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Frosty Pod Rot, disease that affects the cocoa (*Theobroma cacao*) crops in Colombia

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ABSTRACT

Frosty Pod Rot, caused by *Moniliophthora roreri* (Cif. & Par.) Evans et al. (1986), is considered the main pathogenic factor affecting the cocoa crops in Colombia and in other Central and South America countries. In this paper we present relevant characteristics of the disease with emphasis on the symptomatology, the life cycle and epidemiologic elements setting out the ground for its control. We also mention the results of three successful experiences in Colombia (the number of diseased pods obtained was the lowest) using strict removal of affected pods beginning once a week during the first three months and then every harvesting round as the main procedure of cultural control. The removed pods were discarded on the ground.

1. Introduction

In Colombia, cocoa (*Theobroma cacao*) trees are hosts of some species of fungus that cause epidemic diseases favored by particular climate conditions and inadequate management. Frosty Pod Rot, caused by *Moniliophthora roreri* (Cif. & Par.) Evans, (1986), is considered the most important cause of low production levels of cocoa crops not only in Colombia but also in Central and South American countries. (Barros, 1977; Phillips, 2003; Ram et al., 2004; Sáenz, 2007; Ministerio de Agricultura y Desarrollo Rural et al., 2008). In Colombia it is endemic and the intensity of its impact varies according to the weather conditions in the different growing regions. Studies performed during the last five decades allow the establishment of principles for an effective management of this disease, reducing losses and raising the morale of growers in the cocoa farms.

2. Denomination

In Spanish the disease is known as Moniliasis, Monilia, Mancha, Mancha Helada, Nieve, Pasmo, Paludismo, and Pringue. In English the most common name is Frosty Pod Rot. The causal agent is the fungus *Moniliophthora roreri* (Cif. & Par.) Evans et al (Evans, 1986; Griffith et al., 2003). (Fig. 1).

The Cocoa Frosty Pod Rot is an endemic fungus in Colombia with highest incidence registered in the departments of Antioquia, Santander and Nariño; specifically in Urabá and lower Cauca River, Middle Magdalena and Tumaco.

3. Origin

Phillips (2003), located the origin of the disease in the Colombian Middle Magdalena where he found the greatest genetic diversity (groups Bolívar, Co-East, Co-West and Central). Frosty Pod Rot was identified in 1851 to the East and North of the Cauca River in the municipalities of Sopetrán and Santa Fé de Antioquia (department of Antioquia). However, earlier reports indicate that an epidemic outbreak of the disease occurred in Norte de Santander in 1817, one hundred years before Rorer's records in Ecuador (Phillips, 2003).

4. Symptomatology and life cycle

Fig. 2 shows different symptoms and signs; their detection is essential for the optimum management of the disease.

The first symptom of the infection in 2.5 month old pods is the

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Fig. 1. Cocoa pods affected by Frosty Pod Rot.

presence of shiny humps or swellings (Fig. 2A). In 2.5–3.5 month old pods it is the appearance of a brown spot with irregular edges that can completely cover it (Fig. 2B). After 3.5 months the first symptom on the pods is the presence of oily sub-epidermal dots (Fig. 2C) and then comes the sporulation, which is critical given this is the stage where the spreading power of disease becomes optimal (Fig. 2D).

It normally takes up to 30 days from the time of infection to the appearance of the first symptoms; 35 days later a brown spot is visible and 8–9 days after that a white or creamy-white fungus structure appears indicating a high presence of spores ready to be released (Fig. 3). In summary, 73–74 days pass from the moment of infection to the sporulation stage (Rodríguez et al., 2005). Pods contracting the disease prior to three months of age lose 100% of the grains, while those being infected after four months lose up to 10% (Cubillos, unpublished data).

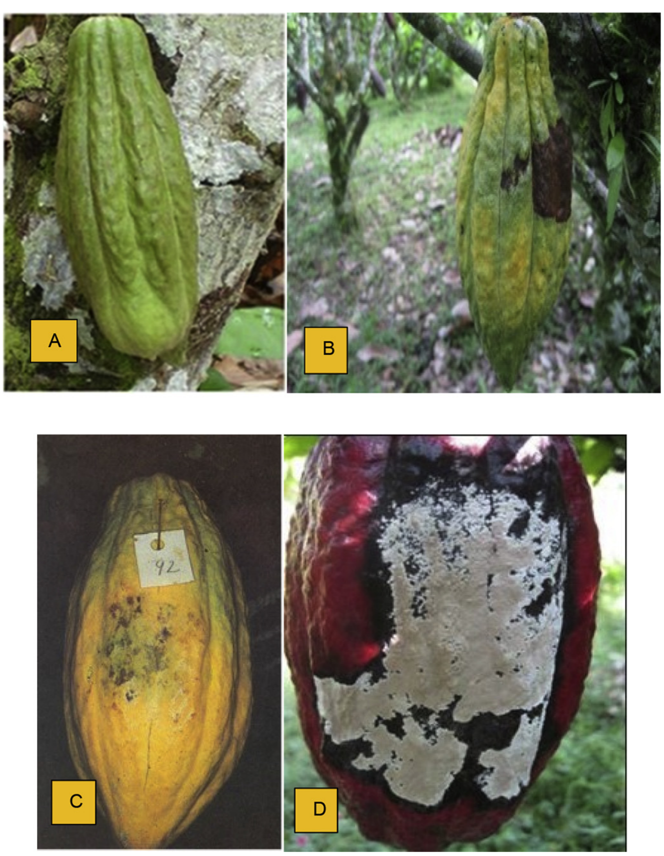

Fig. 2. Symptoms of Frosty Pod Rot infection. **A:** pod before 2.5 months of age. **B:** pod between 2.5 and 3.5 months of age; **C:** pod 3.5 months of age or older; **D:** pod in sporulation stage.

5. Incidence and losses

The incidence of the disease is climate-related, temperature being one of the key elements, in fact, it is greater in warm places than in the moderately-warm areas. Barros (1977) reported incidence levels of 63% in the farm Cacaoteras del Dique (low Cauca River zone, Antioquia, Colombia) and 44% in the farm Estación Experimental Tulenapa (Urabá, Antioquia, Colombia) in crops under eight years old.

According to Cubillos (1981) (unpublished data), incidence of Frosty Pod Rot was reported as 39.4% in the municipality of San Vicente de Chucurí, Colombia (800 m above sea level), 73.3% in El Carmen de Chucurí (500 m above sea level), 48.8% in Rionegro (department of Santander, 600 m above sea level) and 46.4% in Chaparral (department of Tolima, 600 m above sea level).

Maya et al. (2004) performed phytosanitary sampling in the department of Antioquia and found more than 70% of infected pods had 66%–100% of the cocoa grains compromised. According to that, it is possible to apply a severity index of 66% to the incidence figures and estimate minimum losses of 18.2% in San Vicente, 33.8% in El Carmen, 22.5% in Rionegro and 21.4% in Chaparral. These results serve as evidence of the economic impact of Cocoa Frosty Pod Rot in Colombia. Along with the harvest losses, the raw material quality is also jeopardized given the farmers recover affected grains and mix them with healthy ones, undermining the condition of the final product (Fig. 4).

6. Epidemiology

In Colombia, the Frosty Pod Rot became endemic due to the genetic susceptibility to the disease of the cocoa varieties that are grown in the different regions of the country. Among climatic factors favoring the widespread occurrence of the disease, temperature and humidity play the most critical role, being warm-humid regions where the heftiest losses have taken place. The wind is the natural dispersing agent par excellence, causing spores from the infected pods to reach adjacent and distant crops. The prevalence of Frosty Pod Rot is nurtured by pods in the sporulation

Fig. 3. Mature spores of *Moniliophthora roreri.*

Fig. 4. Mix of healthy and unhealthy grains.

stage still attached to the cocoa trees within the growing area (internal sources of infection) which can manage to live through and release infective spores up to nine months and in some cases even later (Evans, 1986). According to Green (Merchán, 1981), the infection gradient of the fungus can reach up to 30 m in the direction of the wind, indicating the critical role played by diseased pods still attached to the trees as one major cause of epidemic outbreaks.

Cubillos (1981), Cubillos and Ardila (unpublished data), González (1983) and Evans (1981, 1986), have determined that infected pods placed on the ground do not have epidemiological relevance given the germination power of spores is quickly nullified and the high humidity makes them heavier; the dispersion of its spores is neutralized due to the weakness of the wind at that level. Furthermore, the saprophytes quickly decompose the pods on the ground (Fig. 5).

7. Control

7.1. Cultural

In 1975 Green determined that Frosty Pod Rot, in its epidemic stage, can reach incidence levels of 55% and pointed out the possibility to decrease them to under 5% by removing the contaminated pods twice a week (Merchán, 1981). That study paved the way for a more effective cultural control. Aranzazu and Cubillos (1977) later indicated that removal of the diseased pods could also be implemented only once a week with similar results.

Cultural control is focused on the removal of all infected pods attached to the trees and their free disposition on the ground in weekly rounds, especially during the first three months following the initiation of control procedures. The purpose of this practice is to interrupt the cycle of the disease through the remotion of secondary sources of infection (internal sources). In the end, diseased pods can be removed from the crop during the regular harvest. A measure that facilitates the remotion process of diseased pods is pruning, because it helps in the detection of the infected units (Fig. 6). Therefore, it is important to prune the cocoa trees just after the main harvest is finished and once again six months later.

In Colombia, the results of campaigns against Frosty Pod Rot carried out during 2005–2007 (Sáenz, 2007; Ministerio de Agricultura y Desarrollo Rural et al., 2008), demonstrated that cultural control of the disease is an effective method given the incidence was decreased to minimal levels and it was maintained after twelve weeks following the implementation of the measures. Three evaluations run in San Vicente de Chucurí at the department of Santander in 2005 show the evolution of the Frosty Pod Rot within controlled crops.

The evaluations compared the results obtained in two clusters of similar cocoa trees (100 units each group). The first underwent cultural control consisting of weekly rounds removing and discarding frosty pods on the ground; the second was subjected to conventional procedures being cleared of infected pods only during harvests. In the farm Villa Luz at the municipality of El Carmen Table 1 shows the number of pods collected during 29 weeks of observation. After first twelve weeks (between weeks 23–39) the cultural control treatment yielded a steady number of frosty pods below 20 per week, while the conventionally treated group fluctuated between 0 and 93. Furthermore, under cultural control measures the sporulation was not frequent, while under conventional treatment most pods had developed that stage.

In La Reforma farm at the municipality of San Vicente de Chucurí, Table 2 shows the number of pods collected during 29 weekly harvest rounds. After first 17 weeks (between weeks 28–39) the

Fig. 5. Sporulated pod five weeks after its disposal on the ground.

Fig. 6. Architecture of cocoa trees submited to an adequate pruning that allows easy detection of diseased pods.

Table 1
Villa Luz farm, municipality of El Carmen in the department of Santander. Number and type of pods collected during 29 follow-up weeks in 2005.

Number of pods								
Week of the year	Cultural control				Conventional			
	Frosty Pod	Other Causes[a]	Health	Total	Frosty Pod	Other Causes[a]	Health	Total
11	151	5	13	169	167	14	17	198
12	0	0	13	13	0	0	0	0
13	143	5	0	148	0	0	0	0
14	0	0	0	0	0	0	0	0
15	98	3	0	101	0	0	0	0
16	0	0	0	0	0	0	0	0
17	54	4	20	78	127	8	15	150
18	0	0	0	0	0	0	0	0
19	22	2	0	24	0	0	0	0
20	0	0	0	0	0	0	0	0
21	21	3	23	47	106	4	17	127
22	22	5	0	27	0	0	0	0
23	20	3	0	23	0	0	0	0
24	19	3	21	43	93	4	14	111
25	20	4	0	24	0	0	0	0
26	18	2	0	20	0	0	0	0
27	17	2	16	35	86	4	13	103
28	15	3	0	18	0	0	0	0
29	17	4	0	21	0	0	0	0
30	16	3	0	19	0	0	0	0
31	19	0	31	50	75	0	23	98
32	17	0	0	17	0	0	0	0
33	18	1	47	66	63	1	32	96
34	19	1	0	20	0	0	0	0
35	17	0	0	17	0	0	0	0
36	16	1	0	17	0	0	0	0
37	15	0	0	15	0	0	0	0
38	19	0	151	170	59	0	93	152
39	18	1	0	19	0	1	0	1

[a] Black pod, squirrels and peckers.

Table 2
La Reforma farm, municipality of San Vicente de Chucurí at the department of Santander. Number and kind of pods collected during 28 observation weeks in 2005.

Number of pods								
Week of the year	Cultural control				Conventional			
	Frosty Pod	Other Causes[a]	Health	Total	Frosty Pod	Other Causes[a]	Health	Total
11	92	15	315	433	206	22	340	568
12	0	0	0	0	0	0	0	0
13	0	0	0	0	92	10	0	102
14	0	10	0	10	0	0	0	0
15	165	0	544	709	48	0	602	650
16	0	0	0	0	0	0	0	0
17	54	4	0	58	63	0	0	63
18	0	0	738	738	0	0	632	632
19	10	0	0	10	0	0	0	0
20	11	0	0	11	42	0	0	42
21	37	2	0	39	42	2	0	44
22	60	3	202	265	78	0	150	228
23	27	0	0	27	0	0	0	0
24	60	0	0	60	150	0	0	150
25	39	4	0	43	0	0	0	0
26	23	0	38	61	62	0	25	87
27	32	6	0	38	41	0	0	41
28	15	0	0	15	0	0	0	0
29	19	0	0	19	25	0	0	25
30	8	0	0	8	15	0	0	15
31	16	5	0	21	14	0	0	14
32	18	2	44	64	22	0	25	47
33	17	3	0	20	21	0	0	21
34	16	3	0	19	61	0	0	61
35	15	1	0	16	42	0	0	42
36	16	12	0	28	44	0	0	44
37	17	0	125	142	28	0	0	28
38	14	0	0	14	31	0	0	31
39	13	3	0	16	30	0	0	30

[a] Black pod, squirrels and peckers.

cultural control cluster yielded a steady number of frosty pods below 19 per week, while in the conventional one the figure ranged between 0 and 61. Furthermore, under control measures the sporulation was not frequent, while under conventional treatment most pods had developed that stage.

In Tres Piedras farm at the municipality of San Vicente de Chucurí, Table 3 shows the number and kind of pods collected during 26 weekly harvest rounds. After first 17 weeks (between weeks 28–39) the cultural control cluster yielded a steady number of frosty pods that fluctuated between 10 and 30 per week while in the conventional one the figure ranged between 0 and 136. In this period the number of diseased pods collected was 189 in the cluster of Cultural Control while in the cluster of conventional cluster was 367 equivalent to a relation 1:2. The relevance factor is that under control measures the sporulation was not common, while under conventional treatment most pods had developed that stage.

The results of these three evaluations indicate that 12–17 weeks following the implementation of the cultural control measures, the number of Frosty Pods decreases below 25 in a cluster of one hundred trees and the amount of sporulated pods is significatively low. The evident improvement is a consequence of timely removal of frosty pods. The cultural control, through the neutralization of the sporulation stage, has a significant impact on the incidence levels of the disease as it stops the spreading process before it begins. It is important to emphasize that the success of the cultural control measures depends on how strict the removal of the contaminated pods is.

Fig. 7 shows the ripe pods of a harvest round applying cultural control procedures in Granja Agrícola La Nacional, located in the municipality of Támesis, Antioquia, Colombia, in December 2011, with an incidence level below 1%, compared to more than 30% when control measures were not applied (Cubillos, unpublished data).

Fig. 7. Round of a cocoa harvest in the Granja Agrícola La Nacional, municipality of Támeis (department of Antioquia, Colombia) in December 2011 with an incidence level below 1% as a result of applying cultural control measures against Frosty Pod Rot.

7.2. Genetic

Different researchers have found that clone ICS-95 resists aggresive strains of *Moniliophthora roreri* (Phillips et al., 2005). In Colombia, Perea et al. (2013) also found that the local clone FEC-2 (Federación El Carmen) is equally resistant. Clones CCN-51, FLE-2 (Federación Lebrija) and FSA-12 (Federación Saravena) were catalogued as moderately resistant. Sánchez and Cubillos (1984) found that the IMC-67 clone is moderately resistant to the Frosty Pod Rot because it inhibits the sporulation process of the fungus.

Table 3
Tres Piedras farm, at the municipality of San Vicente de Chucurí in the department of Santander. Number and type of pods collected during 26 follow-up weeks in 2005.

Number of pods								
Week of the year	Cultural control				Conventional			
	Frosty Pod	Other Causes[a]	Health	Total	Frosty Pod	Other Causes[a]	Health	Total
14	122	8	0	130	1.195	58	0	1.253
15	0	0	0	0	0	0	0	0
16	139	12	270	421	507	0	273	780
17	0	0	0	0	0	0	0	0
18	72	2	0	74	0	0	0	0
19	0	0	0	0	0	0	0	0
20	24	5	107	136	142	0	101	243
21	15	0	0	15	0	0	0	0
22	19	5	0	24	0	0	0	0
23	13	3	57	73	198	0	111	309
24	27	3	0	30	0	0	0	0
25	16	5	0	21	0	0	0	0
26	18	2	42	62	60	0	28	88
27	9	2	0	11	40	0	0	40
28	26	5	19	50	21	0	12	33
29	30	8	0	38	0	0	0	0
30	15	3	0	18	52	0	0	52
31	14	0	0	14	0	0	0	0
32	15	8	0	23	35	0	0	35
33	16	3	92	111	0	0	0	0
34	14	4	0	18	136	0	40	176
35	13	7	0	20	0	0	0	0
36	12	5	0	17	0	0	0	0
37	10	5	112	127	97	0	55	152
38	11	2	0	13	0	0	0	0
39	13	4	0	17	26	0	0	26

[a] Black pod, squirrels and peckers.

7.3. Chemical

Although Ram et al. (2004) state that the disease control can be carried out using copper fungicides, the results achieved in Colombia was not significant enough using such method.

7.4. Biological

Aranzazu found that the fungi *Trichoderma* and *Clonostachys* have antagonistic behaviour on colonies of *Moniliophthora roreri* (Ministerio de Agricultura y Desarrollo Rural et al., 2008). However, there are no known studies supporting this information in field conditions.

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