COCOA GROWERS' BULLETIN

Number 35 July 1984

Contents:

Cadbury Schweppes plc
Bournville
Birmingham B30 2LU
England

Editorial

Global losses of cocoa from *Phytophthora* pod rot (or Black Pod) are enormous. In the authoritative work on the disease (*) it is suggested that 'from 20 to 30 per cent of cocoa pods are lost annually from this disease'. On the basis of world cocoa production of 1,524,000 tonnes this represents a loss of 300,000 to 450,000 tonnes of cocoa. The yield reduction and increased costs of application of control methods are a major factor in the profitability of many cocoa plantings and in some more humid areas of the tropics the pathogen can render some areas unsuitable for cocoa production due to high loss of pods.

The successful control of the disease would therefore be an important breakthrough in improving the productivity of cocoa farms wherever the disease is important. With this in mind we have included in this issue of the Cocoa Growers' Bulletin, a somewhat speculative article contributed by four eminent authors with long experience of researching *Phytophthora* disease on cocoa in Nigeria. These authors suggest that the pathogen on cocoa is primarily a chronic root pathogen. It may be that the poor productivity of many cocoa trees is due to a high level of infection in feeder roots and infection also probably occurs on mature roots. It appears that 'splash' from the ground is an important source of inoculum for the initiation of pod infection sequences and possibly the use of a surface mulch, perhaps comprising a low growing shade tolerant cover crop to break the fall of rain drops, would reduce the chance of splash dispersal of spores. They suggest that there is also a need for a better understanding of the movement of zoospores in various types of soils. Research on these topics might give important information for novel control methods which could involve planting of specific cover crops or the use of systemic fungicide to reduce or control root infections.

We hope that the publication of this speculative article will stimulate researchers in cocoa growing countries to investigate the role of *Phytophthora* in the soil phase of cocoa plantations.

R.A. LASS, Editor.

(*)Opeke, L.K. and Gorenz, A.M. in 'Phytophthora disease of cocoa', ed. Dr. P.H. Gregory, Longman, London 1974.

ISSN 0045-7256

Cocoa Growers' Bulletin is published twice per annum by Cadbury Schweppes p.l.c. as an information service to cocoa growers, plantation staff, extension officers and research workers. It is distributed free with one copy being sent to each name on the current mailing list. Any correspondence, including requests for names to be added to mailing list should be sent to R.A. Lass, Cocoa Department, L61, Cadbury Schweppes p.l.c., Bournville, Birmingham B30 2LU, England.

Review of Production and Consumption

MAY 1982 – JULY 1984

S.J. Turner, Cadbury Schweppes, p.l.c.

REVIEW OF THE MARKET

It is now more than 18 months since the Cocoa Growers' Bulletin included a review of production and consumption. In that time the market has made a significant reversal as the surpluses of 1977/8 to 1981/2 gave way to two years of substantial deficits in the supply and demand equation.

Furthermore, the production situation has been extremely confusing over the last two crop years. Normally, the September or November Gill and Duffus report includes a reasonable forecast of the production in that crop year. Whereas in September and November 1982 Gill and Duffus were forecasting a small surplus for 1982/3, by January they were forecasting a large deficit. Again, in October 1983 Gill and Duffus predicted a small surplus whereas it now looks likely that a deficit in the region of 130,000 tonnes may occur. This confusion in crop prospects has arisen from abnormal weather conditions, particularly affecting the West African crops. At the moment the weather for the 1984/5 crop looks better but the long term effects of the previous two years are difficult to assess. In their latest report Gill and Duffus say that it would seem unduly pessimistic at this stage to anticipate anything other than a substantial increase in production in the new season.

PRODUCTION

Gill and Duffus's latest forecast of 1983/4 production is 1,520,000 tonnes, 19,000 tonnes less than their latest estimate for 1982/3 of 1,539,000 tonnes, and almost 200,000 tonnes less than their final figure for 1981/2 production which has been revised upwards since May 1982 to 1,726,000 tonnes.

The latest, July 1984, report shows a continued decline in production in Ghana over the last five years from 285,000 tonnes in 1979/80 to a forecast 158,000 tonnes in 1983/4. Lower crops than 1982/3 are expected in Brazil and Nigeria, but an improved final outturn is predicted for the Ivory Coast.

CONSUMPTION

The latest Gill and Duffus forecast for 1984 world grindings is 1,630,000 tonnes, compared with an estimate of 1,651,000 tonnes for 1983 and a final figure of 1,603,000 for 1982 (an upwards revision of 14,000 tonnes since May 1982). Grindings in Eastern Europe are expected to decline in 1984, whilst remaining fairly static in the United States and Western Europe.

STOCKS

Gill and Duffus estimate world stocks at the end of the 1983/4 season will fall by 144,000 tonnes to 430,000 tonnes, the lowest level since 1979/80. The Cocoa Agreement Buffer Stock continues to hold 100,000 tonnes of this.

WORLD COCOA PRODUCTION AND GRINDINGS DATA
Reproduced from Gill and Duffus Market Report dated May 1984
(Thousand Metric Tonnes)

PRODUCTION	1980/1	1981/2	1982/3 (Estimate)	1983/4 (Forecast)
Africa	999	1043	856	854
America	528	520	515	480
West Indies	44	50	52	51
Asia and Oceania	92	113	116	135
WORLD TOTAL	1663	1726	1539	1520
Principal Countries				
Ghana	258	225	178	158
Nigeria	155	181	156	115
Ivory Coast	403	457	355	400
Cameroun	120	122	106	108
Equatorial Guinea	8	8	10	10
Brazil	349	314	336	299
Ecuador	81	85	55	60
Dominican Republic	32	40	40	39
Venezuela	14	17	18	18
Colombia	39	42	40	41
Mexico	30	41	42	40
Papua New Guinea	28	30	28	29
Malaysia	43	60	65	80
GRINDINGS				
Western Europe	598	620	626	623
Eastern Europe and USSR	211	201	228	214
North America	207	215	210	210
Central and South America	349	322	348	341
Australia and New Zealand	16	13	12	12
Asia	90	106	107	105
Africa	125	126	120	125
WORLD TOTAL	1596	1603	1651	1630
Principal Countries				
United States	190	199	194	194
Germany (Federal Republic)	167	175	180	182
Netherlands	141	148	157	158
United Kingdom	85	88	77	80
USSR	120	120	137	130
France	52	52	53	50

PRICES

Month-end prices for nearby shipment Ghana cocoa have been:

		£			£
1982	July	976/tonne	1983	July	1691/tonne
	August	1008/tonne		August	1590/tonne
	September	1080/tonne		September	1567/tonne
	October	1019/tonne		October	1502/tonne
	November	1052/tonne		November	1710/tonne
	December	1171/tonne		December	2097/tonne
1983	January	1348/tonne	1984	January	1965/tonne
	February	1301/tonne		February	1713/tonne
	March	1341/tonne		March	1889/tonne
	April	1316/tonne		April	1998/tonne
	May	1521/tonne		May	2215/tonne
	June	1639/tonne		June	1910/tonne

The market has risen fairly steadily in the light of two successive deficits in the supply/demand situation. Gill and Duffus are not yet making any forecasts for 1984/5.

Kew announcement

ANNOUNCEMENT ON CLOSURE OF QUARANTINE FACILITIES AT KEW

The Director of the Royal Botanic Gardens, Kew has decided that facilities for the intermediate quarantine of cocoa at Kew can no longer be provided as a routine service, and the maintenance of the collection of cocoa clones will be discontinued. It is intended however that existing orders for specific clones from the collection will be supplied during 1984 as will any other material that is available.

If there is a renewed demand for the intermediate quarantine of cocoa in the UK in the future, the RBG will be interested to learn of any economically viable proposals and will help in any way possible to establish facilities.

Enquiries about the supply of cocoa clones should be addressed as soon as possible to A.G. Bailey, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, United Kingdom; Telephone: 01-940 1171; Telex: 296694 KEWGARG.

Cocoa Black Pod: a reinterpretation

by P.H. Gregory*, M.J. Griffin**, A.C. Maddison***
and M.R. Ward****

INTRODUCTION

In the main cocoa-producing regions black pod, due to infection by *Phytophthora,* causes loss of yield only during the rainy season. In West Africa and in Bahia, Brazil there is usually a period when the trees are free from infected pods.

To adopt the control strategy of attacking a pathogen at the weakest point in its life cycle, the sources from which infections arise in the rainy season must be identified. This was the main recommendation in a report on a survey made in 1968 (Gregory, 1969) where it was pointed out that although many potential sources are known, it is not clear which of them are significant in the epidemic: they cannot all be equally important.

Following this recommendation, the International Black Pod Research Project was started at the Cocoa Research Institute of Nigeria (CRIN), Gambari near Ibadan, in 1973, with a team of scientists financed by the International Office of Cocoa and Chocolate (IOCC), and with laboratory accommodation, other staff and all plantation facilities for experiments provided by CRIN.

Our object was to identify and evaluate the significance of potential sources of infection, with a view to better control of the disease.

The project ended in 1980, and its organisation, its indebtedness and its findings have been set out in the Team's Final Report edited by Gregory & Maddison (1981). This Report provides a wealth of data on sources of infection and it is now timely to try to distinguish the important from the trivial facts. This paper attempts a critical interpretation of the data. The difficulties are considerable because some of the data are ambiguous, partly as a result of the array of structures that *Phytophthora* can produce. Ambiguities are clearly stated, followed by a choice of the interpretation most consistent with the need of the fungus to survive in a highly competitive environment. This biological necessity, following the route of maximum plausibility, provides a guiding thread through the labyrinth of ambiguity. Alternatives are relegated to a secondary role.

Present addresses:
* *11 Topstreet Way, Harpenden, Herts., AL5 5TU, England.*
** *11 Chatsworth Park, Thornbury, Bristol, BS12 1JF, England.*
*** *Institute Nacional de Investigaciones Agropecuarias (INIAP), Pichilingue, Ecuador. Postal address c/o British Embassy, Quito, Ecuador.*
**** *19 Cotswold Close, Loughborough, Leics., England.*

The invitation from Nigeria to establish the project at Gambari was welcomed by IOCC, partly because CRIN's modern research station is in a region with moderate but not overwhelming incidence of black pod. It proved a fortunate choice because, in addition to the excellent facilities at Gambari, it was discovered early in the research that *P. palmivora* is of minor importance in Nigerian plantations, and that the principal cause of black pod is a hitherto undescribed species, *P. megakarya* (Brasier & Griffin 1979). This simplified our task because *P. megakarya* seldom becomes systemic in flower cushions, unlike *P. palmivora* in Ghana where a substantial proportion of black pods become infected through the peduncle from systemic lesions in cushions.

The International Cocoa Black Pod Research Team investigated the origin of inoculum of *Phytophthora* infecting the pods of cocoa (*Theobroma cacao* L.) with the aim of improving control by sanitation and fungicides. The Team's findings were published in a Report edited by Gregory & Maddison (1981). The Report and additional unpublished data form the basis of the present paper. The Team showed that the epidemic is made up of 'sequences' of groups of pods, each started by an 'initiator'; the basic problem was to trace the origin of the initiators. When the Report was published the origin of 40 per cent of initiators was still unknown. Further examination of the data indicated that the vertical gradient of this category of initiators of unknown origin was continuous with the gradient of another category which had been attributed to splash infection by inoculum from the ground.

It is believed that the inoculum for the lower part of the vertical gradient is carried by what are termed 'ballistic droplets', and for the higher part in the canopy by 'aerosol droplets' which are carried by upward convection. Circumstantial evidence strongly indicates that the source is not the litter layer (which seems largely protective) but the soil beneath the litter. The fungus is considered to multiply in the ephemeral feeding roots, possibly persisting in the soil as dormant encysted zoospores, which on germination swim against gravity to the soil surface where they can be picked up in splash droplets. It is suggested that *P. megakarya* is primarily a root pathogen, although its greatest effect is in pod disease. Implications of this hypothesis for the health of roots are discussed, and possible control by mulching, fungicides and breeding for root resistance are suggested.

METHODS

The Infection Gradient Concept

The search for clues to the location of effective sources at Gambari, involved making detailed and frequent, often daily, records of natural infections on groups of trees, using the infection gradient concept to indicate the most likely source of each infection observed.

This concept depends on the general observation that the number of infections per unit area established by an airborne pathogen tends to decrease with increasing distance from the source. The infection gradient is the slope of the line obtained by plotting number of lesions against distance from source: often conveniently reduced to a straight line by using logarithms. The infection gradient usually parallels a spore deposition gradient, and both are affected by various factors including the geometry of the source and the pathogen's mode of dispersal.

Conversely, by following the direction indicated by an increasing concentration in the field the observer should be led towards the effective source. One pitfall must be avoided: the regular change with distance shown by some environmental factors, such as shade or humidity, can mislead the observer by mimicking an infection gradient. We believe we have avoided this error.

Source Categories

The infection gradient concept was used to assign a probable origin to each *Phytophthora* lesion observed on the group of trees under observation in the various experiments. The criteria used for assigning each infected pod to its probable source category are described by Maddison (1981a). Briefly, these categories are as follows:

Contact with, or splash from, an existing black pod. This is perhaps the most obvious and least subjective category. Splash of inoculum or contact is the commonest mode of infection for all pods. By contrast, few sporangia are liberated into dry air. Operating a Hirst volumetric spore trap (Burkard model) in a severely affected plantation failed to catch any sporangia, although a few were caught when the trap was placed close to a sporulating pod. It is known from previous research that the Hirst trap is not suitable for catching splash-dispersed spores.

From soil and litter by splash and contact. Okaisabor (1971) and Henry (1977) attributed the numerous lesions on pods at the base of the trunk, up to a height of 70 cm, to rain-splash from the ground. Infected pods from 0 to 70 cm above ground were assigned to this category.

Sporulating cankers and infected flower cushions. Contrary to expectation when the project started, relatively few sporulating cankers were found, and moreover pods infected by *P. megakarya* from systemic infections in cushions via the peduncle were rare in comparison with the number of *P. palmivora* cushion infections reported from Ghana. Evidently 'on-tree' sources are not a significant problem in Nigeria.

Ant tents. Several species of ants 'tend' coccids or aphids, which they 'milk' for honey-dew on the peduncles of developing pods. They construct tent-like structures of soil or plant debris to protect the 'cows' from weather and predators. Frequently a black pod lesion occurs close to the tent, especially to those tents made of soil. The complex ecology and interactions between species of tent-building ants involved in this inoculum-source at Gambari were studied by Taylor & Griffin (1981) and by Taylor & Adedoyin (1981). The importance of this category varied considerably from year to year, but it is a significant one in Nigeria.

Insect and rodent damage. The edge of a plantation adjoining bush often suffers badly from rodents. A gap in the canopy favours mirid damage. Such wounds on pods are often sites of black pod lesions.

'No obvious sources'. This important category includes infections apparently 'arising out of the blue', i.e. not near enough to any known source to be reasonably attributable to it. This category puzzled us for years and at the end of the project we were disappointed to have no solution to offer in the Team's Final Report. Recently, while re-examining some of the experimental data, we found evidence leading to a possible solution.

MAPPING SITE OBSERVATIONS OF 1974 AND 1975

To get basic data about the black pod epidemic at Gambari, all pods and cherelles on a group of 9 Amelonado trees, were examined closely every Monday, Wednesday and Friday throughout the 1974 and 1975 seasons. The surrounding 16 trees were also examined, but were recorded in less detail. No control measures were applied, but healthy ripe pods were harvested every three weeks.

To reach all parts of these 25 trees a framework of steel scaffolding was erected so that all pods and cherelles from the ground to the top of the canopy could be observed. A wealth of detail was recorded and analysed by computer (Maddison, 1977; 1981). During the two years 945 *Phytophtora*-infected pods or cherelles were recorded out of a total of 1690 pods, and their probable sources of infection were assessed as shown in Table 1.

TABLE 1

Percentage of black pods assigned to source categories in Mapping Site observations on Amelonado cocoa at Gambari, 1974 and 1975.

Source Category	% Assigned
Contact with or splash from infected pod	71.8
From soil or litter by splash or contact	5.0
Sporulating cankers or infected flower cushions	1.6
Ant tents	5.8
Insect or rodent damage	4.9
No obvious source	10.9

[Source: Maddison, 1981a].

A finding of fundamental importance is that the black pod epidemic is made up of a large number of small groups of infected pods derived from an isolated individual infection. In Maddison's terminology these groups constitute 'infection sequences' each derived from an 'initiator'. During the two seasons each of the 267 initiators gave rise to an average of 2.54 sequence infections.

Hitherto, thinking on cocoa *Phytophthora* has been misled by analogy with the much better known, but quite different, epidemic cycle of *P. infestans* on the annual potato crop in temperate countries, where a few early infections per hectare multiply up to produce the season's blight epidemic. By contrast at Gambari approximately one quarter of the black pods recorded were initiators.

Initiators function, not merely at the beginning of the season as supposed formerly, but continue to arise and set up fresh sequences throughout the rainy season. This discovery was a serious set-back to our hopes for controlling black pod by plantation hygiene.

THE ULTIMATE HYGIENE EXPERIMENT

The 'mapping site' records showed that our task could be re-defined as a search for the origins of initiators. A new way of studying initiators was needed, without the complication of sequence infections to blur the picture, by early depletion of pods which could have become initiators later in the epidemic. This need was met by the so-called 'Ultimate Hygiene' experiment, which was an ambitious project over a substantial area of plantation where the development of sequences was suppressed by removing any infected pods during a daily inspection, and before such potential initiators could become active. Daily inspections were maintained during the rainy seasons of 1975 to 1978 inclusive.

The area used had to be comparatively large because small replicated plots, which may be suitable for fertilizer experiments, are inappropriate for studying movement of airborne inoculum through a plantation. The experimental material consists of a *volume* of trees 5 or 6 metres high, and large plots are essential to allow treatment effects to develop unhindered.

A block of 560 trees was marked out in a large plantation of Amazon hybrid cocoa. All pods were inspected daily from March to November, an exacting task demanding conscientious attention and considerable manpower. For each infected pod the date, height above ground and probable source were recorded. This potential initiator was then removed from the plantation before the lesion could sporulate and set up an infection sequence. This block will be referred to as the 'daily removal plot'. Ripe pods were harvested from the area every three weeks. Thus a picture was built up of the origin of potential initiators, uncomplicated by the presence of any sequence infections derived from them. During 1975 approximately 9 per cent of the total of 15,889 pods on the plot were removed as initiators.

On each side of the daily removal plot were two control plots each of 285 trees. Here infected pods were left in position to sporulate until removed at the next 3-weekly harvest of ripe pods. These plots will be referred to as the '3-weekly removal plots'. On these control plots each initiator gave rise to an average of 2.27 sequence infections.

The results of the four years work on this experiment are summarized by Griffin *et al.* (1981). The proportions of initiators attributed to the sources shown in Table 2, are based on records from 36,208 pods, each of which while maturing on the trees would have been at risk for approximately 145 days after pod set (or 170 days from pollination).

Initiators continued to arise throughout the four years of the experiment, though the number fluctuated considerably from year to year. Numbers of initiators decreased from 1975 to a minimum in the low rainfall year of 1977, but increased greatly again in 1978, mirroring a general increase of black pod at Gambari. And, most significantly, in the wetter year of 1978 the 'soil and litter' and the 'no obvious source' categories increased simultaneously. The decision to continue recording for a fourth year was fortunate, as interpretation of the data for 1975-1977 alone would have resulted in quite a different conclusion.

TABLE 2

Numbers of black pods on the 'ultimate hygiene' experiment, and their attributed sources for the years 1975-1978.

Year	1975	1976	1977	1978
Rainfall (mm)	1042	1013	852	1199
Total harvested pods	12,614	7,282	4,852	7,178
Total initiators	1,212	311	39	720
Sources assigned:				
Soil and litter	585	151	26	208
Ant tents	282	9	2	41
Rodent damage	4	2	1	2
Insect damage	16	23	0	47
Flower cushions & canker	37	3	0	2
No obvious source	288	123	10	420
Total sequence infections from initiators accidentally overlooked or on adjacent plots	63	107	0	88

[Source: after Griffin et al., *1981 with additional data].*

The numbers of initiators from insect damage also fluctuated from year to year, whereas initiators from cankers and infected flower cushions became very few, confirming the view that delayed removal of black pods favours both canker and cushion infection.

Over the four years of the experiment nearly 40 per cent of the initiators were placed in the 'no obvious source' category.

THE VERTICAL INFECTION GRADIENT

Although horizontal gradients are evident within sequences, and were clearly demonstrated experimentally on a small scale (Maddison & Griffin, 1981), our attempts to trace them into the daily removal plot from the contiguous 3-weekly removal plots alongside proved unrewarding and wasted much time.

Recently we decided to concentrate attention on the well-known vertical gradient in more detail. Working from a computer print-out that gave the 1975 data for different heights above ground level in the ultimate hygiene experiment, it became obvious that the two categories we had distinguished as 'splash from soil and litter' and 'no obvious source' formed a single continuous vertical gradient. This gradient could be expressed graphically as a straight line by plotting the log of the number of lesions against linear height above ground, indicating an exponential decrease with height above ground (Figure 1). No great emphasis should be placed on the exponential relationship, however, because the numbers of pods at risk were different at different heights. Generally there are few near the ground and most at about 2 or 3 metres. However, in 1975 tree bases were well furnished with pods to ground level, making continuity easy to observe. This single gradient points to the ground as source. The 'ant tent' gradient, where there is no doubt that soil is carried up from the ground, behaves similarly.

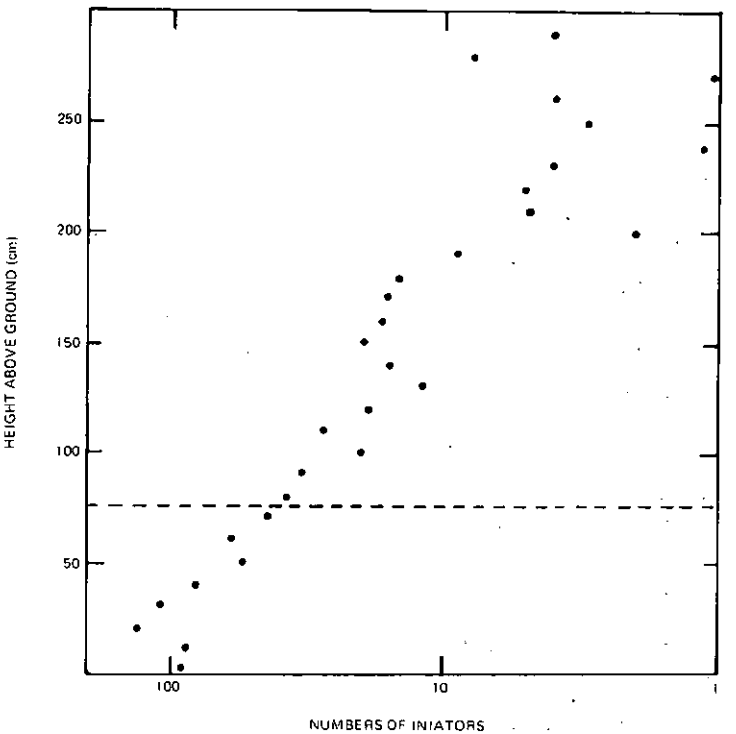

Figure 1.
Vertical gradient of initiator source categories: 'splash from soil and litter' plus 'no obvious source': from 'Ultimate Hygiene Experiment', Gambari 1975. Plotted at 10 cm intervals above ground on linear scale, with pod numbers on a logarithmic scale.

The picture becomes clearer when the height of each initiator is plotted beside daily rainfall (Figure 2). After a delayed start at the beginning of the rainy season, infection from the ground continues almost to the end of the rains. The occurrence of initiators lags 3 or 4 days (often apparently longer for pods high in the canopy) after a fall of perhaps 10 mm or more of rain in a day.

The ground had been suspected as a source earlier (Muller, 1974) while Okaisabor (1974) referred to a widespread belief among Nigerian cocoa farmers that pod rot comes up from damp soil at the beginning of a new season. However, our discovery that this source functions throughout the season alters the situation fundamentally.

Whether sporangia or zoospores are the infective agents carried by the splash droplets, needs investigation, but in the absence of facts, we speculate that the infective agents are probably not the sporangia themselves, but their products, the much smaller zoospores, which are motile in water and perhaps 20 times as numerous which can swim actively in water, or change into resting cysts by developing a resistant cell wall.

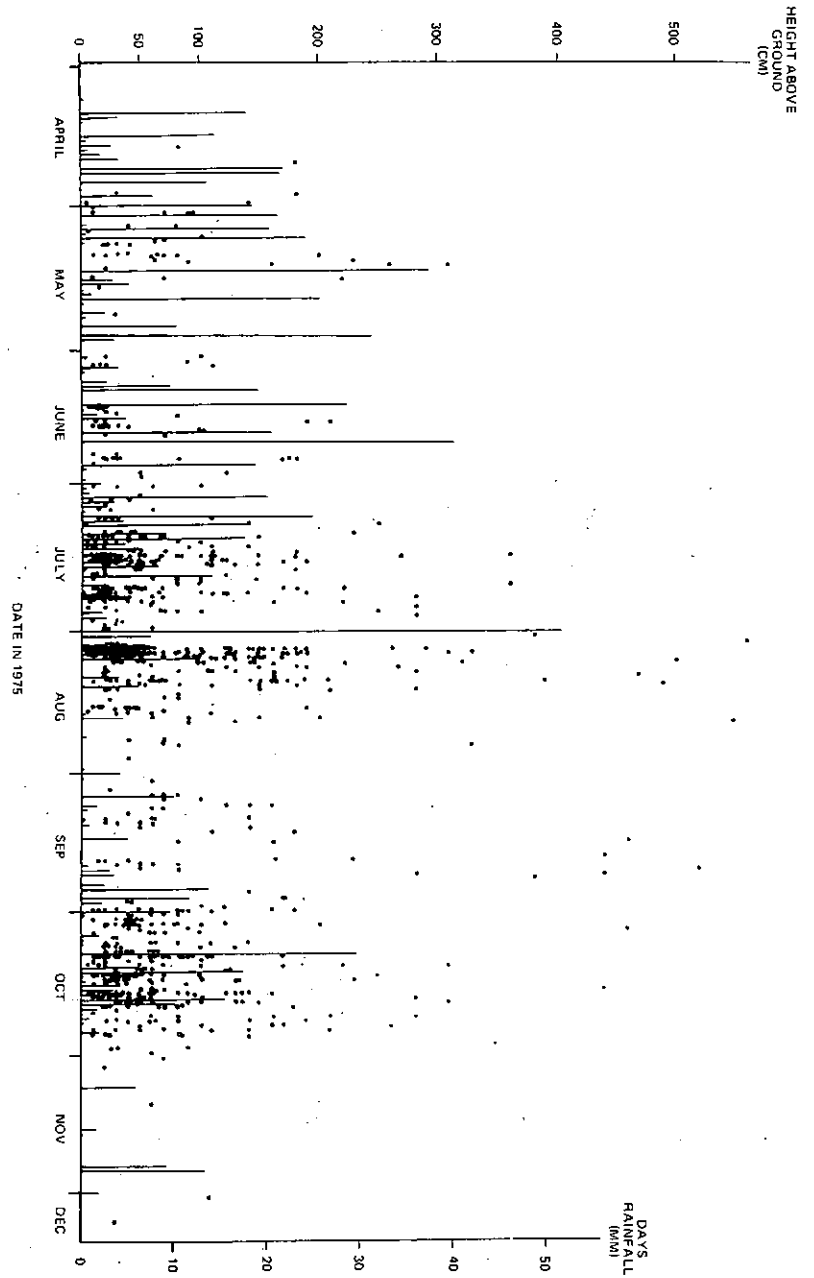

Figure 2.
Data from Figure 1 plotted daily showing height of individual initiator pods above ground, and daily rainfall in mm, Gambari 1975.

Splash as a Mechanism for Zoospore Transport

A vital clue was supplied by Cameron & Carlile (1977) who showed that zoospores of *Phytophthora* tend to swim upwards against gravity (negative geotaxis), a tendency that would presumably be overridden in zoospores swimming near a rootlet by chemical attraction towards cocoa rootlets (positive chemotaxis). Because of this tendency to swim against gravity zoospores will accumulate at the soil surface during heavy rain. Here they will be in a good position to be dispersed by splash in the droplets thrown up from the surface film of water by impacting rain drops, or more likely by impact of drips from leaves wetted by rain. Such surface concentrations of zoospores or zoospore cysts should be looked for by collecting surface water during a tropical downpour.

In a cocoa plantation most rain drops strike leaf surfaces, and the drops reaching the ground will be 'drip' from the canopy. On impacting with the surface water over saturated soil each drop will form a familiar splash corona from whose rays droplets are propelled into the air. Laboratory tests (Gregory, Guthrie, & Bunce, 1959) showed that these splash droplets entrain spores contained in a surface film. The larger droplets are propelled in a trajectory reaching a distance of about 70 cm in still air. These, which we propose to refer to as 'ballistic droplets', have attracted attention in the context of plant diseases. The corona formed by a single drop of say 5 mm diameter falling from a height of 3 m would project about 2,000 potentially spore-carrying ballistic droplets having a wide range of diameters.

The field data summarized in Figures 1 and 2 suggest that these laboratory tests gave an incomplete picture. It seems that the ballistic droplets constitute only part of the splash. There is evidently another component made up of still smaller droplets with negligible trajectories and light enough to be carried even in feeble air currents: these will be referred to as 'aerosol droplets'. They were not detected by the small scale methods used in the laboratory tests cited, but did become evident in the plantation at Gambari. Many of them may be the small 'satellite droplets' formed by separation of pairs of larger droplets. The wisps of mist seen swirling above forest canopy during tropical rainstorms are probably composed of these aerosol droplets.

The ballistic droplets correspond approximately to the 'splash from soil and litter' category, whereas the aerosol droplets correspond to the 'no obvious source' category. But the boundary between them will be indistinct, partly because the spectrum of ballistic droplet sizes is known to be very wide, and the same is probably true of the aerosol droplets.

Consequences of an Infective Aerosol

Fortunately the yield of initiators per splash event is extremely small. A rough calculation using the Gambari data for 1975 shows that 1,000 mm of rain produced an average of only two initiators per tree. Put differently: to produce one initiator required 1×10^9 drops, giving rise to more than 2×10^{12} splash droplets.

Such an aerosol of zoospores or cysts pervading a plantation could account for the findings of Tarjot (1967) in the Ivory Coast where, in a mature plantation, *P. palmivora* was isolated from: soil, old dry cocoa pods, blackened cherelles, bark of shade trees and of cocoa trees.

And while some of the catches of *P. megakarya* in 'pipe traps' by Maddison & Griffin (1981) appear to come from sporulating cankers, others

may be monitoring re-distributed zoospores collected from the aerosol by the relatively large trapping surface area of the canopy.

A step-wise climb of black pods as the season progresses has been reported in the literature. Figure 2 indicates that for initiators this is a misinterpretation. Any apparent climb is due to the detection threshold not being reached higher in the canopy until after a great increase of infection lower down. Moreover, in the 'ultimate hygiene' experiment a climb could not be stepwise because the 'steps' had been removed. This in turn accounts for lack of success in trying to control black pod by removal of pods below 0.8 m at the tree base, as tested on parts of the 'control' plots adjoining the ultimate hygiene plot (Griffin *et al.*, 1981; Adebayo, 1983). The infective aerosol does not ascend by stairs but goes up in the convective 'elevator'.

The data indicates the ground to be a massive and consistent source. But does the inoculum come from the litter layer or from the soil below it? So far the data are ambiguous, but some answers come from another experiment described in the Team's Final Report.

THE POD EXPOSURE EXPERIMENT 1976

To assess the amount of splash infection from the ground in a well-established cocoa plantation, batches of healthy pods were exposed to natural splash from March to August 1976. Four replicate pods were exposed on aluminium angle posts at 8 heights, at intervals of 15 cm starting at 15 cm, and up to 120 cm above ground level (Maddison and Griffin, 1981). Two such sets of posts were set a few metres apart, one set over ground with its normal litter cover of old cocoa leaves, and the other set over bare soil from which litter had been removed. After rain the exposed pods were removed and incubated in the laboratory for a lesion count, while fresh pods were exposed awaiting further rain, for a total of 25 periods in all.

During the six months of the experiment 1,600 pods were exposed. Of 800 pods exposed over bare soil 190 pods became infected, whereas over the intact litter only 36 out of 800 became infected (Table 3). Further, on all 25 occasions there were more infections over bare soil.

TABLE 3

Pod exposure experiment, March to August 1976, Gambari. Percentage pods infected (mean of 4 replicates) when exposed at 8 heights on 25 rainfall occasions (a total of 400 pods over bare soil, and 400 over litter).

	Percentage pods infected								
	Height of pods above ground level (m)								% of
	0.15	0.3	0.45	0.6	0.75	0.9	1.05	1.2	Total
Ground condition:									
Over bare soil	70	53	35	17.5	8.25	5	2	6	23.7
Over leaf litter	6	6	7	4	3	4	2	6	4.5

(Source: after Maddison and Griffin, 1981).

These facts suggest that the litter layer, instead of being a source of inoculum, is acting physically as a shield preventing rain from splashing zoospores up from wet soil to the pods. However, the litter layer is not wholly innocuous. In Nigeria, both Onesirosan (1971) and Ward & Griffin (1981) obtained *Phytophthora* from organic debris in the litter layer. But the field data from this experiment show that bare soil is the potent source, and that by comparison the litter layer acts as a protective mulch.

Again, the data point to the ground as a massive and consistent source. But in what form is *P. megakarya* present in the soil? In particular, do the cocoa Phytophthoras grow on dead organic matter in the soil? The data discussed so far are ambiguous.

THE PHASE BELOW GROUND

Occurrence of Phytophthora in Soil

Phytophthora was generally regarded solely as a pathogen on aerial parts of cocoa trees until Orellana (1954) and Thorold (1955) baited it out of plantation soil using healthy cocoa tissue. Turner & Asomaning (1962) found *P. palmivora* infecting roots of volunteer cocoa seedlings in Ghanaian plantations.

Okaisabor (1970) started systematic studies of *Phytophthora* in soils of Nigerian cocoa plantations. On the floor of a plantation he reported 100 per cent infection of baits placed at 0 to 6 inches (0 to 15 cm) from trunks, decreasing steadily to 51 per cent at 25 or 36 inches (62 or 90 cm). Exploring downwards in three different cocoa soils, recovery of the pathogen was greatest at the surface, decreasing at 3 and 6 inches (8 and 15 cm) and zero at 12 inches (36 cm) depth. In baiting surface soil periodically over the year, Okaisabor found that the percentage of baits infected varied greatly with season:

> 'Throughout the dry season (December to February) no baits were infected, but as the early rains began in March and April, the infectivity of the pathogen in the soil gradually rose. The number of *Phytophthora*-infected baits was very high during the wet months (May to October) but declined sharply to zero by December. These results suggest that *P. palmivora* exists in the soil in a relatively dormant form when adverse conditions prevailed in the dry season. As the rain increases in March and April it gradually breaks through its dormant phase, and its activity in the soil reaches a peak at the height of the rainy season'. (Okaisabor, 1970).

This seasonal pattern was confirmed for plantations at Gambari and Ikom by Ward & Griffin (1981) who commented 'the number of propagules decreased very rapidly towards the end of the rains, perhaps more quickly than might have been expected from the rainfall pattern'. In the unusually dry year of 1977 at Gambari, with low rainfall and thus poor cocoa canopies giving severe drying out of the soil, very few positive isolations could be made from the soil. But isolations were successful again in the wetter season of 1978, suggesting that multiplication had occurred in the soil. This supports the evidence (Table 2) that *Phytophthora* not merely survives in the soil of cocoa plantations, but actually increases again after being depressed by an unusually dry season.

Saprophytic Growth in Soil?

Because chlamydospores of *P. megakarya* were not found in soil or on cocoa trees at Gambari, Ward & Griffin (1981) drew attention to the belief that certain species of *Phytophthora* are able to grow as saprophytes in the soil on dead organic matter.

Zentmyer & Mircetich (1966) placed discs cut from cultures of *P. cinnamomi* on dishes of non-sterile soil in the laboratory. At intervals from 4 to 40 days small samples of soil were taken at distances of up to 6 cm from the inoculum and assayed for *P. cinnamomi*. By the 5th to 20th days the fungus was found at up to 3 cm distance from the inoculum disc. The assumption that this results from invasion of the soil by mycelium has been generally accepted. But, in fact, the presence of mycelium joining the sampling points seems not to have been demonstrated. An equally plausible alternative hypothesis is that zoospores swim out from the inoculum and encyst in the soil.

When Hickman & English (Hickman & Ho, 1966) placed mycelial inocula of *P. fragariae* in non-sterile soil, mycelium failed to grow out from the food base: instead sporangia were formed around the edge of the inoculum, possibly an instance of the phenomenon discovered by Zentmyer (1965) in three species of *Phytophthora* including *P. palmivora* where soil bacteria stimulated production of sporangia.

Infection by the fungus of living cocoa roots seems more plausible than saprophytic growth. The fungus by invading living cocoa tissue unavailable to other fungi gains great competitive advantage. For these reasons we discount the hypothesis of mycelial growth through soil (Gregory, 1981).

Phytophthora on Cocoa Roots

Although Turner & Asomaning (1962) discovered *P. palmivora* infecting roots of volunteer cocoa seedlings in Ghana, no epidemiological significance seems to have been attached to this phenomenon at the time, although it was developed as a seedling test for resistance. The finding was confirmed by Onesirosan (1971) and Okaisabor (1974) in Nigeria on older trees.

More extensive and systematic examinations of cocoa roots were made by the International Research Team at Gambari (Ward & Griffin, 1981). Root samples from the top 50 cm of soil were washed, surface sterilized with calcium hypochlorite, rinsed in sterile distilled water, cut into small pieces or macerated, placed in water in Petri dishes and baited with tissue plugs cut from healthy pods. Sporangia were seen on the baits three or four days later.

Phytophthora was frequently obtained from current and previous year's roots, but only rarely from lateral roots. Between June and November 1979 *Phytophthora* was found in roots of 18 out of 85 trees sampled at Gambari, and 19 out of 38 trees at Ikom in Eastern Nigeria. There were no obvious lesions on the roots tested. No *Phytophthora* was obtained from roots collected before June at Gambari, and in November few samples proved positive at either Gambari or Ikom.

That tests on a few grams of feeding root tissues, representing a minute fraction of the total feeding root system, revealed the pathogen in 37 out of 123 trees tested, suggests a very high incidence of *P. megakarya* (and sometimes *P. palmivora*) in roots, possibly a higher incidence than would be indicated by similar weights of pod tissue taken at random from the same tree.

The fungus must be living inside the tissues of the feeding roots, because, although the surface sterilization method used was adequate to kill vigorous soil saprophytes, the *Phytophthora* survived. But this reveals another ambiguity. Is the fungus temporarily dormant inside the root tissue, invading systemically with negligible damage, as it can when invading flower cushions? Or is it damaging as in pods? If the latter the chance of observing it would be slight? The role of *P. megakarya* in roots needs investigation. Similar questions arise with *P. palmivora* on coconut roots (Harris *et al.*, 1984).

Encystment of Zoospores

In Ghana, Turner (1963) found that *P. palmivora* sporangia germinated in all the soil and root extracts he tested, but the resulting zoospores were inhibited by some factor which held them in a state of suspended animation. Growth and movement were inhibited but the zoospores were not killed however (i.e. a condition of 'fungistasis'). This fungistasis was easily countered by exudates of cocoa leaves, pods and roots. In a crucial experiment, Turner (1965) infested soil with a suspension of *P. palmivora* zoospores that had been passed through filter paper to free it from mycelium etc., and he showed that the inoculum remained viable in soils of intermediate water content for at least 18 months. Bimpong (1969) found that *P. palmivora* zoospores encysted on coming into contact with soil.

Survival as encysted zoospores could explain the Nigerian experiments by Griffin (Ward & Griffin, 1981) in which fibreglass tissue impregnated with cultures of *P. megakarya* and *P. palmivora* was buried in cocoa plantations and in bush soil, and retrieved for viability tests at intervals. Survival was demonstrated for at least 10 to 18 months. How the pathogen survived could not be ascertained, but survival as encysted zoospores would be consistent with Turner's findings.

P. megakarya evidently has low competitive saprophytic ability in soil (in the sense of Garrett, 1981). If the encysted zoospore survival hypothesis is correct, its persistence is better described as *survival* rather than as 'saprophytism'.

For these reasons we discount the hypothesis of mycelial growth through soil, in favour of occupation of the soil by motile zoospores which would soon encyst in a condition of fungistasis. However it is conceivable that zoospores in the soil germinate soon after encystment and survive as dwarf mycelia of the type described by Thomson & Allen (1976) for *P. parasitica* in irrigation water, though on biological grounds this seems less likely than the reversible induced fungistasis suggested by Turner.

RE-INTERPRETATION OF COCOA BLACK POD

The following is suggested for the annual cycle of *P. megakarya* in Nigeria, and with modifications it may well apply to other cocoa *Phytophthoras* elsewhere, and perhaps be relevant to some other *Phytophthora* diseases. Emphasis is placed on the motile zoospores, which are an important character of the genus *Phytophthora* (Figure 3), and on their cysts.

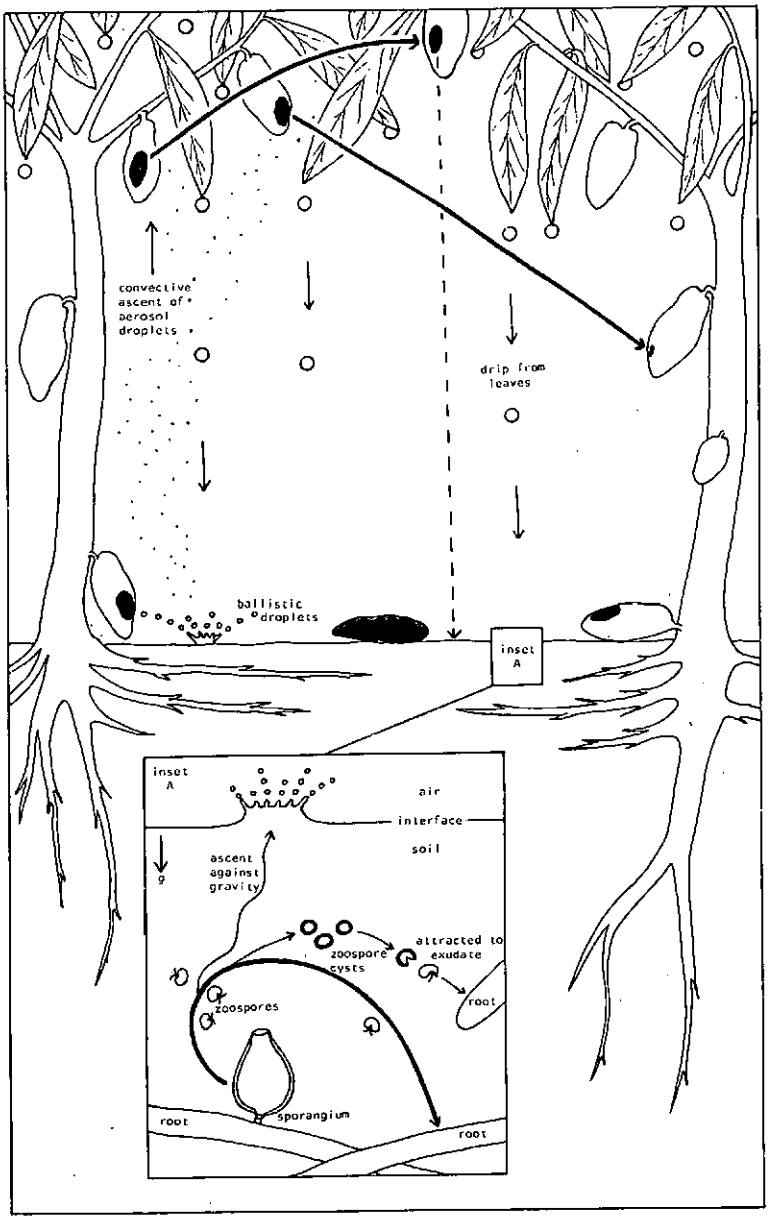

Figure 3.
Multiscale diagram illustrating the hypothetical disease cycle for Phytophthora megakarya at Gambari. The primary cycle on evanescent feeding roots, leading to infection of pods by inoculum propelled by splash during rain is shown.

The basic cycle on roots. P. megakarya is to be thought of as primarily a pathogen of the ephemeral feeding roots of the cocoa tree, probably not causing serious damage under good growing conditions, but becoming harmful when too many feeding roots are invaded.

By analogy with other root-invading *Phytophthoras*, it is supposed that sporangia are produced on the surface of infected roots, liberating motile zoospores into the soil water. These zoospores tend to swim upwards towards the soil surface unless overridden by chemical attraction towards a cocoa root where they will encyst and infect.

Most of the zoospores fail to reach a root and will encyst, remaining dormant for a period until stimulated to germinate, perhaps when the soil crumb is explored by a feeding root, as probably occurs several times in a season.

In the dry season the fungus is assumed to survive either as mycelium *within* infected roots *or* as encysted zoospores under influence of soil fungistasis, an ambiguity not yet resolved. Onset of rain after the dry season will bring renewed exploration by the transient feeding roots in the upper 20 cm of soil, and these could become infected when their exudates stimulate nearby encysted zoospores to germinate.

In comparison with this principal cycle on roots, the above-ground activity of *P. megakarya* may well be of secondary importance for survival, though important in dissemination, and of course vital to the cocoa farmer, who sells beans not roots. It remains to be seen whether *P. palmivora* in Ghana, where cushion infection looms large with a less severe dry season, also depends on the soil cycle.

The secondary cycle on pods. Some weeks after the start of the rain, with the growth of new feeding roots, the zoospore population in the soil is assumed to increase. When the soil is saturated, zoospores will concentrate at the soil surface (possibly as cysts) where some are picked up by ballistic and aerosol droplets and may become initiators of pod infections, which are reinforced by initiators from ant tents and other sources. All these initiators give rise to sequences of infected pods. All kinds of initiators continue to arise through most of the rainy season, setting up sequences until the epidemic stops abruptly before the rains end.

The possibility that *P. megakarya* is primarily a root pathogen, continually re-infecting the ephemeral feeding roots, should be investigated as contributing to the notorious difference in yield of trees in the same plantation. Root systems of sample trees, both productive and unproductive, could be excavated during the rainy season and tested for *Phytophthora* invasion. Local variations in size of soil pores, which could control zoospore motility, should be investigated.

The 'ultimate hygiene' experiment indicated that any return cycle of sporangia, zoospores and old husks which add inoculum to the litter layer was of secondary importance compared with the active cycle on the roots. Future research effort should concentrate on the subterranean part of the annual cycle, both to avoid loss of pods and to correct chronic weakening of the trees. Studies are needed on the growth cycle of feeding roots, and on the nature of the resting phase of the fungus during the dry season. The possible survival as mycelium in old feeding roots, as chlamydospores or as encysted zoospores all need to be examined.

CONTROL: THE WAY AHEAD

The hypothesis suggests why cocoa black pod is so difficult to control. However, even if the pathogen multiplies below ground, and initiators arise throughout the season, control by sanitation does not seem hopeless, although in areas where conditions favour longer sequences than at Gambari the measures might be less rewarding.

Mulching in its broadest sense should be re-examined with the aim of preventing splash from the ground. The lack of success when Newhall, Dias & Salazar (1966) placed a 3-inch (8 cm) layer of 'coffee parchment' around tree bases was attributed to inoculum sources from the canopy outweighing inoculum from the soil. When the International Team at Gambari covered areas of plantation floor with black 'polyethylene' sheeting, the lack of effect could have been due to re-splash of zoospores from ponded rainwater held on the sheeting.

Experiments on the effect of mulching should be done on large plots each perhaps of 100 trees. The following tests could start the project.

– Remove leaf litter from some plots and place material removed on other plots, to test the protective or infective functioning of litter;

– Cultivate low-growing plants as ground-cover, choosing species tolerant of the low light intensity under the canopy. This should check vertical movement of drops and droplets in both directions. Possibly such mulching by natural vegetation explains the surprising absence of black pod from an abandoned cocoa plantation in French Guiana commented on by Braudeau (1962).

Mulching can of course act only against splashed initiators and is unlikely to deter tent-building ants, which would still need separate control measures.

Only if very beneficial would mulching remove the need for fungicidal treatment of pods and canopy. Renewed attention could be given to applying fungicides to the ground, choosing relatively insoluble materials such as unwettable oxides of copper, which might be applied as a powder to save transport of water. Spraying or dusting the soil as well as the trees seems to have been practised in Fernando Po for many years (O.E.K. Laband, pers. comm.). From the continual occurrence of initiators throughout the rains, it may be deduced that fungicidal application to pods will be beneficial at any time.

Systemic fungicides that will reach the roots, either applied to foliage or as a drench to the soil, should be sought to prevent root infection and decrease the inoculum at the soil surface. A choice of compounds may be needed because the fungus, being diploid, may be expected to develop resistance to systemic fungicides fairly rapidly.

Plant breeding should aim at stable root resistance to *Phytophthora,* continuing the screening tests for root resistance developed by Turner & Asomaning (1962) and by Zentmyer *et al.* (1968). Screening the cocoa germplasm pool for root resistance should be started forthwith.

CONCLUSIONS

The new evidence presented demands a re-assessment of the role of the various species of *Phytophthora* in cocoa plantations. Much remains unknown or speculative, and research is needed in the different cocoa producing regions to elucidate the epidemiology on roots in relation to the epidemic on pods.

Field experiments, especially the 'ultimate hygiene' experiment which ran from 1975 to 1978, formed the most important effort of the project and gave a strong indication that *P. megakarya* is primarily a root infector, an indication which we cannot afford to ignore because of the effect of the subsequent pod rot on the cocoa farmer.

This interpretation is speculative but reasonable and is supported by much evidence. It is put forward in order to stimulate a broader investigation of the role of *Phytophthora* in the cocoa plantation.

REFERENCES

Adebayo, A.A. (1983) The importance of lower pods in the control of the cocoa *Phytophthora* pod rot. *Turrialba, 33,* 211-214.

Bimpong, C.E. (1969) Study on factors influencing zoospore motility and chemotaxis in *Phytophthora palmivora* (Butl.) Butl. *M.Sc. Thesis, University of Ghana.*

Brasier, C.M. & Griffin, M.J. (1979) Taxonomy of *'Phytophthora palmivora'* on cocoa. *Trans. Brit. Mycol. Soc., 72,* 111-143.

Braudeau, J. (1962) Les cacaoyers de Guyane Française. *Café-Cacao-Thé, 6,* 198-190.

Cameron, J. & Carlile, M.J. (1977) Negative geotaxis of the fungus Phytophthora. *J. Gen Microbiol., 98,* 599-602.

Garrett, S.D. (1981) *Soil Fungi and Soil Fertility.* 2nd Ed Pergamon Press, Oxford etc. 150 pp.

Gregory, P.H. (1969) *Black Pod Disease Project Report.* London The Cocoa, Chocolate & Confectionery Alliance. 52 pp.

Gregory, P.H. (1981) Speculation on Phytophthora as a cocoa root pathogen. *Proc. 7th Internat. Cocoa Res. Conf., Douala, Cameroun, 1979,* pp. 267-269.

Gregory, P.H., Guthrie, E.J. & Bunce, M.E. (1959) Experiments on splash dispersal of fungus spores. *J. Gen. Microbiol., 20,* 328-354.

Gregory, P.H. & Maddison, A.C. (Editors) (1981) *Epidemiology of Phytophthora on Cocoa in Nigeria. Phytopathological Paper No. 25,* Kew: Commonwealth Mycological Institute. 188 pp.

Griffin, M.J., Idowu, O.L., Maddison, A.C., Taylor, B. and Ward, M.R. (1981) Sources of infection. Chapter 6 in: *Epidemiology of Phytophthora on cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison). Kew: Commonwealth Mycological Institute. pp. 75-95.

Griffin, M.J. & Maddison, A.C. (1981) Detection and movement of inoculum. Chapter 3 in: *Epidemiology of Phytophthora Disease of Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison). Kew, Commonwealth Mycological Institute. pp. 31-49.

Harris, D.C., Cardon, J.A., Justin, S.H.F.W. and Passey, A.J. (1984) *Phytophthora palmivora* on cultured roots of coconut. *Trans. Brit. Mycol. Soc., 82,* 249-255.

Henry, C.E. (1977) Primary sources of *Phytophthora palmivora* (Butl.) Butl. inoculum in Jamaica and methods of control. *Proc. 5th Internat. Cocoa Res. Conf., Ibadan, Nigeria, 1975.* pp. 388-396.

Hickman, C.J. & Ho, H.H. (1966) Behaviour of zoospores in plant pathogenic phycomycetes. *Ann. Rev. of Phytopath., 4,* 195-200.

Maddison, A.C. (1977) Three-dimensional mapping of *Phytophthora* pod rot of cocoa. *Proc. 5th Internat. Cocoa Res. Conf., Ibadan, Nigeria, 1975,* pp. 409-422.

Maddison, A.C. (1981) Three-dimensional mapping of disease incidence. Chapter 5 in: *Epidemiology of Phytophthora on Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison). Kew: Commonwealth Mycological Institute, pp. 62-74.

Maddison, A.C. (1981) Terminology and methods for analysis of *P. megakarya* infection sequences. Appendix 1 in: *Epidemiology of Phytophthora on Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison, Kew: Commonwealth Mycological Institute), pp. 179-181.

Maddison, A.C. & Griffin, M.J. (1981) Detection and movement of inoculum. Chapter 3 in: *Epidemiology of Phytophthora on Cocoa in Nigeria*, (Eds. P.H. Gregory & A.C. Maddison). Kew: Commonwealth Mycological Institute. pp. 31-49.

Muller, R.A. (1974) Effect of prophylactic measures on the dissemination of *Phytophthora palmivora*. Chapter 16 in: *Phytophthora Disease of Cocoa* (Ed. P.H. Gregory). London: Longman. pp. 169-178.

Newhall, A.G., Diaz, F. & Salazar, G. (1966) Results of some soil treatments on black pod rot of cacao caused by *Phytophthora palmivora*. *Cacao, 11,* 10-12.

Okaisabor, E.K. (1970) Epidemiology of *Phytophthora palmivora*. *Rep. Cocoa Res. Inst. Nigeria, 1968-69,* p. 47.

Okaisabor, E.K. (1971) The mechanism of initiation of *Phytophthora* pod rot epiphytotics. *Proc. 3rd Internat. Cocoa Res. Conf., Accra, Ghana, 1969,* pp. 398-404.

Okaisabor, E.K. (1974) Phytophthora pod rot infections from the soil. Chapter 16 in: *Phytophthora Disease of Cocoa* (Ed. P.H. Gregory). London: Longman. pp. 161-168.

Onesirosan, P.T. (1971) The survival of *Phytophthora palmivora* in a cocoa plantation during the dry season. *Phytopathology, 61,* 975-977.

Orellana, R.G. (1954) Contribution to the study of the survival, dissemination and control of *Phytophthora palmivora* of cacao. *Proc. V. Inter-American Cacao Conf., Turrialba, Costa Rica, 1954, Secc. Fitopatologia.*

Tarjot, M. (1967) Etude de la pourriture des cabosses dûe à *Phytophthora palmivora* (Butl.) Butl. en Côte d'Ivoire. Lieux de conservation du parasite pendant la saison sèche. *Café-Cacao-Thé, 11,* 321-330.

Taylor, B. & Adedoyin, S.F. (1981) A general view of ant biology in relation to cocoa. Chapter 9 in: *Epidemiology of Phytophthora on Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison) Kew: Commonwealth Mycological Institute. pp. 132-144.

Taylor, B. & Griffin, M.J. (1981) The role and relative importance of different ant species in the dissemination of black pod disease of cocoa. Chapter 8 in: *Epidemiology of Phytophthora on Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison) Kew: Commonwealth Mycological Institute. pp. 114-131.

Thomson, S.V. & Allen, R.M. (1976) Mechanisms of survival of zoospores of *Phytophthora parasitica* in irrigation water. *Phytopathology, 66,* 1198-1202.

Thorold, C.A. (1955) Observations on black pod disease *(Phytophthora palmivora)* of cacao in Nigeria. *Trans. Brit. Mycol. Soc., 38,* 435-452.

Turner, P.D. (1963) Influence of root exudates of cocoa and other plants on spore development of *Phytophthora palmivora*. *Phytopathology, 53,* 1337-1339.

Turner, P.D. (1965) Behaviour of *Phytophthora palmivora* in soil. *Plant Disease Reporter 49,* 135-137.

Turner, P.D. & Asomaning, E.G.A. (1962) Root infection of *Theobroma cacao* L. by *Phytophthora palmivora* Butl. *Trop. Ag. (Trin.), 39,* 339-343.

Ward, M.R. & Griffin, M.J. (1981) Soil phase of cocoa *Phytophthora*. Chapter 4 in: *Epidemiology of Phytophthora on Cocoa in Nigeria* (Eds. P.H. Gregory & A.C. Maddison). Kew: Commonwealth Mycological Institute, pp. 50-61.

Zentmyer, G.A. (1965) Bacterial stimulation of sporangial production in *Phytophthora cinnamomi. Science, 150,* 1178-1179.

Zentmyer, G.A. & Mircetich, S.M. (1966) Saprophytism and persistence in soil by *Phytophthora cinnamomi. Phytopathology, 56,* 710-712.

Zentmyer, G.A., Mircetich, S.M. & Mitchell, D.M. (1968) Tests for resistance of cacao to *Phytophthora palmivora*. *Plant Disease Reporter, 52,* 790-791.

Flowering of Cocoa

Paulo de T. Alvim
Scientific Director, CEPEC-CEPLAC, Itabuna, Bahia, Brazil.

Cocoa (*Theobroma cacao* L.) belongs to the family Sterculiaceae and its centre of origin is believed to be the headwaters of the Amazon basin, where *Theobroma* and related genera are found in greater proportion than elsewhere. From its centre of origin the species spread mostly in two directions, resulting in the two primary groups of cultivars known as "criollo" and "forastero".

Cocoa is a typical cauliflorous species, the flowers giving the impression of originating directly from the bark of the plant. A cocoa flower is shown in Plate 1. Actually they are formed in minute inflorescences with short internodes and branchlets, originating from the axil of the leaves. Cocoa has two buds in the axils of most of its leaves, a larger one known as the "principal" bud, visible to the naked eye, and a smaller one, the "subordinate" bud, often obscured by the dense indumentum of the stem and located in a depression in the stem between the principal bud and the base of the petiole. The principal bud only grows as a vegetative branch, while the subordinate bud usually forms an inflorescence (Wheat, 1979). Some authors have been able to cause a subordinate bud to grow out as a vegetative branch by decapitating the shoot and destroying the principal bud.

The term "flower-cushion" is commonly used to refer to the site where the inflorescences appear. Each cushion remains active, i.e. produces flowers for many years, apparently only becoming sterile when accidentally injured by cuts (as often happens when the fruits are harvested) or because of bark diseases (such as *Phytophthora* canker).

In young plants the flowers are produced mainly on the trunk, but in mature trees they normally appear in the canopy as well and certainly in most of the branches thicker than about 1 cm in diameter. As the branches become thicker, the flower cushions usually become swollen and the number of flower buds per cushion increases. As a rule, no more than 1 or 2 flowers open per cushion on the same day, but under favourable conditions for flowering it is common to find as many as 5–10 open flowers in old cushions and a much greater number of flower buds at different stage of development. An adult cocoa plant may produce several thousand flowers per year, sometimes more than 50,000, of which only a small proportion (usually less than 5 per cent) are pollinated, and an even smaller fraction (0.5–2.0 per cent) lead to the final crop. From pollination to harvesting the fruit, which weighs from 400 to 800 g and is referred to as "pod", takes from 5 to 6 months to mature, depending on the temperature (Alvim, 1977).

Flower Structure

The individual flower (Fig. 1) has a thin and relatively long (1–1.5 cm) pedicel and a calyx with 3 to 7 (normally 5) sepals measuring 6 to 8 mm long. Prior to anthesis these sepals form an oval body, measuring 5 x 3 mm, at the tip of the pedicel. The corola has 5 petals about 6 – 8 mm long which are divided in two sections: a lower one corresponding to the claw, which is strongly veined and in the shape of a hood (*cucullus*), normally with two red lines, and an upper white blade (lamina) which is flat, flexible, and articulated

to the apex of the claw. The androecium has an outer whorl of 5 sterile and rather long (5–7 mm) staminodes, opposite to the sepals, usually with red pigmentation, and an inner whorl of 5 fertile and relatively short stamens opposite to the petals. The anthers are hidden inside the petal-hoods and have two unilocular thecae which open by a longitudinal cleft. The gynoecium has an ovoid 5-celled ovary with 40 to 60 ovules (two rows of 8–12 in each cell) and five apical stigmas.

FLOWER BIOLOGY

The anthesis of the cocoa flower follows a typical nyctitropic pattern. Normally, the process begins late in the afternoon, when the sepals start to separate from each other, and is completed early in the morning of the next day, usually between 4 and 6 a.m. This pattern has been observed also with leafless branches, detached from the plant, supplied with water and exposed to different treatments of temperature and photoperiodism. The nyctitropic movement remained unalterable under all conditions, suggesting an endogenous stimulus for anthesis.

Cocoa is a species which is pollinated by insects and thus has a flower structure adapted for cross-fertilization. Flowers which are not pollinated within the first 8–10 hours after anthesis will normally fall in the next 24–28 hours. It is now well established that the most effective and important natural pollinators are the tiny midges of the genus *Forcipomyia* (Diptera: Ceratopogonidae) and there are numerous species involved in cocoa pollination (Chapman and Soria, 1983; Winder, 1978). A few other small insects, such as thrips, ants and aphids, may also pollinate the flowers, but *Forcipomya*, because of their size and shape, are more efficient in collecting pollen (when crawling under the petal-hoods which cover the anthers) and in transferring pollen to the stigma (when crawling down the staminodes of a next flower). This is regarded as a case of "mutual-adaptation" between plant and insect. The midges are believed to visit the flowers in search of food and/or perfume, but this has not been experimentally demonstrated. Some authors suggested that the red pigmentation of the staminodes and petal-hoods would be a stimulus to attract the insects, but this hypothesis also is not generally accepted, as flowers of unpigmented cultivars are equally attractive to the midges.

A considerable amount of research has been done on the biology and taxonomy of *Forcipomya.* Of the various species reported as important cocoa pollinators in different regions, the most frequently found belong to the subgenus *Euprojoannisia,* formerly named *Proforcipomyia* (Saunders, 1959; Winder, 1978).

Cocoa flowers may also be "artificially" pollinated by mechanical means, such as, for instance, by agitating the flowers with a hand brush or by blowing air directly on to the flowers with a motorized blower. These treatments have been reported to increase fruit setting and yield when applied to self-compatible cultivars in areas where shortage of natural pollinators is a common problem.

FACTORS AFFECTING FLOWERING

Comparative studies on the seasonal flowering pattern in the various cocoa growing countries show that flower production is primarily controlled, either directly or indirectly, by climatic factors. As a rule, in regions with well defined seasonal variability in rainfall and/or temperature, flowering is much reduced or may be completely inhibited during excessively dry or relatively cold periods (Alvim, 1966; Boyer, 1970; Asomaning *et al.*, 1971). In places with well distributed rainfall and no marked seasonal differences in temperature, cocoa usually produces flowers and fruits throughout the year. Even in such regions, however, flowering is never uniform during the year but varies in intensity under the influence of different factors, some of which are not completely understood. Since different factors may simultaneously affect the flowering process it is often difficult to establish causal relationships for the variability of flowering.

In the author's opinion, fluctuations in flowering intensity are linked to the growth rhythms of the inflorescences themselves, which apparently follow a pattern similar to, but not necessarily synchronous with, the growth rhythms or flushing cycles of the vegetative buds of the plant. Both phenomena are affected not only by climatic factors but also by internal plant factors. Once an inflorescence starts its own "flushing cycle", the young flower buds begin to expand in sequence (as in the case of leaf flushes) this leading to a "wave" of flowering which may last for several days or weeks. The period of fastest growth of the individual buds apparently occurs during the last 10—12 days prior to anthesis, when they expand from the size of a pin-head to fully grown (Gorrez, 1962). The buds apparently do not have a rest period and anthesis occurs as soon as they reach full size (Sale, 1970a). An analysis will now be made of internal and external factors controlling the flowering of cocoa. Regrettably, because of limited research on flower bud initiation in cocoa, it is not always possible to separate the influences of these factors on bud differentiation and bud growth.

Internal factors

Our knowledge about internal or plant factors is based on studies related to the effect of age, girdling, internal correlation, and cambium activity. No attempt has been made to identify the chemical nature of flowering stimulus.

(a) *Age* — The age at which cocoa starts producing flowers varies greatly with cultural practices and genetic origin of the plant. As a rule, high yielding varieties under good management start flowering at the age of about 2 years in the field, while unselected varieties under traditional cultural practices start at the age of 3 to 4 years. Plants growing in nutrient solutions under greenhouse conditions may start flowering before one year of age. An extreme case of genetically controlled premature flowering has been reported for some "criollo" seedlings from Mexico, which began to produce flowers at the age of only 3 months.

In places where there is a marked seasonal fluctuation in flowering it has been observed that this fluctuation is much more pronounced in mature plants than in young ones. These differences may be due not to age itself, but to plant size or to the microclimate around the plants. Smaller plants, because of reduced leaf canopy or less self-shading, are more exposed to solar radiation than larger plants, and this may be an important factor in the

difference in their response to variations in climate. Older plants, on the other hand, because of their larger proportion of nonphotosynthetic tissues which act as a sink for photosynthates, may also be more readily depleted of flower promoting substances than younger plants (Alvim, 1977).

(b) *Girdling* — The removal of a ring of bark from the trunk of mature trees has the effect of increasing flowering on the portion of the trunk above the ring and decreasing or completely arresting flowering below the ring. Approximately forty-five days elapse between girdling and full bloom. Some studies suggest the possibility of using ringing as a method to induce out-of-season flowering or to change the cropping pattern. In Ecuador, where fruit losses carried by the diseases "Witches' broom" (*Crinipellis perniciosa*) and "Monilia pod-rot" (*Monilia roreri*) are strongly seasonal, the method is claimed to be relatively efficient in reducing the disease incidence in some regions (Vera *et al.*, 1982).

(c) *Internal correlations* — Among some cultivars of cocoa it is common to find a few plants which bear no fruit or have a limited crop because of a genetically controlled flower sterility or incompatibility. Such plants, which are usually referred to as "male trees", invariably show very profuse flowering. It has also been observed that in most regions where there is pronounced seasonal variation in flowering, the period of low flowering invariably occurs when the plants have the highest fruit load. These are clear indications of a competitive correlation or a depressing effect of fruits on flowering (Hutcheon *et al.*, 1972).

To study interactions between flowering and fruiting an experiment was conducted in Brazil in which fruits were manually removed every two weeks for a period of two years (Vogel *et al.*, 1982). Flowering intensity which was measured in comparison with untreated plants growing in the same area showed marked increases following fruit removal. Partial fruit removal also stimulated flowering, although not as markedly as when all fruits were removed. The study indicated that fruit size or age appeared to make little difference, as flowering intensity increased following the removal of either young (between 1–6 cm in length) or of nearly mature fruits. In other species, this depressing effect of fruits on flowering has been attributed to growth substances produced by the seeds of the growing fruits, such as gibberelic acid, which is known to inhibit flower initiation.

(d) *Cambium activity* — With the help of a sensitive liquid displacement dendrometer, cambium growth was measured at weekly intervals in Bahia, Brazil, from 1975 to 1978. Simultaneous studies on the flowering pattern of the same plants showed that the period of minimum cambium activity, normally from July to October, coincided every year with the period of minimum flowering. Resumption of cambium growth took place in October or mid-November and was followed by a resumption of flowering about 5 to 6 weeks later. It was concluded that two factors probably contributed to the seasonal decrease in flowering and cambium growth in this study: the relatively low temperature from June to September and the inhibiting effect of the heavy load of fruits in the plants as previously discussed.

External factors

The main environmental factors affecting flowering are shading, temperature and rainfall distribution or moisture availability. Photoperiodism has apparently no effect on flowering of cocoa.

(a) *Shading* — Because cocoa is usually grown in association with larger trees, much attention has been given to research on its response to shading. It is now well established that the benefit of shading is not to provide a low light intensity considered optimal for growth and yield but mainly to counteract unfavourable factors such as moisture stress, nutrient deficiencies, wind damage, etc., which are usually more severe when the plants are grown without shade (Murray, 1957; Alvim, 1977). When such unfavourable conditions are not present or are controlled by methods other than the use of overhead shade, yield is usually higher when the plants are grown with little or no shade.

Several studies have demonstrated that plants grown without shade flower earlier and more profusely than shaded plants. An experiment in Ghana comparing three shade regimes (heavy, light and no shade) showed that flowering followed the same seasonal pattern in all regions but the total number of flowers produced decreased significantly with increasing shade (Asomaning *et al.*, 1971). Conditions for effective pollination were more favourable under light shade than under no shade and fruit set was highest in that regime. However, the final yield was higher under no shade because of reduced loss of fruits from the physiological disturbance known as "cherelle wilt".

Relatively young plants appear to be more sensitive to shade than old ones. This was found in a study in Brazil comparing 12 and about 50-year-old plants, in which shading reduced flowering by two thirds in the former and about one half in the latter (Leite and Muller, 1982).

(b) *Temperature* — The effect of temperature on flowering has been studied both under field conditions and in controlled environment rooms. Field studies in Bahia, Brazil, (Alvim, 1977) and in Cameroon (Boyer, 1970) suggest that flowering was inhibited when the mean monthly temperature dropped below 23°C and that this effect of low temperature appeared to be "indirect" in the sense that it first affected vegetative growth which in turn would affect flowering about two months later (Alvim, 1966). This "indirect" influence was not supported by research under controlled temperature conditions which showed that temperature directly affected the process of flower bud differentiation (Sale, 1969). The two months time lag observed under field conditions may probably be attributed to the fact that flower counts were not based on bud differentiation but on flower dropping. As suggested by the work on the effect of girdling on flowering, the time lag between differentiation and anthesis appears to be about 45 days.

The work under controlled temperature conditions also demonstrated that flowering was greater at day temperatures of 26 and 30°C than at 23°C and at each level of day temperature, flowering was greater at a night temperature of 26°C than at one of 23 or 30°C. The relative effects of temperature were similar on numbers of flowering cushions per plant and of flowers per cushion.

Some recent studies carried out in Bahia revealed that low temperature alone cannot explain the reduced flowering observed in that region from July to October. It has been found that the period of low flowering from July to

August resulted mainly from relatively low temperature but in September-October the heavy load of fruits on the plants appears to be the main cause of low flowering. As mentioned already, fruit removal greatly increased flowering during the period of relatively low temperature, although not as much as during warmer periods.

(c) *Moisture availability* – Among perennial crops grown in the wet tropics, cocoa is regarded as one of the most sensitive to moisture stress. Changes in soil moisture availability during the year are generally recognised as the most important climatic factor controlling the physiological processes of the plant, including flowering. In all producing regions variation in yield from year to year or changes in the cropping pattern during the year are caused primarily by irregularities in the distribution and total volume of rainfall. In many cocoa growing areas good crops have long been known to be associated with favourable rainfall distribution during the year.

The effect of moisture availability on flowering of cocoa has been the subject of much investigation in several countries. Results from field studies in places with a well defined dry season have clearly demonstrated the depressing effect of moisture stress on flowering. Research with plants grown in containers under controlled soil moisture conditions also demonstrated that the flowering rapidly diminishes then ceases altogether when the plants are submitted to moisture stress. This research has also shown that when stressed plants are rewatered or submitted to a "wet regime" following a fairly long (6 months) "dry regime", flowering starts again and becomes exceptionally profuse a few weeks later. This has been interpreted as an indication that flower initiation had been enhanced during the dry regime and only bud development was inhibited by moisture stress (Sale, 1970a).

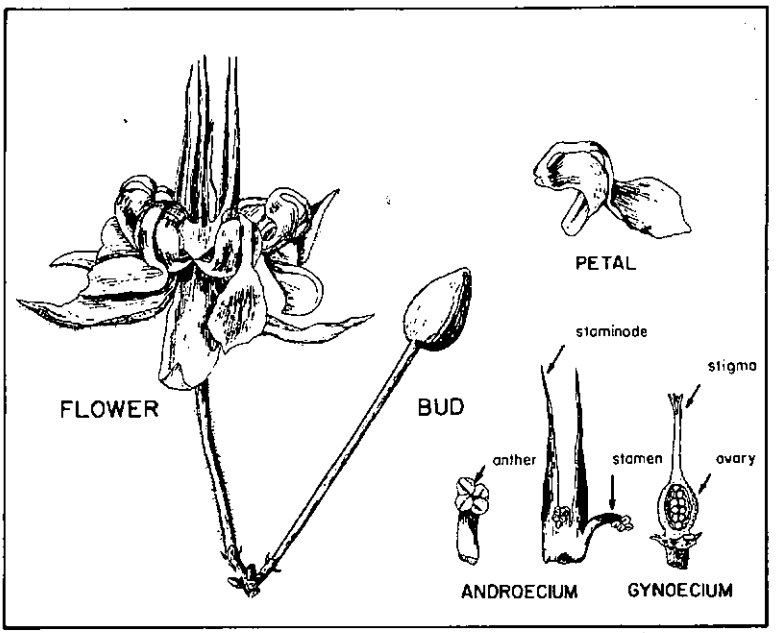

Figure 1. The flower of cacao and its parts

Research with potted plants under controlled atmospheric relative humidity has also shown that flowering of cocoa can be induced by transferring plants from a low (50 to 60 per cent) or medium (70 to 80 per cent) relative humidity to a high one of from 90 to 95 per cent (Sale, 1970b).

Results from phenological studies in Brazil also demonstrated that flowering is greatly stimulated when rain follows a period of moisture deficiency. A similar type of response to a transition from dry to wet conditions has been clearly demonstrated in the case of coffee flowering, but here the flower buds remain in a state of complete rest for as long as the plants are frequently watered and kept under high atmospheric humidity, a "dry shock" apparently being necessary to break the resting period. In the case of cocoa this does not appear to be the case, as the flower buds do not go through a rest period imposed by high water potential and flowers are produced even under conditions of frequent watering or high humidity, although not as profusely as when watering alternates with dry periods. This has been demonstrated in an experiment carried out in a very dry region (about 400 mm of annual rainfall) where cacao was submitted to different irrigation regimes. Plants which received frequent irrigation so as to avoid alternate periods of moisture stress, produced less than half the amount of flowers of periodically stressed plants. The difference between treatments became particularly evident about 7 or 8 weeks after the drier plots were wetted either by irrigation or rain (Silva *et al.*, 1982). It is worth noting that in cocoa a transition from dry to wet periods has a stimulating effect not only on flowering but also on the flushing cycles of vegetative buds.

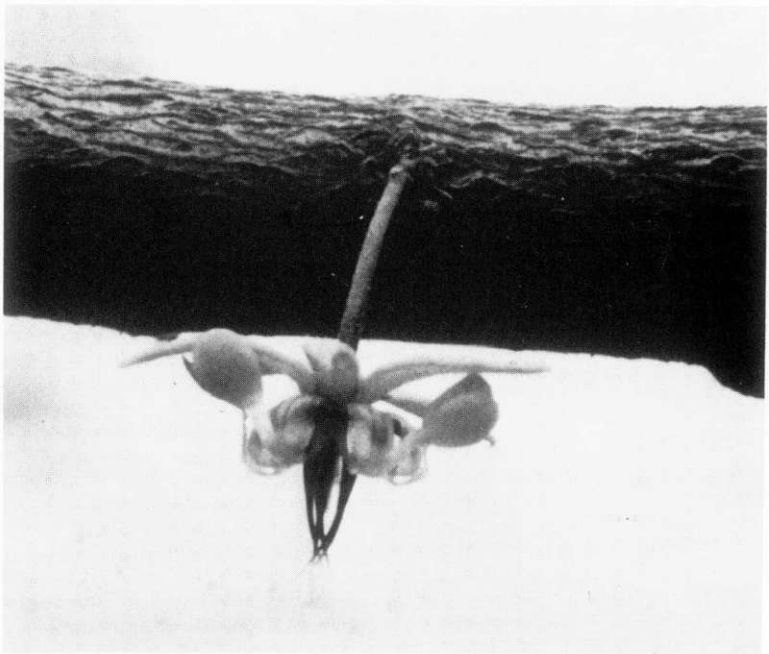

Plate 1. A cocoa flower (K. Hardwick)

REFERENCES

Alvim, P. de T., Correlaçao entre chuva, temperature e produçao do cacaueiro. *Reuniao do Comité Técnico Interamericano de Cacau, VI, Bahia, Brazil,* 1956, pp. 133-136.

Alvim, P. de T., Las necesidades de agua del cacao. *Turrialba* 10, 6-16, 1960.

Alvim, P. de T., Moisture stress as a requirement for flowering of coffee, *Science,* 132 (3423):354, 1960.

Alvim, P. de T., Tree growth periodicity in tropical climates. *The Formation of Wood in Forest Trees.* Zimmermann, M.H., ed. Academic Press, New York, 1964, pp.479-495.

Alvim, P. de T. (1966) Factors affecting the flowering of the cocoa tree. *Cocoa Growers Bulletin 7,* 15-19.

Alvim, P. de T., Eco-physiology of the cacao tree. *Conf. Int. Rech. Agron. Cacaoyeres, 1967,* pp. 23-25.

Alvim, P. de T., A new dendrometer for monitoring cambium activity and changes in the internal water status of plants. *Turrialba,* 25, 445-447, 1975.

Alvim, P. de T. (1977) Cacao. *Ecophysiology of Tropical Crops.* Alvim, P. de T. and Kozlowski, T.T., eds. Academic Press, New York, 279-313.

Alvim, P. de T., Unpublished results.

Alvim, P. de T., Machado, A.D. and Vello, F., Physiological responses of cacao to environmental factors. *Proc. 4th Internat. Cocoa Res. Conf., Trinidad,* pp. 210-225.

Arevalo, A.R. and Soria, S. de J., Evaluación de cuatro metodos de polinización artificial en el aumento de producción de cacao (*Theobroma cacao* L.). *Proc. 5th Internat. Cocoa Res. Conf., Ibadan, Nigeria,* pp. 78-84.

Asomaning, E.J.A., Kwakwa, R.S. and Hutcheon, W.V. (1971) Physiological studies on an Amazon shade and fertilizer trial at the Cocoa Research Institute, Ghana. *J. Agric. Sci. 4,* Part 1, 47-64.

Boyer, J. (1970) Influence des régimes hydrique, radiatif et thermique du climat sur l'activité végétative et la floraison de cacaoyers cultivés au Cameroun. *Café Cacao Thé 14* (3): 189-201.

Bridgland, L.A., Study of the relationship between cacao yield and rainfall. *The Papua and New-Guinea Agricultural Gazette* 8(2): 7-14, 1953.

Cassin, J., The influence of climate upon the blooming of citrus in tropical areas. *Proc. 1st Int. Citrus Symp. 1969,* Vol. 1, Sect. 1, pp. 315-323.

Chan, B.G. and Cain, J.C., The effect of seed formation on subsequent flowering in apple. *Proc. American Soc. Hortic. Sci.* 91:63-68, 1967.

Chapman, R.K. and Soria, S. de J. (1983) Comparative *Forcipomyia* (Diptera, Ceratopogonidae) pollination of cacao in Central America and Southern Mexico. *Revista Theobroma 13* (2):129-139.

Cuatrecasas, J., *Cacao and its Allies: A Taxonomic Revision of the Genus Theobroma.* Smithsonian Institute, Washington, D.C., 1964.

Furr, J.R., Cooper, W.C. and Reece, P.C., An investigation of flower formation in adult and juvenile citrus trees. *Am. J. Bot.,* 34, 1-4, 1947.

Gil, G.F., Martin, G.C. and Griggs, W.H., Fruit-set and development in the pear: diffusible growth substances from seeded and seedless fruit. *Journal American Society of Hortic. Sci. 98,* 51-54, 1975.

Gorrez, D.D. (1962) The flower biology, morphology and pollination and cross habits of cacao. *Philippine Agriculturist 46* (4): 288-302.

Hoad, G.V. and Ramirez, H., La función de las giberelinas sintetizadas en las semillas del fruto para el control de la floración en manzanos. *Turrialba 30* (3): 284-288, 1980.

Hutcheon, W.V., Smith, R.W. and Asomaning, E.J.A. (1972) Effect of irrigation on the yield and physiological behaviour of mature Amelonado cocoa in Ghana. *Trop. Agric. (Trinidad)* 50 (4):261-272, 1972.

Kozlowski, T.T., *Growth and Development of Trees, Vol. 2,* Academic Press, New York, 1971.

Leite, R.M. de O. and Müller, M.W. (1982) Estudos fenológicos em cacaueiros expostos ao sol e à sombra. CEPLAC-CEPEC. *Informe Técnico 1981.* Ilhéus, p. 105.

Lent, R., The origin of the cauliflorous inflorescence of *Theobroma cacao. Turrialba* 16 (4):352-358, 1966.

Leon, J., *Fundamentos botánicos de los cultivos tropicales.* Instituto Interamericano de Ciencias Agricolas de la O.E.A. San José, Costa Rica, 1968, 487pp.

Machado, R.C.R., Alvim, P. de T. and Milde, L.E., Efeito da deficiência de água no solo sobre o comportamento fisiológico do cacaueiro. CEPLAC-CEPEC. *Informe Técnico 1981.* Ilheus, 1982, pp. 61.

Martin, E.J., Efectos de polinización controlada en cacao. *Proc. 8th Internat. Cocoa Res. Conf., Cartagena, Colombia,* pp. 57-60.
Monti, J.R., La périodicité des pluies au Mayumbe et leur relation avec la production de cacao. *Bulletin Agricole du Congo Belge 44* (3): 493-510, 1953.
Murray, D.B. (1957) The use of shade for cacao. *6th Conf. Interam. Cacau,* 111-116.
Posnette, A.F., Pollination of cacao in Trinidad. *Trop. Agric. (Trinidad)* 21, 115-118, 1944.
Posnette, A.F., The pollination of cacao in the Gold Coast. *J. Hort. Sci.* 25, 155-163, 1950.
Posnette, A.F. and Entwistle, H.M., The pollination of cocoa flowers. Cocoa, Chocolate and Confectionery Alliance, Cocoa Conference Report. London 1957, pp. 66-68.
Pound, F.J., A note on a method of controlled pollination of cacao. *Fourth Annual Report on Cacao Research, 1934.* I.C.T.A., Trinidad, pp. 15-16, 1935.
Sale, P.J.M. (1969) Flowering of cacao under controlled temperature conditions. *J. Hortic. Sci. 44,* 163-173.
Sale, P.J.M. (1970a) Growth, flowering and fruiting of cacao under controlled soil moisture conditions. *J. Hortic. Sci. 45,* 99-118.
Sale, P.J.M. (1970b) Growth and flowering of cacao under controlled atmospheric relative humidities. *J. Hortic. Sci. 45,* 129-132.
Saunders, L.G., Revision of the genus *Forcipomyia* based on characters of all stages. *Can. J. Zool.* 34, 657-705, 1956.
Saunders, L.G., Report to A.C.R.I. on the cacao pollination study conducted in Trinidad and Costa Rica, June-September 1957.
Saunders, L.G. (1959) Methods for studying *Forcipomyia* midges, with special reference to cacao pollinating species. (Diptera, Ceratopogonidae). *Can. J. Zool. 37,* 33-51.
Silva, W.S. da, Alvim, P. de T. and Aragao, O.P. (1982) Fenologia do cacaueiro sob regime de irrigaçao diferencial. CEPLAC-CEPEC. *Informe Técnico* 1981. Ilhéus, pp. 35-37.
Skidmore, C.L., Indications of existing correlation between the rainfall and the number of pods harvested at Aburi and Asuansi. *Gold Coast Department of Agriculture Bulletin* 16, 114-120, 1929.
Soria, J., A note on cacao plants which flowered at the age of three months. *Cacao* 6, 11-12, 1961.
Soria, J. and Cerdas, M., Rendimiento del cacao en relación con polinización artificial y abonamiento. *Cacao* 15 (3):11-12, 1970.
Soria, S. de J., Studies on *Forcipomyia* ssp. midges (Diptera, Ceratopogonidae) related to the pollination of *Theobroma cacao* L. Madison, University of Wisconsin. Ph.D. Thesis 129 p. 1970.
Soria, S. de J., Induçao da produçao em cacaueiro com o uso de atomizador portátil na Bahia, Brasil. *Revista Theobroma* 4 (2):3-13, 1974.
Soria, S. de J., Silva, P. and Chapman, R.K., Influence of floral pigmentation on field pollination rates in some cultivated varieties of *Theobroma cacao* L.: some effects on yield. *Revista Theobroma* 13 (2):141-149, 1983.
Soria, S. de J. and Wirth, W., Ciclos de vida dos polinizadores do cacaueiro *Forcipomyia* spp. (Diptera, Ceratopogonidae) e algumas anotaçoes sobre o comportamento das larvas no laboratório. *Revista Theobroma* 5 (4):3-22, 1975.
Soria, S. de J., Wirth, W. and Besemer, H.A., Breeding places and sites of collection of adults of *Forcipomyia* spp. midges (Diptera, Ceratopogonidae) in cacao plantations in Bahia, Brazil: A progress report. *Revista Theobroma* 8, 21-29, 1978.
Takhitajian, A.L., *Origins of the Angiospermous plants.* Soviet Sciences Press. Stebbins, G.L., ed. American Institute of Biological Sciences, Washington, D.C. 1954 68p.
Vera B., J., Mogrovejo J., E. and Moreira D., M. (1982) La polinización suplementaria y cortes en el tallo como practicas simples para incrementar los rendimientos en cacao. *Proc. 8th Internat. Cocoa Res. Conf., Cartagena, Colombia, 1982,* 31-35.
Vogel, M., Existence d'un gradient morphogène au niveau des burgeons végétatifs supérieurs des axes orthotropes chez le cacaoyer (*Theobroma cacao* L., Sterculiaceae). Apparition de la plagiotropie. *Café Cacao Thé* 22, 13-30, 1978.
Vogel, M., Machado, R.C.R. and Alvim, P. de T. (1982) Remoçao de orgaos jóvens como método de avaliaçao das interaçoes fisiológicas no crescimento, floraçao e frutificaçao do cacaueiro. *Proc. 8th Internat. Cocoa Res. Conf., Cartagena, Colombia, 1982* 31-35.
Wheat, D. (1979) Branch formation in cocoa (*Theobroma cacao* L., Sterculiaceae). *Turrialba 29* (4):275-284.
Winder, J.A. (1978) The role of non-dipterous insects in the pollination of cocoa in Brazil. *Bull. Ent. Res. 68,* 559-574.

Ninth International Cocoa Research Conference

E. T. Beauchamp,
Cocoa Chocolate and Confectionery Alliance,
11 Green Street, London W1Y 3RF

General

The organisation of a Conference held about every two years in a different location, with differing local arrangements and varying membership of its International Organising Committee, seems likely to be fraught with difficulty. It is therefore much to the credit of all concerned that the 9th International Cocoa Research Conference held in Lome, Togo, from 12th-18th February proceeded without major difficulties and provided undoubted value for the 155 representatives from 26 countries who attended.

The costs of these Cocoa Research Conferences have been steadily escalating for some years and the Cocoa Producers Alliance, in agreeing to sponsor the 9th Conference with the Togolese Republic, mandated the Conference Organising Committee to curb these costs as far as possible. This was done by classifying the papers submitted for presentation into those selected for oral presentation and publication in the Proceedings, those selected for poster sessions and publication in the Proceedings, and finally those selected for publication alone. In addition, there were a small number of invited contributions on topics of especial interest which were presented and will be published in the Proceedings. Papers were classified by the International Organising Committee on the basis of their submitted summary according to originality and scientific content. It is to be regretted that some summaries were so poorly prepared that misclassification was likely, if not inevitable.

The theme of the Conference was "Priorities for Cocoa Research in the Next Decade" and it had been intended that these priorities would be indicated from the specially invited papers presented by individual producing countries. It is to be regretted, however, that too often these contributions merely reviewed the history of cocoa research, the needs in economic and scientific terms of the area concerned and the current research programme. A major input to the "priorities" theme from this source was therefore lacking.

Much more input was forthcoming from the activities of specialist Working Groups which met during the Conference, dealing with genetics and breeding, by-products and bean utilisation, entomology and pathology. The Technical Advisory Group to the Witches' Broom International Program also met and had discussions about funding of projects within its specific area of interest.

While the benefits of such a Conference to participants reside as much in informal discussions as in the formal presentation of papers, it is to be regretted that in many cases the standard of the formal oral presentation still leaves room for improvement. Too many participants, when presenting papers, ignore the detailed "guidelines" circulated to all participants by the organisers, which clearly lay down the time allotted for presentation and give

many hints about speed of delivery and visual aids. It must be noted that in these two latter aspects the representatives of nearly all countries were at fault. If the standard of the oral presentations can be improved then this must greatly enhance the value of future International Cocoa Research Conferences for all the participants.

In its final session, the Conference approved an overall resolution drawing together the findings of the specialist Working Groups together with a number of other points which had been brought forward during the course of the Conference. These recommendations will now be a matter for consideration by the Cocoa Producers Alliance and also by Governments, international agencies, funding bodies, manufacturers, the trade and all others who have the welfare of the world cocoa industry at heart.

Retrospect

Looking back over the Conference, three clear strands emerge. Firstly, the preoccupation of the African producing countries with the effects of the droughts of recent years on cropping of cocoa. Attention was drawn to the need to find a convenient and reliable test for drought resistance so that such a test could then be used to select potentially useful cultivars. This will be a formidable task and the chance of achieving success may be doubtful.

Secondly, one noted the preoccupation of chocolate manufacturers with raw cocoa quality in order to be able to continue to give good value to consumers in an increasingly competitive food market with ever more tightly drawn food regulations.

And thirdly, there was the preoccupation of all producing countries with the need to conserve wild cocoa germplasm as a matter of urgency. The theme of "Tomorrow may be too late" was most apparent.

While the Conference was undoubtedly successful, perhaps its aims were in any case impossible of full achievement. To attempt to review the whole field of cocoa research in four working days at a Conference of this sort involving simultaneous interpretation into three languages is perhaps to attempt the impossible and it was apparent that some subjects received far less attention than they deserved. This will be hard to rectify, bearing in mind that such a Conference can only be organised on the basis of papers submitted. The 1984 Cocoa Research Conference in Togo was a workmanlike affair and reflected great credit on the organisers. If, as seems likely, the Conference Proceedings can be published before the end of the year, those responsible will not only earn the gratitude of cocoa scientists at large but may also congratulate themselves on a worthy achievement.

REVIEW OF PAPERS

Priorities of Cocoa Research in the Next Decade

The invited papers presented on behalf of the main producing countries showed a variety of priority areas. In the fields of genetics and breeding there was emphasis on the need for collection and conservation of germplasm and also for its evaluation and distribution. Mention was made of the need for additional work on tissue culture techniques to aid speedy distribution of evaluated material. In the broad field of agronomy, calls were made for additional work on such diverse topics as the role and use of mineral

nutrients, the use of economic shade and, perhaps more importantly, for further studies on pollination which was reckoned to be a major restriction on yield in many areas. But, as usual, the major interest in cocoa research was in the field of pests and diseases, with emphasis being placed on the importance of black pod disease, witches' broom, capsids and cocoa swollen shoot virus, in the latter case particularly the need for work on the host/virus interaction.

In this general field there were important papers presented from USA on the quarantine facilities and cocoa collections operated by USDA at Miami, Florida, and Mayaguez, Puerto Rico, and an interesting contribution from Trinidad on the setting up of the International Cocoa Genebank, Trinidad, to act as a repository and an evaluation and distribution centre for cocoa germplasm. A paper from Brazil gave interesting details of the preservation and utilisation of genetic resources of cocoa in the Brazilian Amazon.

Agronomy, Physiology, Soils and Nutrition

The effect of the dry season on the water status of cocoa in Ecuador was presented and another paper presented measurements of similar parameters from Bahia, Brazil. A paper from the University of Liverpool described work testing the theory that the flush cycle is related to plant water status. An interesting paper from Brazil explained the basis for new criteria of fertilizer recommendations in Bahia, where annual applications of fertilizer are made on the basis of soil analysis with a further analysis after 3-5 years to evaluate the residual effect.

Papers presented in a poster session under this heading covered a wide field. One paper examined the correlation between some dendometric measurements, genetic origin and pod production and found pod production is greater when jorquette is between 1.0 and 1.5 m. A further paper from Liverpool, illustrated by excellent scanning electron micrographs, detailed work aimed to determine the time sequence of leaf primordia formation following microsurgery of the apical bud. Control of mosses and lichens on cocoa trunks in areas of very high annual rainfall was discussed in a paper from Costa Rica, showing that some low concentrations of agro-chemicals gave good moss control, while high concentrations adversely affected flowering. A further paper from Ecuador discussed preliminary trials with a chemical growth retardant Paclobutrazol (PP333) for controlling vegetative growth which could be applied at times when immature fruits are highly susceptible to cherelle wilt or for reducing vegetative growth of trees and seedlings during periods of susceptibility to attack from witches' broom. Growth retardation and premature development of the jorquette was achieved, which may also be useful in control of canopy height and formation. Four years' data on the effects of degrees of light and fertilizer on the production of cocoa in the Dominican Republic showed that use of light shade with fertilizer application was the best way of increasing productivity from the current low level of 300 kg/ha.

Genetics and Breeding

Papers in this discipline again covered a wide field, with those from Brazil and Ivory Coast dealing in the former case with an evaluation of the combining ability of cocoa clones and in the latter with the origin and performance of hybrids, and priority measures and future breeding prospects.

This latter paper drew attention to the vast genetic potential remaining untapped, particularly through self-incompatibility and chronic under-pollination, and pointed out that further work on these two aspects was necessary. Work in Brazil on the pathogenicity of isolates and evaluation of resistance of clones to *Crinipellis perniciosa* reported on tests of isolates of the pathogen from other *Theobroma* species (*T. grandiflora, T. speciosa* and *T. subincanum*) and *Herrania* spp. and their effects on *T. cacao.*

Two interesting papers dealt with modern electrophoresis techniques, the first from Togo dealing with the quantification of genetic variability through an enzyme analysis method using electrophoresis on starch or acrylamide gels. Details were given of an extraction method to eliminate tannins and prevent the masking of the enzymes during detection. The second paper, from Ivory Coast, dealt with the discovery of new genetic markers in *T. cacao* by electrophoresis, with six enzyme systems presenting clearly interpretable bands which were thought to give an accurate tool for estimating genetic variability in populations. The method employed studied migration of the components of extracts from young leaves on starch gels.

Diseases

With a Conference in a West African setting, it was inevitable that the diseases of primary concern in West Africa should receive major attention. A number of papers dealt with various aspects of *Phytophthora* pod rot, both in West Africa and the Americas including a Brazilian paper describing what has been called the Single Application Technique for control of *Phytophthora.* This showed that a reduced number of sprays can control infection provided there is no reduction in the total dose per tree which offers savings in labour and machinery while also releasing workers for more frequent harvesting, which should itself result in lower pod losses and fewer infected beans in diseased pods. The population balances of *Phytophthora* species were dealt with in a further Brazilian paper, showing that *P. capsici* is the most commonly occurring species in the State of Bahia, although showing less virulence than the other two species found (*P. palmivora* and *P. citrophthora*). *P. capsici* has a greater tolerance to high and low temperatures, with a greater capacity to produce and release zoospores than the other species, particularly at higher temperatures. Work from Ghana was reported on the possible use of two soil fungi (*Aspergillus niger* and *Trichoderma viride*) as biological control agents of *P. palmivora* and the effect of the metabolites on cocoa seedlings. Further work will aim to find out how to increase the population of these fungi in the soil sufficient to produce metabolites to overwhelm *P. palmivora* while staying below the threshold which causes damage to cocoa roots. A further Ghanaian paper described work carried out at Bangor on the reaction to temperature of *Phytophthora* species from Ghana and Brazil. IRCC work in Togo on the development of a biological test for the identification of phytoalexine substances in various *Theobroma* species, using the technique of thin layer chromotography, was reported and its possible practical application for selection of resistant plant material at an early stage of evaluation.

Population studies were also reported in a paper from Cameroun describing the composition of *Phytophthora* populations in the soil. A full understanding of these might lead to the development of soil treatments around tree bases at the start of the rainy season to reduce a major primary source of inoculum.

Other papers on *Phytophthora* reported trials using systemic fungicides in isolation or mixed with copper-base fungicides in Brazil. The number of pods infected was not reduced by the use of mixtures though they slowed development of the lesions thereby reducing the number of beans infected in a diseased pod and thus gave an economic advantage. A paper from Cameroun reported an in-vitro study of the behaviour of different *Phytophthora* spp. in the presence of Ridomil 25WP on media by measuring mycelial growth, spore germination and sporulation. *Phytophthora megakarya* showed a greater sensitivity to Ridomil than *P. palmivora* and the action of metalaxyl is shown to be fungicidal rather than fungistatic on *Phytophthora* species. The differential reactions of various systemic fungicides of the acylalanine grouping on three species of *Phytophthora* demonstrated clearly specific differences between *Phytophthora palmivora, megakarya* and *capsici* in Togo.

Cocoa swollen shoot virus was considered in papers from Ghana and Togo, the first reporting observations on the purification and detection of CSSV by enzyme-linked imunosorbent assay (ELISA) and imunosorbent electron microscopy (ISEM). A novel purification method was described, giving higher yields of virus particles than previously. The Togo paper dealt with a method for purifying the virus by electrophoresis on a gradient of saccharose.

Work in Ecuador on witches' broom was reported in a paper on the effect of the disease on the establishment of cocoa. Plants from which brooms had been removed in the nursery showed less growth and formed jorquettes later than healthy plants or those with cankers too small to warrant pruning. Prophylactic measures in the nursery would have been of assistance.

The present recommended control method for witches' broom in Brazil is for a single pruning, but epidemiological work in the Brazilian Amazon charting the progress of the epidemic on flushes, flower cushions and pods in three localities showed that for the further reduction of infection there is a need for a second removal of infected tissue in December/February in addition to the present August/September pruning.

The Conference was also reminded that the major diseases are not the only maladies affecting cocoa. Climatic factors and periodicity of pink disease incidence in Bahia was dealt with in a paper showing a correlation between low temperature and vapour tension deficit and in one area there was also a correlation between relative atmospheric humidity and incidence of the disease. This work also showed that the pathogen can survive dry weather by the formation of cankers on diseased branches.

By-product and Bean Utilisation

An important feature of this Conference was the attention given to the utilisation of cocoa by-products other than the 10 per cent of pod weight represented by beans. Work in Brazil was described, aiming to maximise the use of available agricultural potential, producing cacao jelly from pulp with added sugar and soft drinks based on pulp juice. Mention was made of the production of alcohol from pulp and the use of fresh pod husks to provide bulk in cattle diet. Attempts at methane production from pod husk had however not shown good results. Production of alcohol from cocoa sweatings and of animal feed and potash from cocoa pod husk at the farm, village and commercial scale was dealt with in a paper from Ghana with descriptions of appropriate technologies. Other papers on the use of pod husk in feeding of finisher pigs showed that cocoa pod husk can safely replace at least 25 per

cent of the maize component in rations for such animals, while in the case of cattle, papers from Brazil showed that fresh husk is appetising and rapidly digested, with nutritive value only slightly lower than elephant grass. Two papers from Ghana dealt with the use of cocoa pod husk in starter diets of broiler chickens, showing that at least 10 per cent of pod husk can be safely incorporated, and the second paper showed that this can be safely incorporated up to 20 per cent in nutritionally balanced broiler starter diets. A further Ghana paper evaluating the use of husk as a feed ingredient for sheep, using a variety of dried pod husk content in rations and utilising two breeds of sheep and both sexes, showed the growth rate was significantly affected by ration, sex and breed.

An interesting paper from Nigeria examined the optimisation of economic returns from cocoa cultivation as a whole through the efficient use of cocoa by-products, examining in detail how various by-products, including defective beans, pod husk and sweatings, can be economically used. The use of defective beans for production of cocoa butter and of dried and pulverized husk as organic fertilizer, with the extraction of pectin from sweatings, were dealt with in detail.

Entomology (including pests)

Contributions to the Conference reviewing priorities for cocoa research in various areas had touched on the need for further work on pollination and this topic was dealt with in a variety of papers from various origins. A contribution from Ghana showed that both male and female of Ceratopogonid midges are involved in pollination, but ants, psyllids and aphids are of little consequence. A Brazilian paper compared species involved in cacao pollination in the Reconcavo Basin of Bahia and in the south of the State of Bahia. It reported that the identity and relative frequency of pollinating insects in two areas were substantially different even though the areas are fairly close to each other. Work in Ivory Coast reported seasonal variations in pollination and pod production on a cacao smallholding. The general conclusions of this paper were that good pollination results from a favourable convergence for brief periods of flowering and the insect population, chiefly aphids and ants. An overview paper from USA dealt with effects of seasonality on the availability of pollinators in relation to flower cycles, giving a description of the pollinator/reward syndrome of cocoa flowers and also an evaluation of various kinds of insects (including midges and wild bees) as effective natural pollinators.

Rising interest in the problem of the cocoa pod borer (*Acrocercops cramerella*) was reported in a paper from Malaysia dealing largely with behavioural studies. Information was offered from Venezuela where it had been shown that a natural entomopathogenic fungus offered a means of control through parasitation of larvae.

Other reports were made on the chemical control of the spittle bug which attacks the flower cushion of cocoa, the first time that this has been recorded in Bahia, Brazil. Other insect pests dealt with were *Selenothrips rubrocinctus* in the Dominican Republic, where a population peak in September/October at the time of peak leaf flush was reported, and of *Steirastoma breve* in the Brazilian Amazon where infestation levels up to 47.5 per cent were reported. Studies at present are limited to obtaining data for use as a basis of control methods, including biology and population fluctuation, with some testing of insecticides.

A paper from Ghana on the evaluation of synthetic pyrethroids for control of cacao mirids showed that the large number of treatments required (more than four, and preferably six) combined with the high cost of the material, cast doubts on the possible use of these materials to control mirids in Ghana.

Fermentation, Storage, Marketing and Quality

Cocoa research Conferences rarely deal in any detail with the end product, but a contribution from Colombia reported on an economic and nutritional analysis of cocoa as a food substitute and solution to malnutrition in the third world. The use of cocoa butter substitutes in the manufacture of milk chocolate, reviewing the importance and possible repercussions of such use on the world cocoa economy, was also dealt with in a paper from CEPLAC, Brazil, and it is perhaps regrettable that this paper on a most important subject was not presented and discussed in the Conference itself.

Manufacturers' concern with quality, depending on efficient fermentation and drying, was highlighted by an IRCC paper dealing with the development of phenolic compounds during fermentation and showing that these are of considerable economic importance since they have a particular bearing on the colour of the bean (anthocyanins) and a partial bearing on taste (tannins). Quality was again to the fore in a paper from Ivory Coast reporting on the use of novel equipment in cocoa fermentation and drying, with the improvement of quality a priority concern to Ivory Coast where the discount of its cocoa may be linked with defects caused by poor fermentation and drying. Two-part plastic fermentation bins (called 'bacs') of 80 litre capacity were shown to be capable of giving homogenous bean fermentation, and drying on thick black polythene sheeting reduced moisture content to acceptable levels in a shorter time than conventional bamboo mats. A small cocoa drier, using natural convection and suitable for the small producer, using mainly family labour involving minimal cost for purchase of readily available materials, was reported from Brazil. Work in Colombia on the use of wooden trays for fermentation demonstrated the feasibility of using the Rohan system for cocoa smallholdings giving good fermentation of 76-84 per cent of beans and efficient drying using the same wooden trays.

The sorting of commercial parcels of cocoa by an electronic colorometric method, involving passage of the beans in front of photoelectric cells which accepts or rejects them according to a colour standard, was described by IRCC, France. A throughput of 200 kg per hour is quoted, extracting levels of black beans up to about 13 per cent.

Storage in polyethylene bags (four thicknesses) on the farm or in sacks covered with plastic sheeting in the exporter's warehouses, with storage for up to 12 months without loss of quality using certain thicknesses of polyethylene was reported from Brazil.

Extension

Reports were made from Colombia and Ghana on extension work, the first reporting a survey of methods and techniques used for extension work with farmers, noting factors interfering with extension work which were considered under six headings. An account was given of methods successfully employed and recommendations concerning transfer of technology to the farmer. The Ghana paper dealt with rehabilitation of the cocoa industry through the Farm Development Programmes, giving a description of a three-

year rehabilitation programme aimed at stopping the downward trend in production, raising farm yields and stabilising production in a selected area with a high production capacity.

The newer cocoa areas were not forgotten and an interesting paper from Indonesia dealt with the development of bulk cocoa production. Plans were described to improve production from hybrid seed and the development of such seeds through cocoa breeding programmes.

Publication of Proceedings

The 9th International Cocoa Research Conference was largely funded by the Cocoa Producers' Alliance and the CPA will publish the Proceedings as soon as possible.

The Proceedings will be available at the end of 1984, at a price to be fixed, from:

The Secretary-General
Cocoa Producers Alliance
P.O. Box 1718
Lagos, NIGERIA.

or

International Cocoa Research Conference
P.O. Box 205
London WC2N 6NB
UNITED KINGDOM

This price will include postage by sea-mail.

Notes on Contributors

P.H. Gregory

Born 1907. Received Ph.D. at Imperial College 1931. Mycologist, Canada 1931-34; Seale Hayne Agricultural College, Devon 1935-40; plant pathologist Rothamsted Experimental Station 1940-54; professor of Botany, Imperial College 1954-58; head plant pathology Rothamsted 1958-68. F.R.S. Pres. British Mycological Soc. 1951. Author of "Microbiology of the Atmosphere" and many papers on behavioural studies on pathogenic microbes especially air-borne fungi. From 1968-1979 was consultant to the Cocoa, Chocolate and Confectionery Alliance on black pod and other diseases. Editor of "Phytophthora disease of Cocoa" published by Longman in 1974 and with A.C. Maddison of "Epidemiology of Phytophthora on Cocoa in Nigeria", published by CMI in 1981.

M.J. Griffin

Born 1944 in England. B.Sc. Botany and Zoology Honours, Hull University, 1966. Ph.D. Plant Pathology, Hull University, 1969.

Plant Pathologist, Agricultural Development and Advisory Service (ADAS), Kent, England, 1969-73, specialising in diseases caused by *Phytophthora* species.

Cocoa Mycologist/Pathologist working as a member of the International Black Pod Research Team, based at the Cocoa Research Institute of Nigeria (CRIN), 1973-76. The project was financed by the International Office of Cocoa and Chocolate.

From 1976 until present, working in England as an Advisory Plant Pathologist with ADAS at Wye (1976), Leeds (1977-79), and Bristol (1980 onwards), specialising in fungicide resistance.

A.C. Maddison

Born 1945 in England. B.Sc. Honours Botany, Southampton University 1965. Ph.D. Plant Pathology, Southampton 1968.

Plant Pathologist with the International Black Pod Research Project at the Cocoa Research Institute of Nigeria, Gambari, Ibadan (CRIN), 1973-1979.

Since 1981 working on a cocoa research project, at the Instituto Nacional de Investigaciones Agropecurias (INIAP), Pichilingue, Ecuador, under contract to Overseas Development Administration as part of British Technical Assistance to Ecuador.

M.R. Ward

Born 1948 in Uganda. B.Sc. Honours Horticultural Botany, Reading University, 1970. Ph.D. Plant Pathology, Hull University, 1975.

Plant Pathologist with the International Black Pod Research Project at the Cocoa Research Institute of Nigeria, 1975-1979.

Now working on breeding and development of the wheat-rye hybrid, Triticale, from 1981-1983 as Triticale Project Manager for Germplasm Resources Limited; from 1983 with ARC Seeds Inc. based near Loughborough, England, with field trials overseas.

E.T. Beauchamp

Born in England in 1927. Joined the Cocoa, Chocolate and Confectionery Alliance in 1962 after working in the UK Scientific Civil Service and other trade associations. Responsible for administering the Alliance's activities on behalf of the UK chocolate industry in cocoa affairs, particularly cocoa research. Secretary, Cocoa Research Policy Committee of the International Office of Cocoa and Chocolate and also administrator of the Cocoa Research Association Ltd., Ghana Cocoa Growing Research Association Ltd. and London Cocoa Trade Amazon Project.

Cocoa Abstracts

Cocoa abstracts are reprinted from "Abstracts on Tropical Agriculture" published by the Royal Tropical Institute, Amsterdam.

February 1982

A method of rearing the mealybug Planococcoides njalensis on cocoa seedlings FIREMPONG, S. Cocoa Research Inst. of Ghana, Tafo, Ghana – *Revista Theobroma (Brazil)* v. 11(4) p. 229-232; Oct 1981.

A method of rearing the mealybug *P. njalensis* on cocoa seedlings without the presence of its obligatory attendant ant is described. The method prevents the honeydew secreted by the mealybugs from sticking onto their bodies and thus eliminates the source of fungal attack which leads to the extinction of the mealybug colony. The method also prevents the young mealybugs from wandering.

(Developments in pesticide application) Perkembangan alat aplikasi pestisida MANGOENSOEKARJO, S. Balai Penelitian Perkebunan Medan, Medan, Indonesia – *Bulletin Balai Penelitian Perkebunan Medan (Indonesia)* v. 12(2) p. 47, 55-61; Jun 1981.

Developments in pesticide applications tend towards improving operational efficiency through such factors as pest-targeting, spray volume reduction and special nozzle application. Exciting new developments in electrodynamic CDA promise prospects not only of improved targeting and reduced spray drift, but also of selection of droplets of uniform size. The desire for improved economics of pest control through reduction in spray volume and increase in speed of spraying has led to a great deal of emphasis being placed on the use of ultra-low volume (ULV) and very low volume (VLV) techniques. Safety and care for the environment due to pesticide usage may be achieved through suppressing drifts towards non-target areas, preventing runoff and leaching and minimizing hazards to the operators.

Beneficial interactions of coconut-cacao crop combination VARGHESE, P.T., NELLIAT, E.V. and BALAKRISHNAN, T.K. Division of Agronomy, Central Plantation Crops Research Inst. (CPCRI), Kasaragod, Kerala, India – *In: Agronomy Soils Physiology and Economics of Plantation Crops, PLACROSYM 1, Kottayam, 20 Mar 1978* PLACROSYM Standing Committee, np. (India) p. 383-392 1979.

A study on the amount of cacao litter added to the soil in a coconut-cacao crop mix was conducted. Shed leaves collected at fortnightly intervals for a one year period amounted to 818 and 1785 kg/ha/year (oven dry) under single and double hedge systems of planting, respectively. The organic carbon content and the soil fertility improved considerably under the crop mix and was reflected in the enhanced yield of coconut. Soil temperature at 30 and 60 cm depths was 3 to 6°C lower and the variation in the mean monthly soil temperature was least in the mixed cropping system compared to the monoculture of coconut. The yield increase noticed in coconut grown together with cacao in a mixed cropping system is discussed.

Caterpillar and beetle pests of cocoa in India KUMAR, T.P. and NAIR, C.P.R. Central Plantation Crops Research Inst., Calicut, Kerala, India – *Planter (Malaysia)* v. 58(670) p. 3-13; Jan 1982.

A survey carried out to catalogue and study the pests occuring in cocoa showed 16 lepidopteran and 14 coleopteran pests in the cocoa growing areas of Kerala, Karnataka and Tamil Nadu in South India. *Lymantria obfuscata, Lymantria ampla, Zeuzera coffeae, Adoxophyes privatana, Euproctis subnotata, Euproctis guttata* were observed to be the major caterpillar pests. The important beetle pests include *Popillia complanata, Monolepta longitarsus, Sinoxylon* sp. and *Glenea* sp. A brief description of their biology, nature of damage, seasonal occurrence and alternative hosts are given.

Performance of cacao as mixed crop with arecanut BHAT, K.S. Regional Station, Central Plantation Crops Research Inst. (CPCRI), Vittal, Karnataka, India – *In: Agronomy Soils Physiology and Economics of Plantation Crops, PLACROSYM 1, Kottayam, 20 Mar 1978* PLACROSYM Standing Committee, np. (India) p. 377-382 1979.

Cacao, as a mixed crop with arecanut, did not affect the performance of areca during the first ten-year period of plantation. In fact, a beneficial effect, as indicated by the higher yield of areca in the mixed cropped plot (50:50) was obtained.

(Residual value of fertilizers on abandoned black pepper plantations) Nível atual de fertilidade dos solos de pimentais decadentes NEVES, A.D. DE S., PEREIRA, G.C. and MORAIS, F.I. DE O. Departamento Especial de Amazônia (DEPEA), Commissão Executiva do Plano da Lavoura Cacaueira (CEPLAC), Belém, Pará, Brazil – *Boletim Técnico – Centro de Pesquisas do Cacau (Brazil)* no. 87, 10 p. 1981.

Black pepper (*Piper nigrum*) is an important crop in Pará State, receiving heavy fertilizer dressings in the order of 100-180 kg N, 200-900 kg P_2O_5, 200-250 kg K_2O, 0-720 kg CaO and 0-450 kg MgO/ha a year. However, most plantations have to be replaced by other crops like cacao, because the pepper plant is attacked by the fungus *Fusarium solani* f. sp. piperis after 6 to 8 years. This article deals with the residual value of the fertilizers which were applied on these black pepper plantations. Available P in the top 20 cm was very high, showing an average of 30-50 ppm as compared with 1 to 5 ppm on soils without *P. nigrum*.

Investigation of the characteristics of a traditional natural convection cocoa dryer MCDONALD, C.R. and FREIRE, E.S. Commissão Executiva do Plano de Lavoura Cacaueira (CEPLAC), Itabuna, Bahia, Brazil – *Tropical Agriculture (Trinidad and Tobago)* v. 59(1) p. 25-32; Jan 1982.

A production scale, natural convection, wood fired dryer for cocoa was tested during the six month period of the 1978 cocoa harvest in the Bahia region, Brazil. The objective of the test sequence was to determine and investigate the operational parameters of the drying unit with a view to the subsequent development of improvements which could be applied in the field to the existing 25,000 dryers of this type. The design of dryer used was, for the most part, that recommended by the Extension Department of CEPLAC, while care was taken to ensure that the operational procedure was as near as possible to that normally used on farms. The performance of the dryer with different cocoa and wood loadings and with varying plenum chamber heights was investigated. The effect of ambient wind speed and direction was also considered.

Ceratopogonid midges (Diptera, Nematocera) collected from cacao flowers in Caucagua, Miranda, Venezuela SORIA, S. DE J., WIRTH, W.W. and SANCHEZ, P.A. Divisão de Zoologia Agrícola, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 11(4) p. 249-250; Oct 1981.

From taxonomic determinations of midges collected in cacao flowers in Miranda State, Venezuela, four species were identified. The most common species was *Forcipomyia spatulifera*. Further studies on this species are recommended in order to determine its role and importance as a pollinator of cacao in the country.

(Boarmia sp., pest of cacao and Moghamia macrophylla in the Deli-Serdang District) Hama Boarmia sp. pada tanaman coklat dan Moghania macrophylla di kabupaten Deli Serdang PARNATA, Y., ASID, M. and SUBARDJO Balai Penelitian Perkebunan Medan, Medan, Indonesia – *Bulletin Balai Penelitian Perkebunan Medan (Indonesia)* v. 12(2) p. 47, 49-54; Jun 1981.

Due perhaps to a long dry spell, delayed pruning of *Moghamia macrophylla* and the use of an unsuitable insecticide, an outbreak of loopers (*Boarmia* sp.) occurred on a cacao estate in the Deli-Serdang district of North Sumatra. Normally this insect is not a pest, as its population is kept in balance by its parasites and predators.

The pest was brought under control by ceasing the use of the universal insecticide (Sevin 85S, carbaryl), replacing it with a selective one (Dipterex, trichlorphon) and later with *Bacillus thuringiensis* (Thuricide). Proper pruning of *M. macrophylla* was also carried out to correct the environment. Additional notes on the morphology and ecology of *Boarmia* sp. from observations in the laboratory are given here to supplement existing data in the literature.

Quantitative evaluation of climate in humid tropical areas: application to cocoa EMBRECHTS, J. and SYS, C. Ecole Nationale Supérieure Agronomique, Université de Yaoundé, Yaoundé, Cameroon – *Pedologie (Belgium)* v. 31(1) p. 107-119 1981.

An evaluation of climate for land evaluation studies is presented. The method is based on the interpretation of general climatic characteristics as a function of the growth requirements of a specific crop. A climate suitability map for cacao growing in smallholder plantations in southern Cameroon could be drawn. A climatic index allows the calculation of functional relations between yield and climate. This has been done for cacao in Cameroon.

Sources of farm information among Nigerian cocoa farmers MONU, E.D. and OMOLE, M.M. Department of Agricultural Economics and Rural Sociology, Ahmadu Bello Univ., Samaru, Zaria, Nigeria – *Agricultural Administration (UK)* v. 9(2) p. 81-89; Feb 1982.

This paper examines the sources of farm information amongst a sample of cocoa farmers in the Ondo and Oyo states of Nigeria. Radio, agricultural extension agents and other farmers are found to be the most important and useful sources of farm information. Only the state in which the farmer resides and his level of formal education are related to the choice of the most useful source of information. The policy implications are noted.

March 1982

(Role of insect communities and water in the dissemination of Phytophthora palmivora in cacao plantations in the Ivory Coast) Rôle des communautés d'insects et de l'eau dans la dissémination de Phytophthora palmivora dans les cacaoyéres de la Côte d'Ivoire BABACAUH, K.D. Ecole Nationale Supérieure Agronomique, Abidjan, Ivory Coast – *Café, Cacao, Thé (France)* v. 26(1) p. 31-36; Jan 1982.

The role of ants-scale insects communities, notably the association of *Pheidole megacephala* and *Planococcoides njalensis* in the spread of *Phytophthora palmivora* is examined on the basis of observations and experimental data. From foci installed in ant nests or on trees by inoculation of fruit, *Pheidole megacephala* spreads propagules vertically and horizontally. This activity is linked to the community life which they lead with the scale insects. These are systematically sought out and protected by shelters made of various materials including, on occasions, the propagules of the parasite. The epidemiological impact of associations of ants and scale insects is discussed.

(Changes in cacao production factors caused by the swollen shoot virus. 1. Revelation of principal disturbances) Modifications des facteurs de production du cacaoyer provoquées par le virus du swollen shoot. 1. Mise en évidence des principales perturbations LUCAS, P. and PARTIOT, M. Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo – *Café, Cacao, Thé (France)* v. 26(1) p. 37-42; Jan 1982.

Swollen shoot disease was found to reduce cacao yields through its effect on fertility and pollen viability in the dry season and the number of ovules per ovary. The latter factor offers a simple test for the early detection of the disease.

Studies on the reaction of pods of different cocoa accessions to Phytophthora palmivora MOHANAN, R.C. Regional Station, Central Plantation Crops Research Inst., Vittal, Karnataka, India – *Planter (Malaysia)* v. 58(672) p. 99-103; Mar 1982.

Black pod caused by *Phytophthora palmivora* in cocoa is of great economic importance in southern India. Susceptibility of 19 cocoa progenies was tested on nearly mature pods by means of potato-dextrose-agar discs on which *P. palmivora* was cultured for 7 days. All progenies were susceptible but the rate of infection varied. The less susceptible varieties showed poor sporulation on the lesion in contrast to the susceptible progenies.

April 1982

IBPGR Working Group on Genetic Resources of Cocoa, Arlington, Virginia, USA, 8-9 July 1980: report International Board for Plant Genetic Resources (IBPGR), FAO, Rome, Italy – AGP: IBPGR/80/56, 28 p.; Mar 1981.

A Working Group on Genetic Resources of Cocoa meeting was held in the USA on 8-9 July 1980. There it was recognized that the genetic base of hybrid parents is very limited, that there is severe genetic erosion of cacao germplasm resources in Latin America – Criollo types are particularly endangered in Central America, that immediate attention should be given to collections of other species of *Theobroma* and that progress with control of major diseases is limited by the lack of diverse germplasm.

May 1982

(Study on the traditional tubular dryer from the cacao-growing region of Bahia) Estudo do secador tubular tradicional da região cacaueira da Bahia MCDONALD, C.R., CUNHA, J. and FREIRE, E.S. Divisão de Tecnologia e Engenharia Agrícolas, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Boletim Técnico – Centro de Pesquisas do Cacau (Brazil)* no. 91, 39 p. 1982.

To increase the efficiency of the traditional cacao dryer in Bahia, and to improve the quality of the dried cacao, the following aspects were studied: low thermal efficiency of the furnace, overheating of the furnace and heat exchange tube, contamination of the cacao with smoke, drying airflow movement, disuniformity of drying over the area of the drying floor, and heat transfer considerations. Various recommendations are made.

(Phytophthora pod rot of cacao in the State of Bahia, Brazil. 1. Virulence of Phytophthora spp.) Podridão parda do cacaueiro no Estado da Bahia, Brasil. 1. Virulência das espécies de Phytophthora CAMPELO, A.M.F.L., LUZ, E.D.M.N. and RESNIK, F.C.Z. DE Divisão de Fitopatologia, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 12(1) p. 1-6; Jan 1982.

Pod rot of cacao caused by *Phytophthora* spp., is a major disease causing losses of 20-30 per cent in fruit yields. The relative virulence of eight isolates of *Phytophthora* spp. from different sources was evaluated. Unwounded, detached pods of the cultivar Comum were inoculated with mycelial discs. Two isolates of *P. citrophthora* (P16 and P55) were more virulent than the others, whereas *P. palmivora* (P26) was intermediate in virulence. An isolate of *P. capsici* (P23) was less virulent than all the other isolates tested.

(Possibility of transplanting cacao plants with bare roots) Possibilidades de transplante do cacaueiro com raízes nuas ALVIM, R., LIMA FILHO, J.M.P. and AFONSO, C.A. Divisão de Botânica, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 12(1) p. 17-28; Jan 1982.

Cacao seedlings were removed from their polyethylene containers and the roots were freed by either gently washing the soil loose or simply lifting the plants directly. Transpiration was controlled by application of an anti-transpirant (Mobileaf) or leaf removal. Survival rates higher than 90 per cent were obtained following transplant when the foliage was treated with a 10 per cent emulsion of the antitranspirant or when only the two topmost fully matured leaves were left on the seedlings. A root-coating substance (Agricol) capable of reducing root moisture losses did not effectively increase survival rates of bare-root seedlings. Possible advantages of the bare-root technique are discussed.

Budded cocoa for Malaysia BYRNE, P.N. Tun Razak Agricultural Research Centre, Federal Land Development Authority (FELDA), Sungei Tekam, Pahang, Malaysia – *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 84-89 1977.

This article deals with vegetative vs seedling propagation, fan vs chupon budwood material, selection and breeding for vegetative propagation, selection of clones, selection of rootstocks, clone testing, budding techniques, and management of clonal cacao. Research is required on the production of chupon budwood, pruning and training of fan buddings, roots, pollen movement within a cacao plantation and small-scale fermentation techniques.

A spacing trial with single and multiple-stem cocoa ARMSTRONG, K.B. BAL Estates Sdn Bhd, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 93-104 1977.

Cacao spaced at 4.0 x 1.5 m gives higher yields per hectare than at a spacing of 4.0 x 3.0 m. The dense planting has advantages over wider planting when limited overhead shade is used and results in easier management. Optimum spacing will change with the age of the trees and thinning will be required. With seedling cacao the opportunity exists to eliminate poor producers. The experiment does not indicate any benefit accruing from the induction of a multiple stem habit.

Performance of cutback and multiple-stem cacao in the field LEE AIK KIEN Tun Razak Agricultural Research Centre, Federal Land Development Authority (FELDA), Sungei Tekam, Pahang, Malaysia - *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 105-111 1977.

Ten-month old cacao seedlings were cutback. Subsequently, one, two or three stems were allowed to develop. The control consisted of seedlings of the same age without pruning. Observations were taken on establishment and vigour, canopy, basal stem diameter, plant and jorquette height, flowering, harvesting and yield. The three-stem plants yielded more during the first four years, which is probably due to their better vegetative development.

Nutritional disorders of cocoa in Sabah LEE, M.T. Cocoa Research Station, Department of Agriculture, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 112-118 1977.

The use of foliar symptoms and leaf analysis has led to the detection of a number of nutritional disorders of cocoa in Sabah. The similarity in visual symptoms between deficiencies of nitrogen and sulphur, and iron and manganese makes chemical analysis necessary. Calcium deficiency can be confused with vascular streak dieback. The survey revealed nutritional problems many of which have not been reported previously.

Observations on some pests of cocoa in Tawau SHAH, S. BAL Estates Sdn Bhd, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 119-124 1977.

Some insects previously not known as serious pests of cacao have at various times proliferated to the extent of justifying control measures. Observations on life-cycles and attempted control measures are indicated for *Buzura suppressaria* (Geomatridae), *Nacaduba normani* (Lycaenidae), *Clania* sp. (Psychidae), *Acrocercops* sp. (Gracillaridae), *Rhyparida iridipennis* (Eumolpidae), *Hypomeces* sp. (Curculionidae), *Exopholis hypoleuca* (Scarabaeidae), *Ceroplastodes chiton* (Coccidae) and parasites.

Evaluation of a granular systemic insecticide for newly planted cocoa in Peninsular Malaysia THONG, K.C. Dunlop Research Centre, Batang Melaka, Negri Sembilan, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 125-133 1977.

Granular aldicarb 10 per cent a.i. was applied at 2, 4 and 6 g per young cacao plant in field experiments to control *Apogonia* and *Adoretus* leaf damage. Young plants were protected by 2 g aldicarb 10 per cent a.i. which should be increased to 4 g per plant with growth. A maximum interval of 8 weeks is recommended. Aldicarb provided better control than the dimethoate/lead arsenate standard. Yield records seem to indicate a higher cacao bean yield in the presence of aldicarb.

Effect of foliar application of potassium on cocoa yield OJENIYI, S.O. and EGBE, N.E. Cocoa Research Inst. of Nigeria, Ibadan, Nigeria — *Journal of Horticultural Science (UK)* v. 56(3) p. 267-269 1981.

Two years' trials were conducted at 3 places in Western Nigeria to examine the effect of foliar application of K during drought on cocoa yield components. Foliar application of 5 per cent KCl to mature Amelonado trees caused apparent increases in wet bean weight, dry bean weight, husk weight and pod weight, but the only significant effects were those on dry bean weight at 2 sites.

(Control of the major pests and disease of cacao in Soconusco) Control de las principales plagas y enfermedades del cacao en el Soconusco LEON E. F. DE and FRAYRE V. G. Campo Agrícola Experimental Rosario Izapa, INIA/Centro de Investigaciones Agrícolas del Sureste (CIASE), Tapachula, Chiapas, Mexico — *Circular CIASE — Centro des Investigaciones Agrícolas del Sureste (Mexico)* no. 47, 4 p.; Jul 1975.

This is a concise review of chemical control measures against some principal pests and diseases of cacao. Thrips, aphids and black pod disease, *Phytophthora palmivora*, are considered.

(The Compañía Nacional de Chocolates S.A. and the development of cacao cultivation in Colombia) La Compañía Nacional de Chocolates S.A. y el fomento del cultivo del cacao en Colombia MORENO P., L.J. Departamento de Fomento, Compañía Nacional de Chocolates, Medellín, Colombia — *Cacaotero Colombiano (Colombia)* no. 19, p. 21-29; Dec 1981.

This article describes recent developments in Colombian cacao production, and its research and extension organizations. Information is given about on-going agronomic and crop protection research and major recommendations about clones and cultural practices.

(Influence of seedling age on cacao growth following transplanting) Influencia de la edad de la plántula sobre el crecimiento del cacao después del transplante SOUZA, J. DE, GARCIA, J.R. and MULLER, M.W. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *Cacaotero Colombiano (Colombia)* no. 19, p. 39-45; Dec 1981.

Studies were conducted on methods for transplanting cacao and optimum seedling age at transplanting. Seedling survival and growth was better for transplantings of 2 to 6 month old seedlings than for older seedlings or for direct seeding.

Cocoa cultivation under coconut on two estates in Peninsular Malaysia SHEPHERD, R., GILBERT, J.R. and COWLING, P.G. Harrisons and Crosfield Sdn Bhd, Kuala Lumpur, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 28-40 1977.

A short description of cacao nursery practices is presented. Land preparation, planting system, field planting, upkeep and cultivation, pests, diseases, manuring, pruning, thinning and rehabilitation of cacao under coconuts as shade tree are described. A coconut replanting technique between cacao is discussed. Harvesting transport, processing, pre-drying, resting and final drying of cacao are considered. Interplanting cacao between old coconuts did not affect the coconut yields. It is expected that 1120 kg dry beans/ha will be obtained from the cacao. The combined copra and cacao revenue is more than that of oil palms.

Performance of cocoa hybrids in two early progeny trials on BAL Estates LIM HONG KEE, D. BAL Estates Sdn Bhd, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 47-57 1977.

Cacao hybrids produce about 30-40 per cent more than Amelonado seedlings under the experimental conditions at Sabah. Pa35 x Na32, Pa7 x Na32 and Am1 x Pa7 are best suited to BAL conditions. These progenies produce 3.6-3.9 ton dry cacao/ha/year at 11-12 years of age. The best variety is UIT1 x Na32 with very large pods and large beans.

New progeny trials on BAL Estates LIM HONG KEE, D. BAL Estates Sdn Bhd, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 58-77 1977.

Data on yield performance of progenies, yield variation within progenies and performance of progenies during immaturity are presented for cacao trials under BAL Estates conditions. The recommended crosses Pa7 x Sca12, Pa35 x Sca7, UIT1 x Na34, Na32 x Sca12, UIT1 x Sca12 produced more than 2240 kg dry cacao/ha/year during the first 5 cropping years. Triple hybrids did not outyield the high yielding F_1 hybrids except for (UIT1 x Na32) x Sca6. F_2 progenies made between high-yielding trees from early progeny trials seem promising and this type of seed could be produced in BAL seed gardens.

A review of Series II cocoa hybrids CHEE YAU FAH Cocoa Research Station, Department of Agriculture, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 78-83 1977.

Series II trials in cacao have demonstrated the potential of the combination of UIT and SCA breeding material. UIT material has good combining ability. The SCA material is more hardy, more disease resistant to some cacao diseases, and tends to bear more flowers throughout the year. The UIT x SCA hybrids in these trials seem more outstanding than the UIT x NA hybrids in earlier trials.

Vascular-streak dieback of cocoa in Peninsular Malaysia CHAN CHEE LEONG and SYED KAMARUDDIN BIN SYED WAZIR Hilir Perak Station, Malaysian Agricultural Research and Development Inst. (MARDI), Perak, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 134-144 1977.

Oncobasidium theobromae is the causal agent of vascular-streak dieback in cacao. Symptoms and identification, severity of the disease, varietal susceptibility, fungal growth in the cacao plant, spread of the disease and control measures are considered. Epidemiology and control of this new disease need further research.

Cocoa growing in East Java SOENARYO Balai Penelitian Perkebunan Surabaya, Surabaya, East Java, Indonesia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 149-150 1977.

Growing conditions for cacao in East Java are indicated in respect of temperature, rainfall and soil types. About 9300 ha of cacao are planted of which 3459 are mature. A production of 2-3 ton dry beans per hectare is attainable. About 120 interclonal crosses are being tested in East and Central Java. About 30-40 per cent of the production costs go to pest control. Open patches in plantations are normally due to root diseases caused by *Fomes lamaensis* and *Ganoderma pseudoferreum*. *Phytophthora* pod rot is not a serious problem.

An assessment of the development potential for cocoa in Sabah WYRLEY BIRCH, E.A. UK Ministry of Overseas Development, Kota Kinabalu, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 151-160 1977.

A description is presented of the present-day potential for cacao in Sabah in respect of land and soil, seed supplies, diseases, pests, shade supplies and cropping systems, competition from other crops, manpower, marketing and availability of development finance. Sabah has an almost unlimited potential for cacao as far as land availability is concerned. The main limitations to rapid development are management skills and the provision of development funds.

Role of estate cocoa factory in processing cocoa beans HUBBARD, F.T.P. Ingtom Plantations and Cocoa Factory Advisory Services, Ipoh, Perak, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 161-172 1977.

Large-scale cacao processing is described. Improved fermentation box design (170 x 230 x 75 cm) and by pre-treatment before fermentation. Cacao bean drying is fermentation box design (170 - 230 x 75 cm) and by pre-treatment before fermentation. Cacao bean drying is described in respect of drying temperature, drying time, heat sources, drying costs, fans, shape of drying bed, agitation and drying routines. A considerable saving in fuel costs can be made by drying first for 8 hours, followed by 16 hours rest and bulking beans from 2 dryers during the next drying periods. By bulking beans more beans can be dried with the same facility.

New Barico Drier and fermentary ANSELMI, J.A. Balung River Cocoa Estate, Tawau, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 173-183 1977.

A description is presented (including drawings) of a new type of cacao dryer, the Barico Dryer, which can ferment and dry 575 ton dry beans per year. The dryer can operate on any type of fuel and uses half a ton of firewood to produce one ton of dry cacao. The combined unit can process 4 tons of beans/day without mechanical means of agitation. Broken bean percentage with the process is almost nil. Acidity can be reduced to pH 6.2 by low temperature drying during the first 24 hours. This allows further enzymatic conversion of acetic acid to carbon dioxide and water.

Raw cocoa processing: acidity and flavour LIAU, H.T.L. Agricultural Research Centre, Tuaran, Sabah, Malaysia — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 184-196 1977.

Studies in cacao processing methods covering criteria for successful maturation (loss of acetic acid) such as moisture, aeration, temperature and time, are described. Sun drying gives a better maturation. Large-scale maturation in boxes or dryers is described. By good maturation it is possible to produce in Malaysia, beans that are comparable in flavour to West African beans.

Marketing of Sabah cocoa PARSONS, J.W. and ONG KEAN TEONG Commonwealth Development Corp., Singapore, Singapore — *In: EMPA Seminar on Cocoa-Coconuts 1976: proceedings* East Malaysia Planters Association, Sandakan, Sabah p. 197-205 1977.

The first commercial planting of cacao in Sabah was in 1954. The acreage increased from 2155 ha in 1965 to 6700 ha in 1975 and exports rose from 418 tons in 1965 to 5332 tons in 1975. A description of the markets, international marketing, selling prices, processing and position of the smallholders, is presented.

(Agricultural tradition and development: the case of the Ivory Coast) Tradition et développement en agriculture: le cas ivoirien SAWADOGO, A. — *Annales de l'Université d'Abidjan, Série G. Géographie (Ivory Coast)* no. 10, p. 115-130 1981.

The author confirms that traditional agriculture is not a marginal enterprise, but that it is central to the rural economy. The production of cassava, for instance, has doubled over the last 10 years. Industrialization is not an issue as it involves too profound a transformation of society.

(The influence of price intervention on production in the plantation economy of the Ivory Coast) Le déterminisme des prix sur les systèmes de production en économy de plantation ivoirienne RUF, F. Centre Ivoirien de Recherche Economique et Sociale (CIRES), Abidjan, Ivory Coast — *CIRES. Cahiers Ivoiriens de Recherche Economique et Sociale (Ivory Coast)* no. 28-29, p. 89-114; Mar 1981.

This study analyses the imbalance which exists between the yields of coffee and cacao with the aim of proposing a price intervention. The author concludes that a price increment for both coffee and food crops will lead smallholders to greater stability and modernization of their plantations.

June 1982

Short-term toxicity study of irradiated cocoa beans in rats TAKYI, E.E.K. and OFORI MENSI, N. Ghana Atomic Energy Commission, Legon, Ghana — *Journal of the Science of Food and Agriculture (UK)* v. 32(9) p. 933-940 1981.

Ingestion studies of irradiated cacao beans in rats causing haematological problems or unacceptable changes in their growth pattern were explored. It is inferred that the ingestion of irradiated cacao beans at a level of 350 g/kg of normal diet has no different effect from that of non-irradiated beans on rats.

(Your plantation could produce more! Su cultivo puede rendir mas MORENO P., L.J. Departamento de Fomento, Compañía Nacional de Chocolates, Medellín, Colombia — *Cacaotero Colombiano (Colombia)* no. 20, p. 12-14; Apr 1982.

Cacao plantations are found in every part of Colombia. Yields are very low, not exceeding 500 kg/ha on the average. Cultural practices aimed at increasing productivity, such as weed control, pruning, disease control, drainage and fertilizing, are discussed.

(Cacao bean quality required for manufacturing) Calidad de las almendras de cacao: necesidades del fabricante POWELL, B.D. — *Cacaotero Colombiano (Colombia)* no. 20, p. 24-31; Apr 1982.

The quality of cacao beans is estimated by manufacturers according to the following characteristics: flavour, hardness of cacao butter, purity and yield. The various aspects of processing quality are reviewed. Deficient storage and shipping facilities can strongly affect quality. The maintenance of good bean quality is of prime importance for the cacao industry as a whole.

(Fertilizing of cacao with compound fertilizers in the banana-growing zone of the Riofrío region) Abonamiento del cacao con fertilizantes compuestos en el corregimiento de Riofrío, zona bananera QUIROZ R., G., BONILLA M., A. and DELGADO V., J.L. Facultad de Ingeniería Agronómica, Universidad Tecnológica del Magdalena, Santa Marta, Colombia — *Cacaotero Colombiano (Colombia)* no. 20, p. 33-37; Apr 1982.

A field trial was conducted with recommended cacao varieties applying various compound fertilizers. The fertilizers included 13-26-4, 12-6-22-2, 12-12-17-2 and 14-14-14-2 at rates of 350, 400 and 450 kg/ha/year, applied in equal doses at 6-month intervals. Highest yield was obtained with 350 kg/ha/year of 13-26-4 followed by 12-6-22-2, giving 55 and 46 per cent increases, respectively.

Initiation and growth of callus and cell suspensions of Theobroma cacao TSAI, C.H. and KINSELLA, J.E. — *Annals of Botany (UK)* no. 48(4) p. 549-557 1981.

Callus and suspension cultures of cacao, initiated from immature cotyledons of beans from pods harvested 120-130 days after pollination, were established. A modified B-5 or Murashige and Skoog agar medium sustained growth of callus without loss of vigour after each sub-culture and a 15-fold weight increase occurred during the 4-week culture periods at 30 ± 1 °C; coconut water improved callus growth substantially. The optimum hormonal concentrations for growth of the suspensions were 0.5 mg/l 2,4-D and 0.1 mg/l of kinetin in a Murashige and Skoog basal liquid medium. The optimum temperature for suspension growth was 25-30°. The cell number and cell mass of suspensions increased 20-fold in 14 days. No organogenesis or embryogenesis was observed.

July 1982

(Preliminary results of a compatibility test on several cacao clones in Kaliwining) Hasil pendahuluan suatu pengujian kompatibilitas beberapa klon cokelat di Kaliwining SOEDARSONO Balai Penelitian Perkebunan Bogor, Bogor, Indonesia — *Menara Perkebunan (Indonesia)* v. 47(6) p. 173-179; Dec 1979.

A compatibility test on 14 clones of cacao derived from a primary clonal test has been carried out at the Kaliwining Experimental Garden since 1976. Preliminary results showed that DRC 2, DRC 6, DRC 13, DRC 15, DRC 16, KWC 2, KWC 5, KWC 6 and KWC 7 clones had a strong tendency to be self-compatible, while GC 7 clone was self-incompatible. Results with DRC 9, GC 1, GC 2 and KWC 1 clones were still inconclusive. Further investigations are still needed to obtain definite results.

(Black pod disease of cacao due to Phytophthora sp. in Togo: determination of species responsible) La pourriture brune des cabosses du cacaoyer due à Phytophthora sp. au Togo: détermination des espèces responsables DJIEKPOR, E.K., PARTIOT, M. and LUCAS, P. Centre de Recherches, Institut Français du Café et du Cacao (IFFC), Kpalimé, Togo — *Café, Cacao, Thé (France)* v. 26(2) p. 97-108; Apr 1982.

An in vitro study of isolates of *Phytophthora* of the cacao tree in Togo was carried out. Appearance of colonies, morphology of sporocystes, growth on pods and on agar media, sporulation in the field, a sign of compatibility, and observations on the chromosomes, are reported. Two of the species of *Phytophthora* found on cacao are represented in Togo: *P. palmivora* in north-western and southern Kloto (Kloto I) and *P. megakarya* in the Litimé-Adélé region and the north-eastern part of Kloto (Kloto II).

(Search for a fermentation index of cacao. 1. Development of total cacao bean tannins and phenols) Recherche d'un indice de fermentation du cacao. 1. Evolution des tanins et des phénols totaux de la fève CROS, E., VILLENEUVE, F. and VINCENT, J.C. Laboratoire de Chimie-Technologie, Institut Français du Café et du Cacao (IFFC), Montpellier, France — *Café, Cacao, Thé (France)* v. 26(2) p. 109-114; Apr 1982.

A study of the development of polyphenols (total tannins, non-tannins, total phenols) in the cacao bean revealed that: (1) there is a decrease of about 70 per cent in phenolic compounds extracted from non-fermented cacao as compared with fermented cacao; (2) the shape of the decreasing total phenols and total tannins curves are comparable; (3) phenolic compound contents on zero fermentation day is equivalent to that on the 2nd day of fermentation, an anomaly which could be due to the abundance of pulp slowing down the drying rate.

(Search for a fermentation index of cacao. 2. Estimation of the red colouring matter of cacao beans) Recherche d'un indice de fermentation du cacao. 2. Estimation de la matière colorante rouge des fèves de cacao CROS, E., ROULY, M. and VILLENEUVE, F. Laboratoire de Chimie-Technologie, Institut Français du Café et du Cacao (IFFC), Montpellier, France — *Café, Cacao, Thé (France)* v. 26(2) p. 115-122; Apr 1982.

Results of this study showed: (1) the overall decrease in anthocyanin pigments was about 93 per cent and the rate of decrease was at its maximum between the 2nd and 3rd fermentation day; (2) there was an increase in the optical density (OD) (460nm)/O.D. (525nm) ratio from the 2nd to the 8th fermentation day; (3) principal changes in colour occurred between the 2nd and 4th fermentation days and enabled 3 distinct fermentation stages to be characterized: no colour change on the 1st day, reversal of the anthocyan monomers/yellow and brown polymers ratio from the 2nd to the 4th day, little or no colour development from the 4th to the 8th day.

(Technical report 1980) Informe técnico 1980 Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — 364p. 1982.

In this annual report for 1980, the activities of CEPEC's 12 sections, including those dealing with botany, soil science, geology, phytopathology, agronomy, crop diversification, genetics and socio-economic topics, are reviewed. In addition research carried out in the Amazonian region is also reviewed. As well as studies on cacao (*Theobroma cacao*), work done on black pepper (*Piper nigrum*), rubber (*Hevea brasiliensis*) and oil palm (*Elaeis guineensis* and *E. oleifera*), is also discussed.

Fine-root growth dynamics in cacao KUMMEROW, J., KUMMEROW, M. and SILVA, W.S. DA Department of Botany, San Diego State Univ., San Diego, California, USA — *Plant and Soil (Netherlands)* v. 65(2) p. 193-201 1982.

Fine-root density in a mature cacao plantation in Bahia (Brazil) was monitored at weekly intervals. About 40 g/m of fine roots (diameter < 1mm) were found during this period. The relative stability of this value over the six months period contrasted with significant changes in the number of growing root tips per unit of soil volume. A significant negative correlation was found between a shoot growth flush in January and the activity of the fine-root system as measured by the number of new root tips.

August 1982

(Cacao yields and natural vegetation: a study of practical ecology in the forests of Sangha (Congo) and south-eastern Cameroon) Rendements de la cacaoculture et formations végétales: essai d'écologie pratique des forêts de la Sangha (Congo) et du Sud-Est du Cameroun GUILLOT, B. ORSTOM, Paris, France — *Cahiers ORSTOM. Série Sciences Humaines (France)* v. 18(1) p. 63-106 1981.

In the Sangha region (Cameroon), a map of the distribution of cacao output per planter shows that the best yields are obtained in eastern Sembé district where soil studies have revealed the presence of good soils developed on tillite, limestone and argillite. The inventory made in the Ouesso region by the Forestry Department also shows that these soils give rise to well developed natural vegetation cover. Trees characteristic of these soil-vegetation localities might advantageously be used for the identification of good land for cacao cultivation.

(Genetic improvement for resistance to five cacao diseases) Mejoramiento genetico para resistencia a cinco enfermedades de cacao ENRIQUEZ, G. and SORIA V., J. Departamento de Cultivos y Suelos Tropicales, Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica — *In: 6. International Cocoa Research Conference: proceedings, Caracas, Venezuela, 6-12 Nov 1977* Cocoa Producers' Alliance, Lagos p. 41-56 1981.

The most pertinent aspects of the 5 most important cacao diseases, black pod (*Phytophthora palmivora*), witches' broom (*Crinipellis perniciosa*), monila pod rot (*Moniliophthora roreri*), ceratocystis (*Ceratocystis fimbriata*) and swollen shoot are discussed. Research methodologies for resistance screening are summarized and the most important cacao cultivars mentioned in the literature listed.

The status of genetic resistance in cacao to Crinipellis perniciosa BARTLEY, B.G. Instituto Interamericano de Cooperación para la Agricultura (IICA), Turrialba, Costa Rica – *In: 6. International Cocoa Research Conference: proceedings, Caracas, Venezuela, 6-12 Nov 1977* Cocoa Producers' Alliance, Lagos p. 57-69 1981.

The history of the investigations on witches' broom disease resistance is reviewed and the results obtained up to the present time are analysed. The discovery of resistance in the SCA (Scavina) family stimulated investigations on resistance and its combination with desirable agronomic characters. The subsequent infection of F1 progenies of SCA demonstrated the importance of alternations in the host-parasite relationships in genetic terms and the need to review strategies of the exploitations of differential host reactions in relation to other characters, based on present-day concepts of disease resistance and knowledge of the breeding behaviour of the host species.

Viruses and resistance to virus diseases in cocoa POSNETTE, A.F. East Malling Research Station, Maidstone, Kent, UK – *In: 6. International Cocoa Research Conference: proceedings, Caracas, Venezuela, 6-12 Nov 1977* Cocoa Producers' Alliance, Lagos p. 262-266 1981.

Two serologically related viruses, swollen shoot and mottle leaf, are known only from Nigeria and Ghana where swollen shoot has caused extensive damage to the main cultivar West African Amelonado. Some Trinitario and Upper Amazon types are more resistant and tolerant to infection. The strongest resistance and tolerance has been in certain Iquitos and Nanay types. These could be used to produce progeny in which the rate of virus spread and yield depression by infection should be considerably less.

Fruiting pattern of irrigated cocoa in Kerala HASSAN, M.A., NAIR, R.V. and VIJAYAGOPAL, P.D. College of Horticulture, Vellanikkara, Kerala, India – *Indian Cocoa, Arecanut & Spices Journal (India)* v. 4(3) p. 87-88 1981.

Studies were carried out with 8-year-old cacao trees irrigated during the summer. The peak cropping months were July, August, June and October which together accounted for 78 per cent of total annual yield. The least productive months were January, December, February and March, in that order. The total yield during these months was 3 per cent. A significant positive correlation was observed between the number of harvested pods and mean monthly maximum temperature, and a significant negative correlation with the number of rainy days.

(Men in search of trees: the cacao tree and the Akposso in west central Togo) Des hommes à la rencontre des arbres: le cacaoyer et les Akposso dans le Centre-Ouest du Togo ANTHEAUME, B. ORSTOM, Paris, France – *Cahiers ORSTOM. Série Sciences Humaines (France)* v. 18(1) p. 47-62 1981.

This geographical study presents a description of the development of cacao cultivation among the Akposso tribe in west central Togo, paying particular attention to the socio-economic and environmental impact of this crop.

September 1982

Charcoal pod rot of cocoa in Kerala VIJAYAN, M. and WILSON, K.I. College of Agriculture, Kerala Agricultural Univ., Vellayani, Kerala, India – *Planter (Malaysia)* v. 58(674) p. 213-216; May 1982.

After presenting a description of charcoal pod rot caused by *Botryodiplodia theobromae*, this paper proceeds with the morphology of the fungus and the control of the disease. Statistical analysis of the experimental data revealed that Rovral (iprodione) at 2000 ppm was significantly superior to all the other fungicides for the control of the disease. The second best fungicide was Difolatan (captafol) at 3000 ppm.

The influence of ecological and socio-economic factors on the yield of smallholder cocoa plantations in South-Cameroon EMBRECHTS, J. Ecole Nationale Supérieure Agronomique, Yaoundé, Cameroon – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 5-11 1981.

In southern Cameroon there are high and low yielding cacao smallholdings. In the first type climate is the major, and soil factors the minor, influence. In the other type soil factors do not contribute to yield. Difference in yield is essentially due to socio-economic factors. Five suitability classes have been distinguished: moderately suitable, marginally suitable, conditionally suitable, actually unsuitable but potentially suitable, and permanently unsuitable; these classes cover 15, 26, 12, 19 and 28 per cent, respectively, of the area studied.

(Agronomic practices in Colombian cacao plantations) El manejo agronómico en plantaciones de cacao en Colombia GUTIERREZ C., H. Departamento Técnico, Chocolatería Luker, Manizales, Colombia – *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 25-29 1981.

After 14 years devoted to clarify how to increase the yields of cacao in Colombia, the experimental work made at the Luker Farm has established a technological system proved efficient to obtain three times more cacao per hectare as compared with the regular yields obtained. Such a system is based on the correct application of certain agronomic practices. Figures presented on cacao yields in several cacao producing countries show how low they are. It is possible to increase these yields by using adequate management applied to cacao farms.

The interrelationships between shade types and cocoa pest and disease problems in Papua New Guinea SMITH, E.S.C. Lowlands Agricultural Experiment Station, Keravat, East New Britain Province, Papua New Guinea – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 37-43 1981.

The buffering effect on the cacao ecoclimate and the alternative food source provided by shade trees may have a profound effect on the incidence of pests and diseases in cacao. However, there have been few attempts to determine the interrelationships between these pests and diseases and the type of shade used. Many of the present-day problems have arisen from the use of *Leucaena leucocephala* as a shade tree. In contrast, the widespread practice of interplanting cacao under coconut has considerable economic and managerial advantages and generally suffers much less from insect and disease attack than sole planted cacao.

Responses of 10 year-old cacao trees to different thinning and fertilizer treatments MOSES, D.D. and ENRIQUEZ, G.A. – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 45-50 1981.

Different plant densities and distributions as well as response to fertilizer applications at rates of 1500 or 2250 kg/ha of 18:10:6 were evaluated, based on wet cacao yield, tree girth, jorquette height, number and weight of chupons and the incidence of *Phytophthora* infection. At a planting distance of 2 x 2 m thinning out of 50 per cent of the weak trees produced the highest yield, while at 2 x 3 m no thinning at all is best. Generally the lower level of fertilizer application resulted in higher yields of cacao/ha. Lesser plant densities and the lower fertilizer application resulted in lower *Phytophthora* infection.

Calibrating variates for yield of cocoa, as well as the relationships of several cacao features with the environment MOSES, D.D. and ENRIQUEZ, G.A. – *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 51-55 1981.

Calibrating variates for cacao yields were identified and the response of cacao plants subjected to different treatments and to varying climatic conditions interpreted. Several highly significant correlations were observed. The results indicate that the trunk diameter at 0.3 m above the soil can be used in estimating yields, yields can be predicted by the number of pods harvested, temperature and rainfall play important roles in deciding the final yield of cacao, and the greater the yield of cacao the more pods are infected by *Phytophthora* and also lost due to the infection.

Long-term effects of chemical and manual weed control in cocoa. 1. Girth and height increments BONAPARTE, E.E.N.A. Cocoa Research Inst., Tafo, Ghana – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 91-95 1981.

The long-term effects of weed control are of prime importance in perennial crops. The first experiment compared the girth and height increments of four cacao cultivars subjected to three weed control treatments, from the 6th to the 44th month after planting. Weed control with paraquat six times a year was consistently superior to the manual weed control methods. Manual weed control twice a year produced non-significantly higher girth increments than manual weed control six times a year. Amelonado showed the least girth increment, and the differences among the hybrids were non-significant. The height increments followed the same trend. The girth increments during the dry seasons confirmed the superiority of the paraquat treatment over the high slashing methods.

Long-term effects of chemical and manual weed control in cocoa. 2. Flushing, flowering and early yields BONAPARTE, E.E.N.A. Cocoa Research Inst., Tafo, Ghana – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 97-101 1981.

In two experiments cultivars exhibited four to five flushing peaks during the year, including some occasional minor peaks, and periods of relatively minimal flushing. The seasonal pattern of flushing under weed control treatments showed relatively little year-to-year variation in the various cultivars, with few deviations from this consistency. Differences among the weed control treatments were also manifest in the duration to the attainment of 100 per cent flowering of individual trees. In the hybrids, the paraquat treatment (T2) attained 100 per cent flowering after 40 months, and the manual weed control treatments after 50 months. The T2 treatment outyielded the other weed control treatments in the three harvest seasons. Thus the initial superior growth and early yields of the T2 treatment were still being maintained after 6 years in the field.

Flushing, flowering and pod-setting of hybrid cocoa in a cocoa shade/spacing/cultivar experiment AMPOFO, S.T. and BONAPARTE, E.E.N.A. Cocoa Research Inst., Tafo, Ghana – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 103-108 1981.

The cacao cultivar T85/799 x S84 tended to flush with a similar periodicity from year to year but the periods of flushing peaks differed slightly from year to year. Intensity of flushing also differed from year to year. There were generally five flushing peaks in a year. The pattern of pod-setting closely followed that of flower production. The effect of shade and spacing on the periodicity of flushing, flowering and pod-setting was negligible but the onset of flushing was delayed slightly by shade. Shading and close spacing suppressed both flowering and pod-setting.

(Physiological reactions of cacao to water deficiency in the soil) Reações fisiológicas do cacaueiro a deficiência de água no solo MACHADO, R.C.R., ALVIM, P. DE T. and MILDE, L.C.E. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 121-127 1981.

The effect of water deficiency in the soil on leaf water potential, stomatal aperture, turgidity of the cortex, flowering intensity and rate of leaf renewal of seven year old cacao trees was studied. In the greenhouse, flowering intensity was considerably reduced and leaf renewal was absent in the dry regime. However, there was intense foliar renewal out of season one week after the plants were watered normally. The control plants and the plants subjected to the moderate regime remained dormant until the period of maximal growth. Under field conditions normal leaf renewal was observed despite the water deficiency in the soil to a depth of 20 cm but with availability below 30 cm.

(Improvement of cacao: development of an early evaluation test of resistance to drought) Amélioration du cacaoyer: mise au point d'un test d'évaluation précoce de la résistance à la sécheresse SEGBOR, A., DJIEKPOR, E.K. and AMEFIA, Y.K. Laboratoire de Phytopathologie, Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 131-133 1981.

With a perfected test it is possible to assess even at the nursery stage the behaviour of various cacao hybrids recommended for their drought resistance and local Amelonados. It was found that hybrids dI T65/7 and dI T7/12 which transpire less than the Amelonados and dI T86/45 are more resistant to drought.

Foliar analysis as a diagnostic technique in cocoa nutrition. 3. Standard curves and observations AHENKORAH, Y. and HALM, B.J. Cocoa Research Inst., Tafo, Ghana – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 177-182 1981.

The progress made on foliar analysis as a diagnostic technique for cacao nutrition in Ghana is presented. Whilst it is suggested that sampling to determine the optimum N, P and K concentration should be done between March and April, the need for further work in Ghana so that foliar analyses can be related to fertilizer application and crop yield is stressed.

(Evaluation of cacao phosphate fertilizer requirements) Estimation des besoins du cacaoyer en engrais phosphate JADIN, P. Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 199-203 1981.

It is stated that the use of a reference method is necessary to make sure that the phosphate deficiency of a cacao soil is corrected when the N/P ratio in that soil is 1.5 or less. The phosphorus kinetics method by dilution is used for this purpose. It is concluded that the method may be promising, and that there is a possibility to find a chemical analysis method related to phosphorus kinetics.

Cocoa diseases of West Africa ADEGBOLA, M.O.K. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos (Nigeria) p. 243-250 1981.

Black pod disease, canker, seedling blight, leaf fall and chupon wilt, all caused by *Phytophthora palmivora*, pod rot caused by *Thielaviopsis paradoxa*, charcoal pod rot caused by *Botryodiplodia theobromae*, and the physiological disease cherelle wilt are discussed as well as control methods of these diseases. Also various trunk and root diseases and the problem of epiphytes are mentioned.

Preliminary results of research on witches' broom disease of cacao (Crinipellis perniciosa) in the Amazonian region of Brazil EVANS, H.C. and BASTOS, C.N. Commissão Executiva do Plano da Lavoura Cacaueira (CEPLAC), Belem, Pará, Brazil – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 255-256 1981.

Ecology, epidemiology, physiology, resistance, and cultural, chemical and biological control methods are briefly discussed.

The International Black Pod Project: 1979 review MADDISON, A.C. and WARD, M.R. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria – *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 261-266 1981.

The aim of the project has been to deepen the understanding of the epidemiology of *Phytophthora* pod rot on cacao and thereby rationalize and improve control measures. This report briefly outlines findings from detailed observation of the natural epidemic in unsprayed cacao and in cacao subjected to various treatments likely to delay or slow disease development. Tree base treatments (basal pod suppression and insecticide applications to prevent activity of tent-building ants) reduced disease early in the season by blocking the major source – the soil, but later, when accompanied by fungicide, failed to prevent outbreak of disease in the canopy. Some of the reasons for this are discussed, but conclusions regarding control measures are left for the Final Summary Report of the Project which is in preparation.

Speculations on Phytophthora as a cocoa root pathogen GREGORY, P.H. Rothamsted Experimental Station, Harpenden, Hertfordshire, UK – *In: 7. International Cocoa*

Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979 Cocoa Producers' Alliance, Lagos p. 267-269 1981.

In some areas at least, soil is an important source of black pod *Phytophthora*. Evidence points against passive survival or saprobic growth in soil. It is suggested that the fungus may be a pathogen on feeding roots of mature trees (roots of seedlings are already known to be susceptible). Possible resulting loss of yield and replanting difficulties are discussed. Need for a pilot research project (perhaps with a root observation tunnel) is emphasized.

The effects of tree base treatments on the incidence of Phytophthora pod rot WARD, M.R. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 277-284 1981.

Effects of tree base treatments on the incidence of black pods are described. The treatments were basal pod suppression by the removal of flowers below 0.7 m and the application of dieldrin tree base insecticide. Basal pod suppression gave a small reduction in the number of black pods but had no effect on percentage disease incidence due to a 14 per cent reduction in healthy pod yields. Tree base insecticide decreased disease incidence from 12 per cent to 7 per cent and also slightly decreased healthy pod yields. Knapsack application of fungicide was more effective in controlling the disease than motorblow application but the difference between healthy pod yields was small. Two other insecticides, primicid and permethrin had no apparent effect on the disease. The fungicide CGA A5055A gave good control of the disease and increased healthy pod yields by 40 per cent compared with the no fungicide control treatment.

(Perfecting test methods for sensitivity to Phytophthora for use on cacao seedlings and on other dicotyledonous plants with epigeous development) Mise au point de méthodes de tests de sensibilité aux Phytophthora sur semenceaux de cacaoyers et sur autres plantes dicotyledones a développement epigé BLAHA, G. and MULLER, R.A. Laboratoire de Phytopathologie, Institut Français du Café et du Cacao (IRCC), Montpellier, France — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 303-310 1981.

In order to assess the respective aggressivity of various geographical isolates of cacao *Phytophthora*, sensitivity tests were made on very young Amelonado plants and also on a range of plants originating from either temperate or tropical countries. Successive trials on very young cacao seedlings showed differences in pathogenesis between isolates and opened the way to a breeding technique in the laboratory and led to an improvement in the infection method through its standardization. If a whole range of different plants is subjected to infection, it is possible to characterize several strains in relation to the same plant and also a single strain in relation to several plants. The establishment of a range of differential hosts and knowledge of pathogenesis in cacao would, in particular, make it possible to determine the level of parasitic specialization for each isolate.

Variations in yield and disease patterns in a blackpod resistance trial in Ghana DAKWA, J.T. Cocoa Research Inst., Tafo, Ghana — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 311-327 1981.

Variations in cacao yield and proportion of pods infected by *Phytophthora palmivora* were examined for the minor (April-August), main (September-March) and epiphytotic (June-November) periods. In the first 7 cropping years, yield on all progenies increased steadily in all periods but thereafter yield fell at different rates. Amazon x Trinitario and Amelonado crosses always outyielded Trinitario and Amelonado x Trinitario crosses: crosses from susceptible or susceptible x resistant parents outyielded those from selfed resistant or resistant x resistant parents. In all periods, black pod incidence increased from about 30 per cent in the 5th year of the trial to various successive peaks in later years. Variations in disease were consistently less in the main and June-November periods when it rained frequently. Crosses from selfed susceptible or susceptible x resistant parents were more diseased than those from resistant or resistant x susceptible parents.

Phytophthora pod rot research in Papua New Guinea since 1971 MCGREGOR, A. Lowlands Agricultural Experiment Station, Keravat, East New Britain, Papua New Guinea — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 339-345 1981.

In clonal cacao removal of diseased pods gave a considerable yield increase but in open pollinated cacao the yield increase was marginal and the treatment uneconomic. Monthly sprays of cuprous oxide, at an average rate of 20 g a.i. copper per tree, to infected trees only, reduced the average annual infection rate of pods over 40 mm in length from 20 per cent to about 5 per cent and resulted in a yield increase of about 50 per cent. In very high incidence periods yields from treated areas were consistently double those from untreated areas. A yield differential between previously treated and untreated areas persisted for more than six months after spraying was terminated. Of 20 Trinitario clones, K82 and KA2-106 demonstrated a high degree of resistance, while KT140 was classed as moderately susceptible. The remaining seventeen were rated susceptible to extremely susceptible.

(Ridomil, a new fungicide for the control of Phytophthora pod rot on cacao) Ridomil, un nouveau fongicide contre la pourriture brune (Phytophthora spp.) sur cacaoyer EBERLE, J. Agro Div., Ciba-Geigy, Basle, Switzerland — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 361-364 1981.

In Brazil, field trials with the systematic compound Ridomil (metalaxyl) at a rate of 200 g a.i./100 l applied over the entire tree at 5 to 7 week intervals resulted in good control of cacao black pod disease, as did 30-50 g a.i./100 l sprayed on pods at 21 day intervals in Cameroon. Tests in Ghana, Ivory Coast, Papua New Guinea and Nigeria also indicated promising results. No residues in cacao beans are expected after correct use of the fungicide.

(Swollen shoot disease: importance of host plants) Maladie du swollen shoot du cacaoyer: importance des plantes relais AMEFIA, Y.K., BRUNEL, J. and DELECOLLE, B. Laboratoire de Phytopathologie, Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 387-388 1981.

A comparative study of the flora associated with healthy and diseased cacao plantations is in progress. This should make it possible to identify those plants which are liable to harbour the virus and to be the source of the first foci of infection. A study carried out on Commelina, a plant difficult to eradicate, has led to planning a particular method of management of plantations.

(Tests on cacao seedlings: application to the study of anti-oomycetal systemic fungicides) Les tests sur plantules chez le cacaoyer: application a l'étude des fongicides systémiques anti-oomycetes DAGUENET, G. Laboratoire de Phytopathologie, Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 393-397 1981.

A method of studying the effectiveness and translocation of systemic fungicides was used on Amelonado cacao. The fungicides in aqueous suspension were introduced either to the soil or to the leaves of one-month old seedlings being grown in sand in laboratory conditions. Eight days after treatment, the inoculum of *Phytophthora palmivora* was deposited on the stem after section just above the leafstalk insertion of the two primary leaves. The intensity of the attack by the parasite was shown by the extent of necrosis on the stem. In the same way, this measurement was confirmed by isolation of the fungus on the stalk fragments. Application of fosetyl-Al and Curzate, to both soil and leaves, did not have any effect on the development of the necrosis, nor on the growth of the fungus. The absence of necrosis and of *P. palmivora* after metalaxyl application proves that this fungicide travels inside the plant in both upward and downward directions.

Cocoa breeding in Ghana with reference to swollen-shoot disease LOCKWOOD, G. Cocoa Research Inst., Tafo, Ghana — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 407-413 1981.

The Upper Amazon x Amazon x Amelonado hybrids now being planted in areas affected by swollen-shoot are less resistant to infection that the best material available in the breeding programme. In the seed gardens producing these hybrids manual pollination permits substitution of the Amelonado pollen parent with more resistant Upper Amazons. Trials have been made of a range of pollen parents selected for greater virus resistance. It takes at least 10 years to test new cacao varieties and a further 10 years to propagate, plant and bring into bearing large seed production. Such a long delay in providing new seed gardens is unacceptable so five Upper Amazon clones are being propagated and planted. Three were selected because their progenies are relatively resistant to virus infection and trials of possible pollen parents have been established.

(Pests and diseases of cacao in Africa) Les ennemis du cacaoyer en Afrique LAVABRE, E.M. Institut Français du Café et du Cacao (IFCC), Paris, France — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 423-427 1981.

Many of the pests and diseases causing significant damage to cacao in Africa are discussed. Among these are *Sahlbergella singularis* and *Distantiella theobroma* of the Miridae family, *Phytophthora palmivora*, the swollen shoot virus and the insects *Earias biplega, Bathycoelia* spp., *Tyora tessmanni, Selenothrips rubrocinctus* and various borers. Control methods are mentioned.

Cacao pests in Central America SAUNDERS, J.L. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos (Nigeria) p. 429-432 1981.

Actual or potential pests of major economic importance are: Miridae — several species of the genus *Monalonion;* Thripidae — primarily *Selenothrips rubrocinctus;* Scolytidae — as potential transmitters of *Ceratocystis fimbriata* and as killers of young plants; Formicidae — leaf cutting ants, mostly of the genus *Atta;* Phaloniidae — the defoliating caterpillar *Carephoides zuelana;* Termitidae — termites of the genus *Nasutitermes;* Aphidae — the aphid *Toxoptera aurantii;* Cercopidae — the spittlebug *Clastoptera globosa;* Pseudococcidae — mealybugs of little present importance in the absence of major virus diseases; and Tetranychidae — spider mites. The lack of sufficient knowledge of biological and ecological information on which to base the establishment of sound cacao pest management is emphasized. Recommendations are made to fund and initiate long-range investigation programmes.

(Control of cacao pests in South America) Controle de pragas do cacaueiro na América do Sul ABREU, J.M. DE and SORIA V, S.J. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 433-441 1981.

Selenothrips rubrocinctus and the mirid *Monalonion* spp. are the most important cacao pests in South America. Other economically important pests are *Atta* spp., *Colaspia* spp., *Xyleborus, Steirastoma breve, Tetranychus mexicanus* and *Eriophyes reyesi.* The chemical control of these pests is discussed. Side-effects of insecticides on pollinating insects were determined and the most important pests infesting cacao in storage discussed. Methods to protect stored cacao from insect infestation are presented.

(Shade and anti-mirid cacao treatments their influence on yield) Ombrage et traitements, anti-mirides sur les cacaoyers: leur influence sur la production DECAZY, B. Office National de la Recherche Scientifique et Technique (ONAREST), Yaoundé, Cameroon — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos (Nigeria) p. 443-446 1981.

Seven-year old cacao trees were grown either under shade or in full light and in both conditions either or not treated against mirids. Four years later the amount of canopy on the trees in full light and left untreated was significantly lower than that of the shaded treated trees. The cumulative results show that the absence of shade increased yield by 26 per cent, that anti-mirid treatment increased yield by 24 per cent and that treated plots in full light had a yield 55 per cent higher than that of untreated shaded plots.

(Effect of insecticide treatment of cacao against mirids on pollination conditions) Influence des traitements insecticides contre les mirides du cacaoyer sur les conditions de pollinisation LUCAS, P. and DECAZY, B. Office National de la Recherche Scientifique et Technique (ONAREST), Yaoundé, Cameroon — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 447-451 1981.

Lindane was applied against mirids either by thermo-fogging at 320 g a.i./ha or by spraying at 300 g a.i./ha. The effect on the population of pollinating insects and consequently on pollination was negligible in the case of thermofogging and only slightly more pronounced in the case of spraying. The entomofauna was re-established after 2 and 8 days, respectively.

Meloidogyne incognita infection of cocoa seedlings ASARE NYAKO, A. and OWUSU, G.K. Cocoa Research Inst., Tafo, Ghana — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 457-461 1981.

Meloidogyne incognita infection of cacao seedlings in which there were above-ground hypocotyl swellings in addition to large swellings on tap roots and smaller swellings on feeding roots is reported. The disease, which was first observed on seedlings of T63/967 x Sca 6 in a field nursery, was found in gauzehouse inoculation tests to infect three other types of cacao studied (Wacri Series IIJ, Wacri Series IID and Amelonado), but differences in varietal susceptibility were discernible. In the gauzehouse tests, inter-callary and terminal swellings were produced on the tap roots and feeder roots of all the four types of cacao while hypocotyl swellings were produced in T63/967 x Sca 6, Series IIJ and Amelonado. There were significant reductions in root weight and seedling height which in Series IID were drastic.

Effect of physical environment of the abundance of Bathycoelia thalassina (Hemiptera: Pentatomidae), in Ghana OWUSU MANU, E. Cocoa Research Inst., Tafo, Ghana — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 463-468 1981.

Amongst the physical environmental factors influencing the abundance of the cacao pest *B. thalassina* in the field, the most important factor was rainfall which may cause mortality as high as 52 per cent for early larval instars and as low as 3 per cent for eggs. The mortality occurred during the rainy seasons, March-July and September-November. It was concluded that moderate temperature (25-30°C) coupled with a mean monthly rainfall less than 130 mm lead to an increase in the population of *B. thalassina* in the field.

(Some aspects of damage caused and the biology of the cacao pest Selenothrips rubrocinctus, a Thysanoptera) Quelques aspects des dégâts et de la biologie de Selenothrips rubrocinctus, Thysanoptère ravageur de cacaoyer COULIBALY, N. Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 469-472 1981.

Selenothrips rubrocinctus is regarded as a minor pest but its importance is growing in the ecosystem of Ivory Coast cacao plantations. This development is related to the new cultivation techniques which have been adopted as well as to unfavourable climatic conditions over the past few years. Larvae and adults pierce the leaves, causing chlorotic stains and defoliation which may be total when the infection is serious. Pods are not free from attack and become covered with a layer of dead cells, dark brown in colour, which hinder or prevent any estimation of their state of maturity. The female deposits eggs individually under the skin of leaves and pods. Incubation lasted 9 days on average, the development cycle of larvae and pupae was 11 days and adults lived for 25 days.

(Pollinating insects: Forcipomyia, methods of increasing pollination and their effect on production) Insetos polinizadores: Forcipomyia métodos para aumentar a polinização e seus effeitos sobre a produção SORIA, S DE J. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 497-506 1981.

Water-storing plants such as *Uriesea procera* and *Musa* spp. are of particular importance in the agro-ecosystem of the cacao tree in view of their capacity to retain water in the interaxillary spaces of their leaves during dry periods, allowing reproduction of pollinating insects to take place when the leaf debris dries out to the extent of causing mortality. Retention of these natural insect breeding grounds requires no capital outlay and could result in economic benefits. Laboratory research has shown that mass breeding of *Forcipomyia* spp. is promising owing to the fact that the larvae feed on bacteria (such as *Pseudomonas* and *Xanthomonas*) which can be cultivated on cheap substrates.

Global concepts for genetic resources and breeding in cacao BARTLEY, B.G.D. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 519-525 1981.

Suggestions are made for improving the existing situation, where the use of genetic materials in the production of cultivars is limited in relation to the potential variability and to establish controlled germplasm centres. In view of the scarcity of experienced manpower to manage the genetic resources system in relation to the predictable scale of variability to be handled a centralized operation is necessary to effect adequate supervision of the diverse activities and to achieve maximum coordination and efficiency.

(Results of Bahia selections and the yields of hybrids) Comportamento das seleções baianas na produção de híbridos de cacaueiros MARIANO, A.H. and BARTLEY, B.G. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 527-533 1981.

The cacao populations in southern Bahia result from the restricted introduction of origins from the south Amazons. This explains the reduced genetic variability of these populations. The first works directed to the genetic improvement of plantations in Bahia focused on the identification of representative selections from the available genetic base. Selections of the types Comum, Pará and Maranhão were found, as well as several Catongo cultivar clones, characteristic for the absence of anthocyanic pigmentation in the cotyledones, flowers and young shoots.

(Influence of methods of pollination on the cacao crop) Influence des modalités de la pollinisation sur la récolte du cacaoyer (Theobroma cacao L.) REFFYE, P. DE, PARVAIS, J.P. and MOSSU, G. Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 545-552 1981.

Experiments show that the only variable factor affecting the form of distribution of the number of beans per pod is found to be the law of distribution of pollen on the styles of the flowers. Since the biological data of a clone are fixed (number of ovules per ovary, fertility, cherelle wilt owing to an insufficient number of beans), it is possible to determine mathematically the distribution of the number of beans per pod. The distribution parameters are calculable from the experimental data, and these make it possible to use simulation which shows a good measure of agreement with the observation in all the cases analysed. The application of this theory makes it possible to calculate from the observed distribution of number of beans per pod, the genetic characteristics of a given clone which are important criteria for selection, as well as showing the pollen environment from which the crop has resulted.

Experimental methodology in progeny trials with cocoa LOCKWOOD, G. Cocoa Research Inst., Tafo, Ghana — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 553-558 1981.

A basis is provided for the procedures to follow in the early stages of progeny trials with material selected in Ghana for resistance to swollen shoot disease. As long as the progenies within a trial have a common female parent, they are unlikely to vary greatly in vigour or habit and internal guard trees are not necessary. Hybrid varieties are more variable than Amelonado so the 16-tree plots proposed for the latter are probably too small and square 25-tree plots are recommended. It appears that preliminary tests can be made at single sites, but promising material must be evaluated under the full range of conditions in which it may be grown by farmers.

Cocoa fermentation in Ghana and Malaysia CARR, J.G., DAVIES, P.A. and DOUGAN, J. Long Ashton Research Station, University of Bristol, Bristol, UK — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 573-576 1981.

Microbiological methods were designed to detect acid-tolerant aerobic and anaerobic microorganisms. Counts of the total number of microorganisms present were made daily and the numbers of individual species present were estimated. The organisms found were various kinds of yeast, both fermenting and non-fermenting, lactic acid bacteria, acetic acid bacteria and representatives of the genus Bacillus. Although there were some differences in microflora between Africa and Malaysia there was a good measure of similarity between the two. Upper Amazon hybrids were used, and in both countries acid cocoa was produced. Analysis of the cured cocoa from the experimental fermentations and non-acidic Amelonado cocoa shows that the former contains higher levels of acetic and lactic acids and similar levels of citric acid.

The influence of the storage environment on the quality of commercial cocoa with special reference to mouldiness of the beans OYENIRAN, J.O. Nigerian Stored Products Research Inst., Ibadan, Nigeria — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 577-582 1981.

The moisture content of cacao beans with an original moisture content of 6.9 per cent changed in the course of 3 months to 6.5, 7.1, 7.4, 8.5, 9.2, 11.7 and 17.9 per cent when stored at an RH of 65, 71, 75, 81, 84, 90 and 98 per cent. Internal mouldiness in the beans occurred at an RH between 75 and 98 per cent. Eleven fungal species, both xerophylic and hydrophylic, were isolated from the mouldy beans. Beans were also stored either outside in the laboratory veranda or inside the laboratory room. Here only one xerophylic fungus was isolated from mouldy beans.

(Storage of cocoa in a thermally insulated airtight warehouse) Stockage du cacao en hangar hermétique protégé thermiquement CHALLOT, F., PETNGA, E. and ROCHE, G. Office National de la Recherche Scientifique et Technique (ONAREST), Yaoundé, Cameroon — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 583-589 1981.

In a special warehouse, thermally insulated and as airtight as possible, the humidity level of the air was kept below 70 per cent by means of an air dryer. Seventeen tons of grade 1 cacao were treated and stored for more than 15 months. The development of the moisture content, the study of cut tests and organoleptic analysis failed to reveal any significant deterioration of the product. A relative stability of the various chemical elements of the cacao during storage was found, except in the case of ammonia level which was reduced. Insect pest populations did not attain serious levels.

Costing experiment in cocoa: towards the long run AJOBO, O. and FOLARIN, J.O. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria — *In: 7. International Cocoa Research Conference. Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 601-604 1981.

It is widely believed that a cacao farmer can expect about 19 years of positive economic returns from his plantation since the plantation does not reach a profitable stage until 10 years after planting. However, the possibility for a cacao farmer to expect positive gross returns from his plantation after 6 years has been demonstrated; thus the farmer could expect an active 24 years of economic life for his plantation. In terms of yield more dry beans and pods per ha were harvested by closer spacing, while wider spacing had less yield per ha but more pods per living tree. The economic consequences of these phenomena are being studied. The statistical analysis of the data collected from the 4th to the 6th year did not show that any one of the spacing treatments to be superior to any other in terms of the growth parameters studied.

Global problems of cocoa research and extension ADENIKINJU, S.A. Scientific Research Committee, Cocoa Producers' Alliance, Lagos, Nigeria — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 633-635 1981.

Some of the efforts being made to meet the global needs of cacao research and extension are dealt with as well as the inadequacies of current attempts for the identification and meeting of these needs. The benefit of pooling together all the resources of producers and consumers is discussed as well as the role of the International Cocoa Research Conference and that of the International Cocoa Organization in performing this task.

(Extension methods and techniques: their impact on the promotion of cacao growing) Méthodes et techniques de vulgarisation: leur impact sur les efforts de promotion de la culture du cacaoyer SAM, P.D. FAO, Rome, Italy — *In: 7. International Cocoa Research Conference, Proceedings, Douala, Cameroon, 4-12 Nov 1979* Cocoa Producers' Alliance, Lagos p. 637-644 1981.

General aspects of promotion in cacao growing are outlined. Proposed solutions and results obtained, constraints of old methods, transmission and integration methods, new approaches for promotion of cacao growing and the necessity of applying a mass extension in an expanding cacao culture are discussed. Examples of this subject in Cameroon, Ethiopia and Tanzania are briefly dealt with.

October 1982

(Nutritional diagnosis and classification of representative soils from the cacao-growing areas of Amazonia) Diagnose nutricional e classificação de solos representativos dos pólos cacaueiros da Amazônia NEVES, A.D. DE S., CAMPOS, A.X. DE and BARBOSA, R.C.M. — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 105-126 1982.

Several units of soil were classified on the basis of detailed surveys and exploratory inspection. Of these units 20 were considered suitable for cacao growing because of their deep soils (> 100 cm), medium to high natural fertility, good moisture retention and the presence of primary minerals in decomposition. Using samples of soil from the mapped units, biological tests were carried out with cacao plants to determine the limiting nutrients for this crop. The results showed that all soil units studied are deficient in phosphorus. Some soil units displayed potassium, calcium and magnesium deficiencies. In no case was any response found for nitrogen, sulphur or boron.

(Mineralization and the nitrogen cycle in a southern Bahia cacao plantation) Mineralização ciclagem de nitrogênio em uma plantação de cacau no sul da Bahia SANTANA, M.B.M. and ROSAND, P.C. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 157-164 1982.

Nitrogen mineralization, on a plantation of 20-40 year old cacao was measured over a period of a year by actually incubating soil samples in the field. In the same soil, the contribution of litter from shade trees and the cacao itself to the nitrogen content in the soil, on a ten year old plantation, with mixed shade, was evaluated. Mineralization was measured by the presence and absence of N, P and K applied as fertilizer, in soil samples collected at depths of 0-5 and 5-15 cm and incubated for 30 days in plastic bags buried at the same depths. The concentration of nitrogen in cacao tree and *Erythrina* spp. debris showed the important contribution made by this material in enriching soil in the system studied. Biological fixation of nitrogen through the nodular formations of *Erythrina* spp. and finally, nitrogen gains and losses in the cacao plantation shaded with this legume are discussed.

(Cacao-growing soils in the Bahia Reconcavo Basin) Classes de solos para cacau no Reconcavo Baiano SILVA, L.F.DA and LEAO, A.C. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 179-184 1982.

The Bahia Reconcavo Basin consists of a geographically distinctive sedimentary region with soils of varying fertility, texture and relief, bearing witness to its geological formation of continental sediments which are rather discontinuous and varied. Important among these for cacao-growing are the mesotrophic Vertisols and Ultisols, particularly on account of their chemico-mineralogical composition which satisfies the nutritional requirement of cacao. Depending on ecological factors and aspects of soil management the region was divided into zones which were variably suitable for cacao. Emphasis was on natural fertility and possibilities for mechanization, since fertilizers are expensive and labour is scarce. It was concluded that there are 72,360 hectares of soil suitable for cacao, falling into the categories very good, good and fair, i.e. 24 per cent of the region surveyed in this sedimentary bowl could be used to grow more cacao.

Intensive systems of fruit production and their relevance to cocoa POSNETTE, A.F. Cocoa, Chocolate and Confectionery Alliance, London, UK — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 3-8 1982.

Some recent developments in tree fruit production are relevant to cacao but others are not. A transition from traditional 5 m x 5 m spacing to dense planting, about 2.5 m x 2.5 m, has already been made by West African farmers; spacing trials confirmed the merits of close spacing for Amelonado cacao in the early years of cropping. Evidently research is needed on maintaining high yields at maturity of more vigorous types when inter-tree competition diminishes production. Repeated pruning is unlikely to be cost effective. Growth-regulating chemicals used on fruit trees should be tried on cacao. The most feasible solution is the selection of precocious-bearing clones with moderate vigour, or dwarfing rootstocks. Selection for tolerance to full sunlight is also desirable since shade management presents unsolved problems that are accentuated in intensive systems.

Vascular streak dieback of cocoa in India ABRAHAM, C.S. Directorate of Cocoa, Arecanut and Spices Dept., Calicut, Kerala, India — *Indian Cocoa, Arecanut & Spices Journal* v. 4(4) p. 119-120 1981.

The history, distribution, symptoms and epidemiology of *Oncobasidium theobromae* are discussed. Due to the failure of fungicides to control this disease practical remedies are recommended such as pruning of diseased cacao branches some 30-40 cm below the end of visible streaking in the wood, the regular pruning of chupons on the trunk, and within-canopy pruning to improve aeration.

(Storage and transportation of cacao: a bibliographic study) Etude bibliographique: stockage et transport du cacao BOUSSARD, B. Institut Français du Café et du Cacao (IFCC), Paris, France — *Café, Cacao, Thé (France)* v. 26(2) p. 136-144; Apr 1982.

A review of the factors involved in the storage and transportation of cacao beans. After discussing the hygroscopic characteristics of the beans, the author goes on to investigate the effects of various treatments and storage methods on insect infestation and the growth of moulds, and how these can be controlled. Storage problems in both producing countries and temperate countries are dealt with.

Cocoa plantations BRIDGLAND, L.A. Burns Philp Plantations Div., Rabaul, Papua New Guinea — *Monograph — IASER (Papua New Guinea) (What do we do about plantations?)* no. 15, p. 12-20 1981.

The present state of the cacao plantations in Papua New Guinea is reviewed in this article. The paper includes the following headings: cacao production, an estimate of cacao plantings by age groups, production potential from plantation hectarage, reasons for decline of cacao plantations, research and services, finance and the cost price squeeze, management and training and conclusions. The cacao plantations of Papua New Guinea now stand at the crossroads but cannot remain there. They must be furnished with both the incentive and the means to get on with the job of injecting themselves with new life and vigour.

(Establishment of 6 cacao hybrids using the "Turrialba" renovation method) Establecimiento de 6 híbridos de cacao por el método de renovaciçon "Turrialba" ENRIQUEZ, G.A. and PAREDES, L.A. Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica — *In Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 9-13 1982.

The cost of renovating a 49-year old plantation of Matina cacao with interclonal hybrids was studied. The improved material was planted beneath the shade of old cacao which is then removed by gradual pruning as the new cacao grows up. The production from this experiment over the following years was examined. While the new cacao is growing, the old cacao is still partially productive, which can pay for the cost of the renovation, particularly since it responds favourably to the pruning, cleaning and application of fertilizer which is carried out at the time of planting. During the first three years of establishment, the old cacao produced an average of more than 3000 kg/ha of dry weight cacao, while the yield from the first year of the hybrids exceeded 500 kg/ha. After 13 years the yield was 2442 kg/ha.

Studies on cocoa seedling transportation from the nursery and bare-root transplanting into the field ESAN, E.B. Gambari Experimental Station, Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria — *In Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos (Nigeria) p. 15-20 1982.

The conventional method of transporting cacao seedlings from the nursery into the field with ball of earth in heavy-duty vehicles has been practised with utmost difficulty principally because of inadequate transport facilities coupled with the heavy weight of the potted seedlings. The objective of this investigation therefore is the detailed reassessment of the ball of earth and the bare-root methods of transporting and transplanting cacao seedlings. The treatment consisted of enveloping the seedling foliage shoot in a balloon of transparent polyethylene bag and covering of the roots with a damp thick, absorbent, paper. The application of rooting hormone at low concentration also enhanced root development. It was evident that an unassisted farmer could conveniently transport over 1000 seedlings cheaply from the nursery to his farm, transplant his consignment on to the field within two days, and still record over 90 per cent successful re-establishment.

(Viability of bare-root cacao transplanting) Possibilidade de transplante do cacaueiro com raízes nuas ALVIM, R., LIMA FILHO, J.M.P. and AFONSO, C.A. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 21-26 1982.

This paper describes findings which demonstrate the viability of bare-root transplanting of cacao separated from its ball of earth either by washing or direct extraction, using processes involving application of an antitranspirent (Mobileaf) to the foliage and previous reduction in the number of leaves. Mean survival rates of over 90 per cent were obtained when a 10 per cent Mobileaf emulsion was applied to the foliage and the transpiratory surface area reduced to a single pair of fully formed new leaves. Use of a substance (Agricol) recommended for its capacity to reduce water loss through the root system did not lower the mortality rate of the seedlings after transplanting. The possible economic benefits of the bare-root transplanting method are discussed.

(Improvement of factors influencing cacao production: modification of pollinating conditions) Amélioration des facteurs de production du cacaoyer: modification des conditions de pollinisation LUCAS, P. Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 27-29 1982.

In Togo cacao trees are under-pollinated. Pollination is essentially carried out by Diptera, Homoptera and Hymenoptera. Where ants are likely to make an effective contribution to pollination, placing nests in the trees produced a significant improvement. Where pollination is carried out by a large number of different genera the use of colour traps can increase the number of pollen grains deposited on flower styles.

(Supplementary pollination and stem cutting as simple measures to increase cacao yields) La polinización suplementaria y cortes en el tallo como prácticas simples para incrementer los rendimientos en cacao VERA B, J., MOGROVEJO J, E. and MOREIRA O, M. Cocoa Tropical Experiment Station, Instituto Nacional de Investigaciones Agropecuarias (INIAP), Pichilingue, Ecuador — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos (Nigeria) p. 31-35 1982.

In the principal cacao growing areas in Ecuador peak cacao production occurs with the onset of the rainy season, when the proliferation of certain endemic diseases causes losses as high as 60 per cent. Studies have shown that losses caused by disease can be avoided if the receptive flowers on the trunk are manually pollinated and these pods harvested in months which are unfavourable for the development of fungal diseases. The aim of the present study was to try out certain simple management practices at the small farm level which could lead to the avoidance of diseases in the normal harvest curve. It was concluded that by manual pollination plus removal of a ring of phloem from round the trunk 15 cm above the ground, an increase of between 182 and 409 kg of dry weight cocoa can be achieved per hectare, particularly on smallholdings.

(A study of the effect of flowering and pollination conditions on cacao yields) Etude des conditions de floraison et de pollinisation sur les rendements du cacaoyer MOSSU, G., PAULIN, D. and REFFYE, P. DE Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 37-44 1982.

A study of the flowering, ovule count per ovary and analysis of histograms of bean frequency per harvested pod for a given cultivar make it possible to determine all the factors governing production. Over a 30 month period the weekly flowering development of different Amelonado and Amazon cultivars was followed. The correlations between the calculated data and the observed data are highly significant for the different cultivars. The similarities and differences observed between Amelonado and Amazon cultivars during the course of the experiment can be explained perfectly satisfactorily: the first by the remarkable parallels between flowering variation and pollination variation, the latter by the way the data varies in accordance with the wilt point values of the different cultivars.

(Towards integrated weed control in cacao plantations) Hacia un control integral de malezas en cacaotales REYES E, H., REYES, L.C. DE and MARTINSKY, J. Centro de Investigaciones Agropecuarias (CENIAP), Caucagua, Venezuela — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 45-48 1982.

This paper presents the problem of weed control in cacao plantations and the importance that, without doubt, the factors related to the plant, climate and soils as regards weed development, represent. A whole series of studies is presented, in which the characteristics of the weeds and cacao plantations have been observed as well as the effect on them of agronomic, biological and chemical aspects of their control. An integrated strategy of management is presented which, relating all these factors, would make the work of weed control more efficient.

(Development trial of a grafting method for cacao) Essai de mise au point d'une méthodologie de greffage chez le cacaoyer KADJE, A. and NGAMBI NDJAMA, J.M. Institute de la Recherche Agronomique, Ebolowa, Cameroon — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 49-55 1982.

A new grafting technique in which the graft, cut in a shield shape, is inserted in an inverted T incision made on the rootstock below the cotyledon, has been developed. The hypocotyl is bent over immediately after the grafting operation, followed by a period under a polythene tube until the graft has taken. With these innovations the success rate of grafts compared with the control treatment, where unbent grafts remain under a corrugated iron shed is improved. Results from this preliminary study indicate that bending encourages leaf burst and scion development and that in supervising the grafts care needs to be taken as regards lighting, humidity, etc.

(Effects of controlled pollination on cacao) Efectos de polinización controlada en cacao MARTIN, E.J. Servicios Técnicos (Cacao), Limón, Costa Rica — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 57-60 1982.

The low-yielding trend in inter-clonal commercial cacao stands was studied. Trials consisted of a series of controlled crosses which were initiated back in 1960,

checking the compatibility of the parent clones involved, combining ability and fruit set, wilting of young fruit and the number of ripe fruit harvested. This experiment tends to explain that interclonal mixed stands should be established technically in order to enhance proper cross-pollination so as to secure regular commercial yields, stressing fruit set of self-incompatible trees which require foreign pollen for fruiting. A second experiment which covered a period of 30 months showed precocity of two controlled crosses at a rate of 6:1. Such findings tend to explain the low-yielding trend in uncontrolled seedling stands thus favouring the use of proper and selected seedling material of bi-parental stock.

(Influence of climatic conditions, weight and volume of seed on the development of cacao plants in the nursery and subsequently under field conditions) Influência das condições, peso e volume de sementes no desenvolvimento de plantas de cacau em condições de viveiro e posteriormente no campo SOUZA, J. DE, GARCIA, J.R. and MULLER, M.W. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 61-64 1982.

Measurements of diameter, height and number of leaves, taken when the seedlings were 4 months old, showed positive correlations with the weights of seeds but no correlations were found between the volume and the parameters measured. At 8 months – 4 months after being transplanted the same plants which had achieved better development in the nursery continued to prove significantly superior, although the average rate of stem increase was lower than that of the transplanted seedlings which had showed less development. That superiority gradually diminished with increasing age and by 12 and 16 months there was a tendency for the average growth rate of stem to level out. The differences between the more vigorous plants in those planted out in the field in a less developed state gradually became less pronounced.

(Transplanting bare-root cacao seedlings) Transplantio de mudas de cacaueiro com raízes nuas SOUZA, J. DE, GARCIA, J.R. and MULLER, M.W. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos (Nigeria) p. 61-64 1982.

The following treatments were carried out to determine the best method of transplanting bare-root cacao seedlings, in comparison with the method traditionally used (roots encased in soil): (1) seedlings transplanted with a ball of earth; (2) seedlings transplanted with two leaves and bare roots unpruned, and with application of Mobileaf (anti-transpirant); (3) seedlings transplanted with two leaves, bare roots pruned, and with application of Mobileaf; (4) unpruned bare-rooted seedlings, with stems cut to 30 cm from the ground and application of Mobileaf. The stem diameter taken 6 months after transplanting, showed no significant differences between the treatments, while after 12 and 18 months treatments 1 and 2 showed development equal to each other and superior to treatments 3 and 4. The treatments showed the following results with respect to percentage survival up to 60 days after transplanting: 1 and 2: 97.50 per cent, 3: 88.75 per cent and 4: 90.00 per cent.

(Influence of seedling age on the development of cacao after transplanting) Influência da idade da muda no desenvolvimento do cacaueiro após o transplante SOUZA, J. DE, GARCIA, J.R. and MULLER, M.W. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 69-72 1982.

Seven treatments were used in this study: pre-germinated seeds planted out directly in the field, seedlings of 2-6 months and seedlings of 6 months transplanted with bare roots. The results showed that the 2-6 month old seedlings planted out by the traditional method used in the region (roots encased in soil), showed little variation amongst themselves and turned out to be superior both in development and in percentage survival to the 6-month old seedlings, planted with bare roots, and also to the seeds planted directly in the field.

(Programming cacao fertilizer schedules based on correction of anionic and cationic balances in the soil and compensation for depletions by the expected harvest) Programmation de plans de fumure du cacaoyer basés sur la correction des équilibres anionique et cationique dans le sol et la compensation des exportations par la récolte escomptée LOTODE, R. Institut Français du Café et du Cacao (IFCC), Montpellier, France — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 91-104 1982.

Research into fertilizer formulation for cacao in a given soil is based on the knowledge of certain anionic and cationic balances promoting growth and yield. The steps in a computer program for calculating fertilizer requirements depend on the initial soil characteristics and result in a print-out with information on initial characteristics; quantities of fertilizer required to correct the soil; the compensation for depleted elements of the total; the final balance of the exchangeable bases and the time for correct application. Consideration is also given to the number and dates of application according to the elements; soil sampling and specification; and the choice of fertilizers to compensate for depletions only, after soil correction.

(Fluctuations in the water reserve beneath a cacao plantation: relation to the climate) Evolution du stock d'eau sous une cacaoyère: relation avec le climat JARDIN, P. and SNOECK, J. Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 127-135 1982.

Using a neutron probe a record was kept of the fluctuations in the water reserve to a depth of 1 metre around a cacao tree which was not irrigated or receiving any fertilizer. This replenishment was measured during different drying out periods between 1978 and 1981. The variations in the water supply were correlated with climatic formulae of evapotranspiration and climate factors. Highly significant correlations were obtained, leading to the conclusion that climate explains 90 per cent of water variations in the soil. A study has been made of farm techniques (irrigation, fertilizing) to assess their influence on the correlations obtained. The establishment of these relationships opens the way to the introduction of irrigation based on simple climatic data (Colorado tank, radiometer).

(Cacao reactions in south Bahia to increasing doses of nitrogen, phosphorus and potassium) Respostas do cacaueiro no sul da Bahia a doses crescentes de nitrogênio, fósforo e potássio ROSAND, P.C., SANTANA, C.J.L. DE and MIRANDA, E.R. DE Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 137-144 1982.

The effects of applying increasing doses of N, P_2O_5 and K_2O were evaluated on 8 plantations of Catongo cultivar. Data for the period 1971 to 1975 showed, for additions of 90 to 180 kg/ha of P_2O_5, average increases in dry bean production of about 340 to 379 kg per hectare; increases of 153 and 226 kg per hectare were activated for doses of 60 and 120 kg/ha of N, respectively. Addition of 60 and 120 kg/ha of K_2O reduced production. In the period 1976 to 1980, responses to the addition of phosphorus continued the same trend and to the same degree, whereas with N and K_2O additions only slight increases in production were obtained with doses of 120 kg/ha of each nutrient. Analysis of the soils after 10 years of uninterrupted fertilizer application shows a considerable residual effect of phosphorus and potassium.

(Experimental recycling of organic matter on a cacao farm) Essai de recyclage de la matière organique dans une cacaoyère RIVOIRE, P. Institute de la Recherche Agronomique, Ebolowa, Cameroon — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 145-150 1982.

Compost has been manufactured by crushing and stacking rotten pods and salvaged pod husks. Temperature readings taken inside the compost heap showed that the heat produced by fermentation was more than sufficient to destroy spores of *Phytophthora palmivora* brought in with rotten pods. The compost appears to be very rapidly leached, especially its potassium and phosphorus content.

Three month old compost was spread at the foot of young cacao plants which were one and a half years old. In association with *Mimosa invisa* as interrow shade plant, it decomposed very quickly. After one year, there were practically no traces left on the ground. This compost is suitable for use on any crop justifying the application of large quantities of organic matter, cacao nurseries, collections, banana plantations, vegetable plots, etc.

(The effect of phosphorus on the water status in cacao seedlings var. Catongo) Efeito do fósforo sobre o estado hídrico em plântulas de cacau var. Catango PASSOS, E.E.M., MACHADO, R.C.R. and PEREIRA, R.C. Unidade de Execução de Pesquisas de Ambito Estadual (UEPAE), Emprêsa Brasileira de Pesquisa Agropecuária (EMBRAPA), Aracajú, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 151-155 1982.

A study was conducted to investigate the effect of three levels of phosphorus (0, 0.66 and 1.5 mM) on the internal water content of young cacao plants, cultivated in washed sand. To evaluate this effect the leaf water potential, the stomatal diffusive resistance and the transpiration rate were measured. There was a great reduction in the leaf water potential, an increase in the stomatal resistance and a decrease in the transpiration rate in the untreated when compared with the plants that received phosphorus. A smaller expansion of the root system was also observed in the plants with no phosphorus. This contributed to a decrease in root water absorption and, as a consequence, the internal water flow in the plants.

Fertilizer use on cacao rehabilitation projects in Ghana AHENKORAH, Y., HALM, B.J. and APPIAH, M.R. Cocoa Research Inst., New Tafo-Akim, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 165-170 1982.

Different sites covering different soil groups were selected to test the usefulness of N, P and K fertilizers to the Ghana/World Bank Cacao Rehabilitation Project Area. The effect of N was generally negative, causing yield depression ranging from 11-35 per cent at several sites; that of K was negligible; while significant positive yield response with 32 per cent mean (range 22-43 per cent) increase was consistently associated with P. To avoid increasing the debt burden on the farmer, it is recommended that only triple superphosphate, at least 160 kg P/ha, should be incorporated in the rehabilitation exercise on mature farms. Either a bulk or split application in April/May or August of the triple superphosphate is desirable.

Review of results of fertilizer trials on cocoa in Nigeria OJENIYI, S.O. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 171-174 1982.

Results from the various experiments showed that nitrogen and phosphorus fertilizers consistently produced apparent increases in the yield of Amelonado and Amazon cacao varieties. Only basal application of fertilizers containing K, Mg and Ca is recommended. Significant yield responses to soil-applied macronutrient fertilizers might take at least 3 years of fertilizer application to reflect. Early yield responses were observed in the case of foliar applied K and soil-applied boron fertilizers. Significant response of Amelonado cacao to foliar-applied K was observed within 2 years. Within 3 years significant response to soil-applied boron was observed. Broadcast of area around the base of Amazon cacao seedling at the rate of 5-10 g/plant for 2 years increased growth rate. Possible fertilizer rates of application for cacao trees are 120-240 kg/ha/annum N (applied twice), 30-60 kg/ha/annum P, 67 kg/ha/annum K and 6 g boron per tree.

(The use of compound fertilizers for cacao in the district of Riofrío, a banana growing area) Abonamiento del cacao con fertilizantes compuestos' en el corregimiento de Riofrío, zona bananera QUIROZ P, G., BONILLA M, A. and DELGADO V, J.L. Universidad Tecnológica del Magdalena, Santa Marta, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 175-177 1982.

An experiment was conducted to obtain data on nutrition and yield resulting from application of compound fertilizers on commercial cacao plantations. Treatments consisted of three compound fertilizers 13-26-4, 12-6-22-2, 12-12-17-2 and triple 14 in doses of 350, 400 and 450 kg/ha for each and a control. Two equal applications were made in one year with 6 month interval at the onset of each rainy period. Applications were carried out by hand in a circular strip 20 cm wide and one metre from the base of the trunk, which was then covered with soil and fallen leaves. The results showed that the doses of 350 kg/ha/year gave the highest average cacao yield in the case of all four fertilizers used. The best yield responses were obtained using the lowest dose of fertilizers 13-26-4 and 12-6-22-2, which increased yield by 55 per cent and 46 per cent, respectively, when compared with the control.

(Selective edapho-climatic factors in the zoning of cacao growing in southeastern Bahia) Fatores edafo-climáticos pertusum (Homoptera: Membracidae) praga do cacaueiro na Bahia ABREU, J.M. DE and MILANEZ, J.M. SILVA, L.F. DA Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 185-197 1982.

Some failures in cacao planting have been recorded due to poor choice of areas – factors related to soil or climate or both. Two factors may act in isolation, or as in the majority of cases, be inter-related, so that a knowledge of the interaction of climate and soil is essential when evaluating the behaviour of cacao under various ecological conditions. Aspects of the soil linked to agricultural use – fertility, texture, water retention, depth and physiography, and linked to climate – mean air temperature, extremes in air temperature and mean rainfall, the types of area of potential use for cacao cultivation were established, taking into account the integration of these edapho-climatic factors.

Interaction between root and shoot growth in cacao seedlings HARDWICK, K., SLEIGH, P.A. and COLLIN, H.A. Department of Botany, University of Liverpool, Liverpool, UK – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 209-214 1982.

Root growth in cacao seedlings was shown to be clearly rhythmic with periods of high growth rate largely coincident with low leaf growth and vice versa. Although carbohydrate and plant water status are likely to be major factors controlling growth of both root and shoot, details of the mechanism are not clear. Nevertheless this knowledge of the root system behaviour could be of importance in the cultivation of cacao indicating the optimum part of the growth cycle for irrigation, application of fertilizers and for transplantation of seedlings.

The effect of gibberellic acid and various auxins on Ethrel induced wilt of cacao ORCHARD, J.E. and RESNIK, M.E. Divisão de Botanica, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 223-228 1982.

Cherelle can be artificially induced by the application of the ethylene-producing substance, Ethrel (ethephon), to the pedicels of young fruit. This method was used as a screening test to evaluate the potential of some growth regulating substances to reduce wilt. Gibberellic acid (GA) prevented the wilt of 10 to 50-day old fruits when applied in lanolin paste. An aqueous spray of GA only counteracted the action of Ethrel on 10-day old fruits. Naphthalene acetic acid (NAA) only prevented wilt when applied to 10-day old fruits. The application of 2,4-D, 2,4,5-T and 2,4,5-TP did not reduce Ethrel-induced wilt and even provoked wilt immediately following their application in lanolin paste. GA had no effect on fruit growth and development. NAA appeared to reduce fruit growth and alter seed development.

(Measuring transpiration in cacao by variation in soil moisture) Redistribuição de água e transpiração do cacaueiro por variacão da umidade no solo CADIMA Z, A. and ALVIM, P. DE T. Divisão de Geociências, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 265-269 1982.

In a 10-year old cacao plantation with 3 x 3 m spacing six cacao trees were selected for measurement of soil moisture. The volume of transpiration was evaluated from this variable. The trees were isolated by a trench 0.70 m wide and 2 m deep. The ground was watered to saturation point and immediately covered with black plastic to prevent evaporation. Soil samplings were carried out over eight weeks at depths of 0-30, 30-60 and 60-90 cm and at distances of 30, 50 and 100 cm from the trunk. In the first week water losses were very marked at all distances; in the second week this loss was much greater only at the distance of 100 cm. Taking the average for all distances, transpiration gradually fell off. The water transpired in the first week in conditions of total soil saturation was 45 mm/day, falling to 3.4 mm/day in the eighth week.

(Contribution to data on the natural enemies of the beetles (Xyleborus spp.), cacao pests in Bahia, Brazil) Contribuição ao conhecimento dos inimigos naturais das coleobrocas (Xyleborus spp.) pragas do cacaueiro na Bahia, Brazil SORIA, S. DE J. and MACHADO, A.B.M. Divisão de Zoologia, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 289-290 1982.

The most frequent dragonfly in evening swarms was *Gynacantha bifida*. Its role as a predator of *Xyleborus* spp. was proved by examination of food remains in its digestive tract, which consisted almost exclusively of fragments of beetles. It was concluded that the species *G. bifida* merits protection in its habitats around cacao plantations because of its predation on *Xyleborus*, and that it also merits more detailed study to gain greater knowledge of its biological control of *Xyleborus*.

(Evaluation of synthetic pyrethroids in the control of Hoplophorion pertusum: a cacao pest in Bahia) Avaliação de piretroides sintéticos no controle de Hoplophorion pertusum (Homoptera: Membracidae) praga do cacaueiro na Bahia ABREU, J.M. DE and MILANEZ, J.M. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 291-293 1982.

The effectiveness of synthetic pyrethroids in controlling this pest was evaluated in heavily infested cacao trees. An efficiency evaluation was made 8, 24 and 48 hours after application. The average population density varied between 381 and 1526 aphids per tree. The effectiveness of decamethrin in concentrations of 5, 7.5 and 10 g a.i./ha was 98, 97 and 90 per cent, respectively, 48 hours after application. The efficiency of permethrin in doses of 100, 125 and 150 g a.i./ha was 97, 99 and 98 per cent, respectively, 24 hours after application. The efficiency of fenvalerate in doses of 50, 100 and 150 g a.i./ha was 97, 97 and 99 per cent, respectively, 24 hours after application.

Evaluation of five systemic fungicides for control of Phytophthora pod rot of cocoa MCGREGOR, A. Lowlands Agricultural Experiment Station, Department of Primary Industry, Keravat, East New Britain, Papua New Guinea — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 295-299 1982.

Ridomil (metalaxyl) and Nordox (cuprous oxide) gave a substantial and significant reduction in numbers of infections arising from zoospore inoculations and significantly reduced percentage *Phytophthora* pod rot in the field. Aliette (fosetyl-Al) was less effective in controlling natural and artificial infection than either Ridomil or Nordox whilst Curzate CC (copper oxychloride / captafol + cymoxanil) was ineffective at the dose rate used in the trial. Previcur N (prothiocarb) and Terrazole (etridiazole) did not significantly reduce artificial infections on detached pods and were not evaluated further. The Ridomil, Nordox and Aliette treatments gave significantly higher yields than the untreated control in the field trial but only Ridomil and Nordox gave a good profit by spraying. Ridomil was found to be more cost effective and more acceptable to growers than Nordox.

Changes in nematode types and population density in the first two years of cocoa establishment AFOLAMI, S.O. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 301-306 1982.

A plot freshly cleared for cacao planting was sampled to determine the nematode types and their population level. Samples were taken from seedling rhizosphere three months after transplanting, and subsequently at two month interval. *Helicotylenchus* spp., *Meloidogyne* spp., *Scutellonema* spp., *Trichodorus* spp., *Criconemoides limitaneum*, *Hemicycliophora* sp., *Hoplolaimus pararobustus* and *Xiphinema* spp., were recovered in low numbers from samples taken prior to planting. In the second year the nematode population had changed considerably. *Meloidogyne* spp., *Rotylenchulus reniformis* and *Helicotylenchus* spp. became predominant while *Scutellonema* spp. were found only in traces. *Meloidogyne* spp. were found in largest numbers in plots where cacao was intercropped with maize/cowpea, *Rotylenchulus reniformis* and *Helicotylenchus* spp. in plots intercropped with yam. Cassava/cacao plots had the least of all nematode types. There were seasonal fluctuations in nematode populations.

(Some aspects of the biology of Crinipellis perniciosa in the Uraba Region (Colombia)) Algunos aspectos de la biologia de Crinipellis perniciosa, en la region de Uraba (Colombia) ARANZAZU H, F. Instituto Colombiano Agropecuario (ICA), Medellín, Colombia — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 323-328 1982.

Witches' broom disease is considered the main cacao disease in Colombia. It was found that the broom length varied over the year according to the physiological state of the cacao tree. The average time during which the brooms remained in the green state was five weeks; the withering period averaged one week. The minimum time recorded for the start of basidiocarp production was eleven weeks from the time the broom withered. Maximum production of basidiocarps was recorded in the last three months of the rainy season. Among the possible factors, the presence and abundance of saprophytic bodies in competition with the *C. perniciosa* mycelium at certain times of the year should be considered. Generally speaking, the results obtained correspond with the Trinidad reports, based on research carried out more than 40 years ago.

(Insect pests of cacao in Amazonia) Insetos nocivos ao cacaueiro na Amazônia GARCIA, J. DE J. DA and MENDES, A.C. DE B. Departamento Especial da Amazônia (DEPEA), Comissão Executiva do Plano de Lavoura Cacaueira (CEPLAC), Belém, Pará, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 331-333 1983.

With a planted area estimated at some 53,000 hectares, cacao cultivation in Brazilian Amazonia is now presenting serious phytosanitary problems. Damage caused to crops by insects has been on the increase in recent years, especially in areas of widespread deforestation. To identify the principal species present in Amazonia fortnightly counts were made on a regular basis during the years 1977 to 1980, using manual collection, field observations and shock (Knockdown) techniques using applications of 12 per cent HCH. After identifying damage in the field and studies of fauna of various communities, 24 species were singled out as being the principal insect pests to cacao growing in Amazonia. These species are described in terms of resulting economic damage and consideration is also given to the seasons and localities of their highest incidence.

(Recent advances in chemical protection of young cacao plants from pests and the scale insect vectors of swollen shoot in Togo) Progrès récents dans la protection chimique des jeunes cacaoyers contre les ravageurs et les cochenilles vectrices du "swollen shoot" au Togo NGUYEN BAN, J. Centre de Recherches, Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 335-337 1982.

Foliar sprays with triazophos 40 EC, formothion 33 EC and heptenophos 50 EC at the rate of 2.2 g a.i./ha, effectively control scale insects of the genus *Planococcus* for a 30-50 day period (95-100 per cent effective). Decis 18 EC (decamethrin) at 39.6 g a.i./ha is slightly less effective than the organophosphorus sprays. At 1.1 g a.i./ha triazophos 40 EC shows the same performance as at 2.2 g a.i./ha, while at the same concentration formothion 33 EC becomes less active after 10 days. The response of *Tyora tessmani* (Psyllidae) to insecticides is more variable both as

regards immediate effect and persistence. Formothion 60 EC at 2.2 g a.i./ha and tiazophos at 1.1 g a.i./ha give total control of psyllids for one month. Subsequently their persistence is largely dependent on the vegetative state of the cacao.

Field trials with insecticides and spraying equipments to control cocoa mirid Sahlbergella singularis in Nigeria OMOLE, M.M. and OJO, A.A. Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 339-343 1982.

Eleven insecticides were evaluated in the field to control the mirid *Sahlbergella singularis*. Methods of application included atomization using knapsack or motorized mist-blower and thermal fogging using the swingfog machine. Effective control of the mirid was achieved by spraying with Lindex 20 EC (lindane), MIPC (isoprocarb), Capsitox 20 EC, Perfektan 20 EC (lindane), Dursban 40 EC (chlorpyrifos), Sumicidin (fenvalerate) and Elocron 40 EC (dioxacarb), the per cent mortality during the 3rd week of application being 91.3, 93.3, 94.6, 97.5, 97.9, 98.4, 100 and 100, respectively. Other insecticides like WL 43467, Perfekthion (dimethoate) and fenitrothion were effective during the first 2 weeks but lost their efficacy shortly afterwards. In further trials all the miricides evaluated, effectively controlled mirid population 2 weeks after application. Lindane 16 per cent and diazinon 90 SCO mixed with diesel at rates of 2 l and 0.56 l/ha, respectively, were effective.

Early work in the control of the cocoa pod borer (Acrocercops cramerella) in the Philippines VANIALINGAM, THOMAS, E. and MANALO, M.I.J. Cocoa Investors, Hagonoy, Davao del Sur, Philippines — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 345-351 1982.

Renewed interest in the control of the pod borer or cacao moth was initiated in 1979 with a large-scale planting programme of Upper Amazon hybrid cacao under coconuts. Three different larval stages were identified. By locating the actual resting place of the adult during the day, an effective trapping method was devised to estimate populations of the pest within an area. Bagging of pods and chemical control by Agrocide 126 per cent HCH WP) were found to be most effective in reducing adult populations and subsequent pod damage. Decis (2.5 per cent decamethrin EC) and Lannate 190 per cent methomyl WSP) were found to be effective as ovicides. A combined regime of Agrocide and Decis, used in a heavily infested area at alternate weekly intervals reduced incidence by about 80 per cent after two months. However, pod borer infestation increased in these blocks significantly three months from the last application. Biological control approaches are also being considered.

[The problem of rodent pests in cacao farming in the Ivory Coast] Le problème des rongeurs nuisibles à la cacaoculture en Côte d'Ivoire COULIBALY, N. Institut Francais du Café et du Cacao (IFCC), Bingerville, Ivory Coast — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 353-355 1982.

Rodents pose an acute problem, particularly in commercial plantations. Nature and importance of the damage inflicted and also the rodent species responsible for that damage are described. Germinating beans are dug up and eaten on the spot or removed. Pod damage takes various forms. Less than three months after manual removal of all pods showing rodent damage new damage again affected 83 per cent of pods. The first catches revealed the following species: *Hylomyscus* spp., *Praomys* sp., *Crycetomys* sp., *Mastomys* sp. and *Graphiurus* sp. Knowledge of the population dynamics, ethology, reproduction and feeding of the species in question should enable planned control of these pests.

Pathogenic races of Crinipellis perniciosa. WHEELER, B.E.J. and MEPSTED, R. Imperial Coll. of Science and Technology, University of London, Ascot, Berks, UK — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 365-370 1982.

Dead witches' brooms were imported from various areas within Brazil, Colombia, Ecuador, Trinidad and Venezuela. The causal fungus, *Crinipellis perniciosa*, was isolated from mycelium in these brooms and from basidiocarps induced on them. Germinated seeds of West African Amelonado and Scavina 6 cacao were inoculated with basidiospores of selected isolates. Isolates from Ecuador were distinguished by the slower rate of Amelonado seedling death and by marked stem base swelling and broom formation on Scavina 6. An isolate from Ecuador also induced more rapid broom formation on young plants of Amelonado, ICS 1, EET 19 and EET 400 than did an isolate from Brazil. The data suggest that *C. perniciosa* from Ecuador differs from other isolates and perhaps, also, that within these isolates further types may be distinguished.

(Advances in the chemical control of cacao black pod in Bahia, Brazil) Progressos no controle químico da podridão parda do cacaueiro na Bahia, Brasil LELLIS, W.T., FIGUEIREDO, J.M. DE and PEREIRA, J.L. Divisão de Fitopatologia, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 371-374 1982.

Until 1979 the only fungicide used for the control of cacao black pod was Copper Sandoz (cuprous oxide with 50 per cent metallic copper). In the last two years five new fungicides have been introduced with different formulations: an oil-based copper oxychloride formulation with 35 per cent metallic copper v/v; a water based formulation with 36 per cent metallic copper v/v; and post humidifiable formulations which contain metallic copper. Some organic products show promise, opening the way, should the need arise, for copper fungicide substitutes in disease control. To develop new technology for the control of black pod, research is being conducted into the effects of a number of fungicide applications, using the same quantity of product per tree throughout the different treatments in order to reduce manpower and fuel requirements. A hose and nozzle system has been evolved in the development of chemical spraying machines.

(Development and impact of Monilia pod rot of cacao in Costa Rica) Desarrollo e impacto de la moniliasis del cacao en Costa Rica ENRIQUEZ, G.A., BRENES, O. and DELGADO, J.C. Centro Agronómico Tropical de Investigación y Enseñanza, Turrialba, Costa Rica — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 375-380 1982.

It is estimated that there are about 25,612 ha planted to cacao in Costa Rica. In December 1978 Monilia pod rot caused by the fungus *Moniliophthora roreri* was present in some 900 ha of cacao, but subsequent inspections carried out towards December 1979 established that the affected area had spread totalling some 7150 ha. At the end of 1980 the disease was discovered in other cacao growing areas of the country affecting plantations to various degrees. Details are given of a series of measures implemented to combat Monilia pod rot by several institutions.

[Analysis of the evolution and variation in the incidence of witches' broom disease in the Uraba region (Colombia)] Análisis de la evolución y variación de la incidencia de escoba de bruja en la region de Uraba (Colombia) ARANZAZU H, F. Instituto Colombiano Agropecuario (ICA), Medellín, Colombia — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 387-393 1982.

Witches' broom disease is of major concern in Colombia, as it causes heavy losses in yield. High levels of disease were found in trees over 7 years of age, but the incidence could be stabilized at a tolerable level by frequently applied control measures and through isolation of the plantation. The monthly average of broom formation showed a peak in December and January and a minimum in May and June, indicating that the disease follows a well defined annual cycle, broadly influenced by rain distribution, the physiological state of the tree and maximum and minimum periods of basidiocarp formation. Generally speaking, it is possible to make a plan for the integrated control of this disease using self-compatible material with limited and synchronized shooting characteristics, specific times for the collection of brooms, applying systemic fungicides, encouraging saprophytic bodies hostile to the *C. perniciosa* mycelium, and proper application of farming practices.

The relative virulence of Phytophthora palmivora and P. capsici on cacao in Bahia, Brazil LAWRENCE, J.S., LUZ, E.D.M.N. and RESNIK, F.C.Z. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 395-400 1982.

Zoospore suspensions from *P. palmivora* and *P. capsici* were used to inoculate fully-developed but unripe, unwounded, detached cacao pods. After 5 days, no significant differences in virulence were shown but lesion diameters of *P. palmivora* were twice as large as those of *P. capsici*. Suspensions used to inoculate pre-germinated seeds showed that inoculation with *P. palmivora* consistently resulted in lower seedling emergence one month later than with *P. capsici*. Similar results were obtained when stems of seedlings were inoculated, *P. palmivora* producing lesion areas three to four times larger after 18 days than those of *P. capsici*. 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 Bahia, it was concluded that future routine screening should be carried out with both species.

(Advances in the repression of Monilia pod rot in cacao) Avances en la represión de la moniliasis de cacao BARROS N. O. Departamento de Fomento, Compañía Nacional de Chocolates, Medellín, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 401-405 1982.

Reductions in the annual harvest due to Monilia pod rot amount to about one third of the country's actual output. However, this disease can be controlled economically, since evaluation studies of farming control methods presented in this paper are effective in all types of plantations. In field trials introducing measures of growth inhibition into the system, a reduction in the incidence of Monilia pod rot from 30.6 to 8.8 per cent has been achieved in a typical smallholding (less than 100 ha). This resulted in a yield increase from 588 to 1050 kg per hectare. Similarly, on a 232 hectare farm of the plantation type the incidence of Monilia pod rot was reduced from 52.8 to 22.4 per cent, with a consequent increase in yield of from 390 kg to 1100 kg of dry weight cocoa per hectare.

(Quantitative study of broom production on cacao plants affected by Crinipellis perniciosa and its significance in the management of the disease) Estudio cuantitativo de la producción de escobas en plantas de cacao, afectadas por Crinipellis perniciosa y su significado en el manejo de la enfermedad CIFUENTES, C., MAYORGA, M. and PRIETO, E. Facultad de Agronomía, Universidad Nacional de Colombia, Bogota, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 407-413 1982.

Information on the monthly distribution of broom formation and the relation of this to other climatic and agronomic factors constitutes an important basis upon which to establish a programme of broom removal to help reduce the virulence of witches' broom disease of cacao. Broom production records per tree and per stratum and per year were completed fortnightly by counting and removing new infections. There was a progressive increase in the number of brooms produced from January to December, rising to a peak in December and January. Over the year a series of fluctuations were seen in the number of brooms produced. Comparative studies of broom production in leaf buds and flower cushions showed considerable quantitative differences, a greater number of brooms being found in the latter stratum.

Witches' broom disease: wrong experiment right results EVANS, H.C. and SOLORZANO, G.R. Commonwealth Mycological Inst., Kew, Surrey, UK – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 415-418 1982.

Information on the epidemiology of witches' broom disease of cacao is presented. Dead brooms generally require 3-4 months exposure to wet conditions before basidiocarp production is initiated. Suspended brooms produce significantly more (> 3 times) basidiocarps than those on the ground. Brooms on the ground, however, still constitute an important source of inoculum. Basidiospores are common in the air between 22-04.00 hours following an increase in relative humidity (> 95 per cent) and a decrease in temperature (< 24°C) and probably move over a considerable distance (50-70 km). All parts of an unhardened flush are susceptible to infection.

(Development of phytoalexins in some species of the genus Theobroma as a response to infection by Phytophthora: study of various cultivars of cacao and of one interspecific hybrid) Elaboration de phytoalexines chez certaines espèces du genre Theobroma en réponse à l'infection par Phytophthora; étude de divers cultivars de cacaoyers et d'un hybride interspécifique. DAGUENET, G. and PARVAIS, J.P. Laboratoire de Phytopathologie, Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 433-438 1982.

Phytoalexins are considered to be one of the components of plant resistance to diseases. By means of classical biochemical techniques, such a substance of high fungitoxicity was detected in and isolated from the stems of *T. grandiflorum, T. microcarpum, T. speciosum* and in a species of a closely related genus, *Herrania*. In *T. cacao*, cultivars belonging to different groups (Forasteros, Amelonados and Upper Amazons, Catongos, Criollos and Trinitarios) were studied. It was never possible to isolate the phytoalexin present in the other *Theobroma*; however, a similar substance of weaker activity, was detected. The study of the progeny of *T. cacao x T. grandiflorum* showed that certain individuals had a resistance of a type comparable to that of the male parent; in those individuals the phytoalexin characteristic of *T. grandiflorum* could be detected showing that this character is transmissible to the progeny.

Two additional methods for inoculation of seeds of cocoa for evaluating resistance against Phytophthora palmivora SREENIVASAN, T.N. and PERSAD, G.C. Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad and Tobago – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 439-443 1982.

The inocula used were (a) wheat grain infested with Phytophthora and (b) hyphal discs (5 mm diameter) cut off from the periphery of a five-day old culture of *P. palmivora* grown on a potato dextrose agar medium in the dark. In the case of inoculum (a) a single infested wheat grain was placed in contact with a pregerminated seed and covered with fumigated (methyl broxide) potting mixture. Inoculation with hyphal discs was done by placing a single disc on the surface of the pregerminated seed in such a way that the disc was in contact with the cotyledon and radicle. The seed with the hyphal disc was sown in fumigated potting mixture. The potting mixture was kept moist with wet newsprint for six days. Surviving seedlings were counted at weekly intervals. Evaluations of these methods were made together with the two other inoculation methods (culture homogenate and zoospore suspension) previously used.

Occurrence and distribution of cacao diseases in south India MOHANAN, R.C. and KAVERIAPPA, K.M. Department of Biosciences, Mangalore Univ., Mangalore, Karnataka, India – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 445-449 1982.

Approximately 13,000 ha of land is under cultivation with cacao mainly as a mixed crop in coconut or arecanut gardens. A detailed survey was undertaken during the month of September immediately after the south-west monsoon to study the occurrence and distribution of various diseases affecting this crop. Major diseases were black pod (*Phytophthora palmivora*), charcoal pod rot (*Botryodiplodia theobromae*), *Colletotrichum* pod rot and *Colletotrichum* leaf spot (both caused by *Colletotrichum gloeosporioides*), stem canker (*P. palmivora*) and zinc deficiency. Black pod, *Colletotrichum* pod rot and *Colletotrichum* leaf spot were observed in more than 50 per cent of the gardens, while charcoal pod rot, canker and zinc deficiency were noted in less than 50 per cent of the gardens. District wise, black pod and *Colletotrichum* leaf spot were present in all the districts. *Colletotrichum* pod rot was observed in all except one district in Kerala. The distribution of the other diseases varied.

Recent work on vascular-streak dieback disease in Papua New Guinea PRIOR, C. Department of Biology, University of Papua New Guinea, Port Moresby, Papua New Guinea – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 451-454 1982.

The application of a previously reported basidiospore inoculation technique to screening for resistance has been limited by the inability to produce spores in culture and the erratic availability of inoculum from naturally occurring sporophores. Recently the use of a dual culture technique has enabled the production of basidiospores in culture. Cacao callus cultures grown on a synthetic agar medium are inoculated with *Oncobasidium theobromae* mycelium. These cultures have been shown to produce moniloid hyphae like those found in sporophores, but they do not become fertile under laboratory conditions. The necessary stimulus for basidiospore formation may therefore be provided by the physical and biological environment under which sporophores naturally form. A system is described whereby these dual cultures may be exposed to natural environmental conditions with the resulting production of basidiospores. The limitations and potential of this system are discussed.

(Aetiology of cacao black pod in the states of Bahia and Espírito Santo) Etiologia da podridão parda do cacaueiro nos estados da Bahia e Espírito Santo CAMPELO, A. M.F.L. and LUZ, E.D.M.N. Divisão de Fitopatologia, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 455-459 1982.

The fungus *Phytophthora palmivora* has been held responsible for cacao black pod in the cacao-growing states of Bahia and Espírito Santo in Brazil. The survey from 1978 to 1980 in these regions showed a predominance of *P. capsici* (previously known as *P. palmivora* MF_4) on cacao pods in approximately 95.0 per cent of the isolations effected. *P. palmivora* (sensu stricto *P. palmivora* MF_1) was found in about 3.0 per cent of the isolates; its presence was also detected in nursery seedlings and it causes canker in mature plants. The species *P. citrophthora*, pathogenic to pods (2.0 per cent) and to the stems of mature cacao, was subsequently recorded. These findings, although incomplete, indicated that *P. capsici* is the principal causal agent of cacao black pod.

Some differences in isolates of the black pod disease organisms from six cocoa growing countries ASARE NYAKO, A., MULLER, R.A. and BLAHA, G. Cocoa Research Inst., New Tafo-Akim, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 461-471 1982.

Pathogenicity tests on pregerminated West African Amelonado seeds showed that virulence of 34 isolates from Sao Tomé, Cameroon, Togo, Ghana, Ivory Coast and Brazil depended mainly on their ability to produce sporangia in darkness. The only Phytophthora drechsleri isolate tested produced sporangia in darkness and was also highly pathogenic. The ability to produce sporangia in darkness was not related to mating type nor to morphological types.

(Cacao black pod caused by Phytophthora sp. in Togo: determination of causal species) La pourriture brune des cabosses du cacaoyer due à Phytophthora sp. au Togo: détermination des espèces responsables DJIEKPOR, E.K., PARTIOT, M. and LUCAS, P. Centre de Recherches, Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 473-478 1982.

Black pod due to *Phytophthora* spp. is the cause of severe losses in Togo. A phytosanitary survey organized in the different cacao growing regions between 1978 and 1980 showed that losses vary from 10 to 80 per cent according to the area. The Litimé and Adélé regions were worst affected, whereas in the Kloto region losses do not exceed 10 per cent on average, despite a few exceptions on the Kouma Plateau. An *in vitro* study of the colony morphology, the morphology of the sporangia, pedicel length, extent of sporulation and chromosome types of isolates revealed the presence of *P. megakarya* in Litimé, Adélé and part of Kloto, totalling 80 per cent of the Togolese cacao stock, and *P. palmivora* on the Kouma Plateau and the Tové and Agou districts in the Kloto region.

(Study of infection and sporulation by Crinipellis perniciosa, causal agent of witches' broom disease of cacao in Guamal, Colombia) Estudio de la infección y esporulación del Crinipellis perniciosa, agent causal de la escoba de bruja del cacao en Guamal, Colombia CIFUENTES, C., MAYORGA, M. and PRIETO, E. Facultad de Agronomía, Universidad Nacional de Colombia, Bogota, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 485-492 1982.

Results of observations show that 70 per cent of the leaf shoot brooms have a green period of between 4 and 6 weeks. However, it is clear that some 10 per cent of the brooms have a green period of less than 4 weeks and the remaining 20 per cent one longer than 6 weeks. The green period of brooms formed on flower cushions, on branches and on the trunk lasts, on average, between 4 and 6 weeks, and is independent of the time of year and of the stage of development of the crop. The majority of brooms measure between 20 and 35 cm in length. The formation of basidiocarps is preceded by the hydration and softening of the dry brooms. Maximum sporulation occurs 3-4 weeks after maximum rainfall levels have been reached. Maximum sporulation in the first six months was obtained in the month of June. In the second half of the year, maximum sporulation was obtained in October. Finally, a broom may produce basidiocarps for about 2 years in periods of humidity and then die away completely and disappear.

(Prospects and precautions in the use of Ridomil in cacao cultivation) Perspectivas y precauciones para el uso de Ridomil en el cultivo de cacao REYES, L.C. DE and MARIN, C. Estación Experimental, Centro de Investigaciones Agropecuarias (CENIAP), Caucagua, Venezuela – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 527-530 1982.

Phytophthora palmivora is a serious pathogen in cacao plantations and causes severe damage to various organs of the plant and considerable fruit loss. This work presents the possibility of its control by the systemic fungicide Ridomil (metalaxyl) which exhibited, under field conditions, great efficiency, two-dimensional distribution and persistence when using a leaf dose of 300 g c.p./ha, with a single application per production cycle. Its use is recommended, but its application should be limited to combat *Phytophthora palmivora*, since antagonisms were found against fungi of the genera *Colletotrichum, Botryodiplodia* and *Fusarium* in treated pods. This justifies extensive training of technicians and farmers in the use of the product.

Current status of the development of Ridomil for the control of Phytophthora pod rot of cocoa MARGOT, P. and WARNERY, J. Agricultural Div., Ciba-Geigy Ltd., Basle, Switzerland – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 531-534 1982.

In countries where standard spray intervals are relatively long (30 days) and the disease pressure moderate, such as Central and South America and the Far East, Ridomil (metalaxyl) applied at a rate of 250 g a.i./ha in spray volumes of 120-160 l/ha directed at the pods gives better control of *Phytophthora* pod rot than can be achieved with recommended rates of copper fungicides. In regions where the infection pressure is very high and standard spray intervals are short (14 days) such as West Africa, the use of Ridomil permits an extension of the spray intervals to 21 days. Rates in the region of 50 g a.i./ha applied in a spray volume of 100 l/ha show particular benefits over residual fungicides during the period of flowering to young pod development. Season-long spray programmes with Ridomil offer reduction in the total number of sprays that have to be applied.

(Economy of cacao black pod control in Bahia, Brazil: aerial versus ground spraying) Economia do controle da podridão parda do cacaueiro na Bahia, Brasil: pulverização aérea versus pulverização terrestre DORASWAMY, G. and ARAUJO, J.B. DE Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 535-544 1982.

Two methods of fungicide application (cuprous oxide and copper oxychloride) in terms of technical efficiency and degree of economic profitability, using data on production and incidence of the disease, are compared. The results showed that ground spraying is technically more efficient. However, the considerable differences in cost indicated that aerial spraying was more economically efficient. The highest increases in production attributable to spraying were obtained in June and July, while April, May and August showed the lowest values of this variable. The fungicides produced approximately equal practical effects but from a financial point of view cuprous oxide proved preferable.

(Evaluation of four systemic fungicides for the control of Crinipellis perniciosa in Guamal, Colombia) Evaluación de cuatro fungicidas sistémicos para el control de Crinipellis perniciosa en Guamal, Colombia CIFUENTES, C., PRIETO, E. and TOVAR, G. Facultad de Agronomía, Universidad Nacional de Colombia, Bogota, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 545-550 1982.

It is important, within the concept of integrated management of the problem of witches' broom in cacao, to utilize chemicals in the fight against the disease, in the form of certain systemic fungicides which, when applied during the green period of the broom, can circulate and exercise an inhibiting effect on the sporulating potential of the mycelium. In this experiment four systemic fungicides were used: biloxazol, triadimefon, oxycarboxin and pyracarbolid in the maximum, medium and minimum doses recommended by the manufacturers. These were applied in two different ways: one application to green brooms of four different ages formed on flower cushions of branches, and two applications at two different ages of the same broom. None of the treatments were effective during the normal course of the green period or affected growth of the broom, which progressed normally following application of the fungicides.

(Study of the chemical control of witches' broom in cacao) Estudio sobre el control químico de la escoba de bruja del cacao MAYORGA P, M. and ARANZAZU H, F. Estación Experimental Tulenapa, Chigorodó, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 551-555 1982.

Since the formation of basidiocarps of the fungus *Crinipellis perniciosa* occurs only in decomposed dry brooms, the intention was to break the cycle of the disease by restricting the mycelium found inside the brooms, which should lead to a reduction in basidiocarp formation. The following treatments were used: triadimefon, oxycarboxin, agricultural oil and a control, in two methods of application, by spraying or immersion. Oxycarboxin and agricultural oil show most promise as mycelium inhibitors, followed by triadimefon, which was effective both in green and in dry brooms. In the dry brooms which were fruiting, the product had a fungistatic action, inhibiting the fruiting process of the brooms for a period of up to three months. Application of fungicides to green brooms on the tree restricted basidiocarp formation as compared with the control.

Technology transfer to cocoa farmers in West Africa LARYEA, A.A. Lars Agricultural Consultancy, Accra, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 583-591 1982.

Six stages are recognized in technology transfer: (1) research activities, (2) the need to ensure certainty of the result under the varied conditions of use; (3) to reduce the proven technique (innovation) to the level of comprehension and the means of the farmer; (4) diffusion of the innovation through propaganda to make the farmer aware; demonstrations to convince him of the benefits to be derived from the innovation to the point of his readiness to adopt it; (5) assisting the farmer by training and advice on the method of application to obtain the best result; and (6) helping him by the timely provision of the necessary inputs including financial, to enable him to put the innovation into practice. Attempt is made to identify some of the conditions and forces that serve as constraints to successful transfer. Suggestions are made regarding measures to be taken by Governments and the Cocoa Council that would facilitate the transfer to technology to the benefit of the cocoa industry.

(The Compañía Nacional de Chocolates S.A. and the promotion of cacao farming in Colombia) La Compañía Nacional de Chocolates S.A. y el fomento del cultivo del cacao en Colombia MORENO P, L.J. Departamento de Fomento, Compañía Nacional de Chocolates, Medellín, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 593-597 1982.

Cacao has been grown in Colombia for many years; yet there has been such an increase in cacao consumption that, after an exporting period it has been an importer. The government launched a promotion campaign to change this situation, with a view to regaining self-sufficiency and looking to become, once more, an exporter. The Compañía Nacional de Chocolates echoed this concern and in 1958 created a department for the promotion of cacao growing. At its own expense it engaged a number of agronomic and agricultural experts to give direct technical assistance to farmers and established new cacao farms. With these and other activities the Company has contributed towards the growth of cacao farming. Now Colombia is reaching a point of balance between production and consumption.

Progress report on the Pilot Cocoa Extension Project in the Dunkwa district of Ghana GYAMFI, A.A. Cocoa Production Div., Ministry of Agriculture, Accra, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 599-603 1982.

Ineffective extension services have been identified as one of the major factors contributing to the fall in cacao production in Ghana. It therefore became necessary for cacao extension services in the country to be re-organized and managed to be more efficient and effective. Specific objectives are discussed. Although several problems like unattractive producer prices, scarcity of labour and other inputs, poor state of roads and transportation and unavailability of some basic necessities of life confronted the farmers, the project achieved some appreciable results. There is no doubt that the project has shown that a systematic information campaign is very effective in inducing farmer participation in improved agricultural practices.

(Cacao extension work in Alto Beni, Bolivia) Trabajos de extensión agrícola cacaotera en el Alto Beni, Bolivia RODRIGUEZ R, G., DIAZ V, C. and ROMAY M. E. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 605-608 1982.

The present study examines the activities over the last three years of six extension agencies. This covers the development of cacao farming since planting began until 1980, the sequence of activities, the problems encountered and the results achieved. The agencies are described, giving the position and the number of communities and farmers in each. The methods followed in rural training and group inauguration are described, and the activities of rural training in scope and impact achieved are outlined and examined. The establishment of communal nurseries, the problems and methodology involved and the achievements in this direction are mentioned; giving the number of farmers involved per agency for the different years. An account is given of the methods used for the technology transfer principally in connection with the control of witches' broom. The results of the programme are analysed and future activities of cacao extension are outlined.

(Extension and training method in cacao farming in the Ivory Coast) Méthode de vulgarisation et d'encadrement de la culture du cacao en Cte d'Ivoire NIAMKE, J. Société d'Assistance Technique pour la Modernisation Agricole, Abidjan, Ivory Coast – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 609-613 1982.

At present, cacao is the foremost crop in the agricultural economy of the Ivory Coast. In order to achieve quantitative and qualitative objectives, the activities of SATMACI, a state-controlled body in charge of extension in the sphere of cacao farming have mainly been concerned with: creating new farms using selected highly productive plant material and proven modern farming techniques; gradually renovating the entire traditional productive cacao stock; the continual training and permanent recycling of a

qualified and versatile supervisory staff; and increasingly intensive training of registered farmers to help them better understand the technical advice offered.

(Effects of rural extension in the cacao-growing regions of Bahia and Espírito Santo) Resultados da extensão rural nas regiões cacaueiras dos estados da Bahia e do Espírito Santo CARVALHO, A.M.F. DE Departamento Extensão, Comissão Executiva do Plano de Lavoura Cacaueira (CEPLAC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 615-620 1982.

The predominant farming structure (about 85 per cent) consists of small and medium-sized holdings with an area of less than 50 hectares. In terms of cacao production, more than half the production is centred on holdings producing up to 45 ton per annum. The effects of extension on cacao production and productivity have been particularly marked in the last five years. Total production exceeded the 300,000 ton mark and is being maintained above this figure, average productivity at the present time is around 720 kg/ha/year. During 1980 farmers took action against pests on more than 460,000 ha, controlled diseases on approximately 150,000 hectares, applied fertilizers over an area exceeding 220,000 hectares and planted more than 40,000 hectares of cacao.

(Economic efficiency of resources in two groups of cacao-growing estates in the district of Ilhéus, Bahia) Eficiência económica dos recursos em dois grupos de propriedades cacaueiras do município de Ilhéus, Bahia COSTA, A. DA S.C. and REIS, A.J. DOS Departamento de Extensão, Comissão Executiva do Plano de Lavoura Cacaueira (CEPLAC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 621-626 1982.

One group consists of estates where the proprietor resides or lives outside but visits at intervals of no more than 8 days; in the other group the proprietor lives outside and visits less frequently. The purpose of the study was to estimate the relationship between the input levels promoting productivity and the level of cacao tree productivity; the estimated equations for the two groups were compared and the economic efficiency of the cacao-growing enterprises in both groups analysed. The statistical test showed that there was no significant differences in the adjusted functions of productivity for two groups of estates. Resources are not being used to the optimum level. Better results can be expected with better distribution of resources. The way in which decisions were taken did not affect the economic efficiency of the estates.

Producer-countries' share of total benefits from national investments in cocoa research: a case study of Nigeria ABIDOGUN, A. Moor Plantation, National Cereals Research Inst., Ibadan, Nigeria — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 627-632 1982.

Based on the shifts in the supply curve arising from increased productivity due to research, the present value of the flow of producer benefits was estimated and expressed as a proportion of total benefits. The producer benefits were found to be 82 per cent of the total benefit from cacao research. Apart from the distortion in resource allocation which such situation might have engendered it raises some serious issues of international equity. Thus rich consumer countries have been subsidized over the years by poor producer countries. It is stated that one possible approach to solving the problem is to embody in the International Cocoa Agreement provisions for appropriate levels of contribution by consumer countries to research support in producer countries. Such provisions also lead to better allocative efficiency.

(Utilization of physiological disorders induced by cocoa swollen shoot virus: description of a simple biological indexing test) Utilisation des perturbations physiologiques induites par le virus du swollen shoot du cacaoyer (C.S.S.V.): définition d'un test biologique simple d'indexation PARTIOT, M. and LUCAS, P. Centre de Recherches, Institut Français du Café et du Cacao (IFCC), Kpalimé, Togo — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombie, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 681-683 1982.

The average number of ovules per ovary is stable in healthy cacao, does not vary according to biological conditions and is transmitted cumulatively. That number is significantly reduced when the cacao is diseased. This occurs 2 months after artificial infection. A simple biological indexing test consists of monitoring the development of the number of ovules per ovary and would be very useful in verifying the state of health of collections and in quarantine stations.

(Behaviour of cacao cultivars with respect to biting-sucking insects: possibility of early selection of tolerant cacao trees) Comportement de cultivars de cacaoyers a l'égard de quelques insectes déprédateurs: possibilité d'une sélection précoce des cacaoyers tolérants DECAZY, B. and COULIBALY, N. Institut Français du Café et du Cacao (IFCC), Abidjan, Ivory Coast — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 685-688 1982.

A number of studies such as insect counts and observation of the danger they have caused on clones and hybrids, young cacao and mature cacao trees in the Ivory Coast and Cameroon, have shown that trees susceptible when young to attack by bollworms and psyllids remain so for their whole life. In addition, trees susceptible to infestation by psyllids and thrips are equally susceptible to mirid attack. Conversely, cacao trees tolerant to psyllids and thrips are also tolerant to mirids. Behaviour studies of young cacao trees under attack from psyllids, bollworms and thrips give very clear indications regarding their susceptibility to mirids. It is therefore possible to make early selection of cacao cultivars tolerant to mirid infestation.

(Comparative study of 6 cacao hybrids in the Uraba region of Colombia) Estudio comparativo de seis híbridos de cacao en la zona de Uraba, Colombia MEJIA P, V.E. and RONDON C, J.G. Estación Experimental Tulenapa, Chigorodó, Colombia — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 689-693 1982.

Since 1974, research has been in progress into the behaviour of the hybrids SCA 6 x ICS 39; SCA 12 x ICS 6; PA 46 x IMC 67; P 7 x ICS 6; EET 95 x SCA 6 and SCA 6 x IMC 67, in order to identify the best at local level based on production and tolerance to witches' broom and Monilia pod rot. The results obtained so far indicate the hybrid PA 46 x IMC 67 as the best in terms of production and disease tolerance. Another hybrid with better production but lower disease tolerance is P 7 x ICS 6. The hybrids with Scavina genes such as SCA 6 x ICS 39 and SCA 6 x IMC 67 have so far yielded lowest. With respect to vigorous growth, the hybrids compared in the study show similar behaviour for trunk diameter and crown height. Although the crown height appears to have become stable, the diameter of the trunk still continues to increase.

Inheritance of clonal resistance to Ceratocystis fimbriata in cacao hybrids GARDELLA, D.S., ENRIQUEZ, G.A. and SAUNDERS, J.L. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 695-702 1982.

Genetic analysis of a half diallel cross demonstrates effects of general combining abilities of clones and special combining abilities on crosses. These measurements should be used for selecting clones and hybrids to increase resistance. Clones with dominant genes plus genes with an additive effect should be used to improve the resistance of cacao to *C. fimbriata*. Phenotypic variance for survival of 10 cacao hybrids was 38.06 per cent due to additive gene effects, 30.52 per cent due to environmental effects. Clones IMC-67 and SPA-9 probably have dominant genes for resistance to *C. fimbriata*, ICS-45 probably has a heterozygous dominant gene for susceptibility. UF-613 apparently has more paternal than maternal effect on resistance of its progeny.

(Assessment of the productive capacity of 6 cacao hybrids in the Dominican Republic) Evaluación de la capacidad productiva de 6 híbridos de cacao en Republica Dominicana BATISTA, L.J. Estación Experimental del Cacao, Estado de Agricultura, Matalarga, San Francisco de Macoris, Dominican Republic — *In: Proceedings 8th International Cocoa Research Conference, Cartagena,*

Colombia, 18-23 Oct 1981 Cocoa Producers' Alliance, Lagos p. 713-717 1982.

The variables studied were: number of pods and seeds, wet and dry weight of the beans, height and girth of stem and signs of early maturity. At the same time determinations of the presence and frequency of *Phytophthora palmivora* were made. The hybrid with the highest average dry weight yield was SHB 3 with 1356 kg/ha. Production data showed that 47 per cent of the trees have medium yields, producing between 31 and 60 pods; 23 per cent are highly productive with 61-90 pods per tree; 19 per cent have low production with 1-30 pods; and 3 per cent came within the category of unproductive trees. Only 8 per cent showed exceptional production in excess of 90 pods. The hybrids came into production at between 18 and 24 months. The final result shows that the majority of the trees studied are medium and highly productive trees, although the average bean weight of some hybrids was less than 1.0 g. *P. palmivora* was found to be present on between 1 and 0 pods per tree.

(Implications of tests to detect resistance to Ceratocystis fimbriata in cacao) Implicaciones de las pruebas para detectar resistencia a Ceratocystis fimbriata en cacao GARDELLA, D. and ENRIQUEZ, G.A. Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), Turrialba, Costa Rica – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 719-724 1982.

In some cases, objections have been raised against the method used to detect resistance in cacao trees yet in other cases it has been used extensively to detect resistant genotypes. A study was made of the effect of changing the test originally proposed, and comparisons of the results were analysed. Attempts were also made to discover some reasons for these differences. Tests were carried out to detect differing pathogenicity in different isolates, and a study was made of the effect of temperature and inoculum concentration. It was found that temperature had a marked effect on perithecial production and growth of mycelium. Light had very little effect on the behaviour of fungal growth, nor did the inoculum concentration have any very noticeable effect on growth. No differences were found in the growth of various isolates of the fungus on different cacao clones. The response of several species of *Theobroma* to the growth of the fungus was evaluated.

(Genetic improvement for resistance to Ceratocystis fimbriata in cacao) Mejoramiento genético para resistencia a Ceratocystis fimbriata en cacao OCAMPO R, F., MAFLA B, G. and VICTORIA K, J.I. Centro National de Investigaciones Agropecuarias (CNIA), Instituto Colombiano Agropecuario (ICA), Palmira, Colombia – *In: Proceedings 8th International Cocoa Research Conference, Cartegena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 725-730 1982.

In the first six years of the tree's life the incidence of the disease was 0.9 per cent and increased with age of the tree. The progeny of the hybrid PA 46 x IMC 67 has not become infected and a high level of tolerance is displayed by the progeny of TSA 644 x PA 46 and ICS 6 x IMC 67. Tree deaths occurred during dry periods. In order to evaluate hybrid resistance to the pathogen the following methods were compared: bark and wood, colorimetric and punching. The punch method, which consists of replacing a disc of bark with a disc of culture medium containing the fungus with perithecia, was the most consistent and, using this method, the following hybrids were identified as being moderately resistant ICS 6 x PA 121, ICS 6 x IMC 67 and TSA 644 x PA 46.

Breeding for disease resistance to vascular-streak dieback, canker, and black pod in hybrid cocoa TAN, G.Y. Lowlands Agricultural Experiment Station, Department of Primary Industry, Keravat, East New Britain, Papua New Guinea – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 731-734 1982.

A wide range of variability was found for yield and resistance to vascular streak dieback (caused by *Oncobasidium theobromae*) and canker (*Phytophthora palmivora*) among progenies of Trinitario x Amazonian and Trinitario crosses, but no significant difference among progenies was found for black pod disease (also caused by *P. palmivora*). Hybrid progenies were generally higher yielding and more resistant to VSD and canker than the Trinitario crosses. Results demonstrated that the characters of resistance to VSD and canker diseases are genetically controlled, and can be transmitted from the parents to their progenies. Crosses between two disease resistant parents would produce highly resistant progenies. Moreover, it should be possible to combine high yield and resistance to multiple diseases in cacao hybrid progenies.

Susceptibility of clonal cocoa to attack by two insect pests in Papua New Guinea SMITH, E.S.C. and MOLES, D.J. Lowlands Agricultural Experiment Station, Department of Primary Industry, Keravat, East New Britain, Papua New Guinea – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 735-739 1982.

Sixteen clones of Trinitario cacao were assessed for their susceptibility to attack by the larvae of *Glenea aluensis* (Coleoptera: Cerambycidae) and the mirid *Pseudodoniella typica* (Heteroptera: Miridae). Highly significant differences in the clonal susceptibility to attack by both insects were shown and the clones were ranked into five categories ranging from resistant to very susceptible. There was no correlation between the susceptibility of clones based on these assessments or between their susceptibilities to bark canker, and either of the two pests. However, correlations were shown between their susceptibility to *Phytophthora* pod rot infection and both mirid attack and *G. aluensis* infestation. The significance of these findings is discussed in relation to the current breeding and clonal distribution programmes in Papua New Guinea.

Mitigation of cocoa acidity in Peninsular Malaysia CHICK, W.H., MAINSTONE, B.J. and WAI, S.T. Dunlop Research Centre, Batang Melaka, Negri Sembilan, Malaysia – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 759-764 1982.

Malaysian cured cacao beans have been criticized because of excessive residual acidity and weak chocolate flavour. Ad hoc work has given limited insight for quality improvement. Accordingly an experiment was initiated to investigate commercial fermentation techniques. Findings show quick pH determination of no value in assessing cured cacao beans. Treatments, however, acted independently and in varying ways affected volatile and non-volatile acidity in cured beans. Yeast inoculation boosted volatile acidity by 27 per cent while pulp reduction reduced it by 10 per cent. Using a half depth ferment reduced non-volatile acidity by 31 per cent and yeast inoculation by 21 per cent. Non-volatile acidity was shown to be related to taste detected acidity and low values gave better chocolate flavour.

Studies on the possibility of using a combination of moist heat and radiation to control mouldiness in dried cocoa beans APPIAH, V., ODAMTTEN, G.T. and LANGERAK, D.I. Department of Biology, Food and Agriculture, Ghana Atomic Energy Commission, Legon, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 769-776 1982.

Dried cacao beans inoculated with *A. flavus* were treated with a combination of moist heat applied at 80°C and low or high humidity in a specially designed heat treatment chamber for 30 min, followed by gamma irradiation. Conclusions are that moist heat, 80°C applied for 30 min under high humidity (> 85 per cent RH) conditions was better than the same treatment under low humidity (< 40 per cent RH) conditions. The combination of heating at 80°C for 30 min under high humidity conditions prior to gamma irradiation with 4.0 kGy gave the most effective control of *A. flavus*. This combination can therefore be used to prevent mouldiness of cacao beans but the effectiveness of this treatment is augmented by good storage management practices. For effective control the beans have to be stored after the prescribed treatment at less than 80 per cent relative humidity.

The evaluation of some quality parameters of cocoa after the combination treatment of heat and radiation APPIAH, V., ODAMTTEN, G.T. and LANGERAK, D.I. Department of Biology, Food and Agriculture, Ghana Atomic Energy Commission, Legon, Ghana – *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 777-781 1982.

Healthy dried cacao beans were heated at 80°C in a specially designed heat treatment chamber at either low

(< 40 per cent) or high humidity (> 85 per cent) for 30 minutes followed by gamma irradiation with 4.0 kGy. The solidifying curves of the cocoa butter from the treated beans were compared to the control. The combination treatment did not cause any change in the quality of the cocoa butter from the beans. The combination treatment of heat applied for 30 minutes at 80°C high humidity prior to gamma radiation with 4.0 kGy has been found to control mouldiness in cacao beans and since the prescribed treatment has no adverse effect on the quality of the beans, this method of preservation can be applied to cacao beans and they will still remain acceptable to the consumer.

(Cocoa storage in plastic bags) Armazenamento de cacau em sacos plásticos PRADO, E.P., SERODIO, R.S. and ABREU, J.M. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 783-790 1982.

Clear polyethylene bags, 0.1 mm thick and with a capacity of 60 kg were used to test the possibility of increasing the storage life of cocoa beans on the farm. It was found that during the warehousing period storage in plastic bags presented no problems with respect to fungal development or insect infestation, the product being classified as Superior at the close of the experiment (16 months). This type of bagging could be used to store cocoa on the farm, provided that the beans are bagged in proper phytosanitary conditions and with a moisture content no higher than 7.5 per cent (moisture base).

The condition of cocoa on arrival at the major depot in Nigeria MEJULE, F.O. Nigerian Stored Products Research Inst., Lagos, Nigeria — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 791-795 1982.

Comparison of the quality of cacao beans received from Oyo, Ogun and Ondo States were made. The level of insect infestation was made using the sieving method. *Ahasverus advens, Carpophilus* spp., *Lasioderma serricorne, Cryptolestes* sp., *Tribolium castaneum* and *Araecerus fasiculatus* were among the major insects recorded in the order of numbers. The average number of insects found per bag was 18. The average percentage moisture content was 7 per cent and the average weight of debris was 238 g. Comparison of cacao from the three states revealed that the bags of beans from Ondo State had the lowest moisture content, lowest number of insects and lowest weight of debris. The percentage moisture content of cacao was determined by the ventilated oven method.

(Storage of cocoa and derivatives in the south of Bahia (Brazil): preliminary results) Armazenamento de cacau e derivados na região sul da Bahia. (Brasil): primeiros resultados SERDIO, R.S. and PRADO, E.P. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 797-811 1982.

In January 1979 a multidisciplinary and far reaching project was initiated. The project was subdivided as follows: (1) establishment of storage conditions of cocoa and derivatives; (2) basic research into the product-environment relationship in storage; (3) prophylactic and constructive measures for short-term regional storage; (4) new methods of long-term storage for the region; (5) storage conditions in neighbouring regions with a more suitable climate; and (6) long term storage of cocoa derivatives in the cacao growing area of South Bahia. The results and conclusions already obtained will enable technical standards to be published, regional development projects to be carried out and current research to receive greater support.

The effect of pre-harvest fungal infection of cocoa pods on mouldiness of prepared beans OYENIRAN, J.O. Nigerian Stored Products Research Inst., Lagos, Nigeria — *In: Proceedings 8th International Cocoa Research Conference, Cartagena, Colombia, 18-23 Oct 1981* Cocoa Producers' Alliance, Lagos p. 829-833 1982.

Ripe cacao pods bearing pre-harvest infection were collected and the beans examined. The beans were found to be either black, brown or white. Out of the black beans as many as 63.1 per cent were internally mouldy; in the brown beans, 34.4 per cent were mouldy. The moulds isolated from the diseased beans were mainly *Botryodiplodia theobromae; Fusarium solani* and *Macrophoma* sp. occurred in a few beans. If the temperature of fermentation is not high enough, internal mouldiness by pre-harvest moulds would still remain viable and develop further. If high, the mycelium will be killed. It was found that if all the beans with dead mycelium and those with *B. theobromae* and similar species arose from pre-harvest infection, this factor alone possibly contributes nearly a third of the internal mouldiness of commercial cacao in Nigeria.

Annual report for 1980/81 International Cocoa Organization, London, UK — 26 p. 1982.

This annual report discusses the International Cocoa Agreement for 1980, outlines the management of buffer stocks and the International Cocoa Organization's administrative financing, and reviews the world cacao situation (production, grindings, prices, exports) for 1980/81.

The economics of plantation replanting LAM, N.V. Institute of Applied Social and Economic Research, Boroko, Papua New Guinea — *Monograph — IASER (Papua New Guinea) (What do we do about plantations?)* no. 15, p. 21-24 1981.

With the exception of coffee and palm oil, the output and export quantities of other agricultural commodities, including coconuts and cacao have been either stagnant or declining over the past several years. This is due largely to insufficient replanting of the valuable tree crops. The plantations are not able to generate sufficient cash and earnings to finance the necessary tree renewal. Commercial banks generally tend to be interested primarily in short-term financing. Government financial investment, or assistance in agricultural replanting, appears therefore unavoidable. Such a policy initiative is not only feasible financially, it is also justifiable by both institutional and historical precedents. The present lack of trained extension and supervisory personnel may prove to be a significant barrier to any large-scale tree replanting programme.

November 1982

Cocoa: gloomy outlook for former cash-crop king — *New African (UK)* no. 179, p. 54, 61; Aug 1982.

Cacao was for a long time Nigeria's main export cash crop. Between 1951-1956 Nigeria produced 11 per cent of the world cacao crop increasing to 15 per cent in 1966 and declining to 11 per cent in 1979. Actual production was only 180,000 t in 1979. Foreign companies dominated the cacao buying in the past. Afterwards state marketing boards were often given the sole right to buy the crop. However, they took advantage of the poor and relatively powerless farmers by offering low buying prices when this was not necessitated by low world market prices. Over-production and falling world prices have made the crop uneconomic and the government has had to subsidize producers.

Conservation of cacao seed MUMFORD, P.M. and BRETT, A.C. Department of Plant Biology, University of Birmingham, Birmingham, UK — *Tropical Agriculture (Trinidad and Tobago)* v. 59(4) p. 306-310; Oct 1982.

This paper reports results of experiments conducted to investigate the tolerance of *Theobromae cacao* seed to desiccation and to study the effect on seeds of unfavourable storage conditions. Seeds survived several months stored in the pod at 15°C but showed reduced vigour. After removal from the pod, desiccation below 20 per cent moisture (fresh weight basis) killed seeds, as did low temperature, 4°C. Germination was inhibited by many of the substances tested but after prolonged storage normal growth could only be obtained from seeds stored in polyethylene glycol. Seeds were successfully stored in polyethylene glycol for 25 weeks. The growth of the embryonic axes of cacao seeds was explored on different media and under a range of environmental conditions. At 25°C with a 12 h photoperiod small seedlings developed which then remained dormant for at least 18 months. The possibility of exploiting arrested growth in culture for the storage of genetic resources is discussed.

Cocoa by-products and their uses MENON, M.A. Regional Station, Central Plantation Crops Research Inst., Vittal, Karnataka, India — *Planter (Malaysia)* v. 58(676) p. 286-295; Jul 1982.

A review is presented on waste products in cacao production. Attention is paid to cacao pod husks with low theobromine content as cattle feed, cacao shells as a source of cattle feed and theobromine extraction, production of cocoa butter from discarded beans, use of extracted beans as cattle feed, and application of residues

as manure. Data are presented on contents in cocoa by-products.

December 1982

Fine roots in mixed plantations of Hevea and cacao KUMMEROW, J. and RIBEIRO, S.L. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 12(2) p. 101-105; Apr 1982.

Rootlet distribution in mixed plantations of Hevea rubber (*Hevea brasiliensis*) and cacao (*Theobroma cacao*) was analysed. Fine roots of both species occupy preferentially the upper 15 cm of the soil. Two to nine times more Hevea than cacao rootlets were found in all soil samples. Hevea rootlets are three times thicker (0.73 mm) than cacao rootlets (0.22 mm). Thus, 1 g dry weight of cacao rootlets extends over 36 m vs. 6.7 m of Hevea rootlets. Nevertheless, the rootlet surface area of Hevea reached 1 m^2/m^2 vs. 0.5 m^2/m^2 in cacao. These observations suggest that fertilizing in mixed Hevea-cacao plantations of the conventional 7 x 3 m spacing would benefit preferentially the Hevea trees. This would result in higher leaf area indices of Hevea and consequently produce light limitations for the shaded cacao trees.

(Use of cacao husks instead of sorghum grains in feed rations for grazing cattle) Utilización de la cáscara de cacao en sustitución de sorgo, para la suplementación de bovinos en pastoreo COUTINO A, J.L. and RIQUELME V. E. Universidad Autónoma Chapingo, Chapingo, Mexico – *Chapingo Nueva Epoca (Mexico)* no. 31-32 p. 74-78; Sep 1981.

Feeding trials conducted with 20 Holstein calves of 120 kg average live weight in Mexico showed there were no significant differences in daily weight gain between continuous grazing treatment and restricted grazing (7 h) without supplemental feeding. Supplementing sorghum grains or sorghum plus cacao husk meal significantly increased daily weight gains.

(Transpiration of cacao trees measured by changes in the soil moisture) Avaliação da transpiração do cacaueiro através de variações na unidade do solo CAIMA Z, A. and ALVIM, P. DE T. Divisão de Geociências, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 12(2) p. 43-48; Apr 1982.

The soil of a plot containing six 10-year old cacao (*Theobroma cacao*) trees was saturated with water and covered with black polyethylene sheets. Soil samples for moisture content were taken at 30, 50 and 100 cm from each trunk at depths of 0-30 cm, 30-60 cm and 60-90 cm. The first samples were taken 2 days after saturation and subsequent samples were taken weekly for 8 weeks. In the first week losses of water by transpiration were substantial at all distances and depths. The water transpired in the first week corresponded to a water layer of 45.9 mm/day, but by the eighth week this layer measured only 3.8 mm/day.

Preliminary test of a simple and inexpensive system for the mechanical aeration of box-type cacao fermentation LOPEZ, A.S. and MCDONALD, C.R. Divisão de Tecnologia e Engenharia Agrícola, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Revista Theobroma (Brazil)* v. 12(2) p. 57-63; Apr 1982.

A simple system for the mechanical ventilation of cacao during box type fermentation is described and its operation throughout a sequence of 10 tests is outlined. Various modifications were tested and the quality of the resultant chocolate was assessed organoleptically against samples fermented in the normal way. Improvements in end-product acidity were noted in almost all cases though this was often accompanied by increased levels of off-flavours. For all tests the treated samples proved to be at least as good as, and usually better than, the control. Temperature profiles were used to assess performance and to extract information regarding the air-flow patterns within the cacao. The tendency is for air to pass into the box near the walls before turning into the bulk of the cacao.

Studies on bean sweatings of five cocoa varieties ADOMAKO, D., KUMARAN, K. and NAIR, R.V. Cocoa Research Inst., New Tafo-Akim, Ghana – *South Indian Horticulture (India)* v. 30(2) p. 104-106; Apr 1982.

Fresh cacao beans, when kept for fermentation, sweat and give out small quantities of a sweet juice. A study was undertaken with the aim of evaluating 5 promising cacao varieties for quantity of sweatings produced, the quantity of dry matter and sugar for conversion into alcohol or acetic acid, and the pH of the sweatings. Varieties differed widely in respect of yield of beans per 100 pods and the yield of sweatings, both characters being almost independent in expression. The pH ranged from 3.39 to 4.30, white percent dry matter and sugar content ranged from 11.22 to 18.67 and from 7.2 to 14.00 respectively. An inverse relationship between volume of sweatings and dry matter content was observed.

The declining Ghana cocoa industry: an analysis of some fundamental problems NYANTENG, V.K. Institute of Statistical, Social and Economic Research, University of Ghana, Legon, Ghana – *Technical Publication Series – Inst. of Statistical, Social and Economic Res., Univ. Ghana (Ghana)* no. 40, 135 p. 1980.

The basic objective of this study is to analyse the fundamental and controllable problems that affect the cacao industry, by analysing: the demand, supply and distribution of inputs in the industry; the role of the producer price; the relative impact of an increased producer price versus input price subsidy on output of the industry; and the future of the Ghana cacao industry. The importance of sufficient incentives for farmers to increase production is discussed.

January 1983

(The cacao beetle is threatening the cultivation of cacao) Manhoso representa ameaça para a cacauicultura Divisão de Zoologia, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil – *Journal do Cacauicultor (Brazil)* v. 10(109) p. 4; Oct 1982.

The cacao beetle *Steirastoma breve* has been observed recently in the cacao (*Theobroma cacao*) plantations in the Amazon region. The average pest incidence in Brazil is of the order of 30 per cent. Life history and control measures, including the plantation of resistant shade trees are reviewed.

Laboratory screening of cocoa genotypes for drought tolerance RAVINDRAN, P.N. and MENON, M.A. Regional Station, Central Plantation Crops Research Inst., Calicut, Kerala, India – *Planter (Malaysia)* v. 58(677) p. 334-339; Aug 1982.

In this paper, results of screening of cocoa germplasm for drought tolerance/resistance using three tests are presented. The parameters used are heat stability of chlorophyll, proline accumulation ability and germination of seeds under low osmotic potential. The results indicate that certain genotypes are more tolerant to heat degradation of chlorophyll, accumulate more proline under induced stress and give higher germination percentage under low OP. Such types can be selected for further testing for field performance.

The control of cocoa pests and diseases in North Sumatra PARNATA, Y. Balai Penilitian Perkebunan Medan, Medan, Indonesia – *Bulletin Balai Penilitian Perkebunan Medan (Indonesia)* v. 12(4) p. 127, 129-136; Dec 1981.

Pests and diseases of cocoa and their control in Indonesia are reviewed. Attention is paid to plant materials, disease agents, *inter alia*, cocoa swollen shoot virus and red root disease, *Fusarium* and *Botryodiplodia theobromae*, pink disease, and rarely vascular streak die-back; and to insect agents, *inter alia*, *Helopeltis*, borers, mealy bugs, and loopers. Control methods are briefly presented. Emphasis is placed on selective use of pesticides and stimulation of parasites and predators and cultural practices.

February 1983

Losing ground: processes of land concentration in the cocoa region of southern Bahia (Brazil) KLEINPENNING, J.M.G. – *Boletin de Estudios Latinoamericanos y del Caribe (Netherlands) (The struggle for space)* no. 33 (special issue) p. 59-83; Dec 1982.

In this paper a sketch is first given of the course of the colonization process in the region under study during the 19th century. Subsequently, more attention is paid to the processes which have led to an increasing concentration of land ownership and, lastly, a picture is given of the present ownership and occupation relationships resulting from these processes. In conclusion an attempt is made to explain the developments observed in Brazil in general, and in the cacao regions in particular.

Printed by Haines Clark & Co. Ltd., Gooch Street, Birmingham B5 7HE