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Research Article

AGRICULTURAL PRACTICES IN CÔTE D'IVOIRE AND APPARITION AND DEVELOPMENT OF TAPPING PANEL DRYNESS IN *HEVEA BRASILIENSIS* MUELL. ARG

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A B S T R A C T

In rubber tree, *Hevea brasiliensis*, tapping panel dryness manifested by non-exudation of latex from panel after tapping, is a plant response to non-biotic stress. To identify agricultural practices that induce the stress favoring the occurrence and development of tapping panel dryness in rubber tree, in Côte d'Ivoire, a study was conducted in small-older plantations. A diagnostic survey of agricultural practices was made and the lengths of dry panel were measured for two years. Analysis of variance and principal component analysis of the lengths of dry panel in relation to agricultural practices were carried out. Results showed that the tapping panel dryness rate exceeds 30 % in small-older plantations. They also showed that agricultural practices contribute over 60 % to the occurrence and development of tapping panel dryness. These practices were summarized in three main factors: the sensitivity of the planted clone, the bad application of latex harvesting technology and the age of plantation. These agricultural practices that promote the appearance and development of tapping panel dryness are bad. They should be avoided to minimize the tapping panel dryness in rubber tree, *Hevea brasiliensis*.

INTRODUCTION

Rubber tree, *Hevea brasiliensis*, is grown for latex production (Compagnon, 1986). The latex of rubber tree is the main source of natural rubber (Sekhar, 1989). The latter is used in many industries, especially in the tire industry uses over 70 % of world production (CIRAD, 2001). World production of natural rubber was estimated at 11.8 million tons in 2014 (SIPH, 2016). Asia alone accounts for over 91 % of this production with Thailand (4 248 000 tons) in the first world (SIPH, 2016). Côte d'Ivoire, with 311 429 tons of natural rubber produced in 2014, is the first African producer and the World 7th (COMMODAFRICA, 2015). It plans to reach 600 000 tons of dry rubber in 2020 as the Ivorian Rubber Development Plan (Apromac, 2009). To achieve this, it increases the cultivate surfaces, provides producers of performing clones and strengthens the supervisory system. However, this development plan faces some difficulties in its implementation. These difficulties relate to land pressure in the rubber growing area, the use by some planters not authentic and not recommended plant material, the non-respect of the culture conditions, the bad practices of the latex harvesting technology; especially with the increase of the rubber courses and the pressure of the factory owners. Latex harvesting technology is made by the tapping and by the hormonal stimulation. Tapping allows the flow of latex contained in latex cells (Compagnon, 1986; Thomas *et al*., 1995). Hormonal stimulation activates the metabolism of latex cells (Coupé and Chrestin, 1989) and increases the duration of the latex flow (Eschbach and Banchi, 1985; Eschbach 1986). Tapping and hormonal stimulation constitute two stress, mechanical and hormonal, which are applied to the tree for latex production. In some rubber trees, after tapping, the latex does not flow on a part or all of the panel. This phenomenon, which leads eventually to the total cessation of latex production in the tree is called tapping panel dryness (TPD) syndrome (De Faye, 1981). It leads to losses of latex production of the order of 12 to 30 % (De Faye, 1981; Dian, 1997; Rubber Board, 2002); which is a shortfall of about seven to nine million US dollars per year. The

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various investigations to determine the cause of the tapping panel dryness resulted in the fact that it is a physiological dysfunction at the level of the tree (Chrestin *et al*. 1984; IRD, 2005). The tree would respond to physiological non-biotic stress (Peries and Brojier, 1965; Lim, 1973). The origin of the stress being multiple (Jobbe Duval *et al*. 1988), this study aims to identify agricultural practices that induce physiological stress favoring the occurrence and development of tapping panel dryness in rubber tree. It was carried out by determining the lengths of dry panel (LDP) induced by agricultural practices in non-industrial plantations.

MATERIALS AND METHODS

Plant Material

The plant material of this study consists of clones GT 1, PB 217, PB 254, PB 260 and IRCA 18 and seedling of *Hevea brasiliensis*. These clones and seedling from small-older plantations chosen in the traditional area of rubber cultivation located in the south and west of Côte d'Ivoire.

Methods

Study site

The study site is located in the southern and western Côte d'Ivoire. This area was divided into nine (9) rubber growing areas: Bettie, Daoukro Gagnoa, Guiglo, Soubré, Grand Béréby, Tiassalé, Dabou and Bonoua. It is characterized by a bimodal rainfall with two rainy seasons and two dry seasons; and the average annual rainfall exceeds 1 200 mm and slightly to 1 600 mm. The soils are acidic ($4 < pH \leq 5$), ferralitic, deep and very desaturated on the tertiary sand. This region is the traditional area of rubber cultivation in Côte d'Ivoire.

Choice of small-older plantations

Twelve (12) small-older plantations of 1 to 5 ha, half-spiral down tapped and having 2 to 11 years of rubber production were randomly selected in each of the nine (9) rubber growing areas from the list of farmers so as to cover the entire rubber growing area. Or a total of 108 small-older plantations, age ranging from 9 to 18, from which were chosen the study plantations according to the tapping panel dryness rate or length of dry panel (LDP).

Tapping panel dryness statement

A complete tapping panel dryness (TPD) statement was performed in each selected plantation to determine its length of dry panel (LDP). The tapping panel dryness statement is a visual assessment of the latex exudation from panel after tapping among trees in rubber production. During the tapping panel dryness statement, all trees that exude latex over the entire length of the panel after tapping, were considered ‘'healthy trees" and recorded zero (0). The others were considered trees with dry panel and rated from 1 to 6 according to the length of non-producing latex panel. Thus, the following classes of percentage of the length of non-producing latex panel were formed:

- ✓ 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 moderate 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.

Selection of study plantations

In each of the nine (9) rubber growing areas, three plantations were selected according to length of dry panel or tapping panel dryness rate as follows: the plantation having the highest rate of tapping panel dryness, the plantation containing the intermediate rate of tapping panel dryness and the plantation where the tapping panel dryness rate is the lowest. A total of 27 selected sites which constituted the study plantations.

Diagnostic survey

A diagnostic survey of cultural practices and latex harvesting technology was performed on each of the 27 study plantations retained to determine which ones contribute to the occurrence and development of tapping panel dryness. A survey form was developed for this purpose for the collection of data.

Data analysis

The raw data of tapping panel dryness permitted to determine the true length of panel that does not produce latex in a rubber tree or length of dry panel (LDP) according to the equation: $LDP = (0{,}1\ n_1 + 0{,}3\ n_2 + 0{,}5\ n_3 + 0{,}7\ n_4 + 0{,}9\ n_5 + n_6) / N$ (Anonyme, 1993). In this equation, N represents the number of tapped trees of the plantation; coefficients 0.1; 0.3; 0.5; 0.7; 0.9 and 1 correspond to the averages of percentage classes of non-producing latex panel length; and the numbers n1; n2; n3; n4; n5 and n6 represent the number of trees observed per percentage class of non-producing latex panel length. The survey data were used to determine the lengths of dry panel induced by each of the terms of the measured parameters. The analysis of variance of these data was performed to investigate the effect of agricultural practices on the tapping panel dryness in non-industrial plantations. The lengths of dry panel (LDP) were transformed into logarithm base 10 of % LDP + 1 (Log (% LDP + 1) to make normal the distribution and stabilize variances to make possible the analysis (Dagnelie, 1994). The comparison of LDP averages of the terms of agricultural practices was made by the statistical test of Student-Newman-Keuls alpha risk of 5% for structuring the terms of agricultural practices. The principal component analysis of the LDP of agricultural practices was conducted to study the structure of agricultural practices. The LDP was used as an additional variable. The XLSTAT Version 7.5.1 statistical analysis software was used.

RESULTS

Characteristics of the study plantations and rubber growing areas

The 27 study plantations showed a variability of observed parameters. Five clones PB 217, GT 1, PB 254, IRCA 18, PB 260 and seedling, in ascending order of measured tapping panel dryness rate, were planted in the plantations. GT 1 clone was planted in 18 plantations, IRCA 18 and PB 260 clones in two plantations each, and the PB 217 clone in one plantation. It was also noted mixtures of clones GT 1 and PB 254 (GT 1/PB 254), GT 1 and IRCA 18 (GT 1/IRCA 18), and GT 1 and PB 217 (GT 1/PB 217) in three plantations and one plantation of seedling. The tapping panel dryness rate of plantations ranged from 0.76 to 68.34 %. The CHC I 20 plantation of Guiglo rubber growing area presented the highest tapping panel dryness rate (68.34 %). At the rubber growing areas, the Daoukro rubber growing area was the least reached tapping panel dryness with 4.5 % and the most affected rubber growing area was Guiglo with 34.12 % (table 1).

- ✓ no treatment of tapping wounds,
- ✓ deep tapping,
- ✓ stimulation frequencies not suitable to the clones;
- ✓ tapping panels distorted.

Influence of all agricultural practices on the appearance and development of tapping panel dryness

The principal component analysis of the lengths of dry panel (LDP) of agricultural practices showed that agricultural practices contribute 60.5 % to the occurrence and development

Table 1 Some characteristics of the 27 study plantations retained in the 9 rubber growing areas of Côte d'Ivoire

Rubber growing areas	Rubber plantation	Superficie (ha)	Planted clone	Duration of rubber production (year)	Stimulation frequency	% LDP of rubber plantation	% LDP of rubber growing areas
Bettié	PHI 80274	2	GT 1	2	12/y	5.58	
	PVH 180	2	IRCA 18	3	4/y	12.73	15.36
	PVH 673	1	GT 1	2	6/y	28.59	
	PHI 10019	1.5	GT 1	2	10	1.93	
Daoukro	PHI 10065	1.5	GT 1	2	6/y	8.75	4.5
	PHI 10069	2	GT 1	2	6/y	2.82	
	PHI 80104	3	GT 1	9	12/y	18.67	
Gagnoa	PHI 80515	5.5	GT 1	4	12/y	23.14	14.63
	PHI 80282	1.5	GT 1	5	6/y	2.09	
	PHI 40175	3	GT 1	2	4/y	3.44	
Guiglo	CHC I 20	5.3	PB 260	11	6/y	68.34	34.12
	PHI 70070	2	GT 1	6	12/y	30.59	
	PHI 80673	3	GT 1	5	12/y	11.74	
Soubré	PHI 80646	1.5	GT1/PB254	3	12/y	8.51	13.54
	PVH 578	3	GT 1	9	12/y	20.36	
	PHI 81036	4	GT 1	3	12/y	28.35	
Bonoua	PHI 81220	3	GT1/IRCA18	2	8/y	3.53	15.72
	PHI 80443	4.5	IRCA 18	3	12/y	15.41	
	PVH 720	1.5	GT 1	3	12/y	8.75	
Tiassalé	PVH 599	5	GT 1	3	10/y	2.24	9.30
	PVH 396	3	PB 260	6	10/y	16.9	
	PHI 81511	4	GT1/PB217	2	6/y	0.76	
Dabou	PHI 81094	2	GT 1	3	12/y	4.21	7.37
	PHI 81863	1	Seedling	4	24/y	17.13	
Grand	KLA 022	4.17	PB 217	3	9/y	4.14	
Béréby	KLA 014	1.44	GT 1	4	9/y	8.3	8.41
	KLA 003	2.2	GT 1	4	9/y	12.78	

GT: Godan Tapen, IRCA: Rubber research institute in Africa, LDP: Length of dry panel, PB: Prang Besar, PHI: Independent rubber plantation, PVH: Village rubber plantation, KLA: Klanaké (locality of Grand Béréby)

Influence of each agricultural practice on the appearance and development of tapping panel dryness

Analyses of variances of the lengths of dry panel (LDP) of the terms of agricultural practices showed a very highly significant or highly significant "agricultural practice" effect for eleven agricultural practices. Comparisons of the LDP averages helped structure the terms of these different agricultural practices in different groups depending on the tapping panel dryness rate. The highest tapping panel dryness rate were observed in plantations with the following characteristics (table 2):

- ✓ antecedent food crops and perennial crops,
- ✓ maintenance by herbicide and bulldozer,
- ✓ low number of monthly visits by the framer,
- ✓ high density of trees planting,
- ✓ long duration of rubber production of trees,
- ✓ high consumption of bark,
- ✓ high rates of tapping wounds,

Of tapping panel dryness in non-industrial plantation. The most related to F1 axis variables were "LDP, form of the tapping panel, duration of rubber production of the trees and stimulation frequency." The variable "cultural history" was more related to the F2 axis and variables "planted clone and number of visits by the framer" were more related to the F3 axis. The F1 axis has considered 38.73 % of the variability and characterized the severity of the tapping panel dryness. It has been described as tapping panel dryness axis. The variable "cultural history" has been characterized by the F2 axis which expressed 21.73 % of the variability and the F3 axis expressed 14.62 % of the variability and characterized the planted plant material. The representation of the variables in the plan 1.2 showed three distinct groups G1, G2 and G3 (Fig 1). The set of variables constituting the Group G1 has strongly contributed to the F1 axis. This is "form of the panel, stimulation frequency, planted clone and number of visits by the framer." The "cultural history" variable was the G2 group which has greatly contributed to the F2 axis. Variables "duration of rubber production of trees and depth of tapping" formed the G3 group and contributed much to the F1 axis and the F2 axis. In the plan 1.3 variables are also structured in three groups G4, G5 and G6 (Fig 2). The G4 group was composed of the variables "form of the tapping panel, duration of rubber production of trees, stimulation frequency, depth tapping and cultural history" that contributed to the F1 axis. The variable "clone" was the G5 group and has greatly contributed to the F3 axis. The G6 group was composed of the variable "number of visits by the framer," which also contributed strongly to the F3 axis. In the plan 2.3 oppositions between variables "cultural history" and "depth tapping, duration of rubber production of trees" on one hand and "clone" and "number of visits by the framer" on the other hand, have been observed (Fig 3).

Table 2 Structuring the terms of agricultural practices based on the tapping panel dryness rate by comparing the lengths of dry panel averages

Agricultural practices	Significance level	Terms of agricultural practices	% LDP
Cultural history	**0.016 HS**	Previous natural (forest and fallow)	9.12
		Food crops (rice, cassava, maize)	
		Perennial crops (coffee, cocoa)	**13.26**
Site preparation mode	0.770 NS	Machete	12.02
		Bulldozer	10.91
Plantation maintenance mode	**0.018 HS**	Machete	10.49
		Herbicide or bulldozer	**20.84**
Cleanliness of the plantation	0.684 NS	Clean plantation	10.26
		Grassy plantation	13.15
Managment level of producer	**0.003 VHS**	3 - 4 visits/month	3.9
		1 - 2 visits/month	**14.19**
Superficie of the plantation	0.437 NS	1 - 2 ha	10.77
		3 - 5 ha	12.48
Planting density	**0.028 HS**	500 - 600 trees/ha	10.18
		601 - 1111 trees/ha	**17.29**
Plant material preparation mode	0.704 NS	Plants in bags	10.20
		Stump	12.56
Duration of rubber production of trees	**0.01 VHS**	2 years	6.93
	0.02	5 years, 3 years	8.73
		4 years, 9 years, 6 years	**19.54**
Tapping frequency	0.100 NS	d3	10.51
		d4	15.21
Bark consumption	**0.031 HS**	≤ 22 cm/year	8.78
		> 22 cm/year	**14.01**
Wounds rates	**0.001 VHS**	< 50 %	7.77
		> 50 %	**13.00**
Traitment of tapping wounds	**0.001 VHS**	Treated wounds	7.44
		Untreated wounds	**13.44**
Tapping depth	**0.003 VHS**	Normal depth	8.38
		Deep tapping	**13.30**
Stimulation frequency	**0.0001 VHS**	4/y - 10/y	6.98
		12/y - 24/y	**16.53**
Type of stimulant	0.91 NS	Ethrel HP	7.37
		ELS 50	9.20
		Callel	10.27
		Hevetex	11.01
Person performing the stimulation	0.95 NS	Tapper	11.72
		Planter	8.51
Form of tapping panel	**0.0001 VHS**	Normal panel	7.52
		Deformed panel	**16.35**
Compensation mode of the tapper	0.92 NS	Kilo	11.71
		Month	8.75

HS: ighly significant; NS: not significant; VHS: very highly significant. In bold, agricultural practices that influence the onset and development of tapping panel dryness.

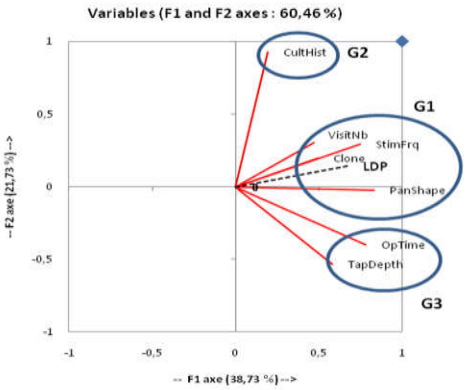

Figure 1 Interrelationship between the agricultural practices according to the explanatory plan 1.2

CultHist: Cultural history; LDP: Length of dry panel; OpTime: Duration of rubber production; PanShape: Form of the tapping panel; StimFreq: Stimulation frequency; TapDepth: Tapping depth; VisitNb: Visit number.

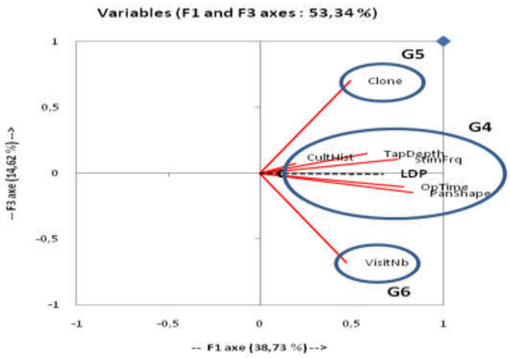

Figure 2 Interrelationship between the agricultural practices according to the explanatory plan 1.3

CultHist: Cultural history; LDP: Length of dry panel; OpTime: Duration of rubber production; PanShape: Form of the tapping panel; StimFreq: Stimulation frequency; TapDepth: Tapping depth; VisitNb: Visit number.

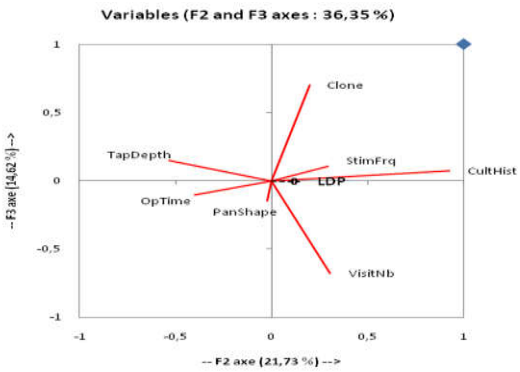

Figure 3 Interrelationship between the agricultural practices according to the explanatory plan 2.3

CultHist: Cultural history; LDS: Length of dry panel; OpTime: Duration of rubber production; PanShape: Form of the tapping panel; StimFreq: Stimulation frequency; TapDepth: Tapping depth; VisitNb: Visit number.

DISCUSSION

The characteristics of the study plantations showed tapping panel dryness (TPD) rates ranging from 0.76 to 68.34 % in non-industrial plantations. These rates are very high compared with those of 12 % and 30 % indicated respectively by Dian (1997) and De Fay (1981). These results indicate that tapping panel dryness found in all rubber plantations. Variability of tapping panel dryness rate can be explained by the parameters observed in the 27 study plantations. Indeed, five clones and seedling were planted in plantations with different durations of rubber production ranging from 2 to 11 years. Similar results were obtained by De Fay (1981), Chrestin (1985), Omokhaf (2004) and Okoma (2008) working on the tapping panel dryness among rubber clones GT 1, RRIM 600, PB 254 and PB 217. The configuration of the 9 rubber growing areas as the TPD rate showed that the rubber growing area of Daoukro was the least reached TPD with 4.5 % and the most affected rubber growing area was Guiglo with 34.12 %. The strong TPD rate in the rubber growing area of Guiglo is attributable to one of the three selected plantations in this area. This is the CHC I 20 plantation, planted with clone PB 260 very sensitive to TPD and is in its eleventh year of rubber production. In the rubber growing area of Daoukro, low TPD rate observed is mainly due to three reasons. First, the Daoukro rubber growing area was a new development area of rubber cultivation in Côte d'Ivoire. Then, the short duration of rubber production of visited plantations. Indeed, the study plantations were in the third year of rubber production. The third reason is that the planted clone GT 1 is a moderately sensitive clone to TPD. Overall, the TPD rates are well above the 5 % considered acceptable (De Fay, 1981; Jacobe and Prévôt, 1989) and highlight the threat posed by the TPD syndrome for Ivorian rubber cultivation. This requires taking action to stem the scourge. The study of the influence of each agricultural practice on the appearance and development of TPD showed that the terms of eleven cultivation and rubber production form different groups according to the TPD rate. The maintenance of the plantation by herbicide and bulldozer, the low number of monthly visits to the plantation by the framer, the high density of trees planting, the long duration of rubber production of trees, the high consumption of bark, the high rate of tapping wounds, the not treating of tapping wounds, the deep tapping, the stimulation frequencies not suitable to the clones and the deformation of the tapping panel induced high TPD rate. These results indicate that these agricultural practices have an effect on the appearance and development of TPD. They show that in addition to clonal very prominent factor in the onset and development of the TPD (De Fay, 1981; Chrestin 1985; Omokhaf 2004; Okoma, 2008), this phenomenon can be aggravated by certain agricultural practices. In effect, the practice of tapping is a mechanical action that induces physiological stress level of the tree. When tapping is profound and touches the cambium, it causes tapping wounds and the tree reacts to these physiological stress by the formation of larger or smaller beads (Compagnon, 1986). Untreated wounds does not promote healing of the regenerated bark and causes the appearance and development of TPD. The high density of trees in plantation creates competition for water and mineral nutrition of trees. Commère *et al*. (1989) showed that the high density of trees in plantation is a physiological factor that causes the TPD in rubber tree. Hormonal stimulation is physiological stress at the tree that activates the metabolism of latex cells (Coupé and Chrestin, 1989) and increases the duration of the flow of latex (Eschbach and Banchi, 1985; Eschbach, 1986). High concentrations of stimulants and higher stimulation frequencies not adapted to the clones further accelerate the metabolism of latex cells and cause deformation of the tapping panel following the physiological stress they induce. The duration of rubber production of trees which is the extension in time of tapping and of stimulation increases the induced physiological stress at trees level. These agricultural practices by inducing physiological stresses which cause the acceleration of the metabolism of laticifer cells are the cause of the TPD. This type of TPD is called TPD induced by overproduction or TPD fatigue (De Fay, 1981; Jacob and Prévôt, 1989). The study of the influence of all the agricultural practices on the TPD showed that agricultural practices contribute 60.5% to the appearance and development of TPD in non-industrial plantations. This rate was expressed by seven agricultural practices that are "the planted clone, the form of the tapping panel, the stimulation frequency, the number of visits of the plantation by the framer, the cultural history, the duration of rubber production of trees and the deep tapping ". These agricultural practices were structured into six groups according to contribution to the appearance and development of the TPD. These results are in agreement with those of the analysis of variances and confirm that agricultural practices promote the appearance and development of TPD. They give a good knowledge of these practices that promote the occurrence and development of TPD in non-industrial plantations and also show how these practices are associated. The results of this study confirm that the type of TPD consecutive to these agricultural practices is the TPD induced by overproduction as pointed out Jacob and Prévôt (1989). The reasons for these agricultural practices are the will of farmers and tappers to increase their gains especially when the price of natural rubber is increasing. To this is added the pressure of the factory owners who require large quantities of natural rubber to power their factories

CONCLUSION

It appears from this study that the TPD syndrome occurs in all rubber plantations. The TPD rate in non-industrial plantations in Côte d'Ivoire exceeds 30 % in some plantations. This rate is unevenly distributed in the rubber growing areas, some of which are more affected by this phenomenon. Daoukro rubber growing area was the least affected by the TPD while Guiglo rubber growing area was the most affected. This study also showed that agricultural practices contribute over 60 % to the appearance and development of TPD in non-industrial plantations. These practices are grouped into three main factors: the clone (the sensitivity of the planted clone) ; the bad application of latex harvesting technology (the cultural history, the maintenance of the plantation by herbicide and bulldozer, the weak supervision of producers, the high density of trees in plantation, the high consumption of bark, the high rate of tapping wounds, the no treatment of tapping wounds, the deep tapping, the stimulation frequencies unsuitable to the clones and the deformation of the tapping panel) and the duration of rubber production of trees (the long duration of rubber production of the trees). These agriculture practices cause physiological stresses that promote the appearance and development of TPD. They are poor agricultural practices and should be avoided to minimize the onset and development of TPD in rubber tree. This study could be complemented by agro soil studies to see the soil effect in the expression and development of TPD.

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