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Study of Biological Factors Likely to Influence Sensitivity to Dry Notch* Disease of Rubber Tree in Three Rubber Production Zones of Cote D'ivoire

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Abstract**—***Rubber production in rubber trees is affected by dry notch disease, the cause of which has unfortunately not yet been fully elucidated. This study aims to evaluate the impact of biological factors on susceptibility to disease across agro-industrial companies in the West (Zagné), South-West (San-Pédro) and South-East (Anguédédou) zones of the Côte d'Ivoire. The method used is the recording of panel sick length (PSL) of rubber trees in relation to their clonal metabolisms and the attacks of the main pests of rubber trees such as Corynespora sp, Fomes sp and Loranthaceae. The results showed that the three cultivated clonal metabolic class were all affected by dry notch of rubber but at different levels with an average of 34.65 ± 1.77 %. Regarding pests, the study revealed that they significantly influence (Pr < 0.05) the sensitivity to dry notch. Rubber trees attacked by Fomes sp displayed a higher rate of diseased notch (50.56 ± 20.30 %) than that of non-attacked rubber trees (30.58 ± 20 %). Similarly, rubber trees parasitized by Loranthaceae displayed higher PSL (38.41 ± 20.55 %) than those of rubber trees free (30.16 % ± 21.62 %). Only rubber trees attacked by Corynespora sp presented lower PSL (15.61 ± 13.69 %) than those of non-attacked rubber trees (39.76 ± 20.22 %). Depending on the different production zones, Loranthaceae infested rubber plantations more than the other two pests.*

Keywords**—*****Pest of crops, rubber tree, stoppage of latex flow, tropical country.***

I. INTRODUCTION

Rubber is a very popular cash crop in Côte d'Ivoire. It is certainly not the only rubber plant in the world, but almost all of the natural rubber used in industries comes from the rubber tree. This is also what makes natural rubber a strategic raw material and rubber growing a dynamic and expanding sector (Thaler, 2013). In 2021, with a production of nearly one million tonnes and a cultivated area of 700 000 hectares, Côte d'Ivoire rose to 4th place, behind the world giants (APROMAC, 2021).

However, it seems that this performance is more linked to the increase in cultivated areas rather than to the productivity of rubber trees. For good reason, in rubber farms, a fairly recurring problem is observed during tapping. This is the phenomenon of dry notch of rubber trees, a disease which results in a partial or total cessation of the flow of latex after tapping (Okoma *et al*., 2011). This syndrome, which is economically serious, has become a priority in rubber growing research programs. The efforts made by Ivorian researchers in 2011, in industrial plantations, reported a national average rate of dry notch of 9 % (Okoma *et al*., 2009). Since then, an increasing evolution of dry notch has been noted in rubber plantations. Unfortunately, the real cause of this physiological dysfunction has not been fully elucidated (Okoma, 2008).

Knowing that the cultivation of rubber trees involves on the one hand, the clone whose sensitivity to dry notch follows a gradient identical to that of the metabolic activity (Okoma *et al*., 2009) and on the other hand, that the attacks of pests constitute opening doors to dysfunctions in trees (Déon, 2012), this study aims to evaluate the impact of biological factors on the sensitivity to dry notch of rubber trees in main areas of Ivorian rubber production.

II. MATERIALS AND METHODS

Study sites

The study was carried out on the basis of surveys and empirical data collection in agro-industrial companies in the Anguédédou, San-Pédro and Zagné zones (Fig. 1). The characteristics of these zones are recorded in Table 1.

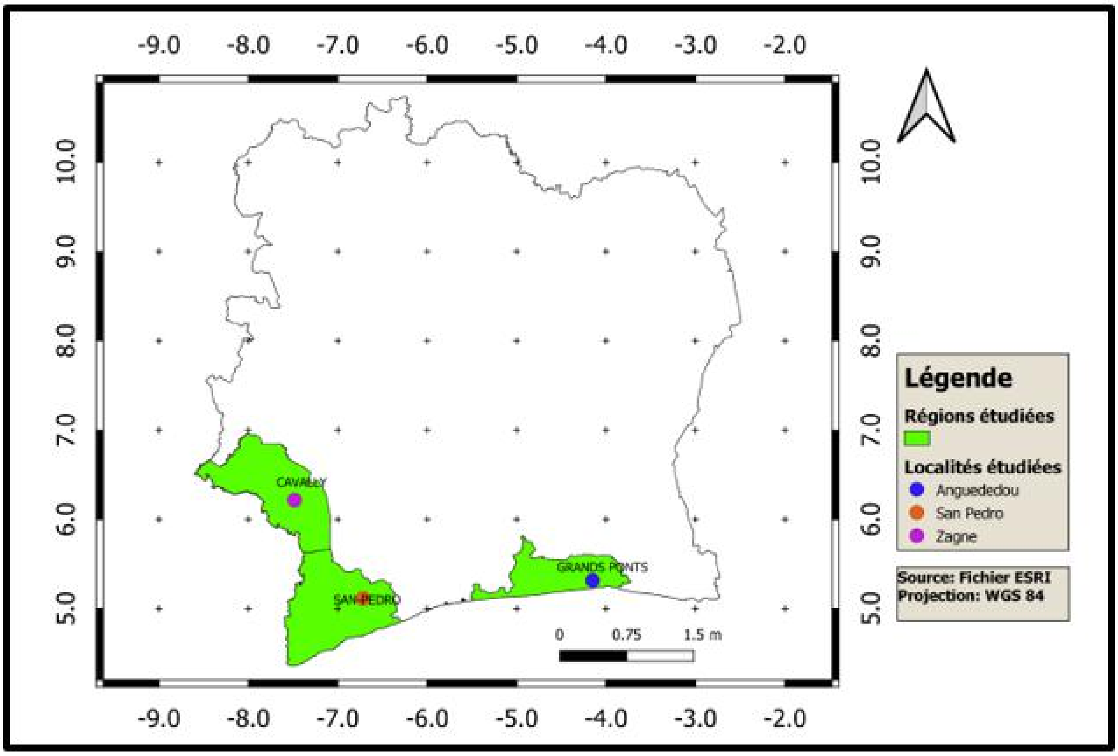


Fig. 1 : Presentation of the different survey sites

Table 1 : Characteristics of the study areas

Localities	Geographic coordinates	Vegetation	Floors	Precipitation (mm/year)	Average temperature (°C)	Insolation (hours/year)	Relative humidity (%)
Anguédédou	5°19'N and 4°09'W	Cleared rainforest	Highly desaturated ferralitic with little gravel content	1800-2000	26	2000-2100	90
San Pedro	4°45'N and 6°38'W	Dense evergreen humid forest	Highly desaturated ferralitic and gravelly	1800-2000	25	1700-1800	90
Zagné	6°13'N and 7°29'W	Dense, humid forest	Humus and ferruginous forestry poor in humus	1200	18-36	1200-1500	72-90

Sources : Brou (2005) and Neobot (2020).

Plant material

The plant material used for this study consists of popularized *Hevea brasiliensis* clones, that is to say clones found both in village and industrial plantations. These clones were identified during surveys and prospections in the main rubber production areas of Côte d'Ivoire and are part of the three classes of metabolic activities.

Data collection device

Surveys for data collection were carried out from October 2020 to February 2021 ; period which corresponds to the end of the 2020-2021 production campaign and which allows us to better appreciate the symptoms of dry notch and the main pests.

Field surveys were carried out taking into account the metabolic classes of the cultivated clones. From one plot to another, a tapper was retained to tap the trees of the chosen diagonal line, eliminating the border trees. The tapping shares of the different tappers selected included an average of 500 trees ; which approximately corresponds to a plot of one hectare in a rural environment taking into account the 6 m x 3 m system which corresponds to 555 trees per hectare. Daily surveys began at 6 : 30 a.m. and ended around 12 p.m. with an average time of 30 minutes per tapper.

Parameters measured

Dry notch survey of rubber trees

The determination of the actual length of notch which no longer produces latex at the level of a tree in operation, also called panel sick length (PSL), was done by visual assessment using the method rapid dry notch survey by Van De Sype (1984). The trees observed were rated on a scale of 0 to 6 depending on the flow of latex after tapping (Table 2). Then, the scores obtained were used to calculate the panel sick length (PSL) using the following formula :

$$\mathbf{PSL = [(0.1\ n1 + 0.3\ n2 + 0.5\ n3 + 0.7\ n4 + 0.9\ n5 + n6) / N] \times 100}$$

With PSL = Panel Sick Length ; N = total number of trees in the plot ; Coefficients 0.1; 0.3; 0.5; 0.7; 0.9 and 1 = class averages of non-latex producing kerf length percentage ; n1; n2; n3; n4; n5 and n6 = numbers of trees observed per percentage class of non-latex-producing bleed notch length.

Table 2 : Dry nock length rating scale (Van De Sype, 1984)

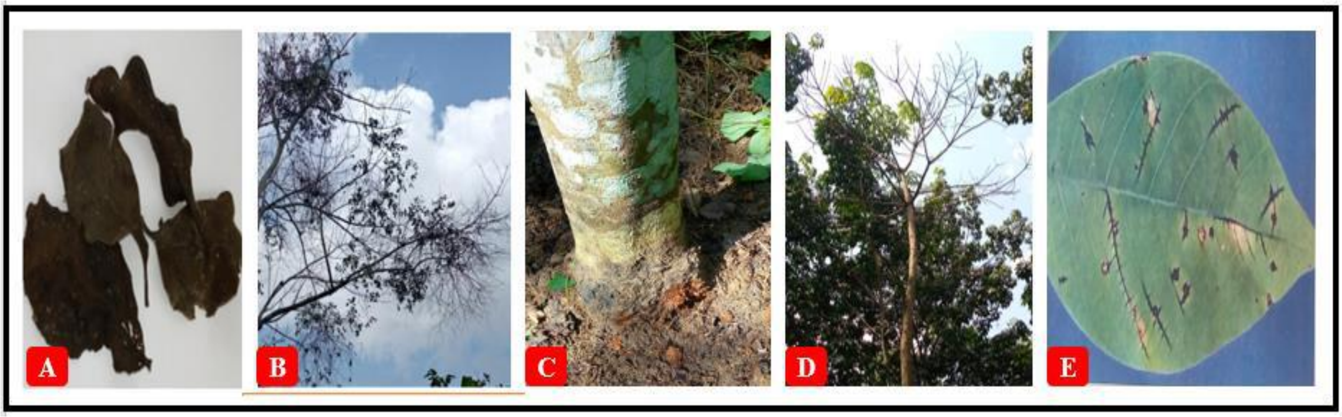
NOTE	(PSL %)	MEANING
0	0	Healthy trees
1	1 to 20	Trees affected by very low level dry notch
2	21 to 40	Trees affected by low level dry notch
3	41 to 60	Trees affected by mid-level dry notch
4	61 to 80	Trees affected by fairly high levels of dry notch
5	81 to 99	Trees affected by high level dry notch
6	100	Trees affected by total dry notch or dry trees

With PSL = Panel sick length

Inventory of rubber tree pests

The inventory of the main pests of rubber trees such as *Corynespora sp* (responsible for leaf fall fungal disease), *Fomes sp* (responsible for root rot fungal disease) and *Loranthaceae* (parasitic plants) was made on the same trees of the chosen diagonal line. During the observations, stops at intervals of 5 to 10 min were marked to inspect the trees using different identification keys derived from the Côte d'Ivoire agricultural advisor's guide (Fig. 2 ; FIRCA, 2013). For each tree observed, the presence (score 1) or absence (score 0) of the parasite was recorded. The impact of pests on rubber trees was assessed by calculating the attack rate (Ta) as follows :

$$Ta = \frac{total\ number\ of\ rubber\ trees\ parasitized}{total\ number\ of\ rubber\ trees\ observed} \times 100$$



A = Leaves of Loranthaceae ; B = Tufts of Loranthaceae ; C = Root attack of Fomes sp ; D = Defoliation linked to Fomes sp ; E = Leaf symptom of Corynespora sp.

Statistical analysis

All data was subjected to analysis of variance using STATISTICA version 7.1 software. The comparison of the means of the parameters studied was carried out using the parametric factorial ANOVA test at the 5 % threshold when the distribution followed a normal law. When the effect of the factor studied was significant, the post hoc Student-Newman-Keuls mean comparison test was used at the 5 % threshold.

III. RESULTS AND DISCUSSION

3.1. Results

3.1.1. Characteristics and lengths of diseased notches in the plots visited

The surveys carried out at the end of the 2020-2021 production campaign in Zagné, San-Pédro and Anguédédou made it possible to visit 281 plots. Depending on the different production areas, the number of plots varied depending on the clones present. The surveyed areas also differed significantly ($Pr < 0.05$) from one zone to another depending on the configuration of the plots visited. The average dry notch rate recorded on all sites was 34.65 ± 1.77 %. The Anguédédou plots were the sickest with an average panel sick length (PSL) of 36.56 ± 17.12 %. They were followed by the Zagné and San-Pédro plots with respective average PSL of 34.33 ± 17.86 % and 33.07 ± 25.37 % (Table 3).

Table 3 : Characteristics and lengths of diseased notches in the plots visited

PRODUCTION AREA	NUMBER OF PLOTS	AREAS (%)	PSL (%)
Zagné	90	51.90 ± 9.72a	34.33 ± 17.86b
San Pedro	131	22.79 ± 17.30b	33.07 ± 25.37c
Anguedou	60	23.28 ± 7.57b	36.56 ± 17.12a
TOTAL/AVERAGE	281	32.22 ± 19.09	34.65 ± 1.77
Pr	-	0.00	0.00

With PSL = Panel Sick Length ; In each column, the results assigned to the different letters are not significantly different (Newman-Keuls test at 5 %).

3.1.2. Influence of clonal metabolism on sensitivity to dry notch

In this study, nine popularized clones were identified, namely PB 217, PB 235, PB 260, IRCA 331, IRCA 230, IRCA 130, IRCA 41, GT1 and RRIC 100. Among these clones, only PB 217 belongs to the class slow metabolism. GT1, IRCA 331, IRCA 41 and RRIC 100 belong to the intermediate metabolic class. PB 235, PB 260, IRCA 230 and IRCA 130 also belong to the rapid metabolic class (Table 4).

Overall, analyzes of variance revealed a significant difference ($Pr < 0.05$) between the panel sick lengths (PSL) of the three clonal metabolisms. The metabolic class most sensitive to dry notch (42.71 ± 17.47 %) was that of rapid metabolism. It was followed by the class of slow and intermediate metabolisms with respectively average PSL of 38.27 ± 20.51 % and 31.45 ± 21.37% (Table 5).

Depending on the different production areas, the three metabolic classes displayed statistically identical average PSL in Zagné. It is only in San-Pédro and Anguédédou that variable levels of sensitivity were recorded (Table 5).

Table 4 : Diseased notch lengths and metabolic class of the different clones identified

CLONES	METABOLIC CLASS	AVERAGE PSL (%)
PB 217	Slow	38.27 ± 20.51ab
GT1	Intermediate	25.97 ± 17.44bc
RRIC 100	Intermediate	53.91 ± 29.72a
IRCA 331	Intermediate	18.37 ± 23.60c
IRCA 41	Intermediate	39.39 ± 17.80ab
IRCA 130	Fast	28.45 ± 30.32bc
IRCA 230	Fast	40.88 ± 29.90ab
BP 235	Fast	55.93 ± 7.85a
BP 260	Fast	32.85 ± 16.02bc
AVERAGE	-	34.65 ± 1.77
Pr	-	0.00

With PSL = Panel Sick Length ; BP = Prang Besar ; IRCA = Rubber Research Institute ; GT1 = Gondang Tapen 1 ; RRIC = Rubber Research Institute of Ceylon ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %) ; (-) = not recorded.

Table 5 : Diseased notch lengths depending on the metabolic class of the clones identified in the different production areas

CLASS METABOLIC	DIFFERENT PRODUCTION ZONES			AVERAGE PSL (%)
	ZAGNE PSL (%)	SAN PEDRO PSL (%)	ANGUEDEDOU PSL (%)	
Slow	35.45 ± 16.88abc	45.17 ± 26.51ab	31.79 ± 9.38bc	38.27 ± 20.51b
Intermediate	34.33 ± 17.63abc	26.57 ± 22.87c	45.47 ± 14.44ab	31.45 ± 21.37c
Fast	38.52 ± 16.05abc	51.73 ± 17.94a	41.45 ± 17.65abc	42.71 ± 17.47a
AVERAGE	35.47 ± 16.99b	33.32 ± 25.30c	38.40 ± 14.71a	35.22 ± 20.96
Pr	0.00	0.00	0.00	0.00

With PSL = Panel Sick Length ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %).

3.1.3. Influenceof the main pests of rubber trees on sensitivity to dry notch

3.1.3.1. Influence of *Corynespora sp*

On a total of 281 visited plots, the analyzes of variance revealed a significant difference (Pr < 0.05) between the panel sick lengths (PSL) of rubber trees and *Corynespora sp* so that the clones parasitized by this disease had had lower average PSLs (15.61 ± 13.69 %) than non-parasitized clones (39.76 ± 20.22 %) (Table 6).

Furthermore, depending on the different study areas, it is only in San-Pédro that *Corynespora sp* attacks were noted. The effects of this rubber tree pest were particularly intense on GT1 (81.03 ± 39.54 %) and PB 235 (100 ± 0.00 %) (Table 7).

Table 6 : Influence of Corynespora sp on sensitivity to dry notch

	Average PSL (%)	Pr
Absence of Corynespora	39.76 ± 20.22a	
Presence of Corynespora	15.61 ± 13.69b	0.00

With PSL = Panel Sick Length ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %).

Table 7 : Influence of Corynespora sp on clonal sensitivity to dry notch according to different production zones

	DIFFERENT PRODUCTION ZONES		
	ZAGNE	SAN PEDRO	ANGUEDEDOU
CLONES	PSL (%)	PSL (%)	PSL (%)
PB 217	0 ± 0.00	29.41 ± 46.25b	0 ± 0.00
GT1	0 ± 0.00	81.03 ± 39.54a	0 ± 0.00
RRIC 100	0 ± 0.00	20 ± 44.72b	-
IRCA 331	-	46.15 ± 51.88b	-
IRCA 41	0 ± 0.00	9.09 ± 30.15b	0 ± 0.00
IRCA 130	-	0 ± 0.00	-
IRCA 230	-	0 ± 0.00	-
BP 235	0 ± 0.00	100 ± 0.00a	0 ± 0.00
BP 260	0 ± 0.00	-	0 ± 0.00
AVERAGE	0.00	50.38 ± 50.19	0.00
Pr	-	0.00	-

With PSL = Panel Sick Length ; BP = Prang Besar ; IRCA = Rubber Research Institute; GT1 = Gondang Tapen 1 ; RRIC = Rubber Research Institute of Ceylon ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %) ; (-) = Clone not recorded.

3.1.3.2. Influence of *Fomes sp*

The table 8 shows the influence of *Fomes sp* on the sensitivity to dry notch of all the plots visited. From a general point of view, the results revealed that rubber trees attacked by *Fomes sp* have a higher rate of diseased notch (50.56 ± 20.30 %) than that of non-attacked rubber trees (30.58 ± 20 %).

Depending on the different production zones, San-Pédro and Anguédédou were the zones most sensitive to *Fomes sp* attacks with a higher prevalence among RRIC 100 clones (80 ± 44.72 %), IRCA 41 (72.72 ± 46.70 %), IRCA 130 (66.67 ± 57.73 %) and IRCA 230 (66.67 ± 51.63 %) (Table 9).

Table 8 : Influence of Fomes sp on sensitivity to dry notch

	Average PSL (%)	Pr
Absence of Fomes	30.58 ± 20b	
Presence of Fomes	50.56 ± 20.30a	0.00

With PSL = Panel Sick length ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %).

Table 9 : Influence of Fomes sp on clonal sensitivity to dry notch according to different production zones

	DIFFERENT PRODUCTION ZONES		
	ZAGNE	SAN PEDRO	ANGUEDEDOU
CLONES	PSL (%)	PSL (%)	PSL (%)
PB 217	3.57 ± 18.89a	38.24 ± 49.32ab	33.33 ± 48.15b
GT1	11.76 ± 33.21a	1.72 ± 13.13b	6.25 ± 25b
RRIC 100	0 ± 0.00a	80 ± 44.72a	-
IRCA 331	-	15.38 ± 37.55ab	-
IRCA 41	5 ± 22.36a	72.72 ± 46.70ab	80 ± 44.72a
IRCA 130	-	66.67 ± 57.73ab	-
IRCA 230	-	66.67 ± 51.63ab	-
BP 235	0 ± 0.00a	0 ± 0.00b	20 ± 44.72b
BP 260	0 ± 0.00a	-	10 ± 31.62b
AVERAGE	4.44 ± 20.72b	25.95 ± 44.01a	25 ± 43.67a
Pr	0.65	0.00	0.00

With PSL = Panel Sick Length ; BP = Prang Besar; IRCA = Rubber Research Institute ; GT1 = Gondang Tapen 1 ; RRIC = Rubber Research Institute of Ceylon ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %) ; (-) = Clone not recorded.

3.1.3.3. Influence of *Loranthaceae*

Analyzes of variance revealed a significant difference (Pr < 0.05) between panel sick lengths (PSL) of rubber trees and *Loranthaceae*. Indeed, plots attacked by Loranthaceae displayed greater diseased notch lengths (38.41 ± 20.55 %) than those of non-attacked plots (30.16 % ± 21.62 %) (Table 10).

Generally speaking, the localities in this study were all sensitive to attacks by *Loranthaceae* with a prevalence in almost all of the clones present (Table 11).

Table 10 : Influence of Loranthaceae on susceptibility to dry notch

	Average PSL (%)	Pr
Absence of Loranthaceae	30.16 ± 21.62b	
Presence of Loranthaceae	38.41 ± 20.55a	0.00

With PSL = Panel Sick Length ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %).

3.2. DISCUSSION

3.2.1. Features and lengths of diseased notches in the plots visited

Data collections carried out in agro-industrial plantations in the Zagné, San-Pédro and Anguédédou zones revealed an average diseased notch length (PSL) of 34.65 ± 1.77 %. This result reflects the scale and complexity of managing dry notch of rubber trees on farms. For good reason, by extrapolation to the national average rate of 9 % noted by Okoma *et al*. in 2009, it can be said that the rate of dry notch has tripled in a decade although the rubber agro-industrialists know the requirements and the best options for exploiting the rubber tree. Dryness of the notch therefore has not only causes, but also symptoms which can be very different (Jacob *et al*., 1990) although leading to the same effects : dysfunction of the laticiferous system and reduction, otherwise the disappearance of latex production from the rubber tree. Among the direct or indirect causes of the disease, we must of course cite overexploitation due to the intensity of tapping or excessive stimulation (Van de Sype, 1984), but also to the season, drought, quality of certain soils (Commère *et al*., 1989). Furthermore, the non-random dispersion of diseased trees has also directed studies towards the search for various pathogens, although the absence of current results does not allow this hypothesis to be ruled out (Nandris *et al*., 1991). Sensitivity to dry notch is also a clonal characteristic (Van de Sype, 1984, ; Sethuraj, 1990) which can be extremely marked ; thus clones PB 235 or PB 260 are very sensitive to this disease, while clones PB 217 or PR 107 are much less so. Symptomatic and evolutionary differences also made it possible to distinguish several forms of dry notch. Some disappear after a fairly long suspension of tapping; they are therefore reversible (Van de Sype, 1984). Others, despite a long rest and sometimes a slight resumption of production, lead inexorably to total drought of the tree (De Faye *et al*., 1989) ; they are therefore much more serious.

Table 11 : Influence of Loranthaceae on clonal sensitivity to dry notch according to different production zones

	DIFFERENT PRODUCTION ZONES		
	ZAGNE	SAN PEDRO	ANGUEDEDOU
CLONES	PSL (%)	PSL (%)	PSL (%)
PB 217	85.71 ± 35.63a	52.94 ± 50.66a	95.83 ± 20.41a
GT1	23.53 ± 43.72b	32.75 ± 47.34b	93.75 ± 25a
RRIC 100	12.50 ± 35.35b	0 ± 0.00b	-
IRCA 331	-	7.69 ± 27.73b	-
IRCA 41	45 ± 51.04b	18.18 ± 40.45b	100 ± 0.00a
IRCA 130	-	33.33 ± 57.73b	-
IRCA 230	-	50 ± 54.77a	-
BP 235	100 ± 0.00a	0 ± 0.00b	80 ± 44.72a
BP 260	7.17 ± 26.72b	-	100 ± 0.00a
AVERAGE	46.67 ± 50.16b	33.58 ± 47.41b	95 ± 21.97a
Pr	0.00	0.03	0.53

With PSL = Panel Sick Length ; BP = Prang Besar ; IRCA = Rubber Research Institute ; GT1 = Gondang Tapen 1 ; RRIC = Rubber Research Institute of Ceylon ; In each column, the results assigned the same letter are not significantly different (Newman-Keuls test at 5 %); (-) = Clone not recorded.

3.2.2. Influence of clonal metabolism on sensitivity to dry notch

In the industrial plantations visited, nine types of rubber clones were identified. These clones were all affected by rubber tree dry notch but to different degrees depending on their metabolic classes. The fast metabolic class was most susceptible to dry notch with a panel sick length (PSL) of 42.71 ± 17.47 %. It was followed by the slow and intermediate metabolic classes with PSL of respectively 38.27 ± 20.51 % and 31.45 ± 21.37 %. These differences could be explained by the fact that clonal sensitivity to dry notch is linked to the metabolic activity of the clones. This hypothesis is further supported by the fact that the study by Chrestin (1985) showed that the dry notch rate increases with the frequency of stimulation. The latter being described as a process of activation of metabolism (Coupé & Chrestin, 1989). We therefore observe that the clones not very sensitive to dry notch have an inactive (or slow) metabolism, the moderately sensitive clones have an intermediate metabolism and the clones very sensitive to this syndrome have a very active (or rapid) metabolism.(Okoma *et al.*, 2009). However, in this study, the slow metabolic class was more sensitive (38.27 ± 20.51 %) at the dry notch than the intermediate metabolic class (31.45 ± 21.37 %). This contrast could be explained by the fact that the low PSL (26.57 ± 22.87 %) clones GT1 and IRCA 331 noted in San-Pédro contributed to reducing the general average of the intermediate metabolic class for all the areas visited.

3.2.3. Influence of the main pests of rubber trees on sensitivity to dry notch

3.2.3.1. Influence of *Corynespora sp*

The study of the influence of the pest *Corynespora sp* on sensitivity to dry notch revealed that clones parasitized by this fungal disease had lower diseased notch lengths (PSL) (15.61 ± 13.69 %) than non-parasitized clones (39.76 ± 20.22 %). It would therefore seem that the rubber trees parasitized by *Corynespora sp*, in this study, were at the start of infestation at the time of the dry notch survey, which is why they produced more latex to defend themselves against the stimulus. Indeed, when we bleed the tree, we incise specialized cells ("laticiferous" cells) and these then release their contents, the latex. It is now believed that these cells constitute a defense system of the plant, the coagulation of the latex released during an incision, or wound, making it possible to quickly seal them and therefore facilitate healing (Hornus & Gohet , 2009). Furthermore, previous studies have shown that the kinetics of hydrogen peroxide production by the attacked rubber tree is very often used to distinguish hypersensitive type reactions from incompatible reactions (Dixon *et al*., 1994). Generally, the first peak of H_2O_2, which is produced at the first contact between the elicitor and the receptor on the host cell, is common to compatible and incompatible reactions while the appearance of a second peak later would be characteristic of the hypersensitive reaction. These kinetics were studied during the interaction of the resistant clone GT1 with *Corynespora cassiicola* and revealed a single H_2O_2 peak, which would reflect the absence of a hypersensitive reaction in the resistant clone to infection (Breton 1997). However, in our study, the GT1 clones grown in San-Pédro were particularly sensitive (81.03 ± 39.54 %) to the dry notch of the rubber tree following *Corynespora sp* attacks revealing, this time, their hypersensitivity to the disease.

3.2.3.2. Influence of *Fomes sp*

The demonstration of the effect of *Fomes sp* on the sensitivity to dry notch of the rubber tree showed that the rubber trees attacked by this fungal root disease had a higher rate of diseased notch (50.56 ± 20. 30 %) to that of unattacked rubber trees (30.58 ± 20 %). This lignivorous soil fungus, by preferentially attacking the main pivot of the rubber tree, diverts its reserves for the benefit of its food (Obouayéba, 2005). It could therefore be that the rubber trees parasitized by the wood-eating fungus were at an advanced stage of the disease. The general yellowing of the leaves and the repeated defoliations (Okoma, 2008) which resulted forced these rubber trees to concentrate all their energy and their sugars (sucrose) on refoliation and defense against the stress suffered to the detriment of the production of the latex. All things which acted on the production performance of the rubber trees by causing dry notches (partial or total stoppage of the flow of the latex) to the extent that the sugar, raw material for the regeneration of the latex, was derived entirely from the defense. This hypothesis is all the more supported by the fact that the study by Hornus & Gohet (2009) showed that the parasitized tree uses its energy and its sugars for the needs of its defense. However, it is depending on the level of sugar available in the latex that we can have a fairly precise idea of the possibility of increasing yield.

3.2.3.3. Influence of *Loranthaceae*

In the industrial plantations visited, the plots attacked by *Loranthaceae* displayed longer panel sick lengths (PSL) than those of the non-attacked plots. This negative influence of this parasite on the production of the tree through the length of diseased notch of rubber trees could be explained by the fact that *Loranthaceae* are parasitic plants which, once fixed on the tree, take water and nutrients ; which weakens host trees and makes them more vulnerable to other types of attacks and diseases (Koffi *et al.*, 2014). As a result, the tree weakened by an attack by *Loranthaceae*, sees its production reduced until it stops completely in certain cases (Koffi *et al.*, 2014). The dry notch disease of rubber trees being the partial or total cessation of the flow of latex after tapping (Okoma *et al*., 2011), it therefore seems normal that the rate of the disease increases simultaneously with the attack on *Loranthaceae* to the extent that the physiological stress resulting from parasitism significantly reduces the production capacities of the tree (Dibong *et al.*, 2010 ; Ahamédé *et al.*, 2017) at a more advanced stage of the attack. In fact, parasites divert the raw sap from rubber trees. Plant growth is then slowed and eventually fades. The ability of trees to produce leaves, flowers, fruits and latex is also reduced due to the diversion of nutrients and water (Koffi *et al*., 2014).

IV. CONCLUSION

At the end of this study, it appears that the dry notch disease of rubber trees continues to be prevalent in agro-industrial plantations in the areas of Zagné, San-Pédro and Anguédédou with a panel sick length (PSL) average of 34.65 ± 1.77 % and a high prevalence (42.71 ± 17.47 %) in clones with a fast metabolic class. Furthermore, the sensitivity of the disease is exacerbated by attacks from the main pests of the rubber tree.

Indeed, from one cultivation zone to another, the influence of pests on the sensitivity to dry notch of rubber trees differed significantly ($Pr < 0.05$). Rubber trees attacked by *Fomes sp*, which were at an advanced stage of the disease, displayed a higher rate of diseased notch (50.56 ± 20.30 %) than that of non-attacked rubber trees (30.58 ± 20 %). In addition, *Loranthaceae*, which were also the most widespread pests in rubber plantations unlike the other two, induced greater PSL (38.41 ± 20.55%) in rubber trees than in rubber trees they were parasitized (30.16% ± 21.62%). Only rubber trees attacked by *Corynespora sp* presented lower PSL (15.61 ± 13.69 %) than those of non-attacked rubber trees (39.76 ± 20.22 %) ; a sign that the attacked trees were at the beginning of an infestation and that they generated a peak in rubber production to defend against the pest.

Faced with the persistence of the effects of dry notch, rubber growers are advised to plant clones with an intermediate metabolic class, in particular IRCA 331, which proved to be the least susceptible to the disease in this study.

Therefore, it would be more judicious to set up experiments to monitor the impact of biological factors on the evolution of rubber tree dry notch disease.

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REFERENCES

[1] Ahamidé I. D. Y., Tossou M. G., Dassou H. G., Yedomonhan H., Houenon J. G., Akoegninou A. (2017). Usages des plantes parasites de la famille des Loranthaceae et variation du niveau de leur connaissance au Nord-Bénin : Implications pour la gestion durable des hémiparasites. *Afrique Science*, 13(5), 222-235.

[2] APROMAC. (2021). Atelier sur les problèmes de la filière hévéa en Côte d'Ivoire. www.apromac.ci. Consulté le 21 Juillet 2021.

[3] Breton F. (1997). Réactions de défense dans l'intéraction Hevea brasiliensis/Corynespora cassiicola et implication d'une toxine dans le déterminisme de la réponse clonale. Université Montpellier 2, Montpellier. 128 p.

[4] Brou Y.T. (2005). Climat, mutations socio-économiques et paysages en Côte d'Ivoire. Mémoire de synthèse des activités scientifiques présenté en vue de l'obtention de l'Habilitation à Diriger des Recherches. Universités des Sciences et Technologies de Lille, 213 p.

[5] CIRAD. (1993). Recueil de fiches de clones HEVEA. Abidjan, Côte d'Ivoire : CIRAD-CP. 170 p.

[6] D'Auzac J. (1996). L'oxygène "toxique" : une défense contre les pathogènes. Parcelles, Recherche, Développement 3 : 153-170 p.

[7] De Faye (1981). Histologie comparée des écorces saines et pathologiques (maladie des encoches sèches) de l'Hevea brasiliensis. Thèse de Doctorat de 3ème Cycle, USTL, Montpellier II, 75 p.

[8] Déon M. (2012). Importance de la cassiicoline en tant qu'effecteur de la Corynespora Leaf fall (CLF) chez l'hévéa. Développement d'outil pour le contrôle de la maladie. Thèse de Doctorat. Université Blaise pascal (France), Ecole doctorale Sciences de la vie, Santé, Agronomie, environnement. 179 p.

[9] Dian K., (1997). Tapping Panel Dryness Research: List of questions. Institute of Rubber Research Development Board, (IRRDB). 1. Annual meeting, Ho Chi Minh City, Vietnam, 11-13 October 1997, 12 p.

[10] Dibong S. D., Biyon B. N., Obiang N. E., Din N., Priso R. J., Taffouo V. D., Akoa A. (2010). Faut-il éradiquer les Loranthaceae sur les ligneux à fruits commercialisés de la région littorale du Cameroun ? *International Journal of Biological and Chemical Sciences*, 4 (3). 1991-8631.

[11] Dixon R.A, Harrison M.J., Lamb C.J. (1994). Early events in the activation of plant defense responses. Annual Review of Phytopathology 32 : 479-501 p.

[12] FIRCA (2013). Production de matériel végétal d'hévéa. FIRCA/APROMAC-Guide du conseiller agricole hévéa Tome 2, document interne, 56 p.

[13] Gohet E., Lacrotte R., Obouayéba S., Commere J. (1991). Tapping systems recommended in West Africa West Africa. Proc. Rubb. Growers' Conf. Rubb. Res. Inst. Malaysia ; ed., Kuala Lumpur, Malaysia, 235-254 p.

[14] Gohet E., Prévot J. C., Eschbach J. M., Clément A., Jacob J. L. (1996). Clone, croissance et stimulation, facteurs de la production de latex. Parcelle Recherche Développement, 3 (1) : 30-38 p.

[15] Gohet E., Chatuma P., Lacote R., Obouayéba S., Dian K. (2003). Latex clonal typology of Hevea brasiliensis modelling of yield potential and clonal response to ethephon stimulation. In : Proceedings of the International Workshop on Exploitation technology, India, 199-217 p.

[16] Jayasinghe C.K. (2000). Corynespora Leaf Fall: the most challenging rubber disease in Asian and African continents. Bulletin of the Rubber Research Institute of Sri Lanka 42 : 56-64 p.

[17] Koffi A. A., Kouassi F. A., N'Goran S. B. K., Soro D. (2014). Les Loranthaceae, parasites des arbres et arbustes : cas du département de Katiola, au nord de la Côte d'Ivoire. *International Journal of Biological and Chemical Sciences*, 8(6), 2552-2559.

[18] Neobot. (2020). Géolocalisation de Zagné. La carte topographique de Côte d'Ivoire, 4 p.

[19] Newsam A. (1960). Plant Pathology Division Report. Rubber Research Institute of Malaysia, 63-70 p.

[20] Okhuoya J.A. (1986). Seasonal and diurnal changes of two leaf pathogens of Rubber (Hevea brasiliensis Muell. Arg.) in the air of Iyanomo, Nigeria. Acta Mycologica 12 : 65-67 p.

[21] Okoma K.M. (2008). Étude de la sensibilité au syndrome de l'encoche sèche chez Hevea brasiliensis Muell. Arg. (Euphorbiaceae). Thèse de Doctorat, UFR Biosciences, Université Félix Houphouët Boigny, (Abidjan, Côte d'Ivoire), 160p.

[22] Okoma K.M, Dian K., Allou D., Sangaré A. (2009). Etude de la sensibilité des clones *d'Hevea brasiliensis* (Muell.

Arg.) à l'encoche sèche. Sciences & Nature 6 (1) : 17-26. Rubber production. Crop Protection 20 : 581-590 p.

[23] Okoma K.M., Dian K., Obouayéba S., Elabo A., Gnage M., Koffi E., Soumahin F., Doumbia S., Kéli J. (2011). Bien diagnostiquer l'encoche sèche chez l'hévéa en Côte d'Ivoire. Fiche technique N°2. 2 p.

[24] Radzia N.Z., Sulong S.H., Hidir S. (1996). The epidemiology of Corynespora leaf fall disease of rubber in Malaysia - conidia dispersal pattern. Workshop on Corynespora Leaf Fall Disease of Hevea Rubber organised by the Indonesian Rubber Research Institute (Medan, Indonésie) : 26-27 p.

[25] Ramakrishnan T.S & Pillay P.N.R. (1961). Leaf spot of rubber caused by Corynespora cassiicola (Berk & Curt) Wei. Rubber Board Bulletin, 5 : 32-35 p.

[26] Thaler P. (2013). « Natural Rubber » : insustainable solutions for modern Economies, sous la direction de Rainer Hôfer, London (UK) RSC, 335-363 p.

[27] Van De Sype H. (1984). The dry eut syndroms of Hevea brasiliensis, evolution, agronomical and physiological aspects. C. R. Coll. Physiol. Amél. Hévéa., Ed., IRCA-CIRAD, Montpellier, France : 249-271 p.