16.135	0.035		
Total	469	19.343			

***:Very highly significant

3.2 Physiological effect due to the duration of rubber production

The lengths of sick panel (LSP) of the first five years of rubber production measured in the 13 rubber clones, all stimulation frequencies to Ethephon (ET2.5 %) combined, varied from 0.79 to 3.31 % (Table 3).

Table 3.Classification of rubber production durations by comparison of averages of sick panel lengths measured in 13rubberclones, all stimulation frequencies to Ethephon (ET2.5 %) confused

Rubber production durations	ASIN LSP averages	LSP averages (%) of rubber production duration	Groups of rubber production duration	LSP averages (%) of groups of rubber production duration	CV (%) of groups of rubber production duration
First year	0.12	0.79	D1	0.79	-
Second year	0.22	1.98	D2	1.98	-
Third year	0.27	2.64	D3	3.07	5.39
Fourth year	0.30	3.25			
Fifth year	0.28	3.31			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

A very highly significant "duration of rubber production" effect was revealed by the analysis of variance of these data (Table 4). The durations of rubber production were structured into three distinct groups D1, D2 and D3 of sensitivity to TPD by comparison of LSP averages (Table 3). These groups had low coefficients of variation. In the first year of rubber production, low rates of TPD were observed. They were medium after two years of rubber production and increased gradually from the third year.

Table 4. Analysis of variance table of sick panel lengths of five years of rubber production measured in 13 rubber clones, all stimulation frequencies to Ethephon(ET2.5 %) confused

Source of variation	Degree of freedom	Sum of square deviations	Mean squares	F value	Signification Pr > F
Duration of rubber *production*	4	2.090	0.523	14.083	< 0.0001 ***
Residual	465	17.253	0.037		
Total	469	19.343			

***: Very highly significant

3.3 Hormonal effect due to the stimulation frequency

The lengths of sick panel (LSP) of the eight stimulation frequencies measured during the first five years of rubber production all rubber clones combined, varied from 1.35 to 5.71 % (Table 5).

Table 5. Classification of stimulation frequencies to Ethephon (ET2.5 %) compared to averages of sick panel lengths measured during five years of rubber production in all13rubberclonesconfused

Stimulation frequencies	ASIN LSP averages	LSP averages (%) of stimulation frequencies	Groups of stimulation frequencies	LSP averages (%) of groups of stimulation frequencies	CV (%) of groups of stimulation frequencies
0 stimulation/year	0.17	1.35	S1	1.34	3.33
2 stimulations/year	0.17	1.15			
4 stimulations/year	0.18	1.53			
6 stimulations/year	0.23	1.98	S2	1.98	-
8 stimulations/year	0.27	2.81	S3	3.03	2.92
10 stimulations/year	0.28	2.89			
13 stimulations/year	0.29	3.39			
26 stimulations/year	0.39	5.71	S4	5.71	-

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP(ASINLSP).

A very highly significant "stimulation frequency" effect was revealed by the analysis of variance of those data (Table 6). Four distinct stimulation frequencies groups of sensitivity to TPD were formed S1, S2, S3 and S4 (Table 5). The coefficients of variation of these groups were low. The S1 group (0; 2 and 4 stimulations per year) induced low LSP. The induced LSP were medium in the S2 group (6 stimulations per year) and higher in the S3 group (8; 10 and 13 stimulations per year). The S4 Group (26 stimulations per year) induced very high LSP.

Table 6. Analysis of variance table of sick panel lengths of eight stimulation frequencies to Ethephon (ET2.5 %) measured during five years of rubber production, all rubber clones confused

Source of variation	Degree of freedom	Sum of Squares deviations	Mean squares	F value	Signification Pr > F
Stimulation frequency	7	2.052	0.293	7.832	< 0.0001 ***
Residual	462	17.291	0.037		
Total	469	19.343			

***: Very highly significant

3.4 Relation between the stimulation class to Ethephon (4/y) and the sensitivity of clones to tapping panel dryness

At four stimulations to Ethephon (ET 5 %) per year (4/y), the lengths of sick panel (LSP) measured in the 13 rubber clones during the first five years of rubber production varied from 0.12 to 4.19 % (Table 7).

Table 7. Classification of 13 rubber clones compared to averages of sick panel lengths measured during five years of rubber production, at a frequency of 4 stimulations to Ethephon (ET2.5 %) per year (4/y)

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 41	0.05	0.12	S1C1	0.18	24.12
AF 261	0.06	0.18			
AVROS 2037	0.08	0.23			
GT 1	0.11	0.49	S1C2	0.78	16.97
RRIM 712	0.14	1.08			
IRCA 230	0.20	1.50	S1C3	1.71	10.29
PB 254	0.22	1.71			
PB 217	0.24	1.71			
PB 260	0.25	1.87			
PB 235	0.26	1.76			
IRCA 130	0.29	2.76	S1C4	3.68	6.45
IRCA 209	0.31	4.19			
RRIC 100	0.34	4.08			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α=5 % with the values of LSP converted into Arc Sine Square Root of.LSP (ASINLSP).

The analysis of variance of these data showed a significant "clone" effect (Table 8). The structuration of clones by comparison of the LSP averages permitted to classify them into four groups S1C1, S1C2, S1C3 and S1C4 according to the sensitivity to TPD (Table 7).

Table 8. Analysis of variance table of sick panel lengths of 13 rubber clones in rubber production during five years, at a frequencyof4stimulations to Ethephon (ET2.5 %) per year (4/y)

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	0.5763	0.0480	2.14	0.0313 *
Duration of rubber production	4	0.2366	0.0591	2.64	0.0452 *
Residual	48	1.0765	0.0224		
Total	64	1.8895			

*: Significant

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3.5 Relation between the stimulation class to Ethephon (6/y) and the sensitivity of clones to tapping panel dryness

When six stimulations to Ethephon (ET 5 %) per year (6/y) were applied to the 13 rubber clones during the first five years of rubber production, the measured LSP ranged from 0.50 to 6.86 % (Table 9).

Table 9. Classification of 13 rubber clones compared to average of sick panel lengths measured during five years of rubber production, at a frequency of 6 stimulations to Ethephon (ET2.5 %) per year (6/y)

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 41	0.06	0.60	S2C1	0.55	0.00
RRIM 712	0.07	0.50			
PB 217	0.16	0.86	S2C2	1.03	8.32
AVROS 2037	0.18	1.21			
AF 261	0.22	1.58	S2C3	2.59	14.46
RRIC 100	0.26	1.75			
PB 254	0.26	2.02			
PB 260	0.31	2.49			
IRCA 230	0.31	3.70			
IRCA 130	0.31	3.40			
GT 1	0.34	3.17			
PB 235	0.43	4.76	S2C4	5.81	6.28
IRCA 209	0.47	6.86			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α=5 % with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

A highly significant "clone" effect was observed (Table 10). The clones were structured into four distinct groups S2C1, S2C2, S2C3 and S2C4 according to the sensitivity to TPD (Table 9).

Table 10.Analysis of variance table of sick panel lengths of13rubber clones in rubber production during five years, at a frequency of 6 stimulations to Ethephon (ET2.5 %) per year (6/y)

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	0.8784	0.0732	3.19	0.0020 **
Duration of rubber production	4	0.4796	0.1199	5.23	0.0014 **
Residual	48	1.1007	0.0229		
Total	64	2.4588			

**:Highly significant

3.6 Relation between the stimulation class to Ethephon (13/y) and the sensitivity of clones to tapping panel dryness

When the 13 rubber clones were stimulated to Ethephon (ET 2.5 %) 13 times per year (13/y) during the first five years of rubber production, the measured LSP varied from 0.37 to 8.32 % (Table 11).

Table 11. Classification of 13 rubber clones by comparison of the averages of sick panel lengths measured during five years of rubber production, at a frequency of 13 stimulations to Ethephon (ET 2.5 %) per year (13/y)

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 209	0.10	0.37	S3C1	0.79	22.64
IRCA 41	0.11	0.86			
IRCA 130	0.15	1.14			
PB 217	0.16	0.81			
RRIC 100	0.18	1.27	S3C2	2.44	22.09
RRIM 712	0.20	1.95			
AF 261	0.29	2.20			
IRCA 230	0.29	3.12			
GT 1	0.29	3.68			
AVROS 2037	0.37	3.69	S3C3	3.76	3.72
PB 254	0.39	4.84			
PB 235	0.51	6.52	S3C4	7.42	7.86
PB 260	0.57	8.32			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α=5 % with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

The analysis of variance of those data showed a very highly significant "clone" effect (Table 12). Comparison of the LSP averages permitted to classify the clones into four distinct groups of sensitivity to TPD S3C1, S3C2, S3C3 and S3C4 (Table 11).

Table 12.Analysis of variance table of sick panel lengths of13rubberclones in rubber production during five years, at a frequency of 13 stimulations to Ethephon (ET2.5%) per year (13/y)

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	1.3310	0.1109	4.91	< 0.0001 ***
Duration of rubber production	4	0.4500	0.1125	4.98	0.0019 **
Residual	48	1.0844	0.0225		
Total	64	2.8655			

: Highly significant; *: Very highly significant

3.7 Relation between the stimulation class to Ethephon (26/y) and the sensitivity of clones to tapping panel dryness

The lengths of sick panel (LSP) of the 13 rubber clones subjected to 26 Ethephon (ET 2.5 %) stimulations per year (26/y) during the first five years of rubber production ranged from 0.25 to 13.50 % (Table 13).

Table 13. Classification of 13 rubber clones by comparison of the averages of sick panel lengths measured during five years of rubber production, at a frequency of 26 stimulations to Ethephon (ET 2.5 %) per year (26/y

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 41	0.06	0.25	S4C1	0.25	0.00
PB 217	0.15	0.65	S4C2	1.32	16.64
RRIM 712	0.19	1.99			

IRCA 209	0.25	2.10	S4C3	3.53	18.48
IRCA 130	0.33	4.10			
AVROS 2037	0.37	3.67			
GT 1	0.39	4.27			
PB 254	0.40	4.85	S4C4	5.42	5.83
AF 261	0.42	4.48			
IRCA 230	0.42	5.61			
RRIC 100	0.45	6.76			
PB 260	0.73	13.26	S4C5	13.38	0.96
PB 235	0.74	13.50			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

A very highly significant "clone" effect was shown (Table 14). Five groups of sensitivity to TPD of the clones were formed. These are the groups S4C1, S4C2, S4C3, S4C4 and S4C5 from the lowest to the highest rates of TPD (Table 13).

Table 14.Analysis of variance table of sick panel lengths of 13 rubber clones in rubber production during five years, at a frequency of 26 stimulations to Ethephon (ET2.5 %) per year (26/y)

Source of variation	Degree of freedom	Sum of squares deviations	Means squares	F value	Signification Pr > F
Clone	12	2.3333	0.1944	7.28	< 0.0001 ***
Duration of rubber production	4	0.7499	0.1874	7.02	0.0002 ***
Residual	48	1.2818	0.0267		
Total	64	4.3651			

***: Very highly significant

Depending on the stimulation frequency to Ethephon (ET 2.5%), all rubber clones changed sensitivity class to TPD with the exception of IRCA 41 clone which remained little sensitive regardless of the used stimulation frequency to Ethephon. The change of sensitivity class in other clones was not significant, however. The AVROS 2037 clone became sensitive as of 13 stimulations per year. From 4 to 13 stimulations per year, the AF 261 and IRCA 230 clones were moderately sensitive and became sensitive to 26 stimulations per year. The IRCA 130 and IRCA 209 clones were very sensitive from 4 to 6 stimulations per year and little sensitive from 13 to 26 stimulations per year. The RRIC 100 clone was very sensitive from 4 to 6 stimulations per year, little sensitive to 13 stimulations per year and sensitive to 26 stimulations per year. The clones PB 217 and RRIM 712 were little sensitive, GT 1 was moderately sensitive, PB 254 was enough sensitive and PB 260 and PB 235 were very sensitive.

3.8 Relation between the duration of rubber production (D1) and the sensitivity of clones to tapping panel dryness

The lengths of sick panel (LSP) measured in the 13 rubber clones after the first year of rubber production (D1) all stimulation frequencies to Ethephon (ET 2.5%) combined, ranged from 0.01 to 2.88 % (Table 15).

Table 15. Classification of 13 rubber clones compared to averages of sick panel lengths measured at the first year of rubber production (D1), all stimulation frequencies to Ethephon (SD2.5%) confused

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 230	0.01	0.01	D1C1	0.03	47.14
PB 254	0.02	0.03			
IRCA 41	0.02	0.04			
RRIC 100	0.02	0.04			
IRCA 209	0.04	0.15	D1C2	0.20	37.24
PB 217	0.07	0.17			
IRCA 130	0.09	0.29			
AF 261	0.14	0.87	D1C3	0.93	4.64
AVROS 2037	0.17	0.97			
GT 1	0.17	0.93			
RRIM 712	0.18	0.95			
PB 235	0.29	2.88	D1C4	2.80	3.78
PB 260	0.31	2.73			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP(ASINLSP).

The analysis of variance of those data showed a very highly significant "clone" effect (Table 16). The structuring of the clones through comparison of LSP averages permitted to classify them into four groups D1C1, D1C2, D1C3 and D1C4 according to sensitivity to TPD (Table 15).

Table 16.Analysis of variance table of sick panel lengths of 13 rubber clones in rubber production during the first year(D1), all stimulation frequencies to Ethephon (ET2.5%) confused

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	0.979	0.082	9.153	< 0.0001***
Residual	81	0.722	0.009		
Total	93	1.701			

***:very highly significant

3.9 Relation between the duration of rubber production (D2) and the sensitivity of clones to tapping panel dryness

When the 13 rubber clones were in rubber production during two years (D2) all stimulation frequencies to Ethephon (ET 2.5%) combined, the measured LSP ranged from 0.07 to 7.15 % (Table 17).

Table 17.Classification of 13 rubber clones compared to averages of sick panel lengths measured at the second year of rubber production (D2), all stimulation frequencies to Ethephon (ET2.5%) confused

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 41	0.03	0.07	D2C1	0.07	-
RRIC 100	0.06	0.17	D2C2	0.17	-
GT 1	0.12	0.53	D2C3	0.66	29.54
AF 261	0.13	0.88			
PB 217	0.13	0.56			

IRCA 209	0.17	1.29			
AVROS 2037	0.18	1.08	D2C4	1.37	24.27
PB 254	0.23	1.73			
IRCA 230	0.25	2.02			
RRIM 712	0.27	2.18	D2C5	2.64	24.31
IRCA 130	0.31	3.05			
PB 260	0.32	3.33			
PB 235	0.49	7.15	D2C6	7.15	-

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α= 5 %with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

A very highly significant "clone" effect was revealed by the analysis of variance of the LSP (Table 18). The clones were organized into six groups of sensitivity to TPD (D2C1, D2C2, D2C3, D2C4, D2C5 and D2C6) (Table 17).

Table 18.Analysis of variance table of sick panel lengths of 13 rubber clones in rubber production during two years (D2), all stimulation frequencies to Ethephon (ET2.5%) confused

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	1.415	0.118	5.275	< 0.0001***
Residual	81	1.811	0.022		
Total	93	3.22			

***: Very highly significant.

3.10 Relation between the duration of rubber production (D3) and the sensitivity of clones to tapping panel dryness

After three years of rubber production (D3) of the 13 rubber clones, all stimulation frequencies to Ethephon (ET 2.5%) combined, the LSP ranged from 0.31 to 5.53 % (Table 19).

Table 19. Classification of 13 rubber clones compared to averages of sick panel lengths measured at the third year of rubber production (D3), all stimulation frequencies to Ethephon (ET2.5%) confused

Clones	ASINLSP averages	LSP averages (%) of clones	Groups of clones	LSP averages (%) of groups of clones	CV (%) of groups of clones
IRCA 41	0.08	0.31	D3C1	0.31	-
GT 1	0.15	0.94			
AF 261	0.17	1.61	D3C2	1.22	28.76
AVROS 2037	0.18	1.10			
PB 217	0.22	1.45			
IRCA 209	0.22	1.91	D3C3	1.98	28.92
IRCA 130	0.27	2.59			
PB 254	0.31	3.07			
PB 260	0.31	3.13	D3C4	3.05	3.00
IRCA 230	0.32	2.95			
PB 235	0.37	4.21			
RRIC 100	0.40	4.74	D3C5	4.83	13.76
RRIM 712	0.47	5.53			

LSP: length of sick panel, ASINLSP: Arc Sine Square Root of LSP, CV: coefficient of variation. The comparison of averages was performed with the Duncan statistical test risk α = 5 %with the values of LSP converted into Arc Sine Square Root of LSP (ASINLSP).

The analysis of variance of these data showed a highly significant "clone" effect (Table 20). The LSP averages permitted to structure the clones into five groups of sensitivity to TPD (D3C1, D3C2, D3C3, D3C4 and D3C5) (Table 19).

Table 20. Analysis of variance table of sick panel lengths of 13 rubber clones in rubber production during three years (D3), all stimulation frequencies to Ethephon (ET2.5 %)confused

Source of variation	Degree of freedom	Sum of squares deviations	Mean squares	F value	Signification Pr > F
Clone	12	1.056	0.088	3.369	< 0.001 **
Residual	81	2.115	0.026		
Total	93	3.171			

**:highly significant

When the duration of rubber production varied, all rubber clones changed the class of sensitivity to TPD except the IRCA 41 clone which remained little sensitive and the PB 235 clone which remained very sensitive regardless of the duration of rubber production. The PB 254 and IRCA 230 clones became sensitive after a year of rubber production while the RRIM 712 and PB 260 clones remained sensitive. From the third year of rubber production, the RRIC 100 clone that was little insensitive, became very sensitive.

IV. DISCUSSION

Our studies on the sensitivity to TPD syndrome of 13 rubber clones for the first five years of rubber production all stimulation frequencies to Ethephon (ET 2.5%) combined, showed that these clones formed five groups of sensitivity to TPD.

The group with very low TPD rate consists exclusively of IRCA 41 clone. This result indicates that the IRCA 41 clone is very little sensitive to TPD. It corroborates in part the large-scale experiment works [2]. In the setting of these works, the IRCA 41 clone is gradually taken from the first to the fifth year of rubber production, from 2 to 13 stimulations per year. The peculiarity of this study, is that eight stimulation frequencies ranging from 0 to 26 stimulations per year from the first to the fifth year were applied. Despite this increased stimulation, the IRCA 41 clone developed a very low level of TPD. Its hardiness to overstimulation is, here, stronger than in previous experiments. The PB 217, AF 261 and RRIM 712 clones show a low level of TPD. Our findings confirm the PB 217 and AF 261 clones in this sensitivity class to TPD as already noted by [28]. However, the AF 261 clone as well as AVROS 2037 having very little agronomic interest and therefore economic interest, will not be considered in the rest of this study.

This study also confirms the fragility to overstimulation of the PB 235 [30]-[27]-[7]and PB 260 clones. The GT 1, the reference clone, showed a moderate sensitivity, which confirms the characteristic of this clone with respect to TPD. Indeed, [5] described the PB 235, GT 1 and PB 217 clones as respectively sensitive, moderately sensitive and little sensitive to TPD. The findings of this study showed that the PB 235 clone belongs to the C5 group, the GT 1 clone to the C3 group and the PB 217 clone to the C2

group. They thus confirm the stability of the control clones already described in a classification [15].

The other clones of this study are classified into groups that do not reflect their known sensitivity level. Changes in the clones' behavior regarding the TPD revealed in this study highlight the influence of the genetic factor on the sensitivity of clones to TPD. This results are in line with those of [15]-[4]-[36]-[37] on a limited number of clones which are GT 1, PR 107, PB 235 and RRIM 600. The relatively high number of clones used in this study (13 clones) denotes of the significance of the genetic factor on the sensitivity of clones to the TPD syndrome.

The study of the LSP evolution depending on the rubber production duration showed three classes of rubber production duration according to the sensitivity to TPD. The LSP is increasingly changing from the first to the fifth year of rubber production. This evolution is rapid during the first two years of rubber production. From the third year, it increases slowly to move towards an asymptote in the fifth year which varies depending on the sensitivity of the clones to TPD. This suggests that a number of clones would be predisposed to express TPD and do it very early in the first two years of rubber production. This would explain the rapid increase in the TPD rates during this time interval. The other clones which later develop this syndrome, would do so following the gradual activation of the metabolism related to the duration of rubber production as highlighted by [15] on the trees of the GT 1 clone. This last process seems to be more influenced by the particular sensitivity of this clone than by the duration of rubber production of the trees [6]. The slow increase in the TPD rates observed from the third year is explained by the swinging (change) of the tapping panel done at this stage in rubber production of rubber tree (tapping panels management chart)[17]. In this study, clones and stimulation frequencies were set to let vary only the duration of rubber production. Thus, the three classes of duration of rubber production obtained reflect well a "duration of rubber production" effect on the sensitivity of the clones to TPD.

When you only have the stimulation frequency to Ethephon (ET 2.5%) varied, the stimulation frequencies get structured in four classes according to the TPD rate they induce. The S1 class from 0 to 4 stimulations per year, which induces the low levels of TPD; the S2 class of 6 stimulations per year, whose induced TPD rates are moderate; the S3 class from 8 to 13 stimulations per year, with high rates of induced TPD and the S4 class of 26 stimulations per year, which induces very high levels of TPD. The distinction of these classes shows a "stimulation frequency" effect in the TPD expression. Our results show otherwise that the LSP increases with the stimulation frequency. These results show that high stimulation frequencies induce and worsen TPD. They also show that even in the absence of stimulation (0 stimulation per year) the TPD appears. This form of TPD is the naturally induced TPD (De Faye, 1981) that appears in unstimulated trees normally tapped, or even in the first tapping (at the opening). It is less severe and different from the TPD induced by overproduction [20], especially by the intensive stimulations. This second form is the most severe TPD. These results corroborate those of the works of [15]-[4]-[20]-[48] on the existence of two types of TPD and on the fact that the gravity of TPD increases with the overproduction of trees. But the studies of these authors have focused only on a limited number of clones: GT 1, PR 107 and PB 235. In the current study, 13 clones were considered. These are the most planted clones or promising clones developed or introduced in Côte d'Ivoire. This has the benefit of knowing at the farm level, the individual behavior of almost all planted clones.

The study of the relationship between the stimulation class to Ethephon (ET 2.5%) and the sensitivity of clones to TPD showed that the clones formed different groups of sensitivity per stimulation class. Except for a few variants, the different groups of sensitivity to TPD of the clones, already known, were confirmed by our results. The IRCA 41 clone was little sensitive whatever is the class of stimulation. PB 217 and RRIM 712 clones were little sensitive. The IRCA 230 clone was moderately sensitive between the S1 and S3 stimulation classes (4 and 13 stimulations per year) and became sensitive to stimulation class S4 (26 stimulations per year). The GT 1 clone was moderately sensitive and the PB 235 and PB 260 clones were very sensitive to TPD. These results confirm the significant role of stimulation (hormonal factor influencing the physiology of latex) in the onset and development of TPD in rubber tree as already noted by several authors: [8]-[20].

The study of the relationship between the duration of rubber production and the sensitivity of clones to TPD showed that when the duration of rubber production varies, all rubber clones change sensitivity group to TPD except for the IRCA 41 clone which remains little sensitive and the PB 235 clone which remains very sensitive. The PB 254 and IRCA 230 clones become sensitive after a year of rubber production while the RRIM 712 and PB 260 clones remain sensitive. From the third year of rubber production, the RRIC 100 clone which was little sensitive, becomes very sensitive. The constitution of different sensitivity groups of clones according to the LSP per duration of rubber production demonstrates the relationship between the duration of rubber production and the sensitivity to TPD: the sensitivity of clones to TPD evolves with the duration of rubber production. This confirms the significant role of the duration of rubber production (physiological factor) in the onset and development of the TPD syndrome in rubber tree [18].

The originality of this study first lies in the rubber production methodology of rubber trees to establish the level of sensitivity to TPD of the tested clones and then in the analysis of results. Whereas in previous works, the IRCA 41 clone showed its good agronomic qualities including low sensitivity to TPD, from the first to the third year, stimulation frequencies increasing gradually to stabilize at 13 per year; in this study, 8 stimulation frequencies ranging from 0 to 26 per year were applied each year during the first five years of experiment. Thus, the sensitivity to TPD of the IRCA 41 clone was tested against both genetic factor (clone) as well as physiological

and hormonal factors (duration of rubber production and stimulation frequency). All types of variation done have in no way modified the degree of sensitivity of the IRCA 41 clone which remained very sensitive to TPD. This clone remained stable in the expression of its sensitivity to TPD even at frequencies of 26 stimulations to Ethephon (ET 2.5 %) per year. This illustrates the low sensitivity to TPD revealed by the IRCA 41 clone. The IRCA 41 clone is a promising clone, with very high level of rubber production and good radial vegetative growth. It is resistant to breakage due to wind, to root rot caused by *Fomes lignosus* [2] and very little sensitive to TPD, as we have just shown. Breakage due to wind and TPD being two important factors of degradation of trees planting, the IRCA41 clone represents an elite clone to advise rubber growers to mitigate the adverse effects of over-exploitation of rubber trees in non-industrial sector.

V. Conclusion

It appears from this study that there is a genetic factor and physiological and hormonal factors among the causes of TPD syndrome in rubber tree. Sensitivity to TPD syndrome in rubber tree depends on the clone. Some clones as IRCA 41, AF 261, PB 217, and RRIM 712 are little sensitive. Others, such as PB 235 and PB 260 are particularly sensitive. Between these two groups of extreme sensitivity, there are clones that have intermediate sensitivity (or moderate). This is the case of the clones AVROS 2037 IRCA 130, IRCA 209 and GT 1, which have moderate sensitivities and the RRIC 100, IRCA 230 and PB 254 clones of relatively high sensitivities. In the class of little sensitive clones, the AF 261 clone has no economic interest because of its very low level of rubber production. In this study, the RRIM 712 clone displays a low sensitivity but this result needs confirmation with regard to the behavior of this clone in other experiments. In the class of moderate sensitivity, the AVROS 2037 clone is excluded because of its very low rubber production. Of the physiological and hormonal factors affecting the latex physiology, this study showed that the severity of TPD changes with the duration of rubber production of clones and the stimulation frequency to Ethephon.

The study of the sensitivity of rubber clones to TPD according to the stimulation frequency to Ethephon and to the duration of rubber production gave the following informations:

- the IRCA 41 clone expresses less the TPD even with high stimulation frequencies (26/y) during the first five years of rubber production;
- PB 235 and PB 260 clones are the most fragile;
- the change of sensitivity class of the other clones is not significant and indicates that the genetic factor is the major factor in the onset and development of TPD;
- between 13 and 26 stimulations per year (13/y and 26/y), the IRCA 230, RRIC 100 and PB 254 clones express a weariness effect
- PB 217 and RRIM 712 clones are little sensitive to high stimulation frequencies. This result deserves confirmation for the RRIM 712 clone.

Among the clones tested in this study, IRCA 41 remains by far the best performing clone. Previously recognized as a clone having a good radial vegetative growth, high rubber production and a good tolerance to breakage due to wind, it presents in this study, a low sensitivity to TPD. The IRCA 41 clone is recommend to plant among clones, especially in non-industrial sector, to enhance the production of natural rubber in Côte d'Ivoire.

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