

PANEL TAPPING MANAGEMENT AND TRUNK PHLOEM NECROSIS OF RUBBER TREE (*Hevea brasiliensis*) IN IVORY COAST

KOUADIO Kouakou Théodore^{1*}, DIAN Kouadio², AGNEROH Thérèse Atcham¹, SORO Nabindou¹, Bah Coumounaho Paul¹

¹Laboratoire de Phytopathologie et de Biologie Végétale, Département de Formation et de Recherches Agriculture et Ressources Animales, Institut National Polytechnique Félix Houphouët-Boigny, BP 1313 Yamoussoukro, Côte d'Ivoire

²Laboratoire Central de Biotechnologie, Centre National de Recherche Agronomique, 01 BP 1740 Abidjan 01, Côte d'Ivoire

*Corresponding author

ABSTRACT

The global objective of this study is to identify the agricultural techniques minimizing bark necrosis at *Hevea brasiliensis*. In a specific way, it is to find out the tapping panel the management technique which minimizes bark necrosis on six clones of rubber tree (IRCA 111, IRCA 109, IRCA 130, IRCA 18, GT 1, PR 107) in the southwest of Ivory Coast. To achieve these goals, the observations related to the number of trees attacked by bark necrosis and tapping panel dryness were made through the complete statement and the dry panel statement. The taking into account of tapping panel dryness in this study is justified by the fact that it may be related to bark necrosis. The importance of bark necrosis and the tapping panel dryness on the clones was checked respectively by the rate of necrosis and the length of the diseased tapping panel cut. It appeared at the end of this study that the management of tapping panels does not influence the development of bark necrosis and tapping panel dryness on the clones of *Hevea brasiliensis* under the d/4 6d/7 conditions of exploitation with modes of stimulation specific to each clone. This agricultural technique which was until suspected to amplify bark necrosis did not show any link with the disease. Indeed the clonal factor influences the rates of the disease. All the clones expressed both diseases, but at different levels. Some clones were shown less tolerant (IRCA 130) or tolerant (GT1) at the same time to both diseases. Tapping panel dryness and bark necrosis do not appear here according to the metabolism of the clones (active, intermediate or slow).

Keywords: bark necrosis, *Hevea brasiliensis*, clones, techniques of panel control, tapping panel dryness

1. INTRODUCTION

Hevea brasiliensis (Euphorbiaceae) is planted for the production of latex composing of 25 to 35% of rubber particles (Hagel et al., 2008; Montha et al., 2016); thus making the rubber tree the main source of natural rubber and therefore a plant of great economic interest. Nowadays natural rubber is a technically unavoidable material in various industries. This is the case in the pneumatic industry, which uses more than 70% of natural rubber (CIRAD, 2001). The world production of natural rubber represented 10 million tons in 2012 (FAOstat, 2014). Asia accounts for almost 95% of this production, with Thailand ranked first. Ivory Coast with 256 000 tons of natural rubber in 2012, is the leading African producer and the seventh in the world (FAOstat, 2014). Despite the interest in this crop, it is confronted with various diseases that attack all organs of the plant. If root diseases such as white root rot and brown root rot caused by *Rigidoporus (Fomes) lignosus* and *Phellinus noxius* respectively seem to be controlled by preventive and curative management methods (Gohet et al., 1991a, Mohammed et al., 2014), it is not still the same for the diseases of the trunk namely the bark dryness disease (tapping panel dryness) and the bark necrosis (trunk phloem necrosis). The bark dryness is a physiological disease with a well-established etiology resulting in the cessation of latex flow and therefore to a significant drop in latex production (Okoma, 2007). On the other hand, even if trunk phloem necrosis results in the same ultimate symptom as the tapping panel dryness, its etiology has been the subject of several speculations. In addition, unlike the tapping panel dryness, this disease can be observed on trees not yet tapped (IRD, 2005). One of the first hypotheses concerning the origin of trunk phloem necrosis was the intervention of a biotic agent responsible for this disease. The hypothesis of the existence of a biotic causal agent (viroids, phytoplasmas, viruses, fungi or bacteria) of trunk phloem necrosis was mainly supported by the linear distribution of the disease on both sides of affected trees (Nandris et al., 1991a). Moreover, the anarchic cell multiplication and the possible elaboration of thyllosoids led to think since the beginning of the research works of the action of a pathogen (Nandris et al., 1991b; Jacob et al., 1994), probably transmitted by the knife of tapping. However, several works, notably those by Peyrard et al. (2006) and Pellegrin et al. (2007) demonstrated that this disease is not caused by a biotic agent. In the absence of concrete evidence (isolation of a pathogen, infection of the host and reproduction of symptoms) as to the origin of the trunk phloem necrosis, the investigations have been increasingly oriented towards the search for a physiological cause. In fact, from the beginning of the etiological investigations, some authors were in favor of such a cause of trunk phloem necrosis. Thus the works of Nandris et al. (2004) have further reinforced this hypothesis of a physiological cause of this disease. They showed a clear correlation between the risk of disease occurrence and the high

mechanical resistance of the soil (low porosity or soil compaction), which impedes water circulation and its absorption through the roots of trees. The physiological observations also showed that necrotic rubber trees showed less root development, resulting in a low supply of water and mineral salts. These are in a situation of water deficit, which increases strongly during the drought (climatic factor) or in case of overexploitation (anthropic factor). Subsequently, these results have been confirmed by other authors by always highlighting a multifactorial physiological disease resulting from an accumulation of exogenous and endogenous stresses (Chrestin et al., 2004; Nizinski et al., 2009; Do et al., 2011; Wongcharoen et al., 2011). In view of the economic pressure exerted by this disease on rubber plantations, the development of control methods is necessary. In the absence of curative control methods, agricultural techniques are increasingly being studied. Indeed, some agricultural practices are suspected of amplifying the development of trunk phloem necrosis. It is within this framework that this study is aimed at identifying the technique of management of tapping panels which minimizes the trunk phloem necrosis in six clones of rubber tree. In addition, trunk phloem necrosis generally occurs on trees previously attacked by tapping panel dryness (Eschbach et al., 1989). It was important to establish the relationship between these two diseases and the panel management.

2. MATERIALS AND METHODS

2.1 Plant material

The plant material consists of six clones of *Hevea brasiliensis* (IRCA 111, IRCA 109, IRCA 130, IRCA 18, GT 1, PR 107). The trees of each of the clones studied were obtained from the San Pedro research station of the Rubber Society of Gô ‘ Société Hévéicole du Gô’ located in the southwest of Ivory Coast. Table 1 shows some characteristics of these clones.

2.2 Methods

2.2.1 Experimental design

The single-tree design 'one tree one repetition' of 6 treatments per clonal plot with 33 trees per treatment was used. Each plot has 198 trees selected according to the homogeneity of their circumference after the elimination of the border trees and the neighboring trees of clearings due to *Fomes*. The six treatments are presented in Table II and represent different techniques for management of the tapping panels.

2.2.2 Production system

The production system used is the half-spiral downhill every four days except Sundays. The clones were stimulated with 2.5% Ethephon at frequencies varying according to the type of metabolism (Table I).

Table I. Some characteristics of the clones studied (CIRAD, 1993)

Clones	Type of metabolism	Biochemical characteristics	Agronomic characteristics
			Fast growth
			High productor
IRCA 18	Active	Average	Resistant to breakage
			Tolerant to tapping panel dryness
			Average growth
			Good productor
IRCA 109	Intermediate	Average	Resistant to breakage
			Tolerant to tapping panel dryness
			Fast growth
			Good productor
IRCA 111	Active	Weak	Sensitive to breakage
			Less tolerant to tapping panel dryness
			Fast growth
			High productor
IRCA 130	Active	Average	Resistant to breakage
			Less tolerant to tapping panel dryness
			Slow growth
			Good productor
PR 107	Slow	Good	Resistant to breakage
			Tolerant to tapping panel dryness
			Average growth
			Average productor
GT 1	Intermediate	Average	Resistant to breakage
			Tolerant to tapping panel dryness

Table II. Motives studied during panel management

Treatments	Motives studied
T1	Continuous descent
T2	Annual shafing at the end of the first year
T3	Annual shafing at the end of the second year
T4	Bisannual shafing at the end of the second year
T5	Bisannual shafing at the end of the third year
T6	Trisannual shafing at the end of the third year

Table III. Notation of trees with partial or total tapping panel dryness

(%) Tapping panel non-Productive of latex	Notation	Number of trees	Signification
0 %	0	n_0	Healthy tree
1 - 20%	1	n_1	Tree with tapping panel dryness very weak
21 -40%	2	n_2	Tree with tapping panel dryness weak
41 - 60%	3	n_3	Tree with tapping panel dryness average
61 - 80%	4	n_4	Tree with tapping panel dryness Much high
81 - 99%	5	n_5	Tree with tapping panel dryness high
100%	6	n_6	Tree with tapping panel dryness total

2.2.3 Data collection techniques

The complete survey is an inventory of all trees in the trial (1188 trees) and a description of their condition. All trees previously removed from the trial due to disease were first reclassified prior to the phase of observations. The trees presenting characteristic symptoms of trunk phloem necrosis (Figure 1) or attacked by visible tapping panel dryness are reported. Thereafter, the bark of apparently healthy trees is scraped with a scraper to check for the presence or absence of internal symptoms of necrosis.

The cases observed and their codification are as follows:

-on the abandoned trees, one distinguishes the abandoned trees for tapping panel dryness "ES"; the abandoned trees for necrotic and cracked bark "ENC"; the abandoned trees for broken trunk: "TC"; the missing trees "M";

-on the level of the trees in exploitation, one distinguishes the trees showing no symptoms of necrosis (apparently healthy tree) rated "0"; the trees having a brown sheet "LB"; the trees with cracked bark "EC".

As for the measurement of the tapping panel dryness, it consisted in following a tapping operator to note for each of the trees of the assay, the flow or not of latex after the tapping. The notification of the tapping panel dryness enabled us to verify the severity of this disease on the trees of the assay by calculating the length of the diseased tapping panel cut. It was done on the trees in exploitation. A distinction is made between trees with no problem of latex flow over the entire length of the tapping panel cut marked "0" and trees that have some difficulties of flowing. In these individuals, the codification is established according to the length of the unproductive panel cut (Table III). The trees with necrotic spots on the panel cut are marked "N". When they are associated with partial or total tapping panel dryness, N is preceded by the corresponding code; for example, 1N means that the tree has 1 to 20% of the tapping panel cut which no longer produces latex and has necrotic spots. The trees in the partial or total tapping panel dryness showing the brown sheet are also mentioned; for example: 1 LB means that the tree has 1 to 20% of the tapping panel cut that no longer produces and that there is a brown sheet on this tapping panel cut. The observation of this brown sheet must be carried out as soon as the tapping knife goes over the tapping panel cut because the latex that flows can quickly mask some symptoms.

2.2.4 Data processing

For each clone, the rate of necrosis (T) according to the treatment applied is calculated. The number of affected trees is determined for each treatment and the rates are calculated for all clones using the following formula: $T = n/N \times 100$ where n is the number of necrotic trees of the treatment and N is the total number of living trees per treatment. The length of diseased tapping panel cut (LEM) per treatment of each clone was determined by the following equation: $LEM = (0.1 n_1 + 0.3 n_2 + 0.5 n_3 + 0.7 n_4 + 0.9 n_5 + n_6) / N$; in which N represents the number of living trees per treatment, the coefficients 0.1; 0.3; 0.5; 0.7; 0.9 and 1 correspond to the averages of classes of percentage of the length of non-latex producing tapping panel cut, and the numbers n1, n2, n3, n4, n5 and n6 represent the number of trees observed per percentage class of length of non-latex- producing tapping panel cut. The formation of tolerance groups to tapping panel dryness was carried out by an analysis of variance of LEM and then by using the DUNCAN test at the 5% threshold with the XLSTAT software version 7.5. Since the LEM are proportions, they have been transformed into the Arc

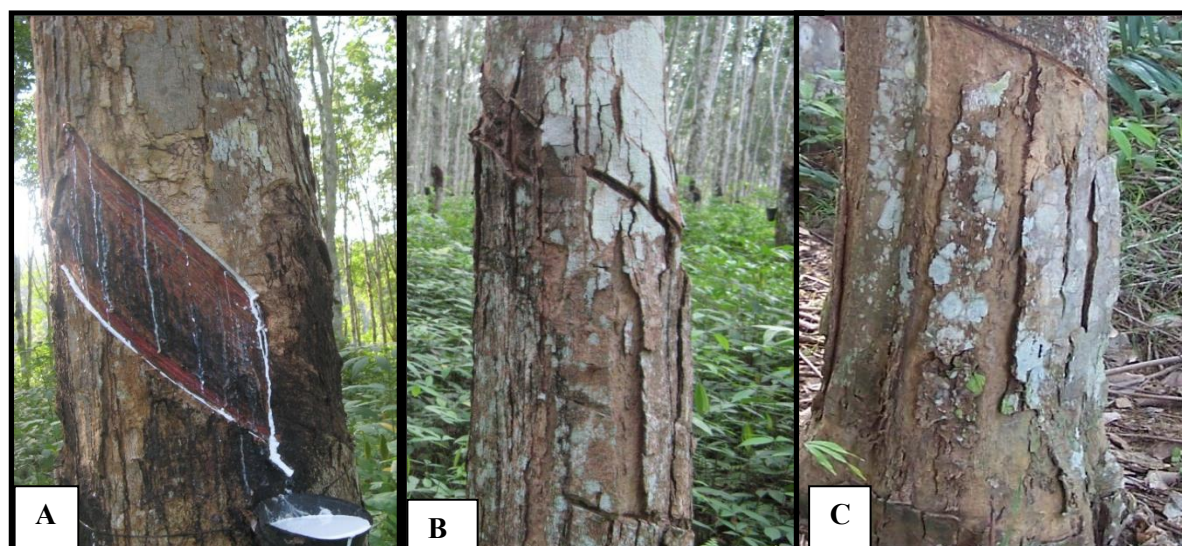


Figure 1. Characteristic symptoms of trunk phloem necrosis of *Hevea brasiliensis*. **A** : Fine cracks of the bark on the superior part of the trunk (clone PB 217) ; **B** : Spacious and numerous cracks (clone IRCA 109) ; **C** : Desquamation of diseased parts (clone PB 235).

Sinus square root of LEM (ASINLEM) to make the distribution normal and the analysis possible (Dagnelie, 2012). The analysis of the management techniques of the tapping panel and clones related to the necrosis rate was done with the chi-square test at the 5% threshold under the SPSS software version 11.5. This test shows the dependence or independence between two qualitative characteristics. The study of the correlation between the LEM and the necrosis rate was carried out with the Pearson test under the XLSTAT software version 7.5.

The Excel 2007 software was used for data processing and graphing.

3. RESULTS

3.1 Influence of the management of the tapping panels on phloem necrosis

The values of the rate of trunk phloem necrosis rate according to the tapping panel management techniques in the six clones are presented in Table IV. The chi-square test at the 5% threshold shows that the asymptotic significance (0.924) is greater than 0.05. Thus, there is no dependence between the panel management and the rate of trunk phloem necrosis. The results of the statistical analysis reveal that the different techniques of management of the tapping panel have

no influence on the appearance of trunk phloem necrosis in the six rubber clones when exploited at the d/46d/7 tapping frequency.

Table IV. Values of the rates of necrosis according to the panel management

Different techniques of panel management	Number of necrotic trees	Number of living trees
T1	15	174
T2	17	168
T3	17	176
T4	12	181
T5	13	184
T6	16	184
TOTAL	90	1067

3.2 Clonal influence on trunk phloem necrosis

The rates of trunk phloem necrosis in the six clones studied are presented in Figure 2. The study of clonal influence on the rate of trunk phloem necrosis was assessed with the chi-square test at the 5% threshold. The asymptotic significance (0.000) is less than 0.05 so there is dependence between the clone factor and the rate of necrosis. In other words, the clonal influence is evident on the rates of necrosis when the trees are tapped in d/4 6d/7. The hierarchical classification enabled assembling clones into three major groups in the ascending order of the rate of trunk phloem necrosis. Group I is constituted by GT 1. This clone, already known for its good behavior with respect to certain constraints (diseases and breakages), is the most tolerant to necrosis. The clones IRCA 109, IRCA 18, IRCA 111 and PR 107 make up group II. They have higher necrosis rates than the clone GT 1 but with a more pronounced susceptibility for the clones IRCA 109 and IRCA 18. The clone IRCA 130 is classified in group III. This clone is the least tolerant to trunk phloem necrosis with a necrosis rate of up to 22%.

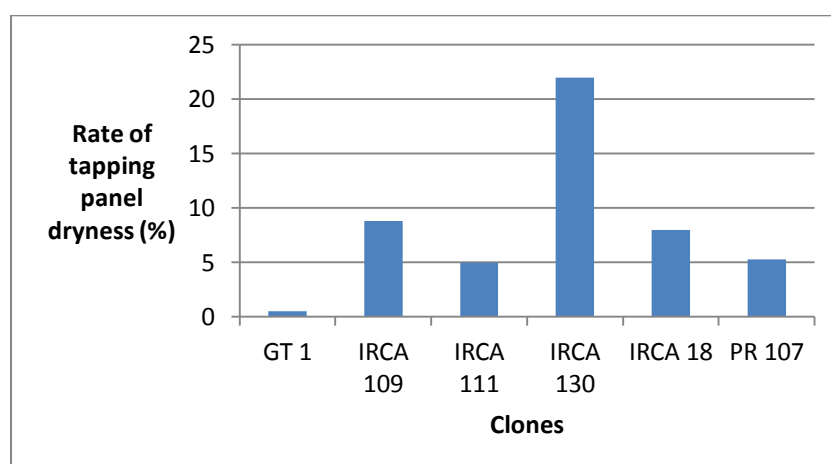


Figure 2. Clonal influence on the rate of tapping panel dryness

3.3 Study of the tapping cut dryness

Table V shows the lengths of the diseased tapping panel cuts (LEM) of the six clones studied according to the management of the tapping panels. The analysis of variance of the lengths of the diseased tapping panel cuts of the six clones subjected to the six panel management techniques showed a very highly significant clone effect ($p = 0.0001$) and a non-significant panel management ($p = 0.984$).

Table V. Length of diseased tapping panel cut of six clones according to the panel management

Clones	Lengths of diseased tapping panel cut (%)					
	T1	T2	T3	T4	T5	T6
PR 107	5,6	6,6	7,3	7,5	4,2	6,4
GT 1	2,5	0,9	3,7	3,9	2,1	1,8
IRCA 18	24,2	21,3	22,6	18,1	19,4	21
IRCA 109	5,2	5,3	6,4	3,6	5,6	4,8
IRCA 111	27	24,4	25	22,7	25	22
IRCA 130	38,8	22	28	34,5	28,3	36
Average	17,2	13,4	15,5	15	14,1	15,3

3.4 Analysis of the effect "management of tapping panels" in the case of the tapping panel dryness

The analysis of variance of LEM showed that there was no significant difference between the treatments of the 5% threshold. The management of the tapping panels therefore has no effect on the occurrence of the tapping panel dryness syndrome in rubber clones under d/4 6d/7 exploitation conditions.

3.5 Analysis of the "clone" effect during the tapping panel dryness

The statistical analysis indicates a difference in resistance to the tapping panel dryness between the rubber clones. This resistance is presented as a quantitative variable, that means that the tapping panel dryness affects all six clones but to different degrees.

The DUNCAN test at the 5% threshold allowed classifying the six clones into four groups according to their tolerance to the tapping panel dryness. These are groups I; II, III and IV in the ascending order of the LEM. Group I comprises clone GT 1. It has the lowest LEM. The clones PR 107 and IRCA 109 constitute group II. These clones have fairly low LEM. Group III consists of the clones IRCA 18 and IRCA 111. The clones in this group are characterized by high LEM. Finally, group IV is composed of a single clone, IRCA 130. This clone has the highest LEM.

3.6 Correlation between tapping panel dryness and trunk phloem necrosis

At the 5% significance level, the correlation between the LEM and the necrosis rate is significant with a correlation coefficient $r = 0.706$ ($r > 0.5$), so the correlation between the tapping panel dryness and necrosis is strong.

4. DISCUSSION

The study of the influence of the management of the tapping panels on the development of trunk phloem necrosis has shown that the different techniques of management of the tapping panel in rubber clones have no effect on the disease under d/4 6d/7 exploitation conditions. The tapping and stimulation frequencies, which together with the management of panels lead to the exploitation system, have shown in previous studies an influence on the rate of trunk phloem necrosis (Niamouké, 2005). According to this author, high tapping frequencies are favorable to the development of necrosis. Similarly, the stimulation frequencies do not appear to have an effect on the rate of necrosis when they are associated with high tapping frequencies.

This study showed that the influence of panel management techniques is not evident on the rate of necrosis in rubber clones for d/4 frequency of tapping. It would therefore be interesting for a thorough study to associate several tapping and stimulation frequencies, notably high frequencies with the different techniques for managing the panel. The frequency of tapping in d/4, considered as a normal tapping frequency, offers a good compromise between the

productivity and the economic lifetime of trees (Gohet et al., 1991b). It therefore does not make possible to reveal a possible relationship between the frequency of tapping and the panel management in relation to trunk phloem necrosis. The high tapping frequencies (d/1 and d/2) should be taken into account for a thorough study as these frequencies are still used by some Asian countries where the panel management is also suspected of amplifying trunk phloem necrosis.

If it is true that the management of panels as an agricultural technique has no effect on the occurrence of necrosis in our exploitation conditions, however, some practices can favor the appearance of trunk phloem necrosis. Indeed, Fragaré (2006) noted three farming practices which are: the opening standard, the system of exploitation and land preparation. According to this author, the late opening of the trees would enable them to develop a high resistance to the disease. Similarly, low tapping frequencies associated with a good stimulation frequency specific to each clone make it possible to reduce the incidence of necrosis. Finally, land preparation before the establishment of a rubber plantation must be done in order to avoid the compaction of the soil.

Concerning the tapping panel dryness, the analysis of variance showed that the management of tapping panels has no effect on its occurrence in the rubber clones under our exploitation conditions in d/4 6d/7. On the other hand, the disease is positively correlated with the following parameters: high tapping and stimulation frequencies, high concentrations of stimulant, physiological and pedoclimatic factors (Jobbe-Duval et al., 1988 cited by Okoma, 2007). The study of the influence of the different components of the exploitation system (panel management, tapping frequency and stimulation frequency) on the tapping panel dryness made it possible to obtain some results. In order to confirm these results, particularly those of the study of the influence of the management of panels on the occurrence of the tapping panel dryness, it would be interesting to carry out a study that would combine all these components to verify their effect on the severity of the disease in rubber trees.

The study of the clonal influence on the rate of trunk phloem necrosis shows us that the clones react differently to the disease in terms of individuals affected. The most important factor in the occurrence of trunk phloem necrosis is the natural predisposition of some clones to the disease, namely IRCA 18, IRCA 109 and IRCA 130. These clones were shown to be less tolerant to the disease during previous studies (Niamouké, 2005 and Fragaré, 2006). The implication of a genetic factor in the occurrence of the disease is confirmed by the present study. The influence of the metabolic activity on the development of trunk phloem necrosis evoked by Nandris et al. (2001) that categorized clones with rapid metabolism as most susceptible to disease is not partly

verified in our clone operating conditions. Indeed, the clone IRCA 111, one of the clones with rapid metabolism was shown to be tolerant to the disease.

For the study of the six clones related to tapping panel dryness, the statistical analysis showed that these clones did not have the same level of resistance to the disease. This observation confirms the existence of a genetic factor influencing the occurrence of the syndrome of tapping panel dryness in rubber clones, as noted by Okoma (2007). Moreover, this study shows that the resistance to the disease is presented as a quantitative variable, that means that the tapping panel dryness affects all clones but with different levels of disease depending on the clones. Similarly, for a given clone, all trees are not affected by tapping panel dryness and those which are attacked do not have the same level of disease. This shows that in addition to the clonal factor, there are other factors that favor the development of tapping panel dryness. The quality of the plant material and the tree environment would influence the occurrence of this condition (Okoma et al., 2009). The genetic factor being the primary factor in the occurrence of tapping panel dryness (Okoma, 2007), the reaction of some clones to the disease is more or less known whatever the conditions of exploitation. The clones IRCA 111 and IRCA 130, which are known to be less tolerant to tapping panel dryness, confirmed this fact in our study. On the other hand, clones GT 1 and IRCA 109 show a high resistance to tapping panel dryness. These results confirm the classification of CIRAD on the behavior of the rubber clones with respect to tapping panel dryness. Moreover, the example of the clones IRCA 109 and IRCA 111 from the same parents and having opposite disease levels clearly illustrates the existence of the clonal factor in the occurrence of tapping panel dryness in the rubber clones.

The correlation between tapping panel dryness and the phloem necrosis is significant at the 5% threshold by the Pearson's test. The two diseases are therefore linked. It has been found during our field observations and in literature searches that trees with trunk phloem necrosis are generally trees previously affected by tapping panel dryness. This result agrees well with that of many authors as to the link existing between the two diseases (Eschbach et al., 1989; Niamouké, 2005; Fragare, 2006). This led Eschbach et al. (1989) to estimate that there is only a problem of tapping panel dryness which always evolves towards the trunk phloem necrosis. However, it should be recognized that there are in plantation cases of tapping panel dryness without necrosis and also cases of trunk phloem necrosis without tapping panel dryness; which enable to make a clear difference between the two diseases. Moreover, although they are both of physiological origin, the symptomatology proper to each disease proves that they are two distinct affections. Indeed, the tapping panel dryness is recognized by the partial or total absence of latex on the tapping panel and the trunk phloem necrosis by the presence of the brown sheet and subsequently the desquamation of the bark. Finally, the divergent attitude of some clones to both diseases confirms once again the clear distinction between them. The clone IRCA 111 less

tolerant to tapping panel dryness is tolerant to trunk phloem necrosis whereas the clone IRCA 109 clone which shows low resistance to trunk phloem necrosis is one of the most tolerant clones to the tapping panel dryness. The presence of the genetic factor cannot be neglected, but this difference in behavior between the clones proves that these are indeed two different diseases.

CONCLUSION

The study that has just been carried out is part of the overall framework for identifying agricultural techniques that minimize trunk phloem necrosis. However, it has expanded to the tapping panel dryness since it is closely related to trunk phloem necrosis. At the end of this study, it should be noted that in the pedoclimatic conditions of the southwest of Ivory Coast, the management of the tapping panels, in continuous descent or swaying at different modalities has no influence on the occurrence of phloem necrosis and tapping panel dryness in the rubber clones under d/4 6d/7 operating conditions. However, the nature of the planted clone plays a key role in the occurrence of trunk phloem necrosis and tapping panel dryness. Clones such as GT 1 and IRCA 130 were very tolerant and less tolerant to both diseases respectively. On the other hand, some clones a priori less tolerant to the tapping panel dryness are not for trunk phloem necrosis and vice versa. The genetic factor is therefore very decisive in the occurrence of the two diseases. It is then necessary to know the predisposition of the clones to the diseases and to take them into account for the choice of the clone to be planted.

REFERENCES

Chrestin, H., U. Sookmark, P. Trouslot, F. Pellegrin, and D. Nandris (2004). Rubber tree (*Hevea brasiliensis*) bark necrosis syndrome: III. A physiological disease linked to impaired cyanide metabolism, *Plant Disease* 88: 1047.

CIRAD (2001). La production de caoutchouc naturel menacée. Reportage. Le caoutchouc naturel, MASSON, M. www.cirad.fr/publication/documents/produitsstrop/1999/caoutchouc99.htm.mars

Dagnelie P. (2012). Principes d'expérimentations : Planification des expériences et analyse de leurs résultats. Les Presses Agronomiques de Gembloux, Belgique. 414p

Do C.A., Pierret F., Couteron P., Lesturgez G., Boithias L., Isarangkool Na Ayutthaya S., Junjittakarn J., Gonkhamdee S., Maeght J. L., Hartmann C., D. Nandris. (2011). Spatial distribution of *Hevea brasiliensis* trunk phloem necrosis within a plot: aggregation but no evidence of constraint on cumulated growth. *Forest Pathology* 41:90-100.

Eschbach J.M., Commere J., Serres S. (1989). Tapping panel dryness in Côte d'Ivoire. *In: International rubber conference*; Rubber research Institute of Malaysia. pp 48-60.

FAOstat. (2014). www.faostat.fao.org

Fragaré A. (2006). Contribution à l'élaboration de méthodes de lutte contre la nécrose corticale chez *Hevea brasiliensis*. Mémoire de fin d'études pour l'obtention du Diplôme d'Agronomie Approfondie. INP-HB/ESA. Yamoussoukro, Côte d'Ivoire. 51p.

Gohet, E., R. Lacrotte, S. Obouayeba, and J. Commere (1991b). Tapping systems recommending in West Africa. *Proc. Rubb. Growers' Conf.* Rubb. Res. Inst. Malaysia, ed., Kuala Lumpur, Malaysia. 10 p.

Gohet, E., T.V. Canh, M. Louanchi, and D. Despreaux (1991a). New developments in chemical control of white root disease of *Hevea brasiliensis* in Africa, *Crop protection* 10(3): 234-238.

Hagel JM, Yeung EC, Facchini PJ (2008). Got milk? The secret life of laticifers. *Trends in Plant Science* 13: 631-639.

IRD (2005). La nécrose de l'hévéa enfin élucidée. Fiche scientifique 221. <http://www.ird.fr/fr/actualites/fiches/index.htm>

Jacob J.L., Prevot J.C. & Lacrotte R. (1994). L'encoche sèche chez *Hevea brasiliensis*. Tapping panel dryness in *Hevea brasiliensis*. *Plantations, recherche développement* 1 (3) : 15-24.

Mohammed C.L., Rimbawanto A. and Page D.E. (2014). Management of basidiomycete root- and stem-rot diseases in oil palm, rubber and tropical hardwood plantation crops. *Forest Pathology* 44: 428–446. Doi:10.1111/efp.12140

Montha S, Suwandittakul P, Poonsrisawat A, Oungeun P, Kongkaew C (2016). Maillard Reaction in Natural Rubber Latex: Characterization and Physical Properties of Solid Natural Rubber. *Advances in Materials Science and Engineering* vol. 2016, Article ID 7807524, 6 pages. Doi:10.1155/2016/7807524

Nandris D., Moreau R., Pellegrin F., Chrestin H., Abina J., and Angui P. (2004). Rubber tree (*Hevea brasiliensis*) bark necrosis syndrome 2: First comprehensive report on causal stresses, *Plant Disease* 88(9): 1047.

Nandris D., M. Nicole, J.C. Thouvenel, J. Giannotti, H. Chrestin, J.P. Geiger, et B. Rio, (1991) a. La nécrose du phloème du tronc de l'hévéa en Côte d'Ivoire 1: Symptomatologie et caractéristiques biochimiques, *European Journal of Forest Pathology* 21: 27-35.

Nandris, D., M. Nicole, J.C. Thouvenel, J. Giannotti, H. Chrestin, J.P. Geiger, et B. Rio, (1991) b. La nécrose du phloème du tronc de l'hévéa en Côte d'Ivoire 2: Etiologie de la maladie, *European Journal of Forest Pathology* 21: 340-353.

Niamouké, T. (2005). Contribution à l'étude de la sensibilité clonale à la nécrose corticale chez *Hevea brasiliensis*. Mémoire de fin d'études pour l'obtention du Diplôme d'Agronomie Approfondie. INP-HB/ESA. Yamoussoukro, Côte d'Ivoire. 50p.

Nizinski, J.J., A. Galat-Luong et G. Galat (2009). Aspects bioclimatiques de nécrose corticale de l'hévéa. *Geographia Technica*, numéro spécial : 355-360.

Okoma K.M. (2007). Etude de la sensibilité au syndrome de l'encoche sèche chez *Hevea brasiliensis* Muell. Arg. Thèse de Doctorat de 3^{ème} cycle, Université Nationale de Côte d'Ivoire.

Okoma K.M., K. Dian, D. Allou, et A. Sangaré (2009). Etude de la sensibilité des clones d'*Hevea brasiliensis* (Muell. Arg.) à l'encoche sèche. *Sciences & Nature* 6(1): 17-26.

Pellegrin, F., N. Duran-Vila, M.M. Van, and D. Nandris (2007). Rubber tree (*Hevea brasiliensis*) trunk phloem necrosis: aetiological investigations failed to confirm any biotic causal agent. *Forest Pathology* 37: 9-21.

Peyrard, N., F. Pellegrin, J. Chadoeuf, and D. Nandris (2006). Statistical analysis of the spatio-temporal dynamic of rubber tree (*Hevea brasiliensis*) trunk phloem necrosis: no evidence of pathogen transmission. *Forest Pathology* 36: 360-371.

Wongcharoen, A., A. Pando, D. Nandris, Y. Hanboonsoon, C. Hartmann, and C. Rouland-Lefe`vre, 2011. Biological activity of soils under rubber trees (*Hevea brasiliensis*) affected by trunk phloem necrosis. *Forest Pathology* 41: 41-47.