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PROCEEDINGS OF THE MEETING OF THE AMERICAN REGIONAL GROUP ON *Phytophthora palmivora* ON CACAO

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Editors:

Gustavo A. Enríquez
George A. Zentmyer

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CONTENT

The meeting of the American Group on Phytophthora palmivora on cacao was sponsored by the following institutions:

- Centro Agronómico Tropical de Investigación y Enseñanza (CATIE)
- American Cocoa Research Institute (ACRI)
- University of California, Riverside
- Comissao Executiva do Plano da Lavoura Cacaueira, CEPLAC
- University of West Indies, St. Augustine
- Fondo Nacional de Investigaciones Agropecuarias Ministerio de Agricultura y Cria, FONAIAN-MAC.
- Instituto Nacional de Investigaciones Agrícolas INIA México

INTRODUCTION

This is the third meeting of the American Regional Subgroup on Phytophthora palmivora in relation to cacao. The first meeting was held in Itabuna, Bahía, Brazil in 1971, and the second in Guayaquil, Ecuador in 1973. A comparable subgroup in Africa has held several meetings. The subgroup concept originated at the International Cocoa Research Conference in Ghana in 1969, when an International Committee was appointed to facilitate exchange of information and to stimulate research on Phytophthora palmivora. Committee members were M. Costa and R. A. Muller of France, P. Gregory of England and G. A. Zentmyer of the United States. Dr. Muller is Chairman of the African Subgroup.

The Regional meetings were planned to encourage and facili-tate exchange of information and discussion of all aspects of research on black pod, in more detail than is possible at the International Conferences. This meeting at CATIE, Turrialba, Costa Rica, provided an opportunity to discuss and to see local problems with black pod in Costa Rica as well as to summarize and coordinate research in other countries of the Americas.

Certainly, black pod is still the major problem facing the cocoa industry on a world-wide scale. World-wide losses were estimated at 10 percent or more, which on an 1980 estimate would equal aproximately 200.000 tons of cacao.

For these reasons, the publication of the Procedings of the Meeting is very important for cacao researchers and growers around the world, in spite of the delay in the publication due to financial problems. The new information on the management of Black Pod, which is a common and important disease widely distributed throughout the cocoa-producing areas of the tropical world, is very valuable and has its own merit for being published.

In this meeting at Turrialba we concentrated on four major aspects of research on black pod: Taxonomy of the fungus, Epidemiology, Resistance and Chemical and Biological Control. Excellent facilities for the meeting and for housing participants were provided at CATIE, in Turrialba, Costa Rica, Through the courtesy of the Director, Dr. Santiago Fonseca and with the fine cooperation of the chairman of Local Arrangements, Dr. Gustavo A. Enríquez.

G.A. Zentmyer
Chairman, American Regional Sub-
group on Phytophthora Palmivora

PARTICIPANTS

Brazil

Jeremy S. Lawrence
CEPEC
Caixa Postal 7
Itabuna, Bahía, Brasil

Joao María Figueiredo
CEPEC
Caixa Postal 7
Itabuna, Bahía, Brasil

Cleber Novais Bastos
CEPEC
Caixa Postal 1801
Belem, Pará, Brasil

Costa Rica

Jesús Sánchez L.
Programa de Plantas Perennes
CATIE
Turrialba, Costa Rica

Luis G. Salazar G.
Programa de Plantas Perennes
CATIE
Turrialba, Costa Rica

Gustavo A. Enríquez
Jefe, Programa de Plantas
Perennes, CATIE
Turrialba, Costa Rica

Jorge Hernán Echeverri
IICA-PROMECAFE
CATIE
Turrialba, Costa Rica

Costa Rica

Federico Dao
IICA
Apartado 55
Coronado, San José,
Costa Rica

Raúl Muller
IICA-PROMECAFE
Apartado 55
Coronado, San José,
Costa Rica

Dennis Mora A.
Universidad de Costa Rica
San Pedro Montes de Oca
San José, Costa Rica.

Lennon Patterson Headly
Apartado 312
Limón, Costa Rica.

Luis Carlos González
Universidad de Costa Rica
San Pedro Montes de Oca
San José, Costa Rica

Sergio Umaña
Laboratorio de Fitopatología
Universidad de Costa Rica,
San Pedro de Montes de Oca,
San José, Costa Rica.

Randolfo Elizondo
Apartado 2560
San José, Costa Rica.

César A. Rodríguez B.
CATIE
Apartado 87
Turrialba, Costa Rica

Costa Rica

Fernando Morales B.
Universidad de Costa Rica
Facultad de Agronomía
San José, Costa Rica

Trinidad

T.N. Sreenivasan
University of the West Indies
St. Augustine, Trinidad
West Indies

Venezuela

Lilian Capriles de Reyes
FONAIAP-MAC
Estación Experimental Caucagua
Caucagua, Edo. Miranda

Humberto Reyes
FONAIAP-MAC
Estación Experimental Caucagua
Caucagua, Edo. Miranda
Venezuela.

México

Luis Siller F.
INIA
Apartado 688-2
México 6, D.F.

U.S.A.

M. Katherine Kellam
Dpt. Plant Pathology
UCR Riverside California
U.S.A.

Purl E. Partello
P.O. Box 991
Little Rock, Arkansas
72203, U.S.A.

George A. Zentmyer
University of California Venezuela
Riverside, California
U.S.A.

SUMMARY

The meeting provided an excellent opportunity for interchange and discussion and should contribute a great deal to increased understanding and control of black pod, with information on the following topics:

Taxonomy

It is evident now that at least four, and possibly five species of Phytophthora can cause black pod of cacao: P. palmivora ("Morphological Form 1"), P. megakarya ("MF 3"), P. capsici type ("MF 4"), P. citrophthora, and P. megasperma (?) a species from Venezuela that needs more study. This provides a striking contrast to the situation as it existed for many years, under which one variable species, P. palmivora, was regarded as the sole cause of black pod.

More detailed taxonomic studies and surveys are needed so that these species can be adequately define and described, and so that more detailed information can be obtained on their distribution and importance.

Epidemiology

Despite the increasing recognition of the fact that the "Phytophthora palmivora" complex can exist in the soil, further information is needed on how the different species survive in the soil and their possible role as pathogens on cacao roots. In as-much as the different species vary in their capability to produce the different spore stages, survival in soil could vary considerably. Dissemination of the pathogens and their role in the development of epidemics could vary greatly with the species. Further detailed studies in this area are urgently needed, as these epidemiological aspects relate directly to control of black pod.

Resistance

Excellent progress has been made in testing for resistance, as evidenced by the reports in the section on resistance. However, there is still a need for uniformity in testing methods in the various research centers around the world that are involved in this phase of research on black pod. Careful comparison and evaluation is needed of methods involving pods, seeds, stems, and of wounded versus nonwounded tissue.

Chemical and Biological Control

In this area, also, particularly in regard to initial screening of test fungicides, further work is needed on uniform methods of comparison. Increasing emphasis is being placed, and undoubtedly will continue to be placed, on the highly effective and selective new organic fungicides. Evaluation of their activity under various field conditions in needed-both in the Americas and Africa.

Also studies on other aspects of control should be intensified. These include: use of organic as well as inorganic fungicides to reduce soil populations of Phytophthora and also if possible to reduce initial infections on pods near the soil, and study of various cultural and biological control measures.

In relation to business discussion of the "Phytophthora palmivora" group, those attending the meeting at CATIE favored keeping the meetings of this group separate from general considerations of cacao disease. The feeling at the Turrialba meeting was that more opportunity for meaningful and more complete discussions would be possible when the meeting only concerned Phytophthora as is the case with the African Group.

The group generally favored holding the next meeting in 1982 (possibly in the period from May to July), with sentiment in favor of a meeting at Itabuna.

This will be discussed further at the International Conference in Colombia in 1982.

G. A. Zentmyer Coordinator,
American Regional Group
Phytophthora palmivora on cacao

TAXONOMY

Chairman: G. A. Zentmyer
University of California
Riverside, California
U.S.A.

In this first session the complicated taxonomic situation in relation to the fungi that can cause black pod of cacao, was summarized and clarified in several presentations. It is now evident that at least four different species of Phytophthora can cause black pod. Following are summaries of the presentations:

1. Morphological Forms of Phytophthora on cacao

T. N. Sreenivasan
Cocoa Research Unit
University of the West Indies
St. Augustine, TRINIDAD, W.I.

Black pod and other diseases of cacao known to be caused by Phytophthora palmivora (Butl) Butler are economically important to all cacao growing countries of the world. The taxonomic position of members belonging to the group of fungi collectively designated P. palmivora was not clear due to reports of parasitism on multiple host plants, creation of strains, forms etc. within the taxon by various workers in the past. Recently considerable advances were made in the field of taxonomy after extensive studies were made of several hundred representative isolates of the pathogen from cacao.

Morphological, cytological, cultural and other charac-teristics were used as taxonomic criteria to reclassify the species of Phytophthora associated with cacao diseases. Three separate species were recognized viz P. palmivora, P. megakarya sp. nov. and a form of P. capsici in the new classification. Each of these species occur in the two (A1 and A2) compatibility types. P. palmivora is cosmopolitan in distribution while P. megakarya and P. capsici are restricted to West Africa and the Western hemisphere countries respectively. The significance of recent reports dealing with taxonomy of Phytophthora is discussed. (Note = the P. capsici type has also been found in Cameroon).

2. Comments on Taxonomy

R. A. Muller
Chief of the Pathology Service of the I.F.C.C., Montpellier, France

The interest shown during last year in the study of cacao pathology has resulted in identification of different species of Phytophthora. Especially the identification of the species P. megakarya in Cameroon and Nigeria constitutes the main results of the research carried out during several years. If one talks only about P. palmivora, one does not understand the differences found among different countries regarding the epidemological scheme as well as the pathological phenomena (attack or absence of attack of organs other than pods), or in the resistance within the same clone of the cacao plant.

Only if one is aware of the presence of different species of Phytophthora the differences can be explained. However, it would be convenient for each country to undertake a careful inventory of the species Phytophthora that affect its cacao plantations, in order to carry out, in a meticulous manner, especially the investigations regarding resistance since each species shows its own behaviour regarding the cacao plant.

One should also be careful not to introduce foreign species of the fungus. One can notice that P. megakarya is the most dangerous species, since it produces the highest levels of pod blackrot. After recent studies carried out in France this species seems to be very specialized to cacao, contrary to the others, and within the cacao plant more specific on pod tissue (BLAHA, IFCC at Montpellier).

3. Species of Phytophthora from Cacao-growing areas of Brazil

Anna María Freire Luna Campelo
CEPEC
Itabuna-Bahía, Brazil

Two thousand four hundred and twenty-five isolates of Phytophthora were obtained from different hosts from cacao-growing-areas of Brazil. One Thousand eight hundred forty isolates were from Bahía, 580 from Espiritu Santo, 4 from Pará, and 1 from Amazonas. Three species of Phytophthora were identified: P. palmivora (MF 1) from leaves, stems, and pods of cacao; P. capsici (MF 4) from pods, rubber branches and soil cultivated with black-pepper; and P. citrophthora* from stems and pods of cacao (Table 1).

The pathogenicity of all three species was demostrated by inoculation test with mycelial discs and zoospore suspensions on unwounded detached cacao pods.

In studies on the sexual compatibility of the isolates, mating types A1 and A2 of P. capsici (MF 4) were identified, but only the A1 mating type was found in Bahia; the A2 mating type of P. palmivora (MF 1) has been found but the A1 mating types has not been detected so far. P. citrophthora did not form antheridia and oogonia when paired with mating types A1 and A2 of P. capsici (MF 4).

The population survey of species of Phytophthora is still in progress but there are indications that P. capsici (MF 4) probably predominates on cacao pods in the cacao-growing areas of Bahia and northeastern Espiritu Santo.

* Identified by M. K. Kellman and G. A. Zentmyer

Table 1. Geographical distribution of *Phytophthora* isolates in cacao-growing areas of Brazil.

Localities		*P. palmivora* (MF1)			*P. capsici* (MF4)			*P. citrophthora*		
		Cacao	Rubber	Black-pepper	Cacao	Rubber	Black-pepper	Cacao	Rubber	Black-pepper
BELEM	(Pa.)						+			
BELMONTE	(Ba.)							+		
BUERAREMA	(Ba.)				+			+		
CAMACA	(Ba.)	+			+			+		
CANAVIEIRAS	(Ba.)				+			+		
CASTANHAL	(Pa.)				+					
FLORESTA AZUL	(Ba.)				+					
ILHEUS	(Ba.)	+			+			+		
ITACARE	(Ba.)	+								
ITUBERA	(Ba.)						+			
LINHARES	(E.S.)				+					
MANAUS	(Am.)	+								
MUCURI	(Ba.)				+					
PARAGOMINAS	(Pa.)					+				
SANTO AMARO	(Ba.)	+								
TAPEROA	(Ba.)						+			
UNA	(Ba.)					+	+			
URUCUCA	(Ba.)				+					
VALENCA	(Ba.)						+			

4. Taxonomic Relationships

G. A. Zentmyer
University of California
Riverside, California
U.S.A.

Ilustrations were shown of sporangia of MF4 (P. capsici) isolates from cacao in Brazil, El Salvador, and Cameroon. All have long stalks with some differences in sporangia morphology. The striking differences in cultural appearance between MF4 isolates and MF1 and MF3 in carrot agar were also illustrated. The sexual stage varies somewhat, in size and shape of antheridia, oogonia, and oospores, as seen in crosses within and between the three species (P. palmivora, P. megakarya and P. capsici).

Studies of protein patterns by polyacrylamide gel electrophoresis showed that each of the three species produce protein bands distinct from the others. Similarities were noted between the MF4 isolates from cacao and the P. capsici type culture. The percentage similarities of protein bands were closer between P. capsici and MF4 than between P. capsici and the other two species (P. Palmivora and P. megakarya, or between P. palmivora and P. megakarya and MF4. Tsao (Univ. of California, Riverside), who has worked extensively on the MF4 isolates from black pepper, feels that there are some substantial differences between some of the MF4's and P. capsici, as originally described. However, of all the described species of Phytophthora, the MF4 types are closer to P. capsici.

EPIDEMIOLOGY

Chairman: T. R. Sreenivasan
Cocoa Research United
University of the West Indies
St. Augustine, Trinidad

1. Resting Propagules of Cacao Phytophthora spp.; Survival in Soil and Production in Host Tissue.

The relative abilities of chlamydospores of Phytophthora palmivora and P. citrophthora to survive in artificially infested soils are being evaluated. After 24 hr in a natural cacao soil infested with chlamydospores of either species, the number of recoverable propagules increased to at least twice that the initial infestation level. The number of propagules then gradually declined over a period of 5 weeks. This may reflect an initial release of zoospores from sporangia produced, as some chlamydospores germinate in the soil.

Several Brazilian isolates were evaluated with respect to oospore production in pod tissue and in agar culture. A cross between capsici (A1) x palmivora (A2) yielded abundant oospores in squares of pod tissue and in agar culture after 7 days. A cross of capsici (A1) x capsici (A2) yielded oospores in pod squares after 14 days but very few oospores were observed in unwounded pod tissue inoculated with capsici (A1) x capsici (A2).

In the field, oospores with amphigynous antheridia, believed to be Phytophthora, were found in broken, blackened, descomposed pod tissue taken from a husk pile in an experimental area of Centro de Pesquisas do Cacau (CEPEC), Bahía, Brazil. P. capsici was isolated from the pod in which the oospores were found.

In CEPEC, soils were collected from four cacao areas and one forest area. Surface litter was removed and soil was collected from an area within 20 cm around the base of each tree and to a depth of 10 cm. Using the pod core baiting technique Phytophthora spp. was recovered from each cacao site, but not from the area not planted with cacao.

2. Isolation of Phytophthora citrophthora from Diseased Cacao in Brazil

M. K. Kellam
University of California
Riverside, California
U.S.A.

Phytophthora isolates from diseased cacao fruits, trunk cankers, and seedling stems in Brazil have been identified as Phytophthora citrophthora. Six isolates from southern Bahía and four isolates from Sao Paulo have been identified as this species. Abundant chlamydospores form after 5 days in carrot agar and subsurface, noncaducous sporangia form after 6 to 7 days. Sporangia are large (up to 70 M m in length) and irregularly shaped, with a length/breadth ratio of 1.6. Frequently sporangia with 2 papillae are observed. No sex organs were observed in pairings with Al or A2 isolates of P. capsici or P. palmivora. A dense aerial mycelium with chlamydospores and sporangia embedded in the hyphal mat was observed on surfaces of inoculated detached 'comun' pods. The relative importance of this species as a cacao pathogen in Brazil is unknown.

3. Survival on soil

R. A. Muller
Chief of the Pathology Service of the I.F.C.C.
Montpellier, France

In an epidemiological scheme specially elaborated for Cameroon for P. megakarya the soil is the preferred site for the conservation of P. megakarya and the infection develops in an ascending way, starting with the lowest pods.

One does not find this survival system in countries where only P. palmivora exists, since this species can equally be conserved in the flower cushions and the bark.

The problem of the mode of conservation of the pathogen in the soil needs to be determinated; this could be done since the abundance of the fungus changes with the season. It is the question of a static conservation (the survival structures falling to the soil), and a conservation as an active form, saprothytic or parasitic on the roots.

4. Soil Phase of Phytophthora palmivora

G. A. Zentmyer
University of California
Riverside, California
U.S.A.

It has been known for many years, since the work of Dade in 1927, that Phytophthora palmivora occurs in soil and can be isolated from soil. This has been confirmed many times, especially in the past 20 years in research in West Africa, the Americas, and the South Pacific Regions. Turner showed in the 1960's in Nigeria that P. palmivora was pathogenic to cacao roots. I also showed that, under ideal conditions for infection (hydropon system), P. palmivora could cause extensive rotting of cacao roots.

The work of the British team in Nigeria over a six year period was briefly summarized. It was recognized in this study that the soil is an important reservoir of inoculum. Apparently the two species in Nigeria (P. megakarya and P. palmivora) have an active phase in the soil; this is especially true to P. megakarya. Baiting soil with cacao pods resulted in good recovery of Phytophthora, especially during the rainy season.

When soil was artificially infested with P. megakarya, the fungus was recovered for periods of up to 18 months, while P. palmivora survived only up to 10 months. Unfortunately in this entire project no information was obtained as to the mechanism of survival in the soil, whether by chlamydospores, oospores in roots, or by some other mechanism.

In tracing the development of an epidemic, early infections were found near the ground (as a result of rain-splash or from ant tents). Approximately 70 precent of subsequent infections in the canopy were found to result from splash from infected pods. Other sources included soil and litter, flower cushions, and ant tents, with also a substantial percentage listed as "no obvious source".

Some data were obtained in the British project indicating that ant control with Dieldrin could reduce black pod incidence. Soil treatments with the fungicides Terrazole and Ridomil gave some promise for control. Data were also obtained on the influence of weather.

RESISTANCE

Chairman: J. Lawrence *
Divisao de Fitopatología
CEPEC
Itabuna, Brazil

1. Progress of the program on resistance of cacao to Phytophthora spp. causing Phytophthora pod rot in Bahía, Brazíl

Jeremy S. Lawrence and
E. D. M. N. Luz
Divisao de Fitopatología
CEPLAC - CEPEC
Itabuna, Bahía, Brazil

The replacement of susceptible cacao types by material possessing durable, race non-specific resistance to Phytophthotra spp., in conjunction with other, reliable preventive control measures, should provide the ideal, long-term solution for combating Phytophthora pod rot. However, before the use of resistant cacao types can be confidently and successfully adopted as a control measure, there is a need to search for more resistant material and to further study the nature and inheritance of resistance to Phytophthora spp. so that breeding programmes can be planned on a more sound and rational basis. Consequently, the principal aims of the present programme at CEPEC are:

1) to continue the search for resistant material

2) to study the inheritance of resistance by F1 progenies

3) to examine the possibility that surface leachates may play a role in the resistance or susceptibility of pods to Phytophthora spp.

* On a Technical Cooperation assignment with the United Kingdon Overseas Development Administration

Evaluation of cultivars for resistance

Cultivars in the CEPEC germplasm collection are being screened with a view to identifying resistant parent material for use in CEPEC breeding programmes. A number of cultivars identified as more resistant were previously reported from Bahía: 'Scavina 6' and '12'; 'UF 613'; 'Catongo' and the Catongo types 'SIC 801', '802', '806', '823', '848', '864' and '891'; 'CAS 1' and '2'; 'EEG 8'; 'PA 121' and '169'; 'TSA 792'; 'TSH 516', '565' and '774'. However, these evaluations were carried out before the discovery that more than one Phytophthora sp. may infect cacao in Bahía, so that true identity of the fungus used in screening was unknown.

Many different test methods have been used by workers in Brazil and elsewhere to evaluate resistance to cacao Phytophthora spp. A previous comparative evaluation of most of these methods showed that the most reliable and consistent technique for testing fruiting cultivars was point-inoculation with standard zoospore suspension of unwounded attached pods, while the most satisfactory methods for assessing hybrid progenies were considered to be inoculation with zoospore suspension of pre-germinated seeds and inoculation with mycelial-discs of seedling-stems. These methods have been adopted in the present work at CEPEC, to compare P. palmivora and P. capsici.

Five isolates each of P. palmivora and P. capsici were inoculated onto fully-developed but unripe detached pods of 'UF-296'. Lesion diameters of P. palmivora were about twice as large as those of P. capsici (Table 1)

Selected isolates were used to inoculate seeds from the crosses 'Catongo x Scavina 6', 'Catongo x ICS-1', 'Catongo x UF - 677' and 'Comun' selfed. Inoculation with P. palmivora consistently resulted in lower seedling emergence than with P. capsici (Table 2).

A similar response was obtained when stems of 'Comun' seedlings were inoculated, P. palmivora producing lesion areas three to four times larger than those of P. capsici (Table 3).

When fully-developed but unripe attached pods of 19 cultivars were inoculated, percentage infection on each cultivar was similar with both species (Table 4), suggesting that there was no difference in the infective potential of their zoospores. However, inoculations with P. palmivora consistently resulted in larger lesion diameters on all cultivars, except 'CC 41'.

Of the cultivars tested to date, 'EET 59', 'EET 376', 'UF 713' and 'Scavina 6' showed most resistance to both Phytophthora spp. (Tables 4 & 5). So far, insufficient strictly comparative testing has been carried out to determine whether cultivars always present the same resistant or susceptible reaction to infection by P. palmivora and P. capsici, but results presented in Table 5 suggest that this might be so with some cultivars.

All inoculation tests clearly showed that P. palmivora was more virulent than P. capsici. However, because P. capsici is probably the predominant species on cacao pods in Bahía, it was concluded that future routine screening must be carried out with both species.

Studies on the inheritance of resistance

Results obtained so far from diallele crosses suggest limitations in the test methods employed, and a reappraisal of the methodology for evaluating resistance of hybrids progenies is required. In comparison to results with seed inoculations, however, results with the seedling stem inoculation method were generally in closer agreement to those expected from reactions of the parent cultivars to pod infection.

The role of pod leachates in resistance to Phytophthora spp.

This study is designed to determine whether surface leachates are qualitatively and/or quantitatively associated with resistance or susceptibility of cacao pods at different ages from known resistant and susceptible cultivars. The existense of such an association could lead to the development of a precise and convenient means of screening for resistance which would obviate the use of the pathogens.

Replicate leachate samples have been collected from the surfaces of wetted pods at 2, 3, 4 and 5 months of age and when fully mature from a selection of cultivars whose responses to infection range from resistant ('EET 59', 'EET 376') to intermediate ('PA 150') and susceptible ('SIAL 325'). Types and amounts of sugars, amino acids, phenols and other substances are being determined by Dr. Alex Lopez of the Bioengineering Division of CEPEC.

Table 1. Percentage of infected pods and lesion diameter of unwounded detached 'UF 296' pods point-inoculated with zoospore suspensions of *P. palmivora* and *P. capsici*.

	Isolate	Compatibility type	% successful infection +	Av. lesion diam. (cm) 5 days after inoculation +1
P. palmivora	P. 17	A2	90	6.0
	P. 20	A2	100	5.8
	P. 26	A2	95	6.3
	P. 50	unknown	95	5.6
	P. 63	A2	100	6.1
				Lsd (0.05) = 1.37
P. capsici	P. 12	A1	100	2.9
	P. 23	A1	95	3.2
	From pod CEPEC	unknown	100	3.0
	From pod CEPEC	unknown	85	2.7
	From pod CEPEC	unknown	90	2.5
				Lsd (0.05) = 0.94

+ 2 replicate tests, 10 pods/isolate/test

Analyses are still in progress but the following sugars have been identified in leachates from various pod ages of the cultivars indicated;

raffinose	'EET 376', 'PA 150', 'SIAL 325'
maltose	'EET 376', 'PA 150', 'SIAL 325'
sucrose	all cultivars
glucose	'EET 376', 'PA 150', 'SIAL 325'
mannose	'EET 59', 'PA 150'
fructose	all cultivars
xylose	'EET 376'
rhamnose	all cultivars

These results are qualitative and as yet no indication as to relative amounts of sugars between pod ages and between cultivars has been obtained.

Table 2 Seedling emegence of pre-germinated seeds inoculated with zoospore suspensions of P. palmivora and P. capsici

Cacao Material (100 seeds inoculated, 40 untreated)	Seedling emergence as % of untreated control 1 month after inoculation					
	P. palmivora			P.capsici		
Test	1	2	3	1	2	3
Catongo x SCA 6	58.3	41	47	99	99	93.3
Catongo x ICS 1	51	39	55	98	96	98.2
Catongo x UF 677	58.5	44	61.9	98.8	91	100
Comun selfed	80	41	62.2	100	100	100

Table 3. Lesion area of 'Comun' seedling-stems inoculated with mycelial- agar discs of P. palmivora and P. capsici.

Isolates		Av. lesion area (cm2) 18 days after inoculation	
		Test 1 +	Test 2 *
P. palmivora	P. 26	1.4	5.5
	P. 20	1.5	
P. capsici	P. 23	0.5	1.3
	P. 12	0.5	
		lsd (0.01) = 0.5	

+ 20 replicate 5 - month - old seedlings per isolate

* 12 replicate 10 - month - old seedlings per isolate

Table 4. Percentage of infected pods and lesion diameter of unwounded attached point-inoculated with zoospore suspensions of *P. palmivora* and *P. capsici*.

Cultivar (≥ 10 replicate pods per sp. per test)	*P. palmivora* % successful infection			*P. palmivora* av. lesion diam. (cm)+			*P. capsici* % successful infection			*P. capsici* av. lesion diam. (cm)+		
Replicate Test	1	2	3	1	2	3	1	2	3	1	2	3
EET 59	65	41	89	1.5	0.7	0.8	65	40	81	0.7	0.5	0.5
EET-376	19	35		4.4	4.9		0	40		0	0.3	
UF 713	45	95		1.0	1.4		45	90		0.6	0.7	
Scavina 6	60			1.6			55			0.6		
'Catongo' (unspecified)	85			1.3			62			0.3		
CEPEC 1 ('Catongo')	100			3.5			95			1.4		
UF 613	60			2.0			55			0.9		
ICS I	70			2.1			65			1.6		
PA 150	65			2.5			75			1.7		
UF 650	100	100		1.4	3.1		82	59		1.2	2.5	
UF 654	91	92		1.6	1.2		95	79		1.1	0.6	
CC 41	100	65	100	1.4	0.6	3.4	90	90	83	3.8	3.8	2.2
UF 667	70	73		4.8	4.0		80	65		0.7	1.0	
UF 677	75			4.7			60			1.2		
UF 221	80	90		4.4	5.1		80	65		3.0	2.9	
UF 296	65	77	89	5.7	7.5	7.9	65	73		5.0	3.4	
UF 668	100	100		1.2	3.4		86	96		1.0	1.6	
R 2	75			1.2			65			0.7		
R 52	80			2.3			70			0.8		

+ Measured 11 days after Inoculation

Table 5. Percentage of infection and lesion diameter of parent cultivars used in reciprocal crosses to point-inoculation of unwounded attached pods with zoospore suspensions of *P. palmivora* and *P capsici*.+

Cultivar (10 replicate pods per Species)	*P. palmivora*		*P. capsici*	
	% successful infection	av. lesion diam. (cm)*	% successful infection	av. lesion diam. (cm)*
EET 59	80	1.0	85	0.6
EET 376	40	3.8	35	0.4
Scavina 6	55	1.7	50	0.7
CEPEC 1 (Catongo)	100	3.0	95	1.3
PA 150	85	2.7	90	1.7
ICS-1	70	2.8	75	1.7
UF 221	90	4.0	80	1.9
SIAL 325	95	4.6	90	2.0

+ Sum of 2 tests

* Measured when av. lesion diam. on the standard susceptible cultivar, UF 296, included in each test attained 6 cm.

2. Resistance studies

R. A. Muller
Chief of the Pathology Service of the I.F.C.C.
Montpellier, France

In order to be effective, the research on resistant varieties should be based on precocious tests regarding the susceptibility of organs other than pods, in other words of very young plants. This will permit rapid study of the successive generation of cacao trees.

But before anything else we should clarify the precision of the precocious tests to be carried out. The test should be verified with the pathogenic species under study, in comparison to the one for which selection is made to determine if the reactions to the infection of the organs chosen for the tests (roots, shoots or leaves) are representative of and correlate with the reaction of the infection of the pods. We do not know if the tests useful for P. palmivora can also be employed for P. megakarya which is more specialized and also more aggressive.

The host parasite relations of the pair: cacao tree-Phytophthora appear to be of a `Horizontal' nature but polygenic, which, without doubt, explains why, when crossing two resistant types of cacao, one finds descendents with a whole array of susceptibility.

3. Cacao varietal resistance to Phytophthora palmivora and its inheritance at Turrialba, Costa Rica

G. A. Enríquez and L. G. Salazar
CATIE
Turrialba, Costa Rica

In preliminary inoculation trials, unwounded, detached pods of 'UF-613' (a cultivar with fields resistance to Phytophthora palmivora) and of 'UF-677' (a susceptible cultivar) were inoculated with zoospore suspension of P. palmivora. These tests gave results similar to the field reaction. However, when wounded pods were inoculated, 'UF-613', was more susceptible than 'UF-677'.

To further evaluate resistance to P. palmivora, unwounded detached pods of 115 clones were inoculated with zoospore suspension. Lesions were measured in six days.

From these extensive tests, three new resistant cultivars were identified, and these will be included in the resistance program. These are: 'P-15', a M[illegible]an Criollo type;'CC-52'and 'CC-132', Trinidadian types.

In field studies of infection with natural inoculation at Turrialba,Costa Rica in 1976-78, several significant results were obtained, as follows:

Parental trees of 'SCA-6' and 'Pound-7' showed more resistance than their progeny. 'UF-676', was more susceptible than 'SCA-6', and the cross 'SCA-6 x UF-676' was slightly more resistant than the mother line 'SCA-6'.

In another comparison 'SCA-6' was more resistant than 'UF-613', and the progeny of crosses with these two clones were less infected when 'SCA-6' was the mother line. In comparisons of 'UF-613','UF-29', and progeny from their crosses, 'UF-613' was more resistant than 'UF-29', and the progeny from 'UF-29 x UF-613' were more resistant than their parents. In another field study 'Catongo' was less resistant than 'UF-676' and much less resistant than 'SCA-6' and 'Pound-7'. The progeny of crosses using 'Catongo' and 'UF-676' were more resistant when 'Catongo' was the mother tree.

Some cultivars were classified differently in these tests than in previous reports, for example, 'UF-613, did not showed as high resistance as was previously indicated. All of the crosses with 'SCA-6' had resistant progeny, especially when 'SCA-6' was the mother tree. When 'SCA-6' was crossed with 'Pound-7', another cultivar with resistance in previous tests, the progeny were more susceptible than either parent.

Previous inheritance studies of natural resistance to P. palmivora indicated that there were few genes and some dominance in the F1. This study suggests several genes with more additive than dominant action. The lack of an F2 population prohibits verification of this observation.

4. Stem inoculation tests

G. A. Zentmyer
University of California
Riverside, California
U. S. A.

The stem inoculation method for testing resistance was briefly described. In this method cacao seedlings growing in the greenhouse are used. It has the advantage of obtaining quantitative data, on canker area, but the disadvantage of a system involving wounding. Results were noted with stem inoculation tests that correlated well with field resistance.

5. Resistance to Colletotrichum gloeosporioides on cacao leaves

L. Muller
CATIE
Turrialba, Costa Rica

Resistance occur to Colletotrichum in some cacao cultivars clones, notably 'SCA-12' while 'UF-221' is very susceptible. Some relation was noted between loss of potassium from leaves and resistance, with 'SCA-12' losing potassium much less rapidly than 'UF-221'. Heavy potassium fertilization increased resistance to Colletotrichum in susceptible clones, especially on 'SCA-12'. The same results may be associated with P. palmivora.

CHEMICAL AND BIOLOGICAL CONTROL

Chairman: Lilian Capriles de Reyes
Estación Experimental Caucagua
Caucagua, Edo. Miranda
Venezuela

1. Chemical control

R. A. Muller
Chief of the Pathology Service of the I.F.C.C.
Montpellier, France

There is a need, because of the very heterogeneous nature of the cacao plant, which is a source of a high natural variability, for experimental methods especially adapted to these conditions, since the latter are the reason why the classical experimental schemes are not very good or not at all useful.

In regard to the research on preventive fungicides a `miniaturized pair' method, is proposed which eliminates the majority of the causes of natural variation.

In regard to the research on systemic fungicides, in order to avoid the testing in the field of numerous formulations, it is proposed to carry out in the laboratory a preliminary trial with young cacao plants.

2. Control of cacao black pod disease with copper fungicides

J. M. de Figueiredo and
W. T. Lellis
CEPLAC-CEPEC
Itabuna, Bahía
Brazil

A fungicide screening experiment to investigate the efficacy of copper fungicides for the control of cacao black pod disease (Phytophthora palmivora) was installed on a cacao farm where a high level of disease existed. Three copper oxychloride formulations: Gafex(R), Recop(R), and Funguran Green(R), and Kocide 6 F(R), a hydroxide formulation were compared with a cuprous oxide, Copper Sandoz(R), as standard formulation. In all copper formulations a sticker, Ag-Bem(R) at the rate of 0.5% was incorporated. Five applications were accomplished during the year at a dose of 4 g of a.i. per plant in a volume of 140 l in water per ha. An analysis of the results (Table 1) suggested that Kocide 6 F(R) and Gafex(R) were more efficient, in terms of better percentage of disease control, and also superior to the other fungicides. All the fungicides tested showed good control of disease when compared to unsprayed plots.

Table 1.Percentage of diseased pods in treated small letters and untreated plots.

Treatments	Replications				Total	Mean
	I	II	III	IV		
Kocide 6F	4.80	4.09	9.63	7.71	26.23	6.56 a
Gafex	9.28	6.55	13.56	7.04	36.43	9.11 a
Cobre Sandoz	7.71	4.33	15.12	12.52	39.69	9.92 ab
Funguran Green	23.24	9.28	12.11	11.46	62.11	15.55 b
Recop	17.85	8.72	18.81	16.85	62.23	15.56 b
Prophylactic control	42.71	31.82	46.09	35.18	155.80	38.95 c

C.V. = 13.80%

D.M.S. a 5% = 5.71

3. The control of black pod of cacao with copper fungicides sprayed in high and low volumes

J. M. de Figueiredo and
W. T. Lellis
CEPLAC-CEPEC
Itabuna, Bahía
Brazil

Over a period of two years, during the months of May to August, experiments were undertaken on cacao farms considered as focal black pod disease areas, to test the efficiency of new fungicide formulations.

Two oil formulations of copper oxychloride were tested at low spray volume. The metallic copper contents of Duriac (R) and Kauritol (R) were 17% and 25% respectively. At high spray volumes, another formulations of copper oxychloride, Coprantol 300 FW(R) with 30% metallic copper was used. These fungicides were tested against standard copper oxychloride, Oxicloreto Sandoz(R) and cuprous oxide, Cobre Sandoz(R), formulations each with 50% metallic copper. The copper oxychloride was applied in low and high volume whereas the latter at high volume.

Analysis of the results, were based on number of healthy and diseased pods on each harvest. The results, indicated that Duriac(R), Kauriton(R) and Coprantol 300 FW(R), were efficent in the control of the disease as the standard Oxicloreto Sandoz(R) and Cobre Sandoz(R) applied at low ahd high volume respectively and were superior to Oxicloreto Sandoz(R) applied at high volume. The new formulations in terms of quantity of metallic copper/tree was 50% less then that used in high volume applications with a wettable powder formulations (Tables 1 and 2).

Table 1. Incidence of black pod disease on cacao pods treated with different fungicides (Arc Sen $\sqrt{\%}$). Bahia, Brazil, 1978.

Treatments	Replications				Total	$\bar{M}$	Tukey 5% = 4.27
	I	II	III	IV			C.V. = 20.41
Duriac - LV*	11.39	10.14	11.09	6.29	38.91	9.72	a
Kauritol - LV	5.56	7.49	12.79	3.93	29.77	7.44	a
Coprantol - HV**	4.33	7.49	11.39	4.01	27.22	6.80	a
Oxicloreto Sandoz - LV	6.80	9.28	9.63	6.80	32.51	8.13	a
Cobre Sandoz - HV	4.33	7.04	7.92	7.04	26.33	6.58	a
P.C. ***	10.31	19.46	25.03	13.94	68.74	17.18	b

*LV = Low volume

**HV = High volume

***PC = Prophylactic control

Table 2. Incidence of black pod disease on cacao trees treated with different fungicides (Arc Sen $\sqrt{\%}$). Bahia, Brazil, 1979.

Treatments	Replications				Total	$\bar{M}$	Tukey 5% = 10.53
	I	II	III	IV			C.V. = 28%
Duriac - LV*	10.6	7.5	9.6	11.2	38.9	9.7	a
Kauritol - LV	14.2	16.2	10.3	20.1	60.8	15.2	a
Coprantol - HV**	8.9	18.7	20.8	10.6	59.6	14.7	a
Oxicloreto Sandoz - LV	12.0	13.4	12.4	8.7	46.5	11.6	a
Oxicloreto Sandoz - HV	27.5	20.4	10.5	15.8	74.2	18.5	ab
P.C ***	28.2	21.0	30.7	31.2	111.1	27.8	b

*LV = Low volume

HV = High volume

= Prophylactic control

4. Competition of organic fungicides in the control of black pod disease of cacao

J. M. Figueiredo and
W. T. Lellis
CEPLAC-CEPEC
Itabuna, Bahía
Brazil

To verify the efficacy of organic fungicides such as Captan(R) 50% N(trichloromethylthio)-4- cychlohexane- 1,2- dicar-boximide); Terrazole(R) 90% (5 - ethoxy -3- (trichloromethyl - 1,2,4 - thiadiazole and Melprex(R) 65% (acetato of N-dodecyl - guanidine) were compared with CEPEC Standard copper fungicide, Cobre Sandoz(R) 50% metallic copper. The fungicides were applied in high volume at following concentrations of the product: Cobre Sandoz - 4%, Captan - 4%, Terrazole - 0.2% and Melprex - 3%. A sticker Ag-Bem at the concentration of 0.5% was added to all fungicide formulations. The sprayings were carried out at monthly intervals during the period of March to August. The black pod evaluation was done by counting harvested mature healthy, diseased and green diseased pods per treatment and the results were presented in percentage of disease incidence.

The experiment was instaled at EMARC area (Baixa Fria) considered as "Foco" of black pod. The experimental design was randomized plots with 5 treatments and 5 replications. Each plot had 30 cacao trees and only 12 trees were used for black pod evaluation. For statistical analysis the percentage of black pod incidence was transformed in Arc sen V %.

The results of the Table 1 showed that there was no statistical difference among fungicides in relation to their efficacy in the control of black pod disease.

Table 1. Incidence of black pod on cacao trees treated with fungicides.

Treatments	Replications					Total	$\overline{M}$
	I	II	III	IV	V		
Captan	14.8	16.0	26.0	32.9	38.8	128.5	25.7 a
Cobre Sandoz	27.6	21.1	16.3	21.1	21.1	107.2	21.4 a
Melprex	26.5	20.8	30.0	26.2	25.9	129.4	25.9 a
Terrazole	21.7	35.5	17.9	22.1	27.7	124.9	25.0 a
Check	32.8	39.1	44.9	39.2	45.5	201.5	40.3 b
Total	123.4	132.5	135.1	141.5	159	691.5	27.7

'. = 23%

.S. a 5% = 12,81

5. Fungicidal spraying and dusting in the control of cacao black pod disease

W. T. Lellis and J. M. de Figueiredo
CEPLAC-CEPEC
Itabuna, Bahía
Brazil

In the selection of a certain type of formulation, disease aspects as well as technical and economical factors have to be taken into consideration.

The use of dusts for disease and pest control is an ancient practice which requires very simple equipments for applications.

With the view to establish more economical options for small growers the efficiency of dusting in the control of the black pod disease was investigated. Two copper formulations were used: Cobre Sandoz(R) dry powder with 9% of metallic copper and Copper Sandoz (R) WP 50% of metallic copper. The treatments were: A - Dusting at 30 days intervals in the months of April, May, June and July. B - Dusting at 15 days intervals in the months of April and June and spraying at 30 days intervals in the months of May and July. C- Spraying in April and dusting at 15 days intervals in the months of May, June and July. D - Spraying at 30 days intervals in the months of April, May, June and July. E - Prophylactic control. Three grams of active ingredients were applied per tree in all treatments. (see Table 1)

The experiment design was randomized blocks with 5 treatments and 4 replications. The evaluations were made by counting diseased mature and immature pods and healthy mature pods. Data were transformed in arc sen V%, and the analysis of the results showed no differences among the systems of fungicidal treatments.

Table 1. Black pod incidence on cacao treated with fungicides. Transformed in Arc Sen $\sqrt{\%}$.

Treatments	Replications				Total	Mean
	I	II	III	IV		
A	5.15	11.39	3.63	6.29	26.47	6.62 a
B	7.27	4.09	7.71	7.04	26.11	6.53 a
C	6.02	7.74	7.27	4.90	25.93	6.49 a
D	4.69	10.31	11.68	15.12	41.80	10.45 a
E	34.20	38.65	38.12	32.33	143.30	35.83 b

C.V. = 22,78

Tukey = 6,77

6. Aerial spraying for the control of cacao black pod disease in Bahía, Brazil

A. Ram and A. G. Medeiros
CEPLAC-CEPEC
Itabuna, Bahía
Brazil

The black pod disease of cacao (Theobroma cacao L.) caused by fungus Phytophthora palmivora (Butl.) Butl. is responsible for an annual loss of 25-30% in cacao production in the south of Bahía, Brazíl. The conventional system of spray application is with the use of motorized knapsack mist blowers. This control measure has certain disadvantages, namely, it is a time consuming operation, involving considerable repair and maintenance of equipment, and specilized labour.

This experiment was conducted to compare the technical efficiency of aerial spraying using a helicopter, with the conventional spraying. The experiment was carried out in two consecutive years. In 1978, it constituted seven trials located in separate municipalities whereas in 1979 except for one site the same localities were used. The experimental layout was a randomized block design. The first year trial had three treatments with seven replications whilst in the second year there were five treatments with six replications. The area of each plot per treatment was 11,200 m2 containing approximately 672 cacao trees.

In the first year, at each site, three treatments were compared: 1) aerial spraying; 2) ground spraying and 3) unsprayed control. Cuprous oxicide was used in both aerial (Cobre Sandoz - 6.4 kg; Ag-Bem (sticker) - 0.5 l. Aterbane (surfactant) - 1.0 l and water to complete 40 l/ha), as well as in ground spraying (Cobre Sandoz - 6.4 kg; Ag-Bem - 0.5 l, Aterbane - 1.0 l and water to complete 12 l/ha). In second year, cuprous oxide and copper oxychloride (emulsified in oil) were used in both spray systems, for aerial: Cobre Sandoz - 4.8 kg, Ag-Bem 0.5 l , Aterbane - 1.0 l. and water to complete 20 l/ha; and Kauritol - 6.8 l, Ag-Bem - 0.5 l and water to complete 20 l/ha; and for ground: Cobre Sandoz - 4.8 kg, Ag-Bem - 0.5 l and water to complete 120 l/ha; and Kauritol - 6.8 l, Ag-Bem - 0.5 l and water to complete 120 l/ha. The normal spray schedule was applied.

In the first two years of the experiment, no significant difference existed in disease control between aerial spraying and conventional ground spraying. The results suggest that aerial spraying is a feasible substitute for conventional spraying in cacao for control of black pod (Table 1 and 2).

Table 1. Comparison between aerial and ground spraying in the control of cacao black pod disease. Accumulated percentage of black pod incidence during a period of 120 days transformed in Arc Sen $\sqrt{\%}$. 1978.

Treatments	Experimental Areas (Replications)							Total	*Average	Significance
	Camaca I	Arataca II	Jucari III	Ibicaraí IV	Itabuna V	Buerarema VI	Urucuca VII		% of BP	Tukey C.V.= 14% D.M.S. a 5%= 8.02
Aerial Spraying	30.98	42.02	22.46	31.24	18.72	15.45	39.17	200.04	28.58	a
Ground Spraying	40.28	32.33	21.97	25.99	15.68	28.04	33.77	198.06	28.29	a
Check	43.22	50.94	34.33	29.67	39.70	35.12	49.43	282.41	40.34	b

Table 2. Comparison between aerial and ground sproyings in the control of cacao black pod disease. Accumulated percentage of black pod incidence during a period of 150 days transformed in Arc Sen $\sqrt{\%}$. 1979.

Treatments		Experimental Areas (Replications)						Total	Average	Significance Tukey
		Camaca I	Arataca II	Jucari III	Ibicaraí IV	Itabuna V	Urucuca VI		% of BP	C.V.=28.07% D.M.S a 5% =2.85
Aerial Spraying	Kauritol	7.49	8.13	12.66	10.94	7.27	9.81	56.30	9.38	a
	C. Sandoz	11.39	8.33	9.10	13.44	6.55	16.95	65.76	10.96	a
Ground Spraying	Kauritol	5.44	7.27	6.02	10.78	5.13	15.68	50.32	8.38	a
	C. Sandoz	4.80	7.27	6.55	11.24	6.55	19.19	55.60	9.26	a
	Check	20.53	22.55	27.83	13.81	16.00	30.26	130.98	21.83	b

7. Fungicides for controlling fungi that attack cacao pods

Ing. Lilliam C. de Reyes and
C. Marín
Estación Experimental de Caucagua
Caucagua, Edo. Aragua
Venezuela

Cacao grows in a warm, humid climate. Its micro-climate favors the development of harmful pathogens, among them, P. palmivora, which attacks both the flower cushions and fruits, as well as the young shoots; the damage it causes amounts to about 30% loss of the crop.

Agronomic and preventive measurements are usually taken in commercial plantations to reduce crop losses, but in plantations with hybrids of potentially high productivity, it is necessary to use chemical sprays in order for the plants to show their full potential.

For the experiment, pods were inoculated in the laboratory and placed in plastic boxes simulating a humid chamber. A small circular disc cut from a pod was replaced with a disc from a fungus culture or sprayed with inoculum according with the test.

Chemical sprays were applied before and after the inoculation.

The effectiveness of the spray is measured by the size of the area affected.

In the field, pods were inoculated with the fungus and then covered with polyethylene to avoid washing during the same day. Morphological Form-1 (MF-1) of the pathogen was used for the inoculation, since it is the most widespread in the area.

Table 1 shows the chemical used, their common names and the dosage rates.

Table 2, summarizes the results obtained in the infected area of the pod, 2 days after treating with the fungus on both wounded and unwounded pods.

In some cultivars it was observed that the infected area was larger than expected. The unwounded pods, as would be expected, showed much less infection. Five of the products tested gave good protection.

A comparative study was made of the best fungicides, by inoculating pods in three fields as explained above. The results obtained are reported in Table 3.

The differences between the treatments were highly significant. Ridomil showed rather outstanding results.

Another trial was made with Ridomil, inoculating wounded and unwounded pods of the cultivar `IMC-67'. The results of the affected area are summarized in Table 4.

An obvious preventive effect of Ridomil was noted.

CONCLUSIONS AND RECOMMENDATIONS

1. Inoculations made in the laboratory are reliable for a 15 day period, while those made in the field are more precise and could be used for many more days.
2. The fungicides Ridomil, Prestan-60, Pelt-44 and Kocide are effective for controlling Phytophthora palmivora.
3. In addition it was observed that the prolonged and indiscriminate use of Ridomil in the field can cause problems with the organisms which are not affected by it.
4. More research is needed on formulations, mode of action, doses, frequency of application, etc. Also work is needed on the practical and economic use in larger plots at the producer's level.

Table 1. Chemical composition and doses of the products used in the control of black pod disease. Caucagua, Venezuela. 1979.

Products	Chemical composition	Doses g/l
Peltar	Methylthiophanate	3.5
Tri-Miltox Forte	Copper carbonate, Copper oxychloride, Copper sulfate	1.0
Urea	Nitrogen	2
Ridomil	Acylalanine	1
Calixin	N-Tridecyl-2,6-dimethylmerpholine	3
Tecto	2-(4-Thiazolyl) benzimidazole	5
Pelt-44	Methylthiophanate	1
Polioxin	3, ethylidene - L - azetidine	
	2- Carboxylic acid	1
Brestan-60	Triphenyltin acetate	1
Cupravit	Copper Oxychloride	5
Benlate	Metyl - 1 (butylcarbamoyl) -2- benzimidazolecarbamate	1
Captan	N-(Thichloromethylthio)-4 cyclohexene- 1,2 dicarboximide	5
Kocide 101	Copper Hydroxide	2
Trimanzone	Manganese ethylbisdithiocarbamate	3
Dithane M-45	Bisdithiocarbamate + Zn	2
Actidione	3- 2-(3,5-Dimethyl-2- Oxocyclohexil) -2- hydroxyethyl glutararnide	5
Triziman-D	Manganese Ethylbisdithiocarbamate	3
Afugan	O,O- drethyl -O- (5-methyl-6- ethoxy-carbonyl- Pyrazolo- 1.5-a(pyrimid-2 yl-) thronophosphate	1
Elosal	Wettable sulfur	5
Fuji-one	di-isopropyl 1,3- dithiolane -2 ylidene-malonate	2.5

Table 2.Infected area,12 days after inoculating cacao pods with P. palmivora, expressed in square centimeters for a total of 2 pods. Cultivar 'Cumbo 177'. 280 square centimeters area to be infected. Caucagua, Venezuela.

Products	Wounded pods	Affected area %	Unwounded pods	Affected area %
Peltar	114	40	36	12
Tri-miltox-forte	78	27	14	5
Urea	103	36	28	10
Ridomil	52	18	1	0.3
Calixin	105	37	32	11
Tecto	154	55	26	9
Pelt-44	109	40	2	0.7
Polioxin	214	76	29	10
Brestan-60	120	42	16	5
Cupravit	194	64	28	10
Benlate	209	74	36	12
Kocide	120	42	2	0.7
Trimanzone	257	91	23	8
Dithane M-45	213	76	26	9
Acti-dione	112	40	12	4
Triziman-D	194	69	6	2
Afugan	366	130	28	10
Elosal	249	89	26	9
Funji-one	468	167	42	15
Captan	113	40	22	7
Control	497	177	56	20

Table 3.Mean (cm2) of infected area permitted by 7 fungicides artificially inoculated pods with P. palmivora in the field. Cultivar 'Cumbo 177'inoculated with discs 5 mm wound. Caucagua,Venezuela.

Treatment	Infected area cm2
Ridomil	20
Kocide	66
Brestan-60	67
Trimiltox	72
Pelt 44	78
Peltar	79
Cupravit	83
Control	96

Table 4. Infected area (cm2) by P. palmivora on cacao pods treated with Ridomil, before and after inoculation. Caucagua, Venezuela, 1979.

Treatment	Infected area cm2 at 6th day	Infected area cm2 at 14th day
Ridomil + fungus	0	2
Ridomil + wound + fungus	0	5
Fungus + Ridomil	6	17
Fungus + wound + Ridomil	16	28
Fungus	11	38
Fungus + wound	87	142