CHEMICAL CONTROL OF

CACAO BLACK POD DISEASE

Report of an International Workshop hold at Itabuna, Bahia - Brasil, in November 11-18, 1977.

Boletim Técnico 63

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I. INTRODUCTION

During a Cacao *Phytophthora* Workshop held at Rothamsted Experimental Station in England in May 1976, it was proposed by Dr. Paulo Alvim of CEPLAC that an international workshop on the chemical control of black pod disease be held in Itabuna in 1977. This proposal grew out of the realization that cacao black pod disease is an international problem and that the development of an effective and efficient method of control requires a coordinate effort of the major research institutions concerned with this problem. Some of the research results in the various countries thus far have been very interesting and have stimulated exchange of information, occasional visits of scientists, and infrequent conferences.

The proposal was accepted and CEPLAC agreed to host this workshop, which was held at the Cacao Research Center of CEPLAC near Itabuna, Bahia, from 16-18 November 1977. The attendance was kept to a minimum and only a few leading scientists actively involved in chemical control of the disease in different countries were invited.

II. PARTICIPANTS

<u>BRAZIL</u>

PAULO DE T. ALVIM	Scientific-Technical Director CEPLAC Caixa Postal 7 45600 Itabuna, Bahia
ARNALDO MEDEIROS	Head, Plant Pathology Division CEPEC/CEPLAC Caixa Postal 7 45600 Itabuna, Bahia

DAVID BUTLER — Climatology Division
Cocoa Research Center
CEPLAC/ODM
Caixa Postal 7
45600 Itabuna, Bahia

ASHA RAM — Plant Pathologist
Department of Plant Pathology
CEPEC/CEPLAC
Caixa Postal 7
45600 Itabuna, Bahia

CLEBER NOVAIS BASTOS — Plant Pathologist
CEPLAC/DEPEA
Caixa Postal 1801
66000 Belém, Pará

ANIBAL A.COUTINHO ARRAZOLA — Plant Pathologist
CEPLAC/DEPEA
Caixa Postal 1801
66000 Belém, Pará

HARRY EVANS — Plant Pathologist
CEPLAC/ODM
DEPEA
Caixa Postal 1801
66000 Belém, Pará

RICARDO TAFANI — Economist
Department of Economy
CEPEC/CEPLAC
Caixa Postal 7
45600 Itabuna, Bahia

ENGLAND

PHILIP H. GREGORY — Consultant on Black Pod Disease
to the Cocoa, Chocolate and
Confectionary Alliance
Rothamsted Experimental Station
Harpenden, Herts AL5 5JQ

FRANCE

RAOUL A. MULLER — Head, Plant Pathology Service
I.F.C.C.
B. P. 5035
34032 Montpellier Cedex

NIGERIA

A. A. ADEBAYO — Asst. Chief Research Officer
Cocoa Research Institute of Nigeria
P.M.B. 5244
Ibadan

M. O. K. ADEGBOLA	Chief Research Officer Cocoa Program Coordinator Cocoa Research Institute of Nigeria P.M.B. 5244 Ibadan
S. A. ADEYEMI	Director Cocoa Research Institute of Nigeria P.M.B. 5244 Ibadan
A. C. MADDISON	Leader, International Black Pod Research Project Cocoa Research Institute of Nigeria P.M.B. 5244 Ibadan
MARTIN R. WARD	International Black Pod Project Cocoa Research Institute of Nigeria Gambari Experimental Station P.M.B. 5244 Ibadan

PAPUA NEW GUINEA

CRIS PRIOR	Research Fellow University of Papua New Guinea Lowlands Agricultural Experimental Station Keravat, East Britain

TRINIDAD AND TOBAGO

T. N. SREENIVASAN	Plant Pathologist Cocoa Research Unit University of West Indies St. Augustine

UNITED STATES

DAVID J. MITCHELL	Professor Department of Plant Pathology University of Florida Gainesville, Florida

III. WORKSHOP PROGRAM

WEDNESDAY, Nov. 16 - Arrival of participants at Ilhéus airport and transfer to Pontal Praia Hotel (Ilhéus)

15:00 - 18:00	-	Country reports on control measures: a. Brazil b. Cameroon c. Nigeria d. Papua New Guinea e. Trinidad and Tobago

THURSDAY, Nov. 17

08:30 - 10:00	-	Visit to experimental sites
10:00 - 12:00	-	Demonstrations on control methods
12:00 - 14:00	-	Lunch break
14:00 - 18:00	-	Reports on current research programs

FRIDAY, Nov. 18

08:00 - 10:00	-	Discussion on future research for increasing efficiency of control methods
10:00 - 12:00	-	Demonstrations on aerial spraying of a cacao plantation
12:00 - 14:00	-	Lunch break
14:00 - 16:00	-	Specific recommendations for future research
16:00 - 17:00	-	Closing session

IV. OPENING SESSION

Dr. Paulo Alvim chaired the workshop. In his opening remarks, he pointed out that the emphasis of the meeting would be on control measures of black pod disease. The areas to be covered included current control measures in practice and current research programs in the participating countries, and recommendations for future research.

Dr. Alvim then introduced Dr. Philip Gregory of Rothamsted Experimental Station. In a brief statement Dr. Gregory pointed out that the pathologist was dealing with more than one morphological type of *Phytophthora palmivora* which exhibit different morphological and behavioral characters. In view of this, black pod control programs that are effective in one part of the world could not be expected to be effective in others. He further emphasized the need for quarantine to prevent the spread of these morphological types.

Following Dr. Gregory's remarks, the participants then reported on the control measures currently being used in their countries.

V. PRESENTATION OF COUNTRY REPORT ON CONTROL OF BLACK POD DISEASE

1. Brazil

In 1977 black pod disease control measures were carried out on 77,000 ha of cacao of a total of 450,000 ha under cultivation in Bahia. It is estimated that loss of cacao production due to black pod disease averages 20-30% annually.

In Bahia, chemical control is concentrated in the areas which have been identified as focal areas of *P. palmivora* infection which represents a total of about 120,000 ha. The use of resistant cacao hybrids is recommended in new plantings, but at present these plantings constitute only a small percentage of the total area under cacao. Nevertheless even with the use of resistant cacao types protective measures will continue to be necessary to obtain satisfactory control of the disease.

Cultural practices recommended to decrease humidity and reduce the amount of inoculum in the plantings include: 1) thinning of shade, 2) maintenance of adequate drainage, 3) pruning of trees, 4) removal of the first infected pods of the season, 5) periodic removal of infected pods during the cropping season, 6) removal of old infected pods, and 7) treatment of husk piles with copper fungicide. In experimental plots, chemical sprays were effective only if applied to the canopy when black pod disease level was less than 1%. Usually, four applications are made in focus areas and two in non-focus areas. Comparisons of high (160 liters/ha) and low volume sprays (12 liters/ha) are being made.

Commercial application of fungicides was first adopted in Bahia in 1967. In 1977 about 960 tons of fungicide were applied and the estimated amount for 1978 is 1800 tons, if the current prices of cocoa continue to make spraying economical.

At present, the most commonly used fungicide in Bahia is cuprous oxide (COPPER SANDOZ) in high volume application with a sticker. Field trials indicated an effective control of about 90% with this fungicide. Copper hydroxide (KOCIDE 101) and copper oxychloride (OXICHLORID SANDOZ) have proven effective when used with a sticker. Low volume applications of cuprous oxide were initially found to be less effective than high volume spray applications. However, recent results have shown that when a sticker and a surfactant (anti-evaporant) are added to the formulation the effectiveness of low volume spray becomes practically the same as that of high volume.

2. Cameroon

Cacao production in Cameroon averages about 100,000 tons annually and it is estimated that losses due to black pod disease are about 50% of the potential crop. On some plantations losses may be as high as 80-90%. There are two rainy periods; March to June and September to November. The flowering peak occurs during the period

April-May, while the main cropping season is in October-December. Trinitarios cacaos are commonly planted and the mean size of the farms is about 1 ha.

Black pod infection initiates from the soil, which is the main inoculum source. The lower pods are infected first, followed by a progressive upward movement of the disease from pod to pod reaching a level of about 2.5 m above the ground by the dry season, July-August. During the second rainy period, all pods may become infected. During the first rainy period, fungicide treatment is restricted to the lower pods, but during the second rainy period all pods are treated. Spraying is carried out using high volume application at 15-day intervals during the rainy periods, resulting in a total of five treatments during each rainy period. To be successful, spraying must be accompanied by prophylactic measures, specifically weekly removal of infected pods during the spray periods and destruction of old infected pods remaining on the trees in the dry periods. Cuprous oxide has been found to be the most effective fungicide, which may give up to 95% control, increasing production by 300-400 kg/ha. This method of control has been found to be more effective in eastern Cameroon where rainfall averages about 1,000 mm annually. In western Cameroon with 3,000 mm of rainfall or higher, black pod disease control is very difficult.

It has been found that the concentration of the fungicide must be adjusted according to the rainfall period. Experience with tetracupric oxychloride (50% Cu) in the Central and Southern regions of Cameroon, where the period of treatments extends over the two rainy seasons, has revealed the following: 1% is the minimum effective concentration during the short rainy season (March-July with a total rainfall of 800 mm), while 1.5% is the most effective concentration for use during the heavy rainy season (September-November with a total rainfall of more than 1 000 mm). Application schedules should be established according to the amount of rainfall but, for practical purposes and considering the cultural level of the farmers, fortnightly applications are recommended.

3. Nigeria

During the past three years, cacao production in Nigeria has averaged about 150,000 tons annually. Losses due to black pod disease are very high, ranging from 30-90%.

Control measures recommended to the farmers involve sanitation and chemical control. Sanitation includes reduction of shade by pruning, removal of infected pods from the farm, removal of mummified pods from the tree and spraying of husk piles with the fungicide being used by the farmer. Treated husk piles may be left on the farm, removed from the farm, or buried.

The fungicides currently adopted are copper based compounds and include Perenox, Copper-Sandoz, Kocide 101, and Bordeaux mixture. Brestan is the only organic compound currently in use. Orthodifolatan, a synthetic metal-free organic compound under test since 1967, has given good results in tests but it is not yet available on the market. However, it has been found that the effectiveness of most of the fungicides is little better than that of Bordeaux misture.

Unfortunately, black pod disease has not been effectively controlled in Nigeria. The principal reason is that most farmers do not carry out the control recommendations of seven applications because either they cannot afford to buy a sufficient quantity of the fungicide or they do not have an adequate supply of labor. A hired laborer now earns between 8 and 10 US$ per day; this is rather expensive for the small farmers. Being illiterate, the farmers do not understand the control recommendations and do not effectively apply them. Other restrainsts include lack of an available source of water on the farm for preparing the fungicides, cost of the spray equipment and unavailability of technical knowledge for its repair and maintenance. As a result there are few sprayers in use in Nigeria. With 40% of the pods developing in the top of the trees, spraying with knapsack sprayers is rather difficult. Today, the small farmers depend more on other crops than on cacao as a source of income.

Before chemicals are recommended to the farmers, they are screened for use in black pod disease control by a microbial assay method or a detached pod technique. Those fungicides that show promise are used in field trials for a period of three years.

Currently, efforts are being directed toward finding resistant types of cacao which might help in reducing losses by the disease.

4. Papua New Guinea

Papua New Guinea has 80,000 ha under cacao. The average yield in the past four years has been 380 kg/ha. Losses due to *Phytophthora* pod rot fluctuate widely both from year to year (because of weather) and over periods of several years (for undetermined reasons). The average loss in the past four years has been about 20%. The current recommendation for chemical control is to spray only individual high yielding and infected trees with 100 g copper oxide or copper oxychloride in 10 liters of water. This is sufficient for one large tree or more than one smaller ones. Recommended machines are hand-operated side pump sprayers, or knapsacks. Frequency of application depends on weather and cropping pattern. Monthly sprays are recommended when the crop is heavy and the disease is severe. Chemical control is barely economic, the main problem being the cost of fungicide.

Resistance has been identified in four clones at the Lowlands Agricultural Experiment Station, Keravat. One of these is agronomically inferior and two are susceptible to vascular-streak dieback. The fourth is one of 13 clones that are distributed to growers as budded plants.

There is communication with growers directly from Keravat,via Department of Primary Industry extension officers, and indirectly via other Departments involved in the cacao industry, such as the Department of Business Development. Field days and training courses are held at Keravat. The government finances research at Keravat, but does not subsidise materials for growers. Open-pollinated seed from selected superior parents is distributed free at the moment, but a charge may be instituted in the future. Community groups wishing to purchase plantations can obtain loans at favourable terms from the Government Development Bank.

Current research on chemical control of black pod involves continuing trials on high volume sprays of cuprous oxide applied to selected trees.

5. Trinidad and Tobago

There are approximately 18,200 ha of cacao in production in Trinidad and Tobago. The average yield of dry cacao per ha during the past 3-4 years has varied from 168 kg to 897 kg. It is estimated that the pod loss to black pod disease averages 15-50%. The current recommendation is to label the individual trees as they become infected and then spray them. The following sprays are being used; Kocide 101, Cupravit Blue, and Perenox. Both high volume manual sprayers and low volume motorized sprayers are used. The frequency of application is from three to six sprays per season and all diseased pods are removed during the period of spraying. The fungicides are applied mainly to the pods and trunks of the cacao trees, very little fungicide being applied to the canopy. The principal problem is climate. In some years, most of the annual rainfall tends to be concentrated in a few days, thereby making it impossible to spray the trees at that time.

At the moment, there are no farms completely planted with resistant cultivars. The evaluation of these plants has been undertaken only recently and in the future this aspect will be considered before the rehabilitation of cacao estates.

Extensive spray trials have been conducted in the past at several locations using different kinds of fungicides. However, morphological forms of *P. palmivora* were not considered in these experiments. The predominant morphological form is the typical cacao type or MF-1.

Communication with the farmer is accomplished mainly through the extension service of the Ministry of Agriculture, Lands and Fisheries. The extension service also arranges field days and seminars especially for the cacao farmers.

The Extension Service receives a special subsidy from the Government for control of black pod disease and is authorized to bear the cost for disease control measures up to 405 ha per estate in Trinidad and Tobago or to pay half the cost of the fungicides employed. A subsidy of 50% of the landed cost of all agricultural equipment is paid to the importer after this equipment has been cleared. The price of this equipment is controlled. Purchase tax exemptions are also granted on imported vehicles for farming purposes. In addition, subsidies are paid to farmers for land preparation, soil conservation practices, fertilizers, farm building, etc. The Government of Trinidad and Tobago also supports the Cocoa Research Unit by direct budget contributions.

A few years ago the Government conducted an extensive research program involving chemical control of black pod disease. Current recommendations are being made on the basis of this program. Currently, feasibility studies are being conducted on the use of ultra low volume sprayers in place of high or low volume sprayers.

VI. REPORTS ON CURRENT RESEARCH PROGRAMS

1. Brazil

The division of Phytopathology is carrying out a broad research program directed largely toward control of black pod disease of cacao. The main lines of research are as follows:

a. Site of application of fungicide on the cacao tree

In this experiment fungicide was applied to the entire tree (including the pods) mainly from under the canopy, to the cacao pods only, and to the entire tree but with the pods covered with plastic bags to prevent their being sprayed, the bags being removed later.

It was found that the fungicide applications to the entire tree gave 91% of control efficiency, to the pods alone, 77%, and to the tree with the pods covered, 85%. The results of this investigation indicate that it is not necessary to cover the entire pod with a film of protective fungicide to control black pod disease. *P. palmivora* is mainly dispersed by rain splash and by rain-water running downward on the branches and trunks of the cacao trees and rain-water, through its redistribution of the applied fungicide may play an important role in the control of the disease. This opens up another avenue for improving the strategy of applying protective chemicals. (See Reference 3 for details of study).

b. Epidemiological studies

Epidemiological studies on black pod disease in Bahia have revealed the following: the relative infection rate ($r = 0.03$ to 0.05 units/day) indicated that time seems not to be an important factor in spread of the disease; rain was the most important factor, causing black pod outbreaks 3 or 4 days later; the mean infection on the pod (8%) comprised one lesion per pod located in the equatorial zone; the time from infection to sporulation was negatively correlated with temperature; dissemination of viable propagules of *P. palmivora* was found to be by rain-water splashed from the soil and in rain-water running down the cacao trunk; the principal inoculum sources in a cacao plantation were identified as soil, cacao husks, mummified pods, flower cushion tissue, bark of the shade tree, and cacao flushing close to the ground. (Reference 3).

c. Screening of copper fungicides

Presently, there are many Brazilian fungicides on the maket with different trade names that are basically cuprous oxide or copper oxychloride in the form of wettable powder or oil emulsion. To determine their effectiveness in black pod control it is necessary to screen them in the field in comparison with standard Copper Sandoz (cuprous oxide) at 4% with 0.5% of the sticker Ag-Bem. The sprays are applied as high volume applications. Several corollary experiments are also being carried out to test each group of copper fungicides in different formulations. Preliminary analyses have shown any information as to which perform better in comparison with the standard Copper Sandoz among the assessed products.

d. Screening of organic fungicides

Several fungicides with different organic molecules are being tested in the laboratory and in the field for control of black pod. Results thus far indicate that several of the organic molecules have potential value for control of the disease. Among these are Tiadiazole, Iodine and two experimental products, CIBA-Geigy (CGA-48988 and DuPont DPX-3217).

e. Comparison of dusting and spraying with copper fungicide

A field experiment is underway to compare copper-based fungicides applied by means of dusting and spraying in December, the period between the two cacao cropping seasons of Bahia. Current practice in Bahia is to initiate fungicide applications when epidemics have already reached relatively high levels of infection. The aim of this experiment is to investigate the effectiveness of early fungicide treatments in reducing primary inoculum and thus limiting disease development in the early stages of an epidemic.

f. Testing of motorized spray machines

Several kinds of motorized knapsack spray machines are being field tested for their effectiveness in controlling black pod disease, using various fungicide formulations.

Most spray machines (for example Atomisa, Polijacto or Trilhotero) are provided with centrifugal pumps or turbines and they provide good coverage whether or not the application is at ultra low volume, low volume, or high volume. The common type of machine available in Bahia (Hatsuta and Yanmar) do not have these mechanisms and can be used only to spray formulations at high volume.

g. Studies on biological control

Husk piles have been identified as a principal source of *P. palmivora* infection in Bahian cacao plantations. The purpose of this project is to study the feasibility of eliminating this inoculum source by treating husk piles with microorganisms which are directly antagonistic to *P. palmivora* or which compete for the same substrate. So far, two microorganisms (a *Penicillium sp.* and an *Aspergillus sp.*) appear promising for the control of *P. palmivora* in husk piles.

h. Microclimate in relation to black pod disease control

This program analyzes those microclimatic factors around the cacao fruit which influence pod wetness with the ultimate aim of determining which criteria are suitable for developing forecasting systems for spraying cacao when environmental conditions are favorable for black pod infection. (Reference 1). Free water is necessary for the germination of *P. palmivora* spores on the pod surface. The key factors are precipitation, humidity, temperature, and windspeed. The cause of the pod wetness is attributed to rainfall or condensation.

Since surface infection occurs only on wet pods, the plantation must be kept relatively open so that the pods dry quickly. Duration of pod wetness is most sensitive to windspeeds of 0.1 to 0.5 m/sec, while speeds above 1.5 m/sec have little additional effect.

It has also been found that when duration of rainfall exceeds 6 hr, the pods remain wet for the entire day, although hours of pod wetness are also influenced by the duration of daily rainfall below 6 hr. The length of time that condensation is present on pods after sunrise can be estimated from the humidity at 09:00 and the rate of increase of air temperature. It is considered that wetness due to condensation will be important to infection by spores transferred by vectors since the entire pod surface is wetted. Rain droplets often remain on the pod longer than condensation, but only wet a small proportion of the pod surface. Spores carried in rainsplash will probably remain in the droplets but those transferred by vectors could remain dry except when condensation is present.

i. Economic considerations of disease preventive treatments

Disease control measures are often expensive and without uniform results, because they are prophylactic rather than curative practices. An indicator that could have influence on the producer's decision to carry out treatments is the probable greater net return as a consequence of the treatments and the "security" of recovering the capital used in the treatments. The treatment will increase total production costs. The final average production cost per "arooba" (15 kg) of cacao depends on (a) total additional cost of the treatment and (b) the additional number of arrobas that are obtained as a result of the treatment. Naturally, it is expected that hight value of the production loss in untreated areas would be larger than that in the treated areas. The difference between these production values will give the net income value of the treatment.

It is possible to determine from the above analysis how many time the net income value exceeds the cost of the treatment. This relation may be called the "Possible Repetition Number". This means that if the net income value of the first tratment were used to finance additional similar treatment at the same cost, the "Repetition Number" would indicate the number of additional treatments that would be possible.

Knowing the production volume of cacao that may be lost with and without treatment applications, it is possible to estimate the expected net income, which may be expressed as "Present Value". (See Reference 4).

In order to be economical, the total capital expenditure on treatments would necessarily be equal to the obtained additional production value after the treatment is affected.

The cost proportion of total production value obtained by the treatment could be greater, equal to, or smaller than the "Effective Value" of the additional production at the moment of its sale. If the cost proportion is greater, as indicated in the first situation, the real capital is not recovered, which means that the treatment is uneconomical. In the second situation, there will be no profits, just the recovery of the real capital employed in the treatment. The third situation shows that there will be a profit in addition to a normal remuneration for the capital invested in the treatment.

2. Nigeria

Initially, Dr. Gregory and Dr. Adebayo referred to the work carried out by the so called International Black Pod Research Project supported by the International Office of Cocoa and Chocolate.

This project was organized in response to the recommendation by Dr. Gregory following his 1968 world-wide survey of *Phytophthora* pod rot problem.

The main objective of the project is to investigate in detail the epidemiology of *Phytophthora* in one area of moderate disease severity and, from this, to develop methods which could be applied elsewhere to determine the relative importance of the various sources and routes of infection. The team has been hosted by the Cocoa Research Institute of Nigeria since 1973, and will finish its program by the end of 1978.

Detailed daily recording has led to the development of a method, sequence analysis, which can be used to estimate the relative importance of the various sources and means of transfer of inoculum.

In Nigeria it is clear that rain splash and pod contact are the main means of spread, and that the soil is the major early season source, especially when aided by tent-building ants. Infection from on-tree sources, such as flower cushions and sporulating cankers, form only a small part of the uncontrolled epidemic. Living vectors appear to play a significant role in the movement of infection up trees and between trees.

Sequence analysis has been applied usefully in determining how spray treatments are failing, and thus can be used to improve control measure.

The team has also studied morphological forms of *Phytophthora* and their relation to epidemiology, disease incidence in relation to weather, and the behavior of the fungus in the soil. Future research will concentrate on separating the on-tree and living vector components of canopy infection, and on the soil phase. (See Reference 2 for a report on this project).

3. Cameroon

a. Fungicide tests

These tests were carried out by the IFCC in the field under normal conditions of fungicide application. The types of fungicide examined were cupric fungicides used alone, cupric fungicides in association with other products, organometallic formulations, and organic formulations. An aqueous suspension of 1% tetracupric oxychloride (50% Cu) was used as a reference with which all fungicides were compared.

i. Cupric fungicides alone

Stabilized bordeaux mixture (Procida), containing 24.5% Cu, prepared as a 0.75% aqueous solution and Burcop, a stabilized solution from McKechnie containing 20% Cu and used as a 0.75% aqueous solution, were equally as effective in controlling black pod disease as the reference compound.

Cuprous oxide (Perenox from ICI and Cacaocobre from Sandoz) containing 50% Cu, used as a 0.5% aqueous solution and Kocide 101 (from Kennecott Copper Corporation) containing 56% Cu as copper hydroxide and used as a 0.7% aqueous solution were more effective than the reference compound.

It was found that it is the nature of the copper compound which basically determines the difference in effectiveness among products rather than the amount of metallic copper. Particle size and the additives used with the commercial formulations also play important roles.

ii. Copper fungicides in association with other products

Moloss (from Procida) a compound containing 38% dried bordeaux mixture (9% copper), 32% maneb and 8% carbatene, in a 0.5% preparation did not have comparable effectiveness with that of the reference compound, even using the same concentrations.

Cupromix (from Rohm and Haas) comprising dried bordeaux mixture and Dithane M45 used at 04% showed less effectiveness than that of the reference compound. Higher concentrations of 0.5 or 0.6% might prove to be more effective.

iii. Organometallic formulations

The following compounds were ineffective of less effective than the reference compound (tetracupric oxychloride):

Zinosan (from Pepro), containing 80% zineb, prepared as a 0.3% aqueous solution; Manesan (from Pepro), containing 80% maneb, as a 0.3% aqueous solution; Antracol (from Bayer), containing 70% propineb as a 0.3% aqueous solution; Polyram Combi (from Basf) containing metiran, as a 0.2% aqueous solutions; Tuzet (from Bayer), a mixture of polyethylene thiuram disulfide, zinc-dimethyl dithiocarbamate and urbacide (methylarsine dimethyl dithiocarbamate), used as a 0.15% aqueous solution.

Among the carbamates, only Dithane M45, containing 80% mancozeb and prepared as a 0.3% solution, seemed to be promising. Further tests with new formulations from Rohm and Haas, with the addition of 1ml/1 of a wetting agent, Triton C3-7, showed that this fungicide was less effective than the reference compound.

Especially satisfactory results were obtained with organic tin compounds. (French legislation forbids the use of tin compounds. These fungicides were not tested in the field, but were used in a comprehensive study undertaken by the IFCC in collaboration with the Ecole Nationale Superieure d'Agriculture du Cameroon, where it was demonstrated that, after treatments carried out with the usual methods, the amounts of tin recovered were negligible, equal to 1/20 of the amount tolerated by the OMS). Brestanol (from Hoechst), containing 47% triphenylstannous chloride, showed superior effectiveness at 0.16% in comparison with the cupric reference suspension and can be used with success up to 12% of the commercial product. Duter (from Philips-Duphar), containing 20% triphenylstannous hydroxide, was superior to the cupric reference compound at a concentration of 0.2% of the commercial product. Stannoram (from Cela Merkx), containing 50% decafentine, used as a 0.2% aqueous solution was equivalent to the reference compound.

iv. Organic formulations

A formulation based on chlorothalonil (G84 from Procida) did not give satisfactory results as a 0.3% aqueous solution.

Ortho Difolatan 80 (from Chevron), a wettable powder with 80% captafol as a 0.3% aqueous solution proved to be at least equivalent to the cupric reference compound. Its emulsifiable form has 500 g of active material per 1 and was inferior to the 0.3% solution of wettable powder (0.24% active material).

Formulation 6509 (from Bayer) showed, starting with a 0.25% concentration, a comparable or slightly higher effectiveness as compared with the cupric reference. The synthesis of the active molecule of this product is very expensive and has been discontinued. Research of other compounds of a similar structure will be carried out.

The antibiotic Actidione, containing 4.2% cyclohexamide was not effective as a 0.5% solution.

v. Systemic fungicides

Terrazole (supplied by Procida), containing 96% ethazol showed no effectiveness in either of the two concentrations used, 50 cc and 100 cc/100 1.

Other, new systemic fungicides examined, none of which showed satisfactory results (VI International Conference on Cacao Research, Caracas, Venezuela, 1977), were: Previcur (from Schoring), CGA 5514 and CGA 5557 (both from Ciba Geigy), tested by the paired tree method and CGA 5181 and CGA 5430 (Ciba Geigy), MK 23 (Procida), R 27180 (Janssen) and 1496 and 1659 (Rhone-Poulenc), tested by inoculation methods.

Because of the water solubility of fungicides, they are easily washed off by rains, thus increasing the frequency of spraying. To increase their adhesion on the plant, some synthetic resins are being studied, with promising results. (Café, Cacao, Thé, Nº3, July-September, 1977).

b. Methods of Testing Fungicides

Assays for testing protectant fungicides were conducted after developing a new experimental method which was both quick and precise. The main feature of the method (Café, Cacao, Thé Nº1, 1969) is the miniaturization of the test, which allows conditions for maximum uniformity.

Instead of using groups of trees with unknown productivity as experimental plots, a number of pods, as uniform as possible at the start the test, were used. In plantations with conditions favorable for the development of black pod disease, pairs of trees were selected that 1) were situated close to each other, with a maximum distance of 5 to 6 m, under the same environmental contions (especially with respect to shade) in such a way as to minimize the effect of the environment, 2) had the same kind of pods (similar in general form and color) to minimize genetic heterogeneity, 3) had trunks bearing identical numbers of healthy pods of similar size at the same height and orientated in a similar fashion. In this way, possible differences in infection were avoided, taking into account that distribution of infection is affected in part by the degree of aggregation of the fruits.

To provide an abundant source of inoculum, five infected pods with fructifications of the fungus on their surfaces were placed around the tree in a ring 40 cm from the foot of each tree.

One tree of each pair (selected at random) served as a check and either was left untreated or was given a reference treatment(control). The remaining tree of each pair was treated with the fungicide being tested. Fungicide applications and records of pod infection were carried out every two weeks and the inoculum source was renewed after each fungicide application. The assessment of each treatment's effectiveness was accomplished by comparing the percentages of diseased pods on each treated tree with that on untreated trees, using the method of Student.

The usefulness of this method was examined in a series of tests and the following conclusions drawn: 1) The evolution of infection was exactly the same as on the untreated trees, 2) infection evolved in a significantly different fashion in trees receiving copper treatments of known effectiveness as compared to those receiving no treatment, 3) significant results were obtained in 30 or 45 days, and in some cases, even after only 15 days, 4) the method's accuracy was very high, with no significant differences at a high degree of probability, 5) with only 15 or 20 pairs of trees it was possible to obtain satisfactory precision, 6) with this quick, precise and inexpensive technique, it is possible to rapidly test many fungicides.

It can be argued that the method does not reflect the intrinsic value of the fungicides, the infection source being artificially enhanced. It is true that the reference fungicide used, a 1% solution of tetracupric oxychloride (containing 50% Cu), allowed a very high infection rate (about 30% of the observed pods), while under more normal conditions it gives more satisfactory results. It is considered, however, that this is of little importance, since the relative value of the test fungicides may be obtained by direct comparison with the control fungicide.

A pod inoculation method was used to test systemic fungicides, the method being the same as that report following the IFCC mission to CEPEC, June-July, 1970. In this method, fungicides were applied either directly to the pods, to the foliage to pods and foliage together, or to the soil. Treatments were applied 1, 3, 5 and 7 days before and after pod inoculation. Pods were point-inoculated with zoospore suspension and fungicide performance evaluated by recording percentage of successful infections and the average daily rate of growth of the subsequent lesions. For each series of treated pods, a series of controlpods were inoculated at the same time but remained untreated. Each plot had 20 pods with 5 replications.

To minimize genetic heterogeneity, it is recommended that a monoclonal plot of susceptible clones or only the trees of the same susceptible clones in a polyclonal plot (for example, a seed production area) be used. In order to reduce the plot's size, each plot may be defined by its number of pods, instead of by the number of trees. It is convenient to study both the young pods and the fully grown but unripe pods, as they can show different reactions.

c. Programs in Progress

Current research programs on the control of *P. palmivora* being conducted by the IFCC involve:

i. Research on fungicides to improve the adhesion of preventive fungicides with the aid of synthetic resins and to test all the systemic fungicides on the market;

ii. Biological research on population studies of *P. palmivora* in which the IFCC laboratories at Montpellier, France, being situated far from the cacao production areas, are appropriate for gathering a world collection of isolates and making comparative studies concerning morphology, cytology, physiology and pathogenicity of *P. palmivora;*

iii. Resistance studies in which selection of resistant cultivars continues in the Ivory Coast and in Cameroon and further studies are being carried out on the inheritance of resistance mechanisms on the physiocochemical bases of susceptibility and resistance and on immunization of cacao trees.

VII. FIELD DEMONSTRATIONS

CEPLAC arranged for the Workshop participants to see a field demonstration at the Cacao Research Center on applying fungicides by means of ground and aerial applications.

1. Demonstration of Ground Spraying

Copper fungicides were sprayed from the ground into the interior of the cacao tree. Three different copper fungicide formulation and five kinds of motorized knapsack sprayers were employed in the demonstration (Reference 5). The fungicide formulations used were:

a. High volume (160 1/ha)
   Water - 10 1
   Sticker (Ag-Bem) - 50 ml
   Copper Sandoz - 400 g

b. Low volume (20 1/ha)
   Water - 13 1
   Sticker (Ag-Bem) - 200 ml
   Oxychloride Sandoz or Kocide 101 - 4.5 kg
   Spray oil - 6.5 1

c. Ultra low volume (12 1/ha)
   Water - 10 1)
   Sticker (Ag-Bem) - 500 ml
   Surfactant (Frenox) - 1 1
   Copper Sandoz - 5.8 kg

The types of spray machines used were:

a. Atomisa (with turbine and centrifugal pump)
b. Hatsuta (without turbine and centrifugal pump)
c. Polijacto (with turbine and centrifugal pump)
d. Trilhotero (with turbine and centrifugal pump)
e. Yanmar (without turbine and centrifugal pump)

2. Demonstration of Aerial Spraying of Cacao

An aerial spraying demonstration of the physical distribution of fungicide by helicopter was made in a cacao plantation at

CEPLAC for the Workshop participants. The helicopter flew 5 m over the canopy of shade trees at an air speed of 72 Kph. The deposition of copper on the cacao trees was collected on Kromekote cards stapled to branches on top of the canopy, in the middle of the canopy, and on the trunk about 40 cm above the ground. One card was placed on one shade tree in the demonstration. Three cacao trees (one under the shade tree, another at the perimeter of the shade tree, and a third in the open) comprised each treatment of which there were five in all. The formulations used included Copper Sandoz in ultra low volume (12 l/ha), Oxychloride Sandoz in low volume (20 l/ha) and a mixture of Polyglicol and Primuline as fluorescent agents (tracers).

Immediately after spraying, the Kromekote cards were collected and examined for droplets of fluorescent particles in the laboratory under ultra-violet light using a binocular microscope.

The laboratory tests showed that the droplets of spray reached all parts of the cacao tree irrespective of its position relative to the shade tree. The shade trees were covered with the spray. Further physical and biological activities of the copper deposits are being investigated.

Aerial spraying of cacao for the control of black pod disease on cacao has possibilities and will be investigated further on an experimental basis next year in Bahia.

VIII. SUGGESTIONS FOR INTERNATIONAL COOPERATION

Dr. Maddison in his presentation of the research program of the International Black Pod Research Project (IBPRP) stated that this project had only one more year to operate. This led to a discussion under the direction of Dr. Alvim as to what might be done if this project should terminate, although the group hoped that the IBPRP would be continued.

The group felt the present workshop had been very useful and worthwhile and expressed an interest in holding others. They also felt that technical relations among the cocoa producing countries of West Africa, the Americas, and European and American cocoa trade associations should be strengthened and expanded. To this end they felt that a truly international program was needed and should be established for black pod control with projects in different cooperating countries. Through a cooperative arrangement, interchange of information and ideas could be established, as well as an exchange of technical personnel. Dr. Alvim remarked that CEPLAC would welcome specialists from any country to come to the Cocoa Research Center for one or two or more months to work on black pod disease problems, while CEPLAC would reciprocate by sending Brazilian specialists to the cooperating country.

The idea of broadening the program of the international committee for black pod disease to give more attention to research and control methods in cacao producing countries of the Americas was also discussed. No specific recommendations were made other than an international coordinator for black pod disease should be named with a correspondent in cooperating countries. The coordinator would collect information on methods of control used in each country and would compile this information for circulation. He would also assist in arranging for an exchange of technical personnel. Dr. Arnaldo Medeiros, Division of Plant Pathology, CEPLAC, has agreed to serve as the International Coordinator.

IX. RECOMMENDATIONS

The Workshop on Cacao Black Pod Control recommended that:

1. Research should be intensified on: a) the aspects of spraying the canopy of the cacao trees and the soil under the trees for black pod disease control, b) the biological control of *P. palmivora*, c) determining the effectiveness of manipulation of shade and ventilation in the cacao plantation on black pod control, d)developing a simple method to measure pod wetness to provide guidance to the plant pathologist in recommending timely spraying to the cacao farmer.

2. Each country should develop its own black pod disease control methodology according to its own circumstances. The different countries should exchange descriptions of their best control methods. The Cocoa Research Center of CEPLAC will serve as international coordinator in organizing a program for exchanging information and technical personnel among the various countries on a regular basis. A correspondent will be named by each cooperating country. CEPLAC will also explore the possibility standardizing experiments being carried out in these countries to provide more comparative results. This requires plantations of the same cultivar to be available in each cooperating country.

3. In view of the existence of different morphological forms of *P. palmivora*, more specific information should be obtained to determine their reactions to disease control measures as influencing the epidemic progress of the disease and possible variation in response to fungicides. A standard set of 10-12 differential cultivars should be selected and tested in each region for resistance or susceptibility to local morphological forms of *P. palmivora*.

4. In the establishment of new plantings, *P. palmivora* populations should be kept low at the start and prevented from building up.

5. Every effort should be made to prevent the transfer of morphological forms of *P. palmivora* between areas within a country and between countries, as for example, by quarantine methods, including the treating of seeds and fruits with Actidione (cyclohexamide).

X. CLOSING SESSION

Cacao farmers and representatives of the Farmer's Council were invited to attend the final session of the Workshop, and those who came shared their experience in black pod control with the specialists and asked them questions.

Among the subjects discussed were:

1. Effect of copper-based sprays on the cacao tree, especially the flower cushion and the bark. The Nigerian representatives stated the Nigerian farmers applied three to five times more copper spray than Bahian farmers. Although there might be visible effects of the spray on the tree, such as discoloration or killing of mosses and other epithytes and on the flower cushions and bark, there was no detrimental effect on cacao production.

2. Effect of copper-based sprays on the health of the spray team. The Workshop specialists stated that in their opinion, spraying was not harmful to the workers if they followed normal spraying precautions. Concerning the spraying machines, it was emphasized that for proper operation they must be well maintained and cared for.

3. Lack of trained spray operators and fungicides. CEPLAC representatives pointed out that the Extension Department and the Vocational School of Agriculture for the Cacao Region (EMARC) offer practical training in spraying for farm workers. With regard to fungicides, CEPLAC sold 960 tons in 1977 at subsidized prices to the cacao farmers and expects to sell about 1,800 tons in 1978.

4. The recommended treatment for cacao husks. The specialists recommended that the husks be sprayed with the fungicide used to control black pod disease in the plantation. Although some of the specialists recommended spreading the husks before spraying, others thought this practice unnecessary. Either burying or removing the husks from the plantation was considered unnecessary and too costly. Furthermore, research has shown that neither the infected husks nor infected pods are an important source of *P. palmivora* inoculum after about three weeks. This is approximately the time required for them to dry out after which *P. palmivora*, although still present, ceases to sporulate. It has also been shown that various saprophytic fungi invade the husk piles and compete with *P. palmivora* for available nutrients. Living vectors only visit fresh husks or puds during a period of about three weeks after infection.

The importance of treating infected cacao husks was emphasized by a Bahian farmer. He reported that in two cacao farms, which were similar in every respect, the husks were removed from only one of the farms and the soil treated with fungicide. The other sanitation practices carried out on the two farms were the same. The results, he said, were striking. The treated farm produced much more cacao than the untreated farm and had very little black pod disease.

In response to a question about the practicality of using a flame thrower in destroying the cacao husks, the specialists felt that its use would not be practical. Because of their high moisture content, not all of the husks would be burned although sporulation would be prevented. Instead, they recommended spraying them with a fungicide.

The use of husks as a by-product in animal feed was also briefly discussed.

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Editor
Jorge Octavio Alves Moreno

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