RESPONSE OF SIX SOURCES OF OIL PALM PLANTING MATERIALS FROM MALAYSIA PLANTED IN THE EASTERN PLAINS OF COLOMBIA TO BUD ROT

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ABSTRACT

Bud rot (BR) is a disease caused by the oomycete Phytophthora palmivora, *which affects oil palm plantations in Latin America. It is one of the most limiting factors in oil palm cultivation in the region. In order to evaluate the agronomic response of commercial cultivars of oil palm in Colombia, six Malaysian cultivars (M1 to M6) and three regional cultivars (R1 to R3) were planted in 2004 under two contrasting agronomic conditions in two locations (Barranca de Upía and Acacías) located in the Eastern Plains of Colombia, where there is disease remission of the palms. One of the parameters evaluated was the reaction of cultivars to BR. The response variables were the area under the disease progress curve (AUDPC) and time to disease remission (RT) in months. There were significant differences in AUDPC and RT among the cultivars planted at Barranca de Upía. However, at Acacias there were no significant differences among the cultivars. M5 and M6 were the Malaysian cultivars with lower incidence of BR at Barranca de Upía. At the same time, M6 was the material with the least time to remission.*

Keywords: bud rot, *Phytophthora palmivora*, area under the disease progress curve, disease remission, agronomic management.

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INTRODUCTION

Bud rot (BR) in oil palm (*Elaeis guineensis* Jacq.) is one of the most important diseases of this crop in Latin and South America. The disease occurs in different oil palm-growing regions, with varying degrees of severity and aggressiveness. Richardson (1995) mentioned that in 1928 there was a severe outbreak of the BR disease from Deli-*Dura* seeds from the Bogor Botanical Garden introduced in Panama, that caused a loss of 27% of palms when they were two and a half years old. The same author also states that at that time, O.A. Reinking described the disease and also obtained microorganism isolates from rotten tissue, finding several bacteria, *Fusarium moniliforme*, and an organism similar to *Phytophthora*. Due to his experience with this genus, particularly affecting coconut palms, Reinking thought the rot in oil palm was caused by this pathogen (Richardson, 1995).

Sánchez *et al.* (1999) using molecular biology techniques, such as restriction enzyme *Hind I* and the primers OPA-04 and OPH-05, determined that there was a variation in banding patterns of isolates of *Phytophthora* sp. from different geographical origins. This could indicate the existence of different species

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or biotypes of the genus that would explain the variability of symptoms observed among regions.

Currently, *Phytophthora palmivora* is considered to be the causal agent of the initial lesions (Torres *et al.*, 2010; Sarria *et al*., 2008a, b) that lead to tissues being colonised by fungi and bacteria that continue the process of decomposition and rotting of the bud-tissue of the palm (Velez *et al*., 2008).

The disease is characterised by a rot that starts at the base of the spear and moves through the central core of undifferentiated leaves, affecting the meristematic zone and making it impossible to grow new leaves, thus hindering the normal development process of a healthy plant. The disease leads to the collapse of new spears, this being the best-known symptom of the disease, but the most critical situation occurs in the crown area. This part of the palm shows severe rotting of soft tissues, which may have different degrees of severity, ranging from relatively rapid recovery of the production of new spears in less severe cases, to the formation of a crater from decomposed and dead tissues, with the possibility of symptom remission in some cases (Martinez and Torres, 2007) (*Figure 1*).

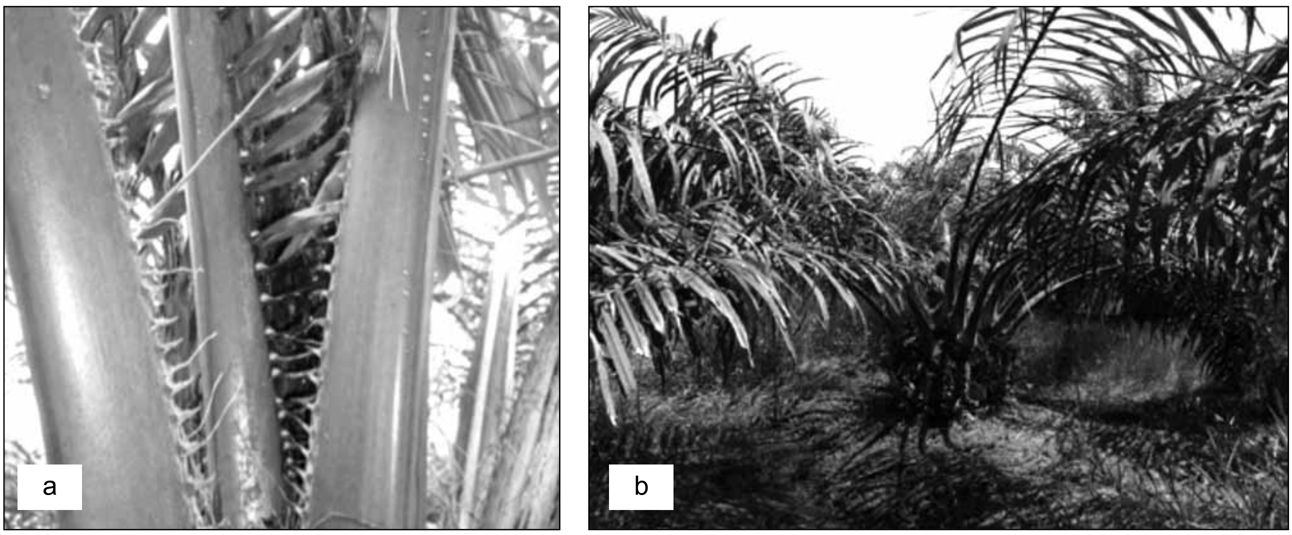
In Colombia, oil palm is grown in well-defined geographical areas that have higher or lower incidence rates of the disease and with varying degrees of incidence and severity. Thus, while in the western oil palm-growing area it is rare to see palms in remission of the symptoms of the disease, the palms in the Eastern Plains show natural disease remission, so the effects of BR are less devastating than in the western area. Evidence of recovery has been found in the Eastern Plains of Colombia with some frequency, but not in the oil palm growing areas of the Colombian Pacific coast (Martinez and Torres, 2007). In the early recovery stages, there is virtually no emergence of new spears, and if new spears do emerge, they are rotten with suberised rachis tissue and do not therefore complete their development. In the later stage, new spear leaves can be found with no rot on the middle and the lower thirds, and in some cases with rot symptoms on the upper third. The new leaves may be short, chlorotic and flaccid (Santacruz *et al.*, 2004) (*Figure 2*).

A palm is considered to be in full remission when there is normal growth with more than 17 healthy fronds, which can also coincide with the emergence of inflorescences above the last frond affected by the rot, as reported by Santacruz *et al.* (2004) (*Figure 3*).

On a commercial scale, there is a differential response to the disease among materials. In the eastern oil palm-growing area of Colombia, Asian materials show the highest incidence rate (65% to 85%) compared to African materials (25% to 71%) (Santacruz *et al.*, 2004).

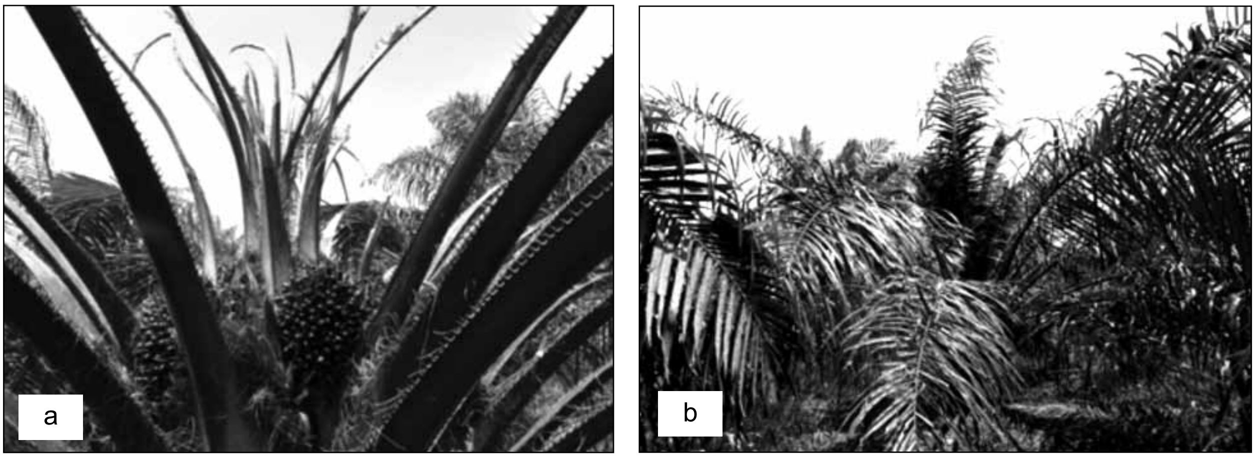
According to De Franqueville (2001), there is no evidence currently that pure populations of *E. guineensis* can be sources of resistance to BR, despite the response differences among origins. Trials conducted to compare the response of various Deli x La Mé crosses in the Shushufindi plantation (Ecuador), showed that the material C 1501 was the most susceptible.

It has been long thought that the low disease incidences are not only due to the genetics of the materials tested, but are also influenced by nutritional conditions and crop management. In this regard, Munévar *et al.* (2001) found statistically significant differences in leaf nutrient concentration



Source: Photographs courtesy of E. Navia.

Figure 1. (a) Rotting of the central core of leaves. (b) Crater-like formation by the death of tissue in the meristematic zone, and the arrest of leaf production.



Source: Photographs courtesy of E. Navia.

Figure 2. Initial state of remission and formation of suberised tissue (a). Emergence of new spears and leaves (b).

Source: Photographs courtesy of E. Navia.

Figure 3. (a) Palm classified as in full remission. (b) Production of new leaves and bunches over the damaged area. The arrow shows the rachis of one the previously affected leaves.

when comparing healthy palm leaves to diseased palm leaves. A similar comparison of soil nutrient concentrations yielded similar results.

To quantify and measure the effect of genetic resistance and the impact of management on the reduction of the disease, epidemiological tools were used, among which is the calculation of the area under the disease progress curve (AUDPC) variable. This is an approach that analyses the disease profile during the development of an epidemic, using a summary measure that is based on the calculation of the sum of areas found under the disease progress curve. This variable is subjected to an analysis of variance (ANOVA) to determine whether or not there are statistical differences between treatments (Madden *et al*., 2007).

The use of epidemiological tools has made possible the identification of the effect of soil type on the development of the BR disease. Ruiz *et al*. (2006) used the progress rate parameter to determine the effect of agronomic practices on the incidence of the BR and on the remission processes under commercial crop conditions, showing that there are differences in disease behaviour attributable to edaphic factors.

Between 2004 and 2005, regional trials were carried out in the country to assess the performance of various commercial materials of oil palm under Colombian growing conditions. Vegetative and reproductive traits, fresh fruit bunch production records, and the presence of pests and diseases variables were recorded. Due to the importance of BR in the Colombian oil palm industry, its effect on planting materials has been considered as one of the important observations in the regional trials. This article specifically shows the results of the effect of BR on different genetic materials under the conditions of the eastern oil palm-growing area of Colombia.

MATERIALS AND METHODS

Location

Plantations located in the municipalities of Barranca de Upía (4º28´39,69¨ N; 72º57´37,51¨ W) and Acacías (3º58´16,07¨ N; 73º34´00,04¨ W), in the Meta Department of Colombia, were selected to conduct the trials. The selection of the plantations took into account differences in agronomic management. The trials were set up in the second half of 2004.

Materials Evaluated

Six materials from the Malaysian seed producers (M1, M2, M3, M4, M5 and M6) and three commercial materials (R1, R2 and R3) commonly grown in the Eastern Plains of Colombia, from a breeding programme different from that of the Malaysian materials were evaluated. The latter will be referred to as regional materials.

Agronomic Management of Trials

The agronomic management of the trials was conducted according to the technical parameters of each of the plantations. In the plantation located in Barranca de Upía, terraces were constructed, straight fertilisers were used and irrigation was carried out during the dry seasons.

In the plantation located in Acacias, no terraces were constructed, compound fertilisers were used and no irrigation was carried out during the dry season. It is important to mention that an irrigation system could not be implemented due to various constraints.

The difference in fertility, largely due to the agronomic management of the two locations, was evidenced by the leaf analysis results in both experiments. For the leaf analysis, samples of Leaf 17 of healthy palms of each material were taken and sent to the leaf and soil analysis laboratory of CENIPALMA. The results are shown in *Table 1*.

The management of BR in both plantations during the evaluation period was limited to the application of an insecticide to prevent possible damage caused by *Rhynchophorus palmarum* larvae feeding on the affected tissue. Additionally, zinc was applied to the crown in the Barranca de Upía plantation.

Experimental Design and Data Analysis

A randomised complete block design was used with seven treatments (Acacias) and eight treatments (Barranca de Upía) with four replications and 20 palms per experimental unit.

Periodic assessments of the BR were performed from the time of planting in order to determine the incidence of the disease and BR remission of the palms. Monthly counts were made for cases of BR and sympton remission. Information on the number of BR cases was gathered in each replication per material tested, and the monthly incidence of the disease on the total number of palms was then calculated. The proportion of remissions in each of the materials was calculated for the total of palms affected by the disease as follows:

$$\text{Remission (\%)} = \text{number of palms in remission} / \text{total number of palms}$$

Disease progress and remission curves were built based on the data of incidence and remission rates. The behaviour of the disease was analysed by calculating AUDPC.

The AUDPC of the disease was calculated by the trapezoidal method (Madden *et al.*, 2007), which assumes that the progress curve can be divided into a series of trapezoids whose areas are calculated and then added up to obtain the final value of the AUDPC. The formula for the calculation is as follows:

$$Ak = \sum_{j=1}^{nj-1} \left(\frac{y_i + y_{j+1}}{2}\right) (tj+1 - tj)$$

where:

j = Period between observations.
n_j = Number of observations.
y = Incidence of the disease.
t = Unit of time used in the evaluations.

In order to meet the assumptions of the ANOVA for statistical analysis, the AUDPC data was transformed with the expression $\sqrt{AUDPC} + 0.5$ $\sqrt{AUDPC} + 0.5$. Where statistical differences between AUDPC values in the materials were found, a comparison of the means was carried out using the Tukey test (5%).

The accumulated data, as well as the number of incidences and remission rates in each material were totalled on an annual basis.

As described by Santacruz *et al*. (2004), for the remission process, the elapsed time (months) recorded between the detection of the disease and remission to healthy palm, was defined by the criterion of producing more than 17 healthy leaves. Individual values of the elapsed time were used to perform the respective statistical analysis

TABLE 1. RESULTS OF LEAF ANALYSIS IN BARRANCA DE UPÍA AND ACACÍAS (COLOMBIA)

	N (%)		P (%)		K (%)		Ca (%)	
	B. de Upía	Acacías	B. de Upía	Acacías	B. de Upía	Acacías	B. de Upía	Acacías
M2	2.58	2.57	0.172	0.168	0.90	1.71	0.81	0.38
M5	2.51	2.73	0.170	0.170	1.07	1.43	0.74	0.51
M1	2.59	2.59	0.172	0.171	0.96	1.39	0.72	0.57
M4	2.45	2.43	0.163	0.155	0.86	1.69	0.69	0.34
M6	2.12	2.70	0.129	0.170	0.81	1.61	0.78	0.39
M3	2.65	2.65	0.170	0.170	1.00	1.45	0.76	0.44
R1	2.73	-	0.174	-	0.72	-	0.89	-
R2	2.60	-	0.173	-	0.78	-	0.88	-
R3	-	2.57	-	0.168	-	1.71	-	0.38

	Mg (%)		S (%)		B (mg kg^{-1})		Fe (mg kg^{-1})	
	B. de Upía	Acacías	B. de Upía	Acacías	B. de Upía	Acacías	B. de Upía	Acacías
M2	0.31	0.09	0.20	N.D.	16.4	13.6	95.0	91.2
M5	0.23	0.15	0.16	N.D.	15.0	19.4	79.2	86.5
M1	0.24	0.19	0.15	N.D.	19.0	14.8	80.9	74.3
M4	0.24	0.17	0.14	N.D.	16.6	15.7	87.4	78.0
M6	0.30	0.20	0.15	N.D.	18.6	17.1	88.7	10.9
M3	0.25	0.18	0.16	N.D.	16.1	16.8	92.8	10.1
R1	0.27	-	0.18	N.D.	22.6	-	93.3	-
R2	0.24	-	0.16	N.D.	19.7	-	98.2	-
R3	-	0.09	-	-	-	13.6	-	91.2

Note: N.D. - not determined.

to determine differences in remission rates among cultivars (ANOVA and Tukey test).

RESULTS AND DISCUSSION

General Analysis of the Disease and Beginning of the Remission Process

The first cases of BR disease appeared in 2006 in the Acacias trial, reaching an incidence rate of 4.43% throughout the trial, by the end of that year. In Barranca de Upía, the disease appeared in 2007 and the average cumulative incidence rate by the end of that year was 16.15%. Considering that both experiments were carried out in 2004, the time that had elapsed until the onset of the first cases was about two years in Acacías and three years in Barranca de Upía. However, incidence data after the first year of the epidemic show that the disease was more aggressive in Barranca de Upía during this period.

The remission process of the affected palms began in 2008 in both locations. However, by this time the epidemic had been going on for one year in the Barranca de Upía trial, and the average remissions reached 6.06% at the end of that period, by this time it had been two years since the appearance of the first cases of the disease in Acacias and the remission rate was 17.94%. Therefore, this allows us to infer that the process of remission started much earlier in Barranca de Upía.

Progress in the Incidence of the Disease and Remission Process of Affected Palms in Barranca De Upía

As mentioned earlier, the first cases of BR in Barranca de Upía occurred in 2007 and by the end of that year the M2 material reached the highest cumulative incidence rate (26.51%), while M4 had the lowest incidence (7.57%) (*Figure 4*).

The annual incidence shows that all the Malaysian materials had a high number of cases in 2008, that is, the second year of the epidemic; and for materials R1 and R2, the majority of cases occurred during the third year of the epidemic (2009) (*Figure 5*).

From the ANOVA of the AUDPC, it was determined that at least in one material the average of the AUDPC was significantly different from the other materials (*Table 2*).

TABLE 2. ANALYSIS OF VARIANCE (ANOVA) FOR AREA UNDER THE DISEASE PROGRAMME CURVE (AUDPC). MALAYSIAN MATERIAL TRIALS - BARRANCA DE UPÍA (C.V. 4.06%)

Source	D.F.	M.S.	F Value	*p* Value
Replication	3	0.00079	0.58	0.6320
Material	7	0.01	4.77	0.0024

Note: D.F. – degree of freedom. M.S. - mean square.

The AUDPC averages of materials M5 and M6 were significantly lower than the other Malaysian materials, indicating that these materials were less susceptible to the disease in the Barranca de Upía trial. However, it is important to note that the averages of these materials were not significantly different from the regional material R1 (*Figure 6*).

The remission of symptoms of affected palms began in 2008, one year after the start of the epidemic in the Barranca de Upía trial. It is important to highlight the fact that by this year, materials M5 and M6 had the highest remission rates (13.95% and 9.19%), *i.e.* these materials had the highest proportion of BR remissions in that year. The same situation occurred in 2009. Throughout the trial, the year 2010 showed the highest percentage of remissions. It is important to note that in that year, materials R1 and R2 had the highest symptom remission rate (51.09% and 62 49%, respectively) (*Figure 7*).

The analysis of the symptom remission progress curve of affected palms showed that the trend was marked by the fact that in 2008 the materials with higher initial remission rates (M5 and M6) were the same materials that by the end of 2010 had the highest cumulative remission rate (*Figure 8*).

In the ANOVA of the average remission time, it was found that at least one of the materials had an average, which was significantly different from the other materials (*Table 3*). Data showed that the coefficient of variation was 11.25%.

The Tukey test for mean separation showed that the average remission times for materials R1 and M6 (16.07 and 16.80 months, respectively) were significantly shorter than the times reported for

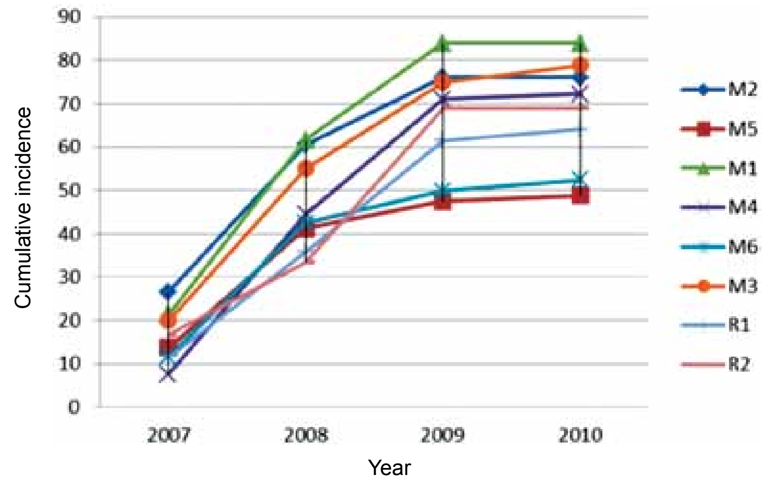
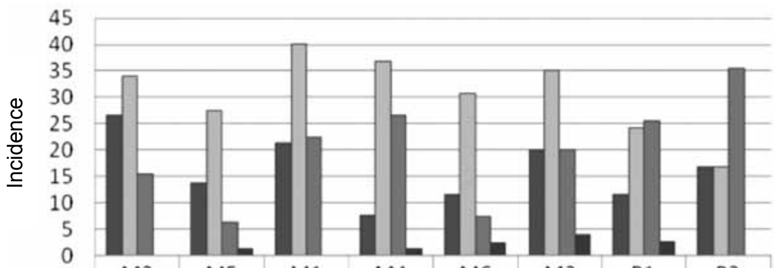


Figure 4. Bud rot progress curves of the Malaysian materials between 2007 and 2010 in Barranca de Upía (Colombia).



	M2	M5	M1	M4	M6	M3	R1	R2
2007	26.51	13.75	21.42	7.57	11.64	20.00	11.58	16.73
2008	34.08	27.50	40.20	36.84	30.72	35.00	24.28	16.73
2009	15.39	6.25	22.37	26.58	7.50	20.00	25.59	35.54
2010	0.00	1.25	0.00	1.25	2.50	3.82	2.63	0.00

Figure 5. Annual incidence of bud rot in the Malaysian and regional materials between 2007 and 2010 in Barranca de Upía (Colombia).

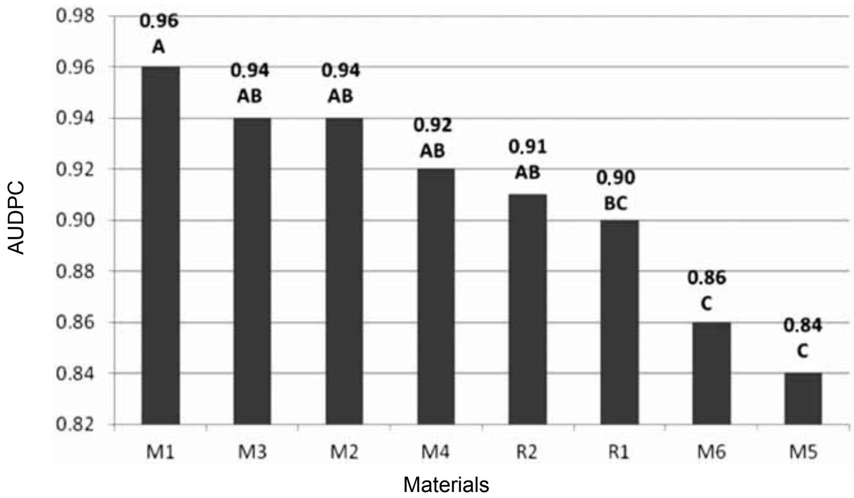
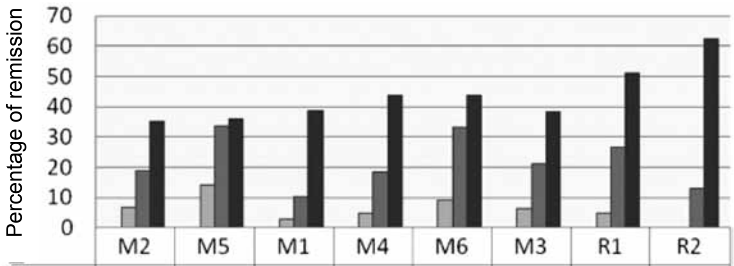


Figure 6. Area under the disease progress curve (AUDPC) of bud rot in the Malaysian and regional materials between 2007 and 2010. Barranca de Upía (Colombia) - Tukey Test (5%).



	M2	M5	M1	M4	M6	M3	R1	R2
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	6.81	13.95	2.88	4.60	9.19	6.25	4.86	0.00
2009	18.75	33.71	10.23	18.57	33.21	21.06	26.77	13.04
2010	35.23	35.93	38.66	43.80	43.60	38.14	51.09	62.49

Figure 7. Average annual remission of the Malaysian and regional materials between 2007 and 2010. Barranca de Upía (Colombia).

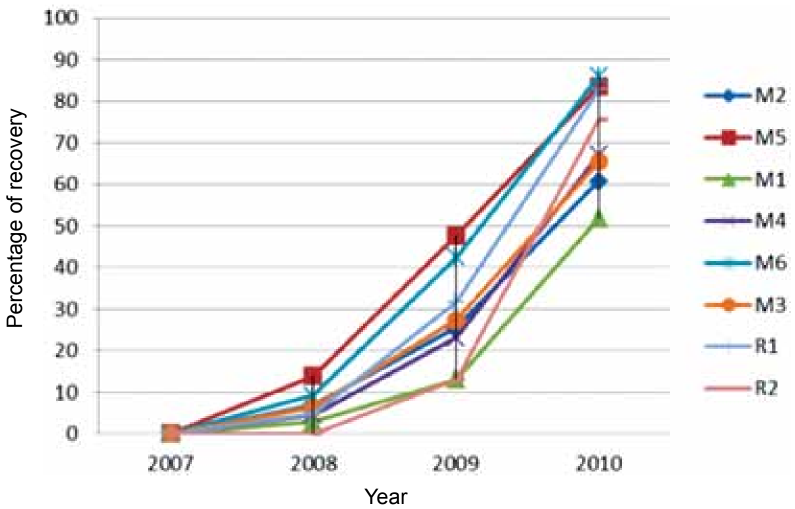


Figure 8. Bud rot remission progress curves of the Malaysian and regional materials between 2007 and 2010.

TABLE 3. ANALYSIS OF VARIANCE (ANOVA) FOR MONTHS TO FULL REMISSION. BARRANCA DE UPÍA (C.V. 11.25%)

Source	D.F.	M.S.	F Value	*p* Value
Replication	3	8.24	0.53	0.6662
Material	7	312.87	8.63	<0.0001

Note: D.F. – degree of freedom. M.S. - mean square.

materials M1, M2, M3 and M4 (26.68, 23.66 , 21.60 and 20.79 months, respectively). Materials M5 and R2 (18.80 and 18.39 months) had shorter average remission times only with respect to M1 and M2 (26.68 and 23.66 months) (*Figure 9*).

Progress in the Incidence of the Disease and the Remission Process of Affected Palms in the Acacías Trial

The first BR cases in this trial occurred in 2006, and by the end of that year the materials with lower incidence were M5 (1.39%) and R3 (0.0%). The material with the highest cumulative incidence rate in this period was M6 with 8.75%.

Disease progress curves show that the development of the disease was similar in all materials during the evaluation period, and the most rapid progress occurred between 2006 and 2008. The cumulative incidence at the end of 2008 for all materials was between 40.0% and 70.0%, and the extreme values were for materials R3 and M5, respectively (*Figure 10*).

The assessment of the annual cumulative incidence rate in Acacías showed that the greatest number of cases occurred in the second year of the epidemic (2007), coinciding with that observed in Barranca de Upía, where the second year of the epidemic also showed the highest number of cases (*Figures 5* and *11*).

The ANOVA of the AUDPC showed that there were no statistical differences among materials, which indicates that the disease progressed similarly in all of them (*Table 4*).

The symptom remission data show that palms began to recover in 2008, that is, two years after the

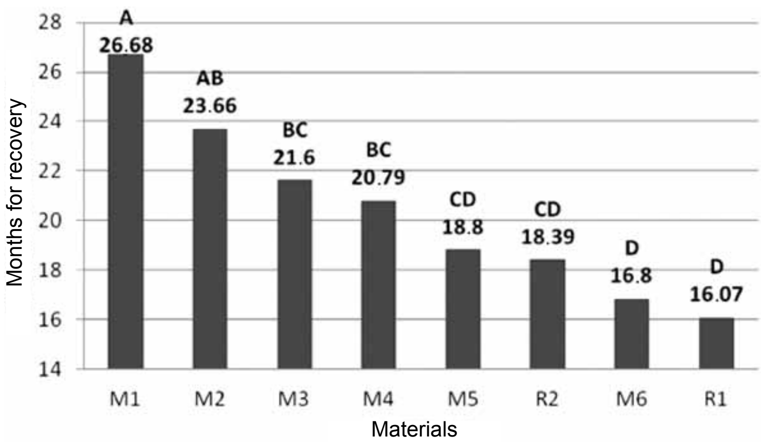


Figure 9. Average remission time (months). Barranca de Upía (Colombia) - Tukey Test (5%).

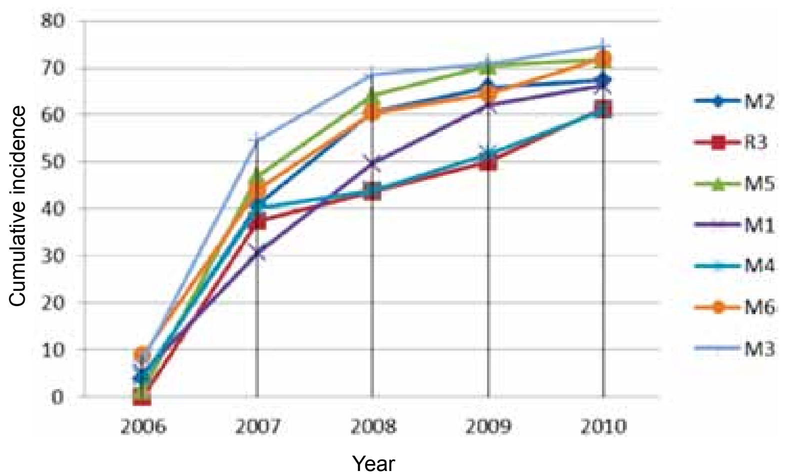


Figure 10. Bud rot progress curves for the Malaysian and regional materials between 2006 and 2010. Acacías, Colombia.

TABLE 4. ANALYSIS OF VARIANCE FOR AREA UNDER THE DISEASE PROGRESS CURVE (AUDPC) FOR BUD ROT - ACACÍAS (C.V. 4.96%)

Source	D.F.	M.S.	F Value	*p* Value
Replication	3	0.0021	1.19	0.3424
Material	6	0.0029	1.69	0.1810

Note: D.F. – degree of freedom. M.S. - mean square.

start of the epidemic. It is important to note that by this time materials R3 and M6 had the highest percentages of remission (23.96% and 23.43%) within the group of materials evaluated. In 2009, materials M5, M4 and M6 had the highest remission rates, with values of over 40.0% (*Figure 12*).

From the analysis of remission progress curves, it can be inferred that from 2009 onwards, two groups were formed. One group had values below 70.0% (M1, M3 and M2), while materials R3, M4, M6 and M5 showed values above 70% (*Figure 13*).

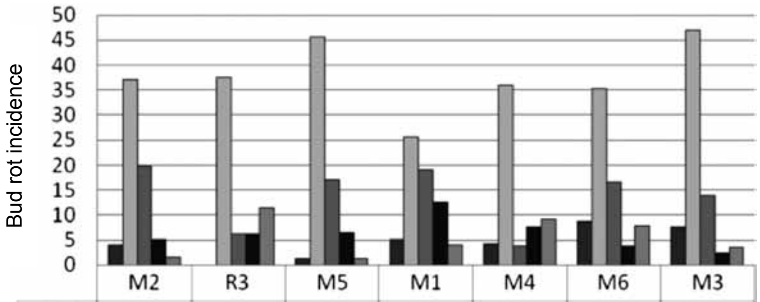
The ANOVA for the average remission time variable showed statistically significant differences among materials. The coefficient of variation was 14.73% (*Table 5*).

The Tukey test showed that the material M3 had an average remission time significantly higher with respect to the Malaysian materials M4, M5, M6 and regional material R3. This indicates that affected palms of material M3 had a slow remission rate (*Figure 14*).

TABLE 5. ANALYSIS OF VARIANCE (ANOVA) FOR MONTHS TO FULL REMISSION. ACACÍAS (C.V. 14.73%)

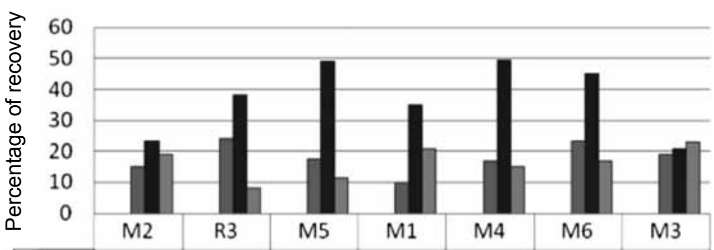
Source	D.F.	M.S.	F Value	*p* Value
Replication	3	4.14	0.42	0.7401
Material	6	27.65	2.81	0.0415

Note: D.F. – degree of freedom. M.S. - mean square.



	M2	R3	M5	M1	M4	M6	M3
2006	3.95	0.00	1.39	5.13	4.19	8.75	7.63
2007	37.03	37.50	45.67	25.53	35.97	35.33	46.97
2008	19.70	6.25	17.08	19.01	3.82	16.51	13.95
2009	5.20	6.25	6.39	12.50	7.70	3.88	2.50
2010	1.47	11.39	1.27	4.08	9.27	7.83	3.55

Figure 11. *Annual incidence of bud rot in the Malaysian and regional materials (2006-2010). Acacías, Colombia.*



	M2	R3	M5	M1	M4	M6	M3
2006	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2007	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2008	15.06	23.96	17.52	9.92	16.67	23.43	19.05
2009	23.25	38.14	48.94	34.97	49.53	44.95	20.88
2010	19.03	8.13	11.35	20.92	15.05	16.76	23.13

Figure 12. Annual bud rot disease remission rates of the Malaysian and regional materials (2006-2010). Acacías, Colombia.

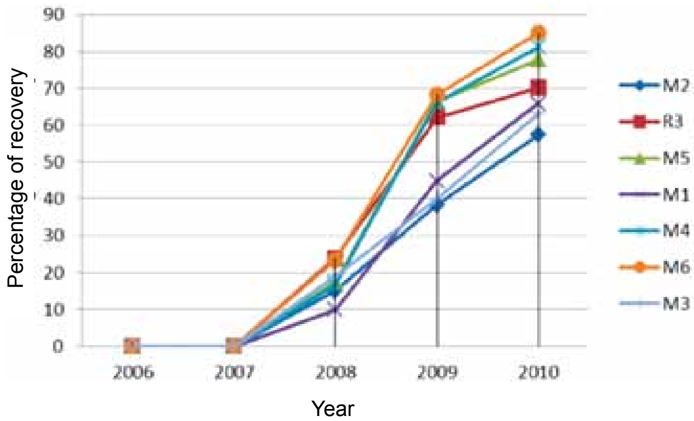


Figure 13. Bud rot remission progress curves for the Malaysian and regional materials (2006-2010). Acacías, Colombia.

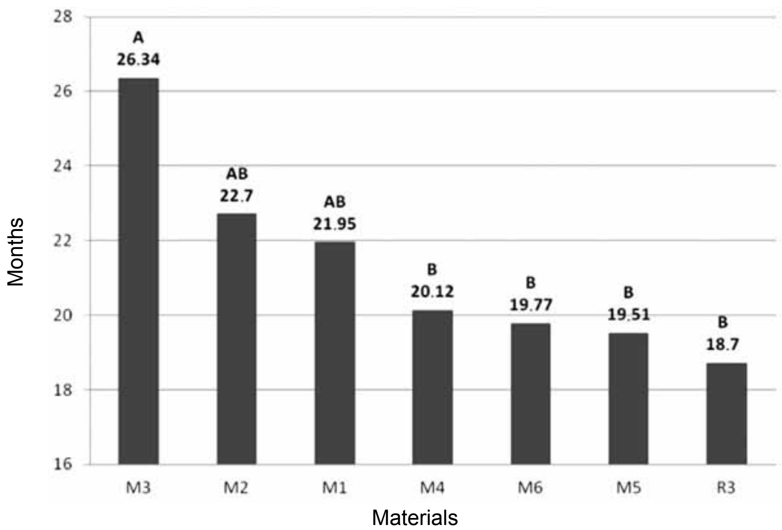


Figure 14. Average remission time (months) Acacías (Colombia) - Tukey Test (5%).

It is important to note that the materials, when planted under better crop management (Barranca de Upía) showed a different response to the disease and in remission time. They were thus less susceptible to BR and showed faster recovery.

Rocha (2007) notes that although full BR remission occurs naturally in palms planted in the Eastern Plains of Colombia, oil palm growers should not be passive about the disease. It is important to develop strategies to manage diseased palms because not doing so will extend the unproductive period due to the delayed remission, and also strengthen the sources of the disease. From this perspective, tasks such as early disease detection, removal of affected tissue, nursery management, suitability of soil for planting, drainage management and nutrition, application of fungicides and bactericides, prevention of damage by *Rynchophorus palmarum* (Martinez *et al*., 2009) are important aspects of an integrated BR management strategy. This will enhance the response of highly productive materials in areas where the disease occurs and will increase the opportunity for affected palms to recover.

CONCLUSION

The results have shown that although all the Malaysian materials were affected by the BR disease at both locations, some materials, namely M5 and M6, in Barranca de Upía showed lower susceptibility to the disease. Furthermore, material M6 showed a shorter time to full remission compared to the other Malaysian materials evaluated. In Acacías, all the Malaysian materials were similarly affected by the BR disease and they all required similar times to full remission.

Some of the Malaysian materials showed significantly better tolerance to the BR disease and shorter times to remission but required good agronomic management for these benefits to be achieved.

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REFERENCES

De FRANQUEVILLE, H (2001). Pudrición del cogollo de la palma aceitera en América Latina. Revisión preliminar de hechos y logros alcanzados. CIRAD - Departamento de Cultivos Perennes. 35 pp.

MADDEN, L; HUGHES, G and VAN DEN BOSCH, F (2007). *The Study of Plant Disease Epidemics*. American Phytopathological Society, St. Paul, Minnesota. 421 pp.

MARTÍNEZ, G and TORRES, G (2007). Presencia de la Pudrición de Cogollo en la palma de aceite en plantas de vivero. *Revista Palmas Vol. 28 No. 4*: 13-20.

MARTÍNEZ, G; ARIAS, N; SARRIA, G; TORRES, G; VARÓN, F; NOREÑA, C; SALCEDO, S; AYA, H, ARIZA, J; ALDANA, R; MARTÍNEZ, L; MOYA, O and BURGOS, C (2009). Manejo integrado de la Pudrición del Cogollo (PC) en Palma de Aceite. Cartilla técnica No. 1. Cenipalma, Bogotá. 24 pp.

MUNÉVAR, F; ACOSTA, A and GÓMEZ, P (2001). Factores edáficos asociados con la Pudrición de Cogollo de la palma de aceite en Colombia. *Revista Palmas Vol. 22 No. 2*: 9-16.

RICHARDSON, D (1995). La historia del mejoramiento genético de la palma aceitera en la compañía United Fruit en América. *ASD Oil Palm Papers No. 11*: 1-22.

ROCHA, P (2007). Sanidad de la palma de aceite: diagnóstico e investigación integral liderada por el gremio palmero colombiano. *Revista Palmas Vol. 28 No. 2*: 87-98.

RUIZ, E; TOVAR, J; TORRES, E and ÁVILA, M (2006). Uso de herramientas epidemiológicas para determinar la influencia de condiciones del suelo y prácticas agronómicas sobre la incidencia y recuperación de la enfermedad Pudrición del Cogollo (PC) en la zona oriental. Cenipalma. *Ceniavances No. 135*: 4 pp.

SÁNCHEZ, N; AYALA, L; ALVAREZ, E and GÓMEZ, P (1999). Patogenicidad, identificación y caracterización molecular de *Phytophthora* spp. en palma de aceite. Cenipalma. *Ceniavances No. 60*: 4 pp.

SANTACRUZ, L; ZAMBRANO, J and AMÉZQUITA, M (2004). Comportamiento de la Pudrición de Cogollo en la Zona Oriental de Colombia. *Revista Palmas Vol. 25 No. Especial, Tomo II*: 220-230.

SARRIA, G; TORRES, G; AYA, H; ARIZA, J; RODRÍGUEZ, J; VÉLEZ, D; VARÓN, F and MARTÍNEZ, G (2008a). *Phytopthora* sp. es el responsable de las lesiones iniciales de la Pudrición del Cogollo (PC) en la Palma de Aceite en Colombia. *Revista Palmas Vol. 29. Edición Especial*: 31-41.

SARRIA, G; TORRES, G; VÉLEZ, D; RODRÍGUEZ, J; NOREÑA, C; VARÓN, F; COFFEY, M; ELLIOT, M and MARTÍNEZ, G (2008b). Caracterización morfológica y molecular de *Phytophthora palmivora* agente causal de las lesiones iniciales de la Pudrición del Cogollo (PC) en la Palma de Aceite en Colombia. *Fitopatología Colombiana, 32(2)*: 39-44.

TORRES, G; SARRIA, G; VARON, F; COFFEY, M; ELLIOT, M and MARTÍNEZ, G (2010). First report of bud rot caused by *Phytophthora palmivora* on African oil palm in Colombia. *Plant Disease, 94(9)*: 1163.

VELEZ, D; NOREÑA, C; SARRIA, G; TORRES, F VARÓN and MARTÍNEZ, G (2008). Evalución y cuantificación de estructuras de *Phytophthora palmivora*, el responsiable de la Pudrición del Cogolla (PC) de la Palma de Aceite. *Fitopatologia Colombiana, 32(2)*: 45-50.