COCOA GROWERS' BULLETIN

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Contents

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EDITORIAL

It is vital to prevent spread of plant diseases between countries and effective plant quarantine is therefore very important. Many plant diseases (and some pests), including some which affect cocoa, have been transferred from country to country or even from continent to continent through ignorance or carelessness. This usually occurs due to the movement of vegetative material and the only safe way to move such material is through some intermediate quarantine station such as the US Department of Agriculture Station at Miami, Florida; IRCC Montpellier, France; the Cocoa Research Unit (University of the West Indies) station in Barbados; or the new Quarantine Station at the University of Reading in the UK. Cocoa seeds are a comparatively safe form of movement: viruses are not known to be seed-borne and the transfer of fungal diseases by seeds could only occur through negligence or the omission of normal fungicidal treatment.

The recent spread of witches' broom disease of cocoa from the Amazon Basin of Brazil to the long-established cocoa growing area in the State of Bahia demonstrates the need for continued quarantine. So far the first of these outbreaks of witches' broom appear to have been contained by prompt action by the Brazilian authorities. A second outbreak has not yet been controlled and might be serious.

A welcome initiative was recently taken by the International Board for Plant Genetic Resources (IBPGR) and the American Cocoa Research Institute who hosted a meeting in Florida in September 1988 and have presented the findings as a booklet entitled 'FAO/IBPGR Technical Guidelines for the Safe Movement of Cocoa Germplasm'. This booklet is available from IBPGR Headquarters, c/o FAO, Via delle Terme di Caracalla, 00100 Rome, Italy. It is strongly recommended that all readers of the Cocoa Growers' Bulletin involved in the movement of germplasm should obtain a copy.

The need for the expansion of intermediate quarantine facilities for cocoa has been clear for some time and so the UK Biscuit, Cake, Chocolate and Confectionery Alliance recently initiated the expansion of the cocoa quarantine station at the University of Reading which is now fully operational. The first article in this issue contains a description of the arrangements and operations of this station by the scientist responsible - Dr Paul Hadley. A wide range of material has now completed quarantine at Reading and is available for distribution to contributors to the quarantine project. More material will become available from there in the coming months.

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- REVIEW OF PRODUCTION AND CONSUMPTION
November 1988 - October 1989
S.A. Wakeling, Cadbury Limited

PRODUCTION

Our last review was based on Gill and Duffus Cocoa Market Report No. 332, dated November 1988. In their latest Report No. 335, dated October 1989, estimates of world production for 1986/87, 1987/88 and 1988/89 have been increased by 17,000, 35,000 and 115,000 tonnes respectively.

The estimate for 1988/89 indicates a record crop of 2,399,000 tonnes which is 200,000 tonnes greater than the previous record crop of 2,199,000 tonnes in 1987/88. The major increases came from Cote d'Ivoire and Ghana with percentage increases over 1987/88 of 22 per cent and 62 per cent respectively. In tonnage terms, the combination of Cote d'Ivoire and Ghana produced 262,000 tonnes more in 1988/89 than in 1987/88. The large increases experienced in Cote d'Ivoire and Ghana were the result of favourable weather conditions and improved incentives to cocoa producers in Ghana. Brazil remains the second largest cocoa producer despite a reduction from 402,000 tonnes in 1987/88 to 333,000 tonnes in 1988/89. The declining producer price, coupled with high interest rates and adverse climatic conditions have put severe pressure on the Brazilian cocoa producers. Malaysia dropped from third largest producer in 1987/88 to fourth in 1988/89 mainly due to a reduction in the crop from Sabah.

Forecasts for 1989/90 appear for the first time in Report No. 335. The world crop is forecast at 2,410,000 tonnes up by just 11,000 tonnes on 1988/89. The main growth areas are Ghana, Nigeria, Malaysia and Indonesia. Although the Cote d'Ivoire crop forecast is for a reduction of 80,000 tonnes on 1988/89, it is still a very large crop. A major development in Cote d'Ivoire has been the reduction of the producer price from CFA 400/kilo during the 1988/89 maincrop to CFA 250/kilo for the 1989 mid-crop and thence to CFA 200/kilo for the 1989/90 maincrop.

CONSUMPTION

The Gill and Duffus Cocoa Market Report No. 335 estimates grindings for 1989 of 2,092,000 tonnes an increase of 4.5% over 1988 (2,001,000 tonnes). The report forecasts 1990 world consumption at 2,173,000 tonnes an increase of 3.9% over 1989. The most notable feature of the increase in grindings is the performance of Western Europe where grindings by 1990 are forecast to have increased by 31% over the levels of 1986. This compares with an increase of 3% for grindings by the origins over the same time period. The growth in Western Europe follows an expansion in grinding capacity together with growth in sales of their products.

The impact of relatively low cocoa prices on manufacturers' raw material costs should support growth in grindings over the next few years.

STOCKS

The continued production surpluses since 1984/85 has resulted in a large increase in world stocks both in absolute terms and as a proportion of world grind. By the end of 1988/89 world stocks are estimated at 1,074,000 tonnes and by 1989/90 they are forecast at 1,305,000 tonnes. Even after accounting for 250,000 tonnes held by the ICCO buffer stock this will equate to six months grindings being available in September 1990.

INTERNATIONAL COCOA AGREEMENT

The ICCO Council met in London on 11-15 September 1989. The meeting came close to agreement over a package of measures to rationalise the operations of the buffer stock and activate the Witholding Scheme (as per the 1986 Cocoa Agreement). At the last moment the Council failed to agree on a suitable mechanism for the payment of witholding expenses and the whole package failed to obtain the support of either the EEC group or Cote d'Ivoire. Further meetings are planned to attempt to resolve this impasse.

PRICES

The continued imbalance between production and consumption over the past five seasons has meant that cocoa prices have maintained a downward trend. There have been two conflicting forces acting upon prices over the past year. Firstly, technical factors have affected the immediate supply of cocoa by moving price up (e.g. the sales policy of Cote d'Ivoire), while the underlying long-term over supply situation has been pushing prices down.

Average monthly prices in pounds/tonne for nearby shipment Ghana cocoa have been:

1988		1989	
January	1180	January	1064
February	1118	February	1067
March	1015	March	995
April	992	April	899
May	1048	May	832
June	1096	June	902
July	1140	July	943
August	1082	August	916
September	976	September	847
October	967		
November	1078		
December	1091		

WORLD COCOA PRODUCTION AND GRINDINGS DATA

Reproduced from Gill and Duffus Market Report 335
Dated October 1989
(all figures in thousand metric tonnes)

Production	1985/6	1986/7	1987/8	1988/9 (estimate)	1989/90 (forecast)
WORLD TOTAL	1961	1994	2199	2399	2410
Africa	1109	1115	1188	1450	1406
S.America	593	571	623	556	555
W.Indies	52	53	64	51	49
Asia & Oceania	207	255	324	342	400
PRINCIPAL COUNTRIES					
Cameroon	118	123	131	124	110
Ghana	219	228	188	305	330
Equatorial Guinea	6	7	7	8	8
Cote d'Ivoire	585	602	665	810	730
Nigeria	110	80	150	160	185
Brazil	376	369	402	333	345
Colombia	48	51	55	52	52
Ecuador	96	76	80	90	75
Mexico	39	38	48	45	45
Venezuela	10	12	12	10	12
Dominican Republic	40	41	52	40	40
Malaysia	125	164	222	220	255
Papua New Guinea	32	32	36	38	38
Indonesia	33	41	49	65	85

GRINDINGS	1986	1987	1988	1989 (estimate)	1990 (forecast)
WORLD TOTAL	1879	1905	2001	2092	2173
Western Europe	678	706	777	841	890
Eastern Europe & USSR	253	248	231	256	257
N.America	399	391	388	358	341
Central & S.America	220	255	266	274	288
Australia & N.Zealand	6	1	1	1	1
Asia	146	149	168	187	231
Africa	177	156	169	175	165
PRINCIPAL COUNTRIES					
United States	200	236	244	249	262
Germany (FR)	201	209	233	248	260
Netherlands	183	196	216	234	253
USSR	163	148	138	160	160
United Kingdom	87	95	101	112	123
Brazil	236	231	220	182	163
Cote d'Ivoire	107	95	105	120	110

THE UNIVERSITY OF READING QUARANTINE PROJECT

P. Hadley*, T. Lee* and J.M. Thresh**

INTRODUCTION

In little more than two centuries, the commercial growing of cocoa has extended from its centre of origin in South America to West Africa, the Far East and Oceania. Now, cocoa has become an important crop throughout the Humid Tropics. However, much of the material that has been used for commercial plantings in each of these areas has been drawn from a very narrow genetic base. It has long been recognised that there is a need to improve the genetic diversity of material available to cocoa breeders and this has led to scientific expeditions to collect wild cocoa over the last 50 years (Soria, 1970; Allen & Lass, 1983, 1987; Almeida et al., 1987). Much of the material collected in these expeditions is now maintained in national and international germplasm collections in Central and South America, and in the Caribbean (Table 1). However, because these collections are situated in cocoa producing areas, it is not appropriate to transfer this material directly for use elsewhere. This is because of the risk that pests and particularly diseases, that are endemic to cocoa in South America will be transferred to other areas which are presently free of such problems. The principal

TABLE 1: NATIONAL AND INTERNATIONAL GERMPLASM COLLECTIONS IN CENTRAL AMERICA, SOUTH AMERICA, AND THE CARIBBEAN MAINTAINING PRIMITIVE COCOA GENOTYPES COLLECTED FROM THE WILD

STATION	LOCATION	COUNTRY
Centro Agronomica Tropical de Investigacion y Ensenanza (CATIE)	Turrialba	Costa Rica
Departamento Especial da Amazonia, CEPLAC	Belem	Brazil
Instituto Colombiano Agropecuaria	Palmira	Colombia
Estacion Experimental Tropical	Pichilingue	Ecuador
International Cocoa Genebank, Trinidad (ICG,T) at University of West Indies	St Augustine	Trinidad
IRCC	Sinnamary	French Guiana
U.S.D.A. Agricultural Research Station	Mayaguez	Puerto Rico

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threat comes from witches' broom disease (caused by Crinipellis perniciosa) which occurs only in South and Central America. The risk of the spread of this disease is well illustrated by its recent identification from cocoa plantings in the State of Bahia.

It should be noted that the collections at CATIE and ICC,T have been designated as primary collections by the International Board for Plant Genetic Resources (IBPGR) and the germplasm from these centres is therefore freely available to all who request it.

Similar threats also arise when cocoa is transferred between newer regions of cocoa cultivation. For example, authentic Cocoa Swollen Shoot Virus is only known to be present in West Africa and vascular streak dieback caused by (Oncobasidium theobromae) is only found in the Far East. For these reasons, cocoa germplasm should not be transferred from one cocoa producing region to another unless the material first passes through a period of intermediate quarantine in a non-cocoa producing country where the material can be safely screened for pests and diseases (Frison and Feliu, 1989).

In recent years, the major intermediate cocoa quarantine centre was at the USDA Sub-Tropical Research Station at Miami, Florida. However, over the last two and a half years a new quarantine facility has been established at the University of Reading, UK to increase the availability of cocoa germplasm. The Department of Horticulture at Reading University has had a large cocoa research programme underway for some years and as part of its work it had maintained a collection of cocoa clones, which had been previously held at the Royal Botanic Gardens, Kew until cocoa quarantine activity there ceased some years ago.

GROWING CONDITIONS AT READING

The first phase of the project began in Spring, 1987 and was devoted to establishing the growing facilities required. These are located at the School of Plant Sciences Field Unit, about 5km from the main University of Reading Campus which is 35km from Heathrow airport, London. Initially, a tunnel covered with polyethylene having a floor area of approximately $100m^2$ was used to house the cocoa. This has now been expanded to two tunnels. This utilised much of the technology developed earlier during the construction of the main cocoa research glasshouse on the University Campus. To enable both high temperatures and high humidities to be maintained, even when external air temperatures fall below freezing, the house is covered with two layers of a novel polyethylene film (Thermofilm IR). This film contains an infra-red filter to increase its insulating properties whilst retaining a high transmittance to visible light. The two layers of film are separated by an air gap which is maintained by blowing air between the two plastic films using an internal fan. The inner skin is warmer than the outer due to the insulating effect of the air gap and this reduces condensation, allowing high humidities to be maintained even under very cold external conditions. Heating is provided by an oil-fired air heater which distributes warm air evenly around the tunnels through a perforated polyethylene pipe. This air heater has been modified so that its main fan is switched on continuously to ensure that the air within

within the tunnels is uniformly stirred. Cooling, when required, is provided by a single fan at one end. When this is turned on, cool air from outside is drawn through vents at the opposite end of the tunnels. Heating and cooling are controlled by solid state controllers. A high pressure misting system provides additional humidification as required. The houses are maintained at a nominal day temperature of 28°C and a night temperature of 19°C, with a 12 hour thermoperiod. Relative humidity is usually maintained between 75% and 85% (see Figure 1 for layout of facility).

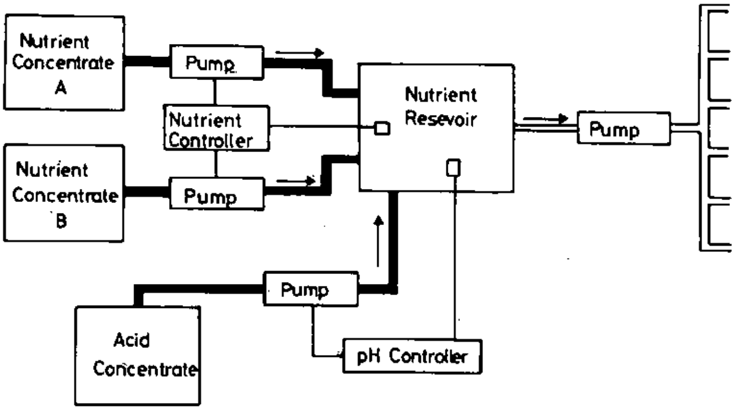

FIGURE 1: Schematic Diagram of Nutrient Control & Distribution System of Cocoa Quarantine Glasshouse at Reading University

Plants are arranged on benches positioned about 30cm above the floor of the houses. Cocoa is very sensitive to nutrient disorders and does not grow well for long in conventional potting composts. This is because nutrient imbalances build up quickly and soon affect plant growth. At Reading, the problem has been overcome by growing plants in a completely inorganic medium of vermiculite, sand and gravel, which is irrigated with a modified "Long Ashton" nutrient solution. The growing medium is free-draining so that frequent irrigation is possible without any danger of waterlogging, enabling unused salts to be washed out of the rooting medium with the drainage from each pot. The nutrient solution is held in a recirculating central tank (Figure 1) which is fed with tap water through a float valve. When required, nutrient solution is pumped through a network of drip lines enabling each pot to be irrigated with the same volume of solution. The timing and duration of each irrigation is controlled by a small microprocessor controller. As nutrient is pumped out of the central tank, it is replaced with tap water. A conductivity probe immersed in this central tank is connected to a controller which pumps concentrated nutrient from two stock tanks to maintain nutrient concentration within the central tank.

It is very important to maintain the medium at around pH 5.8-6.5 since either too high or too low a pH can also lead to nutrient imbalances due to certain elements being rendered unavailable under these conditions. To achieve this, a probe senses the pH of the nutrient solution. This is connected to a controller which pumps a mixture of dilute nitric and phosphoric acids into the nutrient solution when the pH rises to maintain the slightly acid conditions required for optimal growth.

The system is set to irrigate the plants on up to seven occasions per day depending on the season (fewer irrigations are required during the winter months). The system has the added advantage that it is automatic and requires only periodic replacement of the acid and nutrient stock solutions and checks of drip lines for blockages (see Figure 2 for schematic diagram of nutrient control and distribution system).

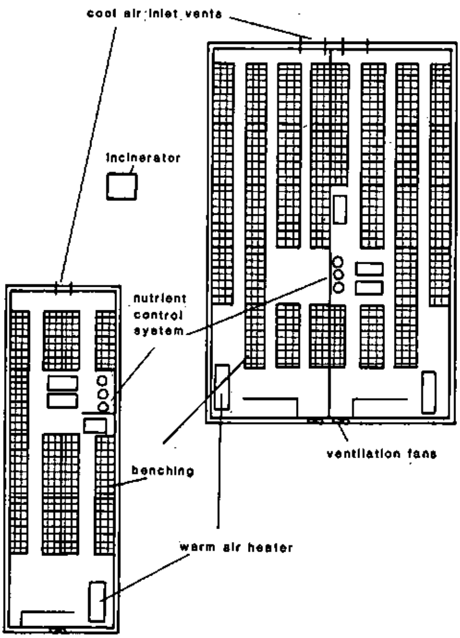

FIGURE 2: Schematic Diagram of Cocoa Quarantine Glasshouse at Reading University

QUARANTINE PROCEDURES

The quarantine procedure adopted at Reading follows the guidelines outlined by Thresh (1960) and more recently by Frison and Feliu (1989). In the absence of any information on the occurrence of cocoa viruses in South America, the procedure is based on experience gained with swollen shoot and other viruses of cocoa in West Africa. Additional tests may become necessary as further information becomes available or as new methods of virus detection are introduced.

Suitable germplasm for quarantine is obtained initially as budsticks, the condition of which can vary enormously on arrival. Factors influencing condition include the time spent in transit, the conditions of the donor tree and the treatment of the budwood whilst in transit. On receipt, material is first budded onto approximately 3-month-old seedlings of the variety West African Amelonado. This variety should be distinguished from others also referred to as Amelonado. When infected with Cocoa Swollen Shoot Virus (CSSV) it develops conspicuous leaf and stem symptoms and these are well documented (Thresh, 1960 and many other publications).

A patch bud method of budding has been adopted which is widely used for cocoa propagation. A small rectangular piece of budwood containing a dormant bud is grafted onto a seedling where an approximately equivalent sized piece has been removed from below the cotyledonary node. The patch is then secured with grafting tape. This is removed after approximately 14 days when it is usually apparent which grafts have formed a good union. Provided sufficient material is available, the successfully grafted plants are divided into two groups. The first group is retained for quarantine procedures. Here evidence of virus transmission from the bud patch to the mother plant is checked by regular observations of root stock and sion for symptoms over a period of approximately 18 months. The other group is used for propagation and for these plants, the shoot of the mother plant is removed. The latter procedure may surprise many who are used to gradual cutting and bending of the shoot to encourage the development of the bud before the shoot is finally removed when the bud is growing vigorously. However, immediate removal of the shoot appears to work effectively, at least under Reading conditions, and the bud usually grows out rapidly. As well as checking for virus transmission all the material is checked regularly for pest and other disease problems. Since the majority of the material in quarantine is of South American origin, the main potential disease threat comes from witches' broom disease. Any material suspected of being infected (either with virus or fungus) is immediately destroyed by incinerating the affected plants and any derived from them.

Where difficulty has been experienced in grafting material, priority is given to propagation rather than quarantine tests. The latter are then begun later once the propagated material can itself be a source of budwood for grafts to West African Amelonado. This normally takes between 8 - 10 months.

Clonal material that has passed through quarantine can be supplied as budwood. Material is freely available to those who contribute to the funding of the quarantine work, which is coordinated by the Biscuit, Cake, Chocolate and Confectionery Alliance (BCCCA). The contact address is BCCCA, 11 Green Street, London W1, Telephone: 01.629.8971, Telex: 24738, Fax: 01.493.4885. The consignee is expected to meet the transport costs. Budwood is normally supplied as 2-3 budsticks, each of 7-10 mm in diameter and containing 3-5 buds. An import permit from the destination country is required before material can be dispatched. Treatment of the budsticks prior to dispatch varies and depends on the phytosanitary requirements stated on the import permit, but includes dipping in an insecticide and a fungicide solution. Each consignment of budwood is examined by inspectors of the Plant Health Division of the Ministry of Agriculture, Fisheries and Food of the UK who then supply a Phytosanitary Certificate, which will accompany the budwood together with a quarantine certificate from the University of Reading. The ends of the budsticks are then coated in paraffin wax, wrapped in damp paper towels and placed in a polythene bag to aid retention of moisture during transit.

Cocoa budwood is valuable fragile material, which needs to be transported as quickly as possible. Although material has been sent successfully via air freight, it is preferable to transport it via personal couriers. This avoids problems such as exposure to adverse temperatures and the delays at customs likely to arise during unaccompanied transit.

Since the beginning of the Reading project the size of the cocoa collection has increased to a current figure of some 150 clones. The rapid increase in the size of the collection has led to an accommodation problem in arranging both propagation and quarantine. Hence, a new facility consisting of a twin span, polythene-clad houses with a total floor area of 300m^2 has been commissioned recently. This is separated into two compartments and uses the same heating, ventilation and nutrient/irrigation control systems described above. The new house will form the main area for maintaining the collection whilst plant propagation and quarantine procedures are carried out in the smaller of the two houses (Figure 2).

Intermediate quarantine of cocoa germplasm is a key step in the safe movement of the genetic material required for crop improvement programmes. Without such procedures to ensure that only healthy material is distributed, cocoa production is threatened by the inadvertent introduction of novel pests and diseases. The object of the quarantine facilities at Reading is to provide an essential step in the global distribution of cocoa germplasm. It is not, however, concerned directly with the conservation of cocoa genetic resources. This latter role is taken up by both national and international germplasm collections (Table 1).

A list of clones available at Reading can be obtained from the authors at the address above. Requests are welcome from any group interested in receiving material from Reading and material can be made available once suitable financial arrangements have been agreed.

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A REVIEW OF THE RESEARCH ON CHEMICAL CONTROL OF WITCHES' BROOM DISEASE OF COCOA

H. Laker* and S.A. Rudgard**

INTRODUCTION

Witches' broom disease of cocoa caused by Crinipellis perniciosa (Stahel) Singer was first reported from Suriname in 1895. The disease is presently confined to South America in Bolivia, Brazil, Colombia, Ecuador, Guyana, Panama, Peru, Suriname, Venezuela and in the Caribbean islands of Grenada, St. Vincent, Trinidad and Tobago. It was observed for the first time in Bahia, Brazil, the largest concentration of cocoa plantings in the Americas in 1989. These countries between them produce about 35% of the world's cocoa. Rudgard & Lass (1985) valued annual losses caused by the disease in the Amazon Region of Brazil, Colombia, Ecuador, Trinidad and Venezuela at US$120 million, or roughly 30% of expected production from those countries. Annual pod losses have reached 70 - 90% in parts of the Amazon region.

Fungicide use against witches' broom disease was first reported by Van Hall & Drost (1909), and many chemicals have since been evaluated in locations where the disease is economically important. Baker & Holliday (1957) explained that spraying against the disease had not been adopted commercially because of high costs and insufficient disease control. If control were improved and costs reduced, fungicides might be a valuable part of an integrated programme together with phytosanitation and other practices. The introduction of systemic fungicides in the 1960's renewed interest in the quest for a chemical to control witches' broom disease. An additional critical factor was the increasing importance of cocoa in the Amazon region where the crop was considered a potential source of revenue which was ecologically acceptable (Rudgard, 1987). The disease is endemic on wild cocoa in the region and became serious with the introduction of large plantings of susceptible genotypes in the 1970's. Infection rapidly reached epidemic proportions, causing over 90% pod infection on some potentially high yielding farms in Rondonia (Evans, 1981). Phytosanitary pruning first suggested by Stahel (1915) remains the only remedial measure recommended, and in some cases no effort is made to control the disease. Phytosanitation is labour intensive, and it has been suggested that over 95% of brooms in heavily infected areas would need to be removed to reduce disease incidence on pods significantly (Rudgard & Butler, 1986).

The disease remains a serious problem in the coastal region of Ecuador where over 200,000 hectares of cocoa are affected. A combination of Crinipellis and Moniliophthora pod diseases has kept production low and caused some plantations to be abandoned (Evans, 1981). Much of the cocoa still in production in the region north of Guayaquil is in urgent need of rehabilitation as years of heavy

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disease pressure and partial neglect have taken their toll. No control measures are applied for either disease, and crop management in general is minimal.

Farms with fair to good productivity might support control of witches' broom disease with an efficient chemical in a system of integrated control. Rudgard & Lass (1985) noted that due to the inadequacy of other control measures, fungicides offered a short term means of containing the disease, creating economic stability for the development of other systems. However, control of disease must not be contemplated as an isolated exercise, but as part of general management of the crop (Evans & Prior, 1987).

Results of trials of various compounds against witches' broom disease have often been only published in annual reports of research institutions, many of which have limited circulation. This review attempts to collate all these published research findings with the objective of identifying strategies for future investigations.

ACTIVE COMPOUNDS

Inorganic protectant fungicides (Copper)

Fungicides were first applied to infected cocoa trees during the devastating outbreak of witches' broom in Suriname which finally caused planters to abandon cocoa cultivation in that country. Van Hall & Drost (1909) sprayed trees with Bordeaux mixture to control witches' broom but found no reduction in disease. However, the unpublished work of ter Laag in Suriname on rehabilitation of a cocoa estate using a combination of sprays and phytosanitation was taken up by Stahel (1915), who recommended spraying Bordeaux mixture once or twice a year to supplement broom removal every two to four weeks. When the disease was first observed in Trinidad, Stell (1928) advocated the recommendations of Stahel.

Experiments conducted from 1932 to 1939 with copper and sulphur fungicides applied as sprays and dusts were inconclusive (Thorold, 1953). In further investigations by Thorold between 1940 and 1946, incidence of vegetative brooms was significantly reduced during a programme of 20 monthly canopy sprays with Bordeaux. A similar regime confined to the cropping region also significantly reduced incidence of diseased pods (Table 1). Further trials of Bordeaux by Holliday (1954) and various authors in Brazil consistently proved the efficacy of applications to pods. Intervals of 28 and 14 days between sprays and doses of 1 or 2% all gave significant control except for 1% applied every 28 days in Brazil. Holliday (1954) also found that 0.5% copper did not reduce disease sufficiently to be significant.

Bordeaux mixture is difficult to mix and apply on a large scale, and it was abandoned in favour of formulated copper compounds despite their higher cost. Early tests of commercial formulations gave unpredictable and often non-significant reductions in numbers of diseased pods (Table 1). In a series of trials in Trinidad where pod losses due to witches' broom were less than 20%, monthly applications of Perenox (cuprous oxide) and Blitox (copper oxychloride) did not

TABLE 1: REDUCTIONS IN POD LOSS FOUND WITH SPRAYS OF COPPER FUNGICIDES AT VARIOUS RATES AND INTERVALS

Compound	Year	Copper Conc'n (%) (i)	No. of appl'n per yr	Interval (days)	% diseased pods unsprayed	% Red'n due to spray (ii)	Ref. (iii)
1. Bordeaux	1942	1	10	28	10	64 s	1
	1943	1	10	28	32	44 s	1
	1950	1	6	28	5	69 s	2
	1951	1	5	28	13	36 s	2
	1951	0.5	5	28	13	23 ns	2
	1984	1	8	14	56	41 s	3
	1985	1	8	14	72	57 s	3
	1986	2	6	28	84	32 s	4
	1986	2	12	14	84	51 s	4
	1986	1	6	28	84	25 ns	4
	1986	1	12	14	84	43 s	4
	1986	1	9	14	49	31 s	12
2. Cuprous Oxide							
2.1 Perenox	1950	1	6	28	5	52 ns	1
	1951	1	5	28	13	34 ns	1
	1952	1	4	28	19	46 ns	1
	1977	1	12	7	45	56 s	5
2.2 Copper Sandoz	1958	2	12	28	67	68 s	6
	1958	2	24	15	39	66 s	6
	1979	2	4	30	33	39 s	7
	1980	2	3	45	49	28 ns	8
	1980	2	5	30	49	31 ns	8
	1980	2	10	15	49	34 ns	8
	1981	1	4	30	54	5 ns	9
3. Copper oxychloride							
3.1 Blitox	1952	1	4	28	19	42 ns	1
	1955	1	8	28	29	7 ns	10
3.2 Cupravit	1973	1	8	15	38	55 s	11
	1981	1	4	28	60	0 ns	9
3.3 Kauritol	1984	1	6	15	30	43 s	13

Key:

(i) : Cuprous oxide and copper oxychloride are expressed as % copper equivalent to Bordeaux

(ii) : Found by percentage decrease in % diseased pods in treated vs untreated
s: significant, ns: not significant from authors' statistics

(iii): References: 1 = Thorold, 1953; 2 = Holliday, 1954; 3 = Silva & Rodrigues, 1985; 4 = Bastos et al., 1987a, 5 = Cronshaw, 1979; 6 = Tollenaar, 1959; 7 = Anon, 1980; 8 = Bastos, 1982; 9 = Almeida, 1982; 10 = Holliday, 1960; 11 = Reyes & Reyes, 1973; 12 = Bastos et al., 1987c; 13 = Almeida & Andebrhan, 1984.

give significant control of the disease (Holliday, 1954; 1960). Blitox did not reduce pod infection even when applied every 15 days in a higher rainfall area of the island (2500 mm/year).

Assessments of the activity of copper fungicides on test plants inoculated with C. perniciosa under controlled conditions were only reported in 1984, nearly 80 years after copper was first applied to cocoa to combat the disease (Silva & Rodrigues, 1985). When sprayed pods were shielded from rain, Bordeaux mixture and the oxide and oxychloride of copper demonstrated equal protectant activity on inoculated pods (Table 2). Infection was reduced from 90% to less than 10% in all but one case. When these compounds were sprayed on to pods in the field during 5 months of a normal inoculum period, reduction in disease was not so marked (Bastos et al., 1987b). The Sandoz cuprous oxide gave no significant advantage over unsprayed pods, but Bordeaux mixture reduced disease by over 65%, close to results achieved in previous experiments (Table 1).

Field investigations with Copper Sandoz in Brazil clearly showed its inability to control witches' broom even in areas of high disease

TABLE 2: EFFECTS OF COPPER COMPOUNDS ON POD DISEASE RESULTING FROM ARTIFICIAL INOCULATIONS AND NATURAL FIELD INFECTION

Compound	Inoculated protected pods (i)		Field Infection (ii)	
	Copper conc'n(%)	% Diseased pods	Copper conc'n(%)	% Diseased pods (iii)
Bordeaux Mixture	1	4.7a	-	-
	2	6.7a	-	-
	3	1.7a	3	9.0b
Cuprous oxide (Sandoz)	1.5	6.7a	3	18.3ab
Copper oxychloride	1.5 (iv)	16.7a	3 (v)	10.4b
Control	-	91.1b	-	28.4a

Key:

(i) : Individual pods hand sprayed 24 hours before inoculation - pods protected from rain (Silva & Rodrigues, 1985)
(ii) : Fungicide applied as sprays, eight applications at 15 day intervals (Bastos et al., 1987b)
(iii) : Figures followed by the same letter are not significantly different, P <0.05
(iv) : Recop (Sandoz)
(v) : Coprantol (Ciba-Geigy)

incidence on pods, in contrast to Bordeaux Mixture which continued to give significant control of the disease under various conditions (Table 1). A significant reduction in pod disease was also achieved with Bordamil, a ready made Bordeaux mixture formulation (Bastos et al., 1987b).

Summarising the field trials on copper in various countries over nearly 50 years is comparatively easy. Doses ranged from 0.5 to 3% copper, spray intervals from 7 to 45 days, and the number of applications per year from 3 to 24. None of these three variables had a consistent effect, unless intervals were too great (45 days) or the dose too small (0.5%). Bordeaux mixture reduced pod disease by between 25 and 70% compared to unsprayed treatments. It was generally the most effective copper formulation, and the others never reduced disease more than Bordeaux in the same situation. However, it is unlikely that Bordeaux will be recommended to farmers owing to difficulties in preparing it.

Tests of copper fungicides in controlled conditions in 1984 clearly indicated that activity of copper was reduced or lost once the fungicide was put into a standard field trial. Several authors have observed this and Holliday (1960) noted that the young pods susceptible to witches' broom were also expanding fast and thus the deposits became diluted. Rain is known to erode copper fungicides (Hislop & Park, 1960), and must reduce their activity.

Organic Protectant Fungicides

Organic protectant fungicides with broad spectra of activity have also been tested against *C. perniciosa*. A wide range of products have become available commercially over the last twenty years and most have been evaluated *in vitro*, *in vivo* or both. *In vitro*, most inhibited basidiospore germination below 50 ppm and mycelial growth below 100 ppm (Bastos, 1979; Bastos & Medeiros, 1979).

Field evaluations of broad spectrum protectants have been conducted in several countries with compounds such as mancozeb, chlorothalonil, captafol and triphenyltin acetate (Reyes & Reyes, 1973; Cronshaw, 1979; Almeida, 1982; Silva & Rodrigues, 1985). Triphenyltin acetate gave significant control applied every 30 days. Captafol has been tested twice in Brazil applied as a spray every 2 weeks, and shown no activity. Chlorothalonil was found to reduce pod infection especially when applied as a flowable formulation in Ecuador to trees where artificial pollination had concentrated pods on to lower parts of trees' architecture. Witches' broom was only one of three diseases in the trial, but the incidence of pods infected by *C. perniciosa* was reduced from 45% to 13%.

Many of these compounds were tested in Brazil using seedlings in nursery houses and protected pods in the field (Silva & Rodrigues, 1985; Coelho, 1986). Five compounds all gave good control of the disease when applied 20 hours before inoculation, and in most cases activity was reduced by increased intervals (Table 3).

The same conclusions could be drawn from these results as were drawn from work on copper. There are several organic protectant compounds that control C. perniciosa in artificial conditions at least as well as copper. Spray trials in the field have seldom shown activity, most probably due to the combination of poor tenacity, host growth and methods of application. It is unlikely that an organic protectant compound would be used by farmers to control witches' broom unless its effect is significantly better than copper owing to the higher price of organic compounds. Recent environmental tests in the USA and elsewhere have raised doubts about the safety of captafol, triphenyltin acetate and the dithiocarbamates (e.g. mancozeb). Commercial availability of such compounds is under threat and they may yet be withdrawn.

TABLE 3: EFFECTS OF FIVE PROTECTANT FUNGICIDES APPLIED AS SPRAYS TO SHOOTS AND PODS AT DIFFERENT INTERVALS BEFORE INOCULATION WITH CRINIPELLIS PERNICIOSA

Compound	Seedlings	Pods		
	20h	10 days	5 days	20h
Mancozeb	3.8 a	30.0 a	6.7 a	22.5 a
Thiram	3.1 a	-	-	5.8 a
Triphenyltin acetate	6.9 a	30.0 a	10.0 a	17.5 a
Chlorothalonil	7.6 a	56.7 b	30.0 b	10.0 a
Captafol	6.9 a	33.3 a	13.0 a	1.7 a
Control	74.6	76.7	56.7	93.3

NOTE: Figures in the same column followed by the same letter are not significantly different at $P<0.05$.

Source: Derived from Silva & Rodriguez, 1985 & Coelho, 1986.

Systemic chemicals in live plant material

The discovery of systemic chemicals with curative post-infection activity was a major advance in chemical control of plant diseases and boosted expectations for a fungicide to control witches' broom disease. Unlike the protectants, systemics are taken up by the plant and may be redistributed in its tissues. Good activity against C. perniciosa was shown by many of the compounds during in vitro tests (Table 4). Most showed limited activity against basidiospore germination, and almost all active ingredients controlled mycelial growth of the saprophytic stage.

The first group of fungicides to show activity in vivo were the triazoles. Triadimefon reduced infection when used as a pre-inoculation spray on growing flush shoots of seedlings (Anon, 1980). It also significantly reduced pod losses from 49% to 27% when sprayed in the field at 320 g a.i./hectare every 15 days from December to April (Bastos, 1982). Longer intervals of 30 and 45 days were associated with slightly reduced activity that made the treatment effect non-significant. Eight applications every 15 days at the higher dose of 425 g a.i./hectare from January to April significantly reduced pod infection from 72% to 46%. There was also an 82% increase in yield of dry beans (Silva & Rodrigues, 1985). Other more recent work has revealed pre-inoculation activity of three more triazoles, a test compound PP969 (ICI Agrochemicals), hexaconazole and triadimenol (Lins, 1985; McQuilken et al., 1988). PP969 suppressed broom formulation for at least one shoot growth period, but brooms were formed in the second flush cycle. The other two compounds gave good post-inoculation curative effects, when sprayed, and also suppressed necrosis where some hypertrophy occurred. Triadimenol was tested as a soil drench for small plants (less than 1 year old) in UK, Brazil and Trinidad, and showed good protectant and curative activity (Bastos, 1987; McQuilken et al., 1988; Laker, 1989).

TABLE 4: EFFECTS OF SYSTEMIC FUNGICIDES ON GERMINATION OF BASIDIOSPORES AND GROWTH OF SAPROPHYTIC MYCELIUM IN VITRO

Active Ingredient	Chemical Group	Basidiospores ED50 (i)	Mycelium IG50 (ii)
Oxycarboxin	Carb.acid anilide	12	31
Pyracarbolid	" " "	10	3
Flutolanil	Benzanilide	1	0.2
Benomyl	Benzimidazole	20	187
Carbendazim	"	500	2500
Thiophanate methyl	"	100	100
Propiconazole	Triazole	50	6.3
Triadimefon	"	100	0.9
Triadimenol	"	200	0.6
Hexaconazole	"	70	0.4
Tridemorph	Morpholine	20	3
Fenpropimorph	"	20	23

Key:

(i) : ED50 : Dose required to reduce germination of basidiospores by 50%

(ii) : IG50 : Dose required to reduce growth of mycelium by 50%

Sources: Derived from Lins, 1985; Laker et al., (1988); McQuilken et al., 1988

Activity tests of other systemics in Brazil using pre-inoculation sprays on to seedling shoots and young pods included propiconazole, oxycarboxin, tridemorph and fenpropimorph. None of these compounds showed any significant activity (Coelho, 1986). Oxycarboxin and tridemorph also had no significant effect on pod disease when sprayed directly on to pods at 15 day intervals

(Coelho, 1986; Reyes, pers. comm.). One other group of systemic fungicides has been shown to include compounds with good curative activity. Flutolanil, a benzanilide fungicide, suppressed broom formation when applied as a soil drench to nine month old clonal plants (Laker, 1989).

Field tests of the three most promising compounds, (triadimenol, hexaconazole and flutolanil) have been conducted in various countries since 1986. Short interval spray regimes in Brazil produced no significant effect on pod disease with triadimenol in Brazil (Bastos, pers.comm.). Smaller scale trials of sprays of triadimenol and flutolanil in Trinidad significantly reduced pod disease from 22% to 10% (Laker, 1989). Annual soil treatments under mature trees did not reduce either pod or vegetative infection in Trinidad.

Systemic fungicides as antisporulants in necrotic tissue

The use of eradicant chemicals against witches' broom disease was first reported by Desrosiers & Bolanos (1955). In a field experiment in Ecuador, brooms were sprayed with two general action biocides, sodium pentachlorophenate or dinitro-o-cresol and basidiocarp formation was reduced to 13% of the level in untreated brooms.

TABLE 5: RELATIVE ACTIVITY OF PRINCIPLE SYSTEMIC FUNGICIDES AGAINST C. PERNICIOSA IN LIVE AND NECROTIC VEGETATIVE TISSUE

	Sprays/drench treatment to seedlings or pods		Antisporulant spray	
Compound	Protectant	Curative /eradicant	Necrotic brooms	Green brooms
Oxycarboxin	-	-	+++	+++
Pyracarbolid	+ (S)	NT	NT	++
Flutolanil	+++ (S/D)	+++ (S/D)	++	++
Benomyl	-	-	-	NT
Propiconazole	-	-	++	++
Triadimefon	+ (S)	+ (S)	+++	+
Triadimenol	+++ (S/D)	+++ (S/D)	++	++
Hexaconazole	+ (S/D)	+ (S/D)	+	+
Tridemorph	-	-	++	-

Key:

+++, ++, + : levels of activity on a relative scale
- : no significant activity registered
S : Spray
D : Drench
NT : Not tested

Sources: Derived from various publications referred to in text

Large reductions in both the percentages of brooms which sporulated and the numbers of basidiocarps produced per broom have been recorded from all countries where systemic fungicides have been tested (Mayorga & Aranzazu, 1982; Cifuentes et al., 1982; Lins, 1985; Coelho, 1986; Reyes, personal communication; Laker, 1989). Another common phenomenon has been a delay in initiation of basidiocarp production after application, even though many basidiocarps may eventually be produced. Such delays have been recorded with all the major anti-sporulants which have shown good activity, namely oxycarboxin, triadimefon, propiconazole and triadimenol (Table 5). Lins (1985) argued that delayed fructification would expose shoots to less inoculum, and if the delay were sufficient, to none at all.

ECONOMICS OF SPRAYING

Activity of fungicides tested in the field for control of witches' broom on pods has been presented here as the percentage reduction in pod loss. Proportional improvement in loss or total yield is only part of the evaluation of any spray programme, as the practice must also give sufficient economic return if it is to be acceptable to farmers (Newhall, 1968). Plantations with consistently low production are less likely to give sufficient return, because trees may not be capable of high yields due to age and poor maintenance. The most favourable combination for spraying would be where trees are vigorous and potentially productive and pod losses are high, so that an effective control programme could recover sufficient weight of dry cocoa (Holliday, 1954). Studies of cost-benefits of fungicidal control of C. perniciosa have only been conducted on copper spray programmes.

Yield increases after spraying have not always been directly related to reduced disease incidence (Tollenaar, 1959; Coelho, 1986), and detailed economic studies of potential cost-benefit should not forecast increased income on this one variable response. Improved flowering and fruit set, and more vigorous shoot growth are other beneficial effects noted with copper. The possible return is also complicated by the use of integrated programmes including phytosanitation, when labour costs are already high (Holliday, 1954). Two detailed studies of cost-benefits of copper spraying using motorised mistblowers were conducted in Brazil, with phytosanitation (Bastos et al., 1982) and without (Coelho, 1986). Coelho applied Bordeaux mixture eight times and obtained a higher cost-benefit ratio than Bastos et al., found with 4 applications of Copper Sandoz (Table 6). Disease control was better with Bordeaux and over 500 kg of dry cocoa was produced compared with 100 and 150 kg using Copper Sandoz. Spray costs were higher for the Bordeaux regime and yet profitability was more dependable. A fundamental factor that determined relative returns from year to year in the Copper Sandoz experiments was the cocoa price/labour cost ratio, as was also shown in the study on cost-benefits of phytosanitation by Rudgard & Andebrhan (1988). Copper Sandoz would have been uneconomical to apply in 1980 and marginally so in 1981. Few crop management practices could give the farmer guaranteed profitability in years of low disease incidence. Disease management by fungicides will not be adopted where economic returns vary widely, especially in small to medium farms with low capital reserves.

TABLE 6: ECONOMIC ANALYSIS OF TWO SPRAY REGIMES TO CONTROL WITCHES' BROOM DISEASE ON PODS OF COCOA

Year	Yield (kg/ha)		Price Cocoa ($c/kg)	Labour Sanitation (Value $c)	Spray cost (Value $c) S (iii)	Crop saved (Value $c) C	Cost Benefit Ratio C/S
	Unsprayed	Sprayed					
1. Bordeaux mixture(i)							
1984	464	1034	12.2	-	3003(246)	6954(570)	2.3
1985	464	1034	18.0	-	4850(269)	9418(523)	1.9
2. Cobre Sandoz(ii)							
1978	521	672	49.4	15760	3580(72)	7460(151)	2.1
1980	734	830	90.4	17140	14990(165)	8680(96)	0.6
1981	348	454	130.4	27500	11690(90)	13820(106)	1.2

Key:

(i) : applied 8 times at 15 day intervals
(ii) : applied 4 times at 30 day intervals
(iii) : Figures in parentheses are kg dry cocoa equivalents ($c is local Brazilian currency, cruzados)

Source: Derived from Bastos et al., 1982; Coelho, 1986.

POSSIBLE STRATEGIES FOR USE OF FUNGICIDES

Pereira (1985) produced a number of possible strategies for the control of witches' broom using chemicals, mainly centred on mixed schedules of compounds with different modes of action. It was emphasized that protecting production was one priority and reducing inoculum sources in the canopy another. The former would require a broad-spectrum protectant such as copper, and the latter a combination of curative and eradicant properties. Research summarised here indicates copper as a better candidate as protectant than organic products, if residual activity can be improved. The large volume of work on copper available from the literature confirmed its activity under artificial environments but with at least partial loss of activity in the field. More research is required on surface doses achieved from mistblower and knapsack sprays and reduced biological effect of copper residues due to host growth and rain erosion. It may also be necessary to adapt spray equipment to improve initial doses for greater retention, test new formulations with adjuvants and determine correct spray intervals.

Protectants will not reduce the amount of inoculum, and systemic chemicals might be used with phytosanitation to eradicate sources of inoculum. Systemic compounds would be applied to inhibit broom formation and eradicate mycelium from diseased shoots and flowers. Active systemics can be classed into two categories, those with antisporulant effect only, and those with effect both in live and necrotic host tissue. The former would be of little use unless the compound can be shown to translocate into developing brooms and act as a complete eradicant. Repeated application of such chemicals would not be cost-effective, and Pereira (1985) only recommended one or two doses. Compounds known to translocate might be applied to the soil, avoiding the high costs and inefficiency of spraying. Soil applications also have the advantage of slow, sustained release of active ingredient to the tree. Such reduction of broom incidence and sporulation would only be effective if inoculum is a factor limiting disease incidence. Rudgard & Butler (1986) have shown that inoculum was only limiting at very low levels in Rondonia, Brazil, so cumulative effects of inoculum reduction would have to be tested in trials.

High disease pressure may provoke infection and distortion of seedlings and young trees (Maddison & Mogrovejo, 1985), which interfere with establishment of canopy architecture and delay tree development. Repeated early infections also interfered with rehabilitation of old plantations in Ecuador, and there was a need for a systemic treatment to keep young trees healthy until they could become established. Translocation would be more rapid in younger trees, and systemic chemicals could be good candidates for establishing healthy seedlings.

A final caveat concerning the use of systemics on older, pod-bearing trees relates to the possible accumulation of residues in beans, which may alter quality and flavour. If present in sufficient amounts, such residues could raise problems of toxicity, and tests of beans must be conducted during preliminary trials. Further development must not be undertaken without proof that no residues remain in the beans.

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THE CONTROL OF COCOA SWOLLEN SHOOT DISEASE IN GHANA

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INTRODUCTION

Cocoa swollen shoot disease is caused by a mealybug-transmitted virus that occurs in all the main cocoa-growing areas of West Africa. Somewhat similar diseases have also been encountered in Java, Trinidad and Sri Lanka, where they appear to be unimportant and have received relatively little attention.

Swollen shoot disease has caused very serious losses in Ghana, where infection is now more prevalent than ever before despite great expenditure for more than 40 years on control programmes. The various possible approaches to control have been reviewed periodically (Posnette, 1951; Thresh, 1958; Adegbola, 1971; Kenten and Legg, 1971). This paper considers the current situation in Ghana and the control policy now being implemented.

POSSIBLE CONTROL MEASURES

Eradication

Cocoa swollen shoot disease does not spread quickly or far in any considerable amount and it is therefore amenable to control by eradication. This was demonstrated in early Ghanaian trials in which outbreaks were controlled simply by removing all trees found with symptoms, or more effectively by removing them and also their symptomless neighbours (Posnette, 1943). These results were confirmed in later experiments done on a larger scale (Anon., 1945) and provided the justification for the official eradication campaign introduced in Ghana in 1946 and still being operated.

Eradication has been the principal means of control adopted in Ghana and there have been many progress reports on the campaign, most recently by Owusu (1983) and Thresh (1988). Serious problems have been encountered and they largely relate to the expense and difficulty of operating routine survey and treatment operations on a massive scale and with the required efficiency (Figure 1). There have also been major disruptions and discontinuities due initially to opposition from farmers to the removal of infected trees and later, between 1962 and 1965, to a withdrawal of official support. More recently there has been a diversion of resources from disease control to other activities and a complete reorganisation of the extension staff involved. An additional limitation of the approach adopted until recently is that only trees with symptoms have been removed, together with a relatively small proportion of symtomless 'contacts'. This was done even though it was known that more drastic procedures would have been more effective in controlling outbreaks (Thresh and Owusu, 1986).

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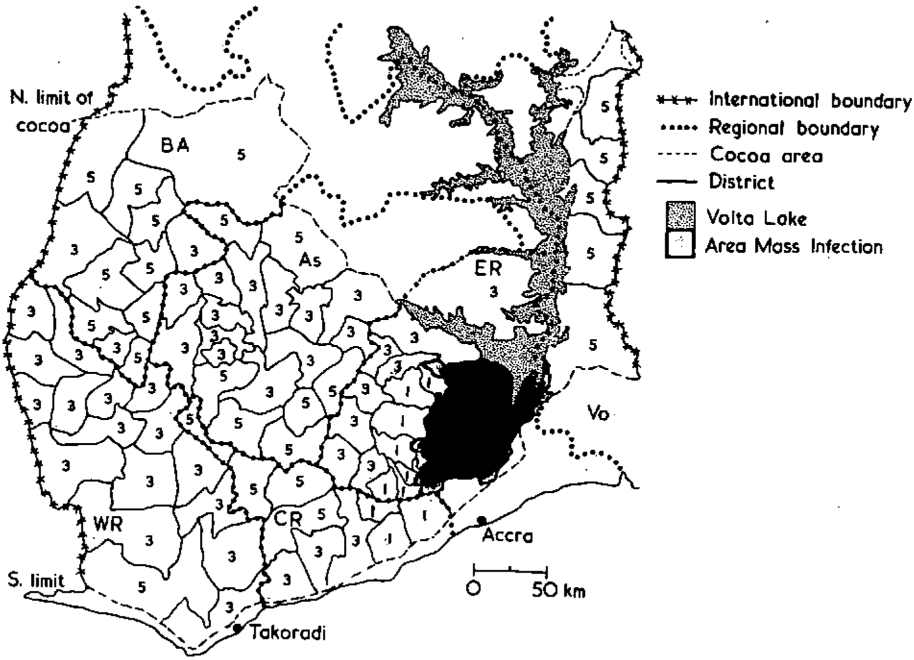

As = Ashanti, BA = Brong Ahafo, CR = Central Region, ER = Eastern Region, Vo = Volta Region, WR = Western Region

FIGURE 1: Sketch map drawn in 1986 of southern Ghana showing the northern and southern boundaries of the cocoa-growing area. The area of mass infection that is worst affected by swollen shoot disease is shown in solid black. The remaining cocoa areas are to be surveyed at intervals of 1, 3 or 5 years as indicated by the figure for each district.

These features of the campaign explain why few of the treated outbreaks have been controlled and why so many have been treated only after considerable delay. Many others have been left untreated, especially in the worst-affected parts of Eastern Region designated the 'Area of Mass Infection' (AMI). There is currently an enormous back-log of untreated outbreaks and because of this and the 1984-1985 reorganisation of the cocoa extension services in Ghana there has been a complete reappraisal of the eradication campaign and a revision of previous practices. The current objective is to make the most effective use of the decreased resources now deployed and to utilize fully the epidemiological information presently available. An important recent innovation has been to adopt different policies in the AMI and in the remaining areas of scattered outbreaks where infection is much less prevalent.

The policies now being implemented in the different areas are described in the following sections.

Actions in Areas of Scattered Outbreaks: Routine survey operations were resumed in 1985 in the scattered outbreak areas after having lapsed for several years. It is intended to survey all cocoa farms annually in the 'cordon sanitaire' immediately to the south and west of the AMI (Figure 1). Elsewhere, the cocoa will be inspected at intervals of 3 or 5 years depending on the previous incidence of infection. All outbreaks found are to be treated and the adjacent cocoa will then be brought under regular six-monthly inspection. Re-treatments will be done as necessary at each site until no further infection has been found over a period of two years, when the outbreak is deemed to have been controlled.

Cutting out measures are being enforced and the methods used are more drastic than any adopted previously in Ghana. All trees with symptoms are to be destroyed, together with adjacent symtomless trees to distances of 5, 10 and 15 metres around outbreaks of 1-10, 11-100 and >100 infected trees, respectively. This will ensure the removal of many of the latent and missed infections that previously would have remained and contributed to further spread.

The new measures should control outbreaks more readily than in the past but their effectiveness will not be known until they have been used for several years. Meanwhile, it is already apparent that the swollen shoot disease situation has deteriorated considerably since the last complete survey of the cocoa areas in the 1970's. The outbreaks being found are larger and more numerous than had been expected, especially in the cordon sanitaire. Some of the first outbreaks found contained more than 2000 infected trees (Figure 2) and they occurred at densities of up to 78 per 1000 ha of cocoa surveyed (Table 1). This has slowed progress and the proposed timetable for surveying the cocoa-growing areas has not been maintained (Table 1). By July 1988 after operations had been in progress for almost three years only 16.6% of the cocoa-growing area had been surveyed including less than half the cordon sanitaire which should have been assessed annually.

There have also been long delays in treating the many outbreaks found due to the large numbers of trees to be removed. By the end of July 1988 only 956 (18.3%) of the 5231 outbreaks found had been treated and there was a back-log of more than 3.65 million infected trees, of which about 2.97 million occurred in the parts of Eastern Region outside the AMI (Table 2).

Since July 1988 the main emphasis in the control campaign has been on treating the known outbreaks and survey operations have been greatly curtailed. Consequently there has been an improvement in the proportion of outbreaks treated which increased from 18.3% in July 1988 to 26.0% in May 1989. Even so it was then estimated that the back-log of trees to be removed was 5.15 million, of which 4.47 million occurred in the Eastern Region. The magnitude of the task now confronting the authorities is apparent when these figures are considered in relation to the total of 2.5 million trees removed in the three years to July 1988.

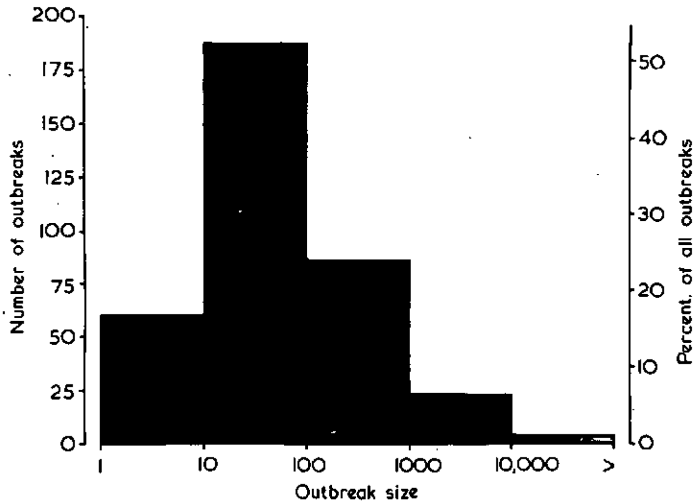

FIGURE 2: Frequency distribution of outbreak size within the <u>cordon sanitaire</u> of Eastern and Central Regions that is to be inspected annually. Data for numbers of infected trees recorded in 332 of the outbreaks found in 1985 and 1986.

TABLE 1: SUMMARY OF THE MOST RECENT SURVEY AND CUTTING OUT OPERATIONS OUTSIDE THE AREA OF MASS INFECTION : 1985 - 1988

Region (i)	% Area Surveyed	Cocoa Surveyed (1000 ha)	Outbrks treated/ found	% Outbrks treated (ii)	Trees removed per Outbrk	Density of Outbrks (iii)
As (3/5)	19.7	93.3	98/468	20.9	1,294	5.0
BA (3/5)	18.6	111.8	25/46	54.3	584	0.4
CR (1/3/5)	15.3	44.6	154/1390	11.1	1,771	31.2
EA:						
Cord S. (1)	46.8	30.3	270/2355	11.5	3,490	77.7
Rest (3)	12.7	31.9	60/203	29.6	1,222	6.4
Vo (5)	8.1	18.8	10/10	100.0	937	0.5
WR (3/5)	13.4	77.5	339/759	44.7	1,530	9.8
Total	16.6	408.2	956/5231	18.3	2,048	12.8

NOTES:
- (i) Intended to be surveyed at intervals of 1, 3 or 5 years as indicated in parentheses; codes for Regions as per Figure 1
- (ii) Mean number of visibly infected and symptomless trees removed per outbreak during initial and re-treatment operations
- (iii) Number of outbreaks found per 1000 ha of cocoa surveyed

A feature of the most recent phase of the eradication campaign is that few trees have been removed during re-treatment operations which accounted for only 0.3% of all the trees destroyed by July 1988 (Table 2). Another notable feature of the results is that 41.5% of the treated farms have been completely denuded of cocoa during the most recent cutting out operations. This proportion is greater than in previous phases of the eradication campaign and can be explained by the large size of the outbreaks being treated and the more drastic measures now employed (Kenten and Legg, 1971). Treatments and re-treatments are much more efficient when farms are denuded at an early stage of operations rather than over a prolonged period. This is because it is costly and inconvenient to keep on visiting farms where outbreaks are continuing to spread from infected trees that have remained despite earlier treatment. It is much more effective to clear farms quickly rather than piecemeal and in small numbers over a prolonged period.

Actions in Area of Mass Infection (AMI): Control measures in the AMI were almost entirely neglected for many years and numerous outbreaks were reported in the 1970's survey at intensities of up to 448 per 1000 hectares. Many of the outbreaks were very large and they have since become even larger and more numerous. It is therefore no longer feasible to treat them all as originally intended. The aim is to concentrate attention on plantings made in the 1970's either by the extension services, or as part of the major Suhum cocoa rehabilitation project. The total area exceeds 30,000 ha and

TABLE 2: SUMMARY OF THE MOST RECENT CUTTING OUT OPERATIONS IN GHANA : 1985-1988

Region	No.of farms denuded/ treated (i)	Trees Removed (No)			No.of trees to be removed (ii)
		Initial	Re-treatment	Total	
Ashanti	50/153	126,655	189	126,844	67,345
Brong Ahafo	0/26	14,468	132	14,600	4,613
Central	208/358	272,653	99	272,752	491,234
Eastern					
AMI	149/536	576,683	695	577,378	N/A
Cordon S.	324/802	939,900	2501	942,401	2,915,282
Elsewhere	14/114	73,242	86	73,328	58,032
Volta	8/13	9,337	0	9,337	0
Western	257/419	515,137	3521	518,658	115,233
Total	1010/2,421	2,528,075	7,223	2,535,298	3,651,739

NOTES:

(i) The number of farms completely denuded during control operations as a proportion of the total number treated

(ii) Estimate based on the 4,275 untreated outbreaks known to occur outside the Area of Mass Infection in July 1988.

includes 'block plantings' of up to some 240 ha and about 21,000 ha of young cocoa which was established during routine 'plant-as-you-cut' disease control operations. Some of the 1970's plantings were later abandoned or they were destroyed during the serious bush fires that occurred at the end of the severe dry season of 1982-1983. Nevertheless, many of the 1970's plantings survive and the indications are that these plantings are not yet seriously affected by swollen shoot disease, especially where they form large contiguous stands or where there is some isolation from major sources of infection (Ollennu et al., 1989). All the outbreaks found in recent plantings are to be treated and retreated as necessary using the revised procedures being used outside the AMI.

Large areas of the AMI are still suitable for cocoa production and there has been considerable replanting by farmers in recent years. However, many of the replanted trees have been established in small groups in, or near, untreated farms where swollen shoot disease is rife (Thresh et al., 1988b). Rapid infection of new plantings is inevitable in these circumstances and new measures are being introduced to decrease the risks incurred. Farmers are being encouraged to plant in large compact blocks to reduce the proportion of trees in the vulnerable peripheral areas. Financial support will not be provided unless farmers use the most virus-resistant of the hybrids available and plant a minimum of 1 ha and provide isolation of at least 10 m from any other cocoa.

It is already apparent that farmers, or even groups of farmers, will have difficulty in meeting the 1 ha and 10m requirements and consequently few will be able to take advantage of the financial inducements being offered. Concessions are being considered and one possibility would be to decrease the minimum size to 0.5 ha and to enforce a cocoa-free cordon only where new plantings adjoin older areas of untreated cocoa. This is likely to achieve at least some of the benefits of size and isolation and would be a big improvement on former practices without being unduly restrictive.

Barrier Crops and Mixed Cropping

Much of the spread of cocoa swollen shoot virus occurs over short distances by mealybugs walking between the interlocking branches of adjacent trees. This means that spread is greatly facilitated by the common practice in Ghana of planting to the boundary of the land available, with little or no break between adjacent cocoa farms or from earlier plantings on the same farm (Thresh et al., 1988b). There are likely to be great advantages in growing a non-host crop around the boundary of cocoa plantings to decrease spread from adjacent sources of infection (Figure 3a). Similarly, large plantings could be sub-divided into smaller units to restrict spread once infection has occurred (Figure 3b, 3c).

The likely benefits of some form of barrier or mixed cropping system have long been apparent (Cornwell, 1958; Thresh, 1958) but they have not been evaluated. Moreover, there has been no attempt to develop suitable crop combinations that are likely to be adopted by farmers. There is considerable scope for collaboration between virologists and agonomists and the time is opportune following a big decrease in the proportion of land that is planted with cocoa and the increased interest of farmers in coffee, cola other tree crops as well as in food production.

Resistant/tolerant cultivars

One of the reasons why swollen shoot disease has caused such serious problems in Ghana is that the main cultivar grown is the West African Amelonado, which is both vulnerable and sensitive to

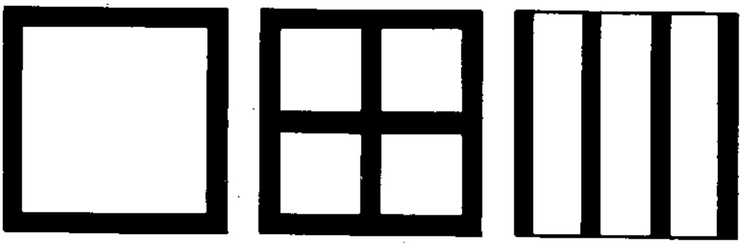

Fig. 3a Fig. 3b Fig. 3c

FIGURE 3: Barrier rows or interplanting of a non-susceptible crop (solid black) to protect cocoa plantings from infection or to restrict spread once infection has occurred.

CSSV infection. Trees usually die after infection with virulent strains of the New Juaben (1A) type that are prevalent in the Eastern Region and some other parts of Ghana. An obvious means of control would be to introduce cultivars with immunity or high levels of resistance to infection, or with sufficient tolerance to enable them to grow and yield satisfactorily even after becoming infected. Such cultivars are not yet available, though the merits of this approach were appreciated from the outset and a considerable effort has been made over many years to select resistant or tolerant genotypes from those already being grown in Ghana or from subsequent introductions (for detailed review see Thresh *et al.*, 1988a).

Some genotypes of Upper Amazon parentage are more difficult to infect than Amelonado and they also tend to be less sensitive to infection (Posnette and Todd, 1951). These features are likely to have contributed to the generally successful performance in Ghana of the 'F_3' Upper Amazon and the Series II hybrids (Upper Amazon x Amelonado and Upper Amazon x Trinitario) that have been used widely since the 1950's for new plantings and to replace Amelonado trees destroyed by swollen shoot disease or removed during eradication operations (Thresh et al., 1988b). However, until 1985 none of the parental types of the Series II hybrids was selected specifically for resistance to swollen shoot virus. A decision was then taken to use virus-resistant Upper Amazon pollen parents in each of the four official seed gardens supplying the Eastern Region. Fifteen of their Inter-Upper Amazon progenies have been approved for distribution. They are likely to be considerably more resistant to infection than the Series II hybrids used since the 1960's and to be at least as good in yield, resistance to black pod and other respects.

In the latest phase of the resistance breeding programme, both male and female parents are being selected for their resistance to infection in the hope that they will produce hybrids likely to be more resistant than those now recommended. There are also prospects of identifying new and possibly more effective, sources of resistance in some of the recent introductions not previously evaluated or in recently collected material from the Upper Amazon Basin that is now available in Central and South America. However, progress is likely to be slow and difficult because resistance is inherited quantitatively and screening techniques are imprecise. There will be even greater difficulty in developing varieties with sufficient tolerance to withstand infection which would then make it unnecessary to continue the eradication campaign. Suitable screening techniques for tolerance have not been developed. Moreover, tolerance appears to be a somewhat unstable characteristic that is markedly influenced by environmental conditions and highly tolerant sources have not been identified.

It is already apparent from field trials in the AMI that existing levels of resistance are totally inadequate in 'high risk' areas where there are many nearby sources of infection (Ollennu et al., 1989). This emphasises the need to establish resistant varieties in large compact blocks to decrease edge effects. There should also be the greatest possible isolation from adjacent plantings and the entire area in which any replanting is done should be surveyed regularly and treated as necessary to eliminate all known sources of infection.

Mealybug Control

The natural spread of swollen shoot virus is by several species of mealybug (Pseudococcidae). These insects have sucking mouthparts and they infest the pods, leaves and stems of cocoa. Populations tend to be inconspicuous and some species including the main vector in Ghana (Pseudococcoides njalensis) are usually attended by ants that construct protective carton tents of soil and debris. Only males have wings and, as they do not have functional mouthparts, all virus spread is by female adults or nymphs. These walk between the inter-locking branches of adjacent cocoa trees, but they are also occasionally blown over greater distances by wind.

An obvious method of controlling swollen shoot disease is by eliminating or decreasing vector populations, but this is not readily achieved. One reason for this is that the vectors are indigenous species and natural populations are restricted by the activities of many insect parasites and predators. Attempts to increase mortality by introducing additional parasites or fungal pathogens have been unsuccessful. More promising results were obtained by using formicides to control the attendant ants, but the trials were abandoned because the chemicals used had undesirable side effects and led to a big increase in pod-mining insects and other cocoa pests (Thresh and Owusu, 1986).

Trials were conducted in the 1950's with some of the original organo-phosphorus systemic insecticides. One was used in a large field trial in attempts to improve the effectiveness of eradication measures in bringing outbreaks under control (Hanna and Hetherington, 1957). This approach seemed to be successful but it was not pursued as numerous applications of insecticides were necessary and the material used was expensive, had a high mammalian toxicity and caused an undesirable taint of the cocoa beans. Little further attention has been given to the use of insecticides for controlling mealybugs, although they have been used routinely for over 20 years to control cocoa mirids.

A fresh initiative is possible using the wider range of insecticides now available. Further studies are long overdue as a reduction in mealybug populations on the trees around outbreaks being treated would greatly facilitate control by eradication and lead to a big increase in efficiency (Thresh and Owusu, 1986). There is less scope for using insecticides routinely to control mealybugs on cocoa because these insects are only important as virus vectors and cause little direct yield loss or other forms of damage.

Mild Strain Protection

It has long been known that mild strains of cocoa swollen shoot virus will protect trees from the severe effects of related virulent strains (Posnette and Todd, 1955). The possibility of adopting this approach to control was fully appreciated from the outset. However, it was not pursued because the deliberate dissemination of a mild strain was incompatible with the attempts being made in the 1950's to control all known outbreaks, irrespective of the virulence of the strains involved. The situation has changed completely now that control measures have been abandoned in large areas of the AMI. Mild strains could now be deployed effectively in these areas and especially at sites of limited size where adequate isolation is not possible and a large proportion of the trees are at the periphery.

The original studies on mild strain protection were with the Amelonado cultivar and there is an obvious need for further research using the Upper Amazon progenies now grown. Such studies are in progress and it is important to check that the original strains have remained avirulent and uncontaminated and that they protect satisfactorily against the virulent strains now prevalent in the AMI. It is also necessary to develop effective means of disseminating the mild strains, as they are not readily transmissible mechanically or by vectors. One possibility would be to graft-inoculate seedlings in the nursery or soon after planting in the field. Another would be to propagate from mild-strain-infected sources using stem cuttings or by budding onto seedling rootstocks. These studies merit high priority and require a multi-disciplinary approach involving virologists, agronomists and breeders. The studies should be started forthwith because they will take several years to complete and mild strains could have an important role to play in future disease control strategies. There are already precedents with virus diseases of other plantation crops including papaya ringspot and citrus tristeza (Fulton, 1986; Gonsalves, 1989).

DISCUSSION

Over the last 50 years swollen shoot virus (CSSV) disease has caused incalculable damage to the cocoa industry in Ghana. More than 190 million trees have been removed since 1946 in attempted control programmes and millions more have been killed or seriously debilitated by the disease. There has also been a massive diversion of research and extension personnel and resources that could otherwise have been used to improve cocoa or other agricultural production. Despite all this investment, CSSV is now more prevalent in Ghana than ever before and it will become even more widespread unless the latest control measures are implemented quickly, fully and effectively.

The strategy now adopted continues to be based primarily on eradication and this is likely to be the situation for some years to come. However, there is considerable scope for decreasing rates of reinfection in the worst-affected areas by planting large blocks away from known sources of infection and by using Inter-Upper Amazon hybrids that are partially resistant to infection. There is no immediate prospect of further innovations because suitable insecticides to control mealybug vectors and varieties that are truly resistant or tolerant of infection are not yet available. Additional studies are also required on cross-protection, barrier crops and mixed cropping systems before suitable definitive recommendations can be made. In the long-term, there are good prospects of deploying the whole range of possible approaches in an integrated disease control programme likely to be more effective than the one now adopted.

Meanwhile, it is essential that the latest control measures that were introduced in 1985 should be operated more effectively than they have been to date. It is particularly important to maintain the proposed schedule of survey operations in the different cocoa growing areas and to avoid the present long delays in carrying out the initial treatments and re-treatments of the many outbreaks being found. Otherwise, the situation will continue to deteriorate and it will become increasingly difficult to achieve any satisfactory degree of control, even in those areas that are still not seriously affected.

ACKNOWLEDGEMENTS are due to Cocoa Services Division, Accra for Figure 1 and for the data summarized in Figure 2 and Tables 1 and 2.

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COCOA IN THE COLOMBIAN COFFEE REGION

A. Agudelo* and B. Saenz**

INTRODUCTION

The Colombian coffee region is situated in the Equatorial zone of South America in the Andes mountains, between latitude 2° - 9° North and longitude 73° - 77° West. Several temperature zones exist in this region according to altitude. The coffee zone is located between 800 and 2000 meters above sea level, covering an area of 3,600,000 hectares, of which 1,000,000 are planted with coffee (Figure 1).

Coffee production is the main source of revenue for this region, which is one of the most socio-economically developed areas of Colombia. There are many other commercial crops also planted in the zone such as citrus fruit, plantains, sugar cane, vegetables and cocoa, in which modern cultivation techniques are used to sustain high yields and good profitability.

Cocoa is increasingly being planted at the lower altitudes (800 to 1,300m) of the zone. It has great potential due to the exceptional conditions of soil, climate, good genetic material, excellent rural infrastructure, processing, technology and system of plantation agriculture. A cocoa drink based on the whole cocoa bean is part of the breakfast of many rural workers in Colombia as it has high nutritional value in terms of vitamins and calories. Much of the present production of cocoa is consumed within Colombia in the form of this cocoa drink.

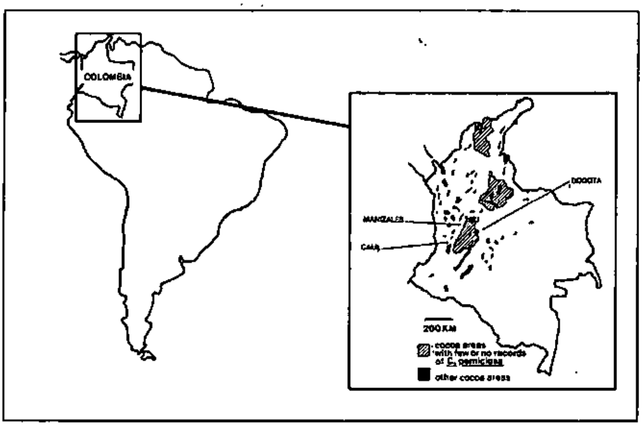

FIGURE 1: Map of cocoa areas of Colombia

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COCOA TECHNOLOGY

Current methods of cocoa production in this region are the result of 30 years of experience, combined with recent research in all aspects of the crop and the adoption of technology developed in other cocoa producing countries. The recent advances have been promoted by extension services provided by professionals from institutions like Federacion Nacional de Cafeteros and Chocolataria Luker. Essentially, plantation management has centred on the use of early bearing and highly productive genetic material, with plantings made under good ecological and physiological conditions. Hybrids have been developed from crosses between Amazon types and Trinitarios or Colombian selections to give a group of 26 hybrids for distribution to farmers (Table 1). The soils are of volcanic origin, with exceptional physical properties such as depth and water-holding capacity. The soils are highly productive, however their moderate fertility often makes the addition of soil dressings and fertilizers necessary (Table 2). The sloping land where cocoa is planted varies from undulating to steeply sloping, sometimes with slopes 100% and over. The excellent soil structure usually means that soil erosion is not a problem and because cocoa is a tree crop it tends to conserve soils and further prevent their erosion. The annual rainfall varies between 1,800 and 2,600 mm per year and monthly totals between 100 and 300 mm. There is a dry season in which some periods without rain are occasionally as long as 20 days (Figure 2 and 3). These characteristics mean that cocoa can grow well in regions where average temperatures are between 21.5°C and 22.5°C especially on west-facing slopes (Table 3) and it has thus been possible to raise the altitude limit for growing cocoa into regions only planted traditionally with coffee (Figure 2).

TABLE 1: HYBRID DISTRIBUTION IN THE COFFEE ZONE OF COLOMBIA

1.	IMC - 67 x ICS - 6	14.	ICS - 6 x PA - 121
2.	IMC - 67 x EET - 62	15.	ICS - 39 x SPA - 9
3.	PA - 46 x IMC - 67	16.	ICS - 95 x IMC - 67
4.	PA - 46 x ICS - 1	17.	SC - 21 x SPA - 9
5.	PA - 150 x ICS - 6	18.	SPA - 12 x ICS - 39
6.	TSH - 565 x IMC - 67	19.	P - 7 x IMC - 67
7.	TSH - 565 x ICS - 6	20.	P - 7 x Catongo
8.	TSH - 565 x R - 30	21.	P - 7 x ICS - 1
9.	TSH - 792 x ICS - 6	22.	TSA - 644 x ICS - 6
10.	EET - 8 x IMC - 67	23.	TSA - 654 x ICS - 6
11.	EET - 400 x ICS - 39	24.	R - 30 x IMC - 67
12.	EET - 400 x ICS - 60	25.	UF - 613 x IMC - 67
13.	EET - 400 x IMC - 67	26.	UF - 613 x Catongo

A new cropping system has been developed for cocoa by coffee farmers taking into consideration the above characteristics. This is based on maximum use of solar energy by means of a higher planting density of between 1,500 to 2,500 trees per hectare. The objective is to create an adequate leaf area index in a continuous canopy with the largest possible number of productive branches developed by careful structural pruning. These channel photosynthetic products into fruit production increasing yield per unit area of ground.

TABLE 3: TEMPERATURE DATA FOR GRANJA LUKER
(altitude 1,100m above mean sea level)

Average Mean Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1981	22.7	23.5	23.4	22.8	22.5	22.6	22.9	23.0	22.4	22.4	22.3	22.5	22.8
1982	22.2	23.1	23.3	22.9	22.7	23.5	23.3	23.7	23.3	22.0	22.1	22.6	22.9
1983	24.0	24.1	24.1	23.5	23.5	23.8	23.3	23.5	23.1	22.5	22.7	21.8	23.3
1984	22.0	22.3	23.1	22.8	22.4	22.9	22.7	22.8	22.5	22.5	22.5	23.7	22.7
1985	22.7	23.1	23.2	23.1	22.8	22.8	22.8	22.8	22.5	22.2	22.4	22.5	22.7
1986	22.7	22.3	22.8	23.0	23.2	23.0	23.5	23.4	23.3	22.3	22.7	23.2	23.0
1987	23.2	24.5	24.2	23.7	23.6	24.0	23.9	23.8	23.4	22.8	23.1	24.4	23.8
1988	24.0	23.7	24.7	23.3	23.5	22.6	23.1	22.6	22.3	22.7	22.7	22.7	23.1
1989	22.7	22.7	22.2	24.0	23.7	22.8	23.1						

Mean Minimum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1981	16.9	18.4	18.1	18.0	18.2	18.4	17.4	17.8	16.8	18.0	17.8	18.0	17.8
1982	17.0	17.7	16.9	17.5	18.3	18.1	16.9	16.7	17.4	17.1	17.3	17.4	17.4
1983	16.9	17.7	17.9	17.8	17.7	17.3	16.5	16.5	16.6	16.0	16.4	15.7	16.9
1984	15.3	16.0	16.2	16.2	15.9	16.0	16.1	16.1	16.7	17.2	16.9	17.9	16.5
1985	17.6	16.3	17.5	17.1	17.2	17.1	15.9	15.9	16.5	16.5	16.1	15.8	16.7
1986	16.1	16.8	17.4	18.1	18.0	17.7	16.2	16.2	16.7	17.2	17.1	17.5	17.2
1987	17.0	18.2	18.4	18.9	18.3	17.7	16.6	16.6	16.8	16.9	16.5	18.2	17.5
1988	18.6	18.5	17.7	19.0	18.5	18.1	18.1	18.1	18.4	18.6	18.5	18.0	18.4
1989	18.5	17.8	17.5	18.5	18.5	18.3	18.8	18.8					

Absolute Minimum Temperature

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1984	12.5	14.5	12.5	14.5	14.0	14.6	14.5	14.4	15.5	16.0	14.5	16.5	14.5
1985	15.5	13.5	15.5	11.5	14.5	13.5	14.5	14.0	14.5	10.5	11.5	11.0	13.3
1986	11.5	15.5	16.5	16.0	16.0	16.5	14.0	14.0	14.5	13.0	14.0	15.5	14.8
1987	13.0	16.0	16.0	17.0	17.0	16.5	16.0	16.0	14.5	14.0	14.0	15.0	15.3
1988	15.5	16.0	13.0	17.5	17.0	17.0	16.0	16.0	15.5	17.0	17.0	15.0	16.1
1989	17.0	14.0	14.5	16.0	15.5	16.5	16.0	16.0					

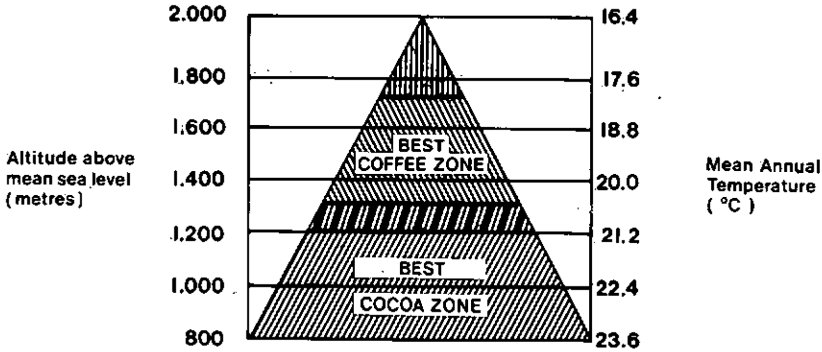

FIGURE 2: Variation in mean temperature levels with altitude in Colombia

Cocoa research in Colombia has obtained successful results in pest and disease management and this has reduced pod losses.

TABLE 2: ANALYSIS OF SOILS, VOLCANIC ASHES

PH	:	5.0 - 5.5
Organic Material	:	9.3 - 10.3%
Phosphorus	:	0 - 4.0 ppm
Potassium	:	0.19 - 0.31 m.e./100 g
Calcium	:	1.4 - 2.2 m.e./100 g
Magnesium	:	0.4 - 0.6 m.e./100 g
Origin of Material	:	= Andean volcanic ash of the Pleistocene era

Source: National Federation of Coffee Growers

A TYPICAL MODEL FARM

Cocoa plantations in the coffee region are usually small farms (3 hectares on average) and they produce 60% of the national cocoa production, equivalent to 43,000 tonnes. However, in the last few years, the trend in the size of plantations has been increasing towards bigger farms of about 15 hectares. A higher level of technology has improved production to yields of over 1,500 kg of dry cocoa beans per hectare per year.

A typical farm representative of these new estates is the "Finca La Argentina", situated at the centre of the most important coffee region of the country. This is near large population centres, adequately supplied with rural services and with a suitable infrastructure and technical support. The conditions are as follows:

Latitude	5° 03' North
Longitude	75° 41° West
Total Area	120 hectares
Area in Cocoa	15.5 hectares
Altitude	1.350 metres above mean sea level

Average Temperature	22.0°C (Range 17°C - 24°C)
Rainfall	2400mm/year (207 rainy days)
Relative Humidity	80%
Hours of Sunlight	2.1 hours facing west
Soils	Open, chalky texture of granular structure. Depth undefined. Undulating ground.
Ecological Formation	Humid subtropical woodland forest

The main activity on this farm is coffee cultivation with 78 hectares of mature coffee planted at 10,000 bushes per hectare giving a yield up to 5 tons of dry coffee beans per hectare per year.

The cocoa fields were established on old grazing lands, and plantains were used as a temporary shade for the cocoa. This temporary shade crop, besides providing shade necessary for the new plantation, provided enough income to the grower to pay the establishment costs of cocoa during its first unproductive years. After the third year, the shade crop was cut out and the cocoa plantation left with no shade. The cocoa fields were planted at the rate of 2,000 to 2,500 trees per hectare without permanent shade, but with application of herbicides for weed control. Structural pruning was necessary where canopies became tangled or too high. There were two applications of fertilizer per year, alternating a complete fertilizer with either phosphorous or calcium, and insecticides were applied as and when necessary. Diseased pods and branches (e.g. those with witches' brooms) were collected weekly, and ripe pods harvested every other week.

The production of dry cocoa beans per hectare (Table 4) suggests that planting density and precocity of cropping are the two factors which favoured the high yield by unit area. Costs, including interest on loans, were recovered by the end of the fifth year after planting. These costs included planting the temporary plantain shade and cocoa crops, and construction of roads and accommodation for labourers.

TABLE 4: YIELDS (DRY COCOA/HECTARE)

Lot	Ha	Production dry cocoa								
		82	83	84	85	86	87	88	89	Total
		tonnes/ha/annum								
1	2.5	20	298	680	689	1752	1716	1523	1423	8.101
2	4.8	10	222	436	501	1617	1309	1184	1270	6.549
3	5.4	-	83	269	415	1444	1531	1125	1160	6.027
4	2.8	-	91	358	408	1630	1973	1193	1574	7.227

Note: Lots 1 & 4 planted at 2.0 x 2.0m & Lots 2 & 3 at 2.0 x 2.5m. Lots 1 & 2 were planted in July 1981, Lots 3 & 4 in October 1981.

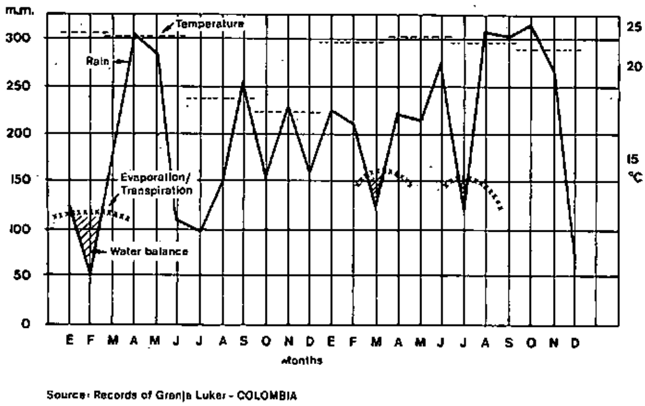

FIGURE 3: Climatic measurements, Hacienda Palestina, Caldas, Colombia

CONCLUSIONS

The technology of the cocoa crop has advanced rapidly in Colombia in the last 15 years, particularly in the lower coffee region due to adoption of different management and cropping systems. These advances are:

1. Planting of crops in those areas with the best ecological conditions;
2. Use of vigorous genetic material;
3. High density of planting;
4. High exposure to sunlight of an adequate leaf area index;
5. Physiological and economic criteria for management of pruning, shade and fertilizers;
6. Successful phytosanitary methods for control of pest and diseases;
7. Better management of fermentation and drying processes.

This experiment has successfully extended the altitude and temperature zones for cocoa cultivation, proving that large areas of the Andes could be used for this crop. Cocoa would also diversify land use in these traditional coffee areas, and derive benefit from the high quality of infrastructure and availability of excellent managerial skills.

There is a need for studies on the developing maximum yield/hectare and attempts to minimisation of costs of management practices such as weed and pest control, harvesting and processing.

IMPROVEMENT OF MALAYSIAN COCOA BEAN FLAVOUR BY MODIFICATION OF HARVESTING, FERMENTATION AND DRYING METHODS - THE SIME-CADBURY PROCESS

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European cocoa powder and chocolate manufacturers have traditionally depended upon West African countries for their supplies of cocoa beans. This historic dependence has developed a preference by the final customer for products made from beans with a West African flavour. Increasingly however, there is concern amongst European manufacturers about the adequacy of West African supplies.

Of the alternative sources of beans, currently Malaysia is probably the most obvious. Output has increased steadily and the industry has demonstrated a willingness to provide the quality demanded. Unfortunately, Malaysian cocoa beans presently have an excessively acidic flavour, weak chocolate flavour and certain other off-flavours. These flavour defects severely limit its use by cocoa powder and chocolate manufacturers throughout the world. Malaysian beans are therefore discounted against West African beans below the value which can be attributed to the difference in fat yield between the two sources.

As a result of this significant price difference certain Malaysian producers have developed methods to reduce the acidity in their beans (Schwartz, Wong & Bridger, 1981; Chick, Mainstone & Wai, 1982; Li Liau & Lee, 1983; Yap 1983; Shepherd, Chong, Taylor & Menneer, 1986). Likewise, cocoa bean processing plant has been used by cocoa powder and chocolate manufacturers to reduce the impact of acid beans in cocoa and chocolate production (Werner & Rapp, 1985; Schmitt, 1985; Bonora & Chiappa, 1987). Neither approach ahs been completely satisfactory and the use of Malaysian cocoa beans in both cocoa and chocolate production remains limited.

In view of their common interest in improving the flavour of Malaysian cocoa, Sime Darby Plantations and Cadbury Limited have worked together on a cooperative project. This project assumed that the undesirable flavours in Malaysian cocoa beans and their weak chocolate flavour are not endemic but arise from differences between Malaysia and West Africa in the way cocoa beans are harvested, fermented and dried (Duncan, 1986).

In West Africa cocoa is farmed mainly by smallholders with a very few hectares each. Because these smallholders rely upon family and neighbours for labour, and their work time is shared with other crops and social and domestic matters, the detail of their cocoa harvesting, fermentation and drying is variable. Due to the very much larger scale of operation on Malaysian estates an industrial and

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more uniform approach to cocoa bean processing has been adopted employing fixed or contracted labour to do specific tasks. As a result of these differences and erroneous assumptions about what "normal" West African processing methods were, current Malaysian processing methods differ both in detail and scale from those of West African farmers (Duncan, 1986). In Malaysia pods are harvested less ripe and split immediately after harvesting. The beans are then fermented for a longer time and the ferments are turned more frequently than in West Africa. In Malaysia, after fermentation the beans are dried in hot air dryers rather than by the sun. The characteristic flavour of West African cocoas results from "bulking" of the cocoas from many different farmers, with each farmer processing his beans in a slightly different way and producing a slightly different product. In contrast the uniformity of the Malaysian processing method means that any flavour bias of the method is likely to be amplified.

Tests designed to investigate these processing differences were performed during 1987 and 1988 at Sime Darby's Merlimau Cocoa Estate, Melaka, Peninsular Malaysia.

PROJECT APPROACH

The objective of the project was to develop a modified processing method suitable for the Malaysian situation which would produce a cocoa closer in flavour and quality to West African.

The approach taken was:

1. To identify the differences between harvesting, fermentation and drying practices in Ghana and Malaysia which influence flavour;

2. To determine the optimum processing conditions for these processing stages;

3. To translate these conditions into a practical fermentary based process.

The only processing differences investigated were those that appeared likely to be controllable by simple and practical means on a typical estate. These were:

- the time between pod harvesting and splitting;
- the fermentation regime;
- the drying process.

Unlike in the approach of Lewis & Lee (1985) other parameters such as pod ripeness at the time of harvest and the specific genotype of the cocoa tree were not considered to be controllable parameters in practice. Thus no attempt was made to investigate their influence on flavour or to standardise them in the present studies. However, in order to minimise any bias they might cause in results due to chance differences between the pods used in the tests, the experimental design included randomisation and replication of tests, separation of replicates in time and split-batch methodology.

MATERIALS AND METHODS

Initially three sets of tests were designed to determine the influence of fermentation regime, pod storage duration and drying method on flavour, and to identify their optimum process conditions. A fourth set of tests was performed to investigate artificial drying conditions which mimicked as closely as possible those observed during sun drying.

THE INFLUENCE OF FERMENTATION REGIME ON FLAVOUR

The range of fermentation treatments (durations and turning times) typically practised by Ghanaian farmers was outlined by Duncan (1986) and is covered by tests shown in Table 1. All the test ferments were replicated three times over a period of five weeks.

Lewis & Lee (1985) had demonstrated that pod ripeness at harvesting and pod storage significantly influences flavour, the latter over-riding the former at pod storage periods of about ten days. In order to limit flavour differences in degree of pod ripeness at harvest, all test ferments used beans from pods which had been stored for 9 days after harvesting.

TABLE 1: Matrix of fermentation tests performed to investigate the impact of Ghana fermentation treatments on flavour

Fermentation duration (hours)	Treatment code for single turn at indicated hours after start of fermentation				
	No turn	24	48	72	96
72	F 72/T0	F 72/T24	F 72/T48	-	-
96	F 96/T0	F 96/T24	F 96/T48	F 96/T72	-
120	F120/T0	F120/T24	F120/T48	F120/T72	F120/T96

F = fermentation hours; T = timing in hours, of a single turn

Ferments were all carried out in wooden boxes of 1.0m x 1.3m x 0.42m deep. Boxes were filled and the beans were covered with plastic sacks. After fermentation the beans were coned and quartered to give a sub-sample of about 35 kg which was dried in the sun. The remainder of the beans were dried in a 60°C stream of air on a partitioned circular bin dryer (currently the general Malaysian practice - referred to here as 60°C air-stream drying).

THE INFLUENCE OF POD STORAGE ON FLAVOUR

Typically Ghana farmers can leave pods from 2 to 20 days after harvesting before splitting them and commencing the fermentation. To explore the impact of this on flavour, beans from pods which had been stored for 0, 5, 9 and 12 days after harvesting were fermented in the boxes described above.

The fermentation treatment used in these tests was F120/T48 which is five full days fermentation (about 120 hours) with one turn after about 48 hours. This treatment had previously been identified as being the optimum and most reproducible of those outlined in Table 1. A sub-sample of about 35 kg was obtained from each test and sun dried as described above. Tests involving 0, 5 and 12 day pod storage were each replicated twice. Those involving 9 day pod storage were replicated four times. Beans remaining from these were dried in a 60°C air-stream on a partitioned circular bin dryer.

THE INFLUENCE OF DRYING METHOD ON FLAVOUR

In West Africa, cocoa beans are sun dried after fermenation. Due to the scale of operation and weather conditions in Malaysia, beans are usually dried in a stream of hot air. To investigate the impact of this difference on flavour, the flavour of sun dried and hot air (60°C) dried beans from all of the test fermentations listed in Table 1 were compared.

The beans from the four ferments described in Section 2 above involving 9 day stored pods were sutdied throughout sun drying and drying in a 60°C air-stream. Flavour changes with drying time, the drying process conditions and other physical and chemical measurements outlined below were measured.

DEVELOPMENT OF AN IMPROVED ARTIFICIAL DRYING PROCESS

These drying tests indicated the need to develop an artificial drying process which achieved the same drying process conditions recorded during the sun drying of beans. Tests were designed to achieve these process conditions and to determine their impact upon flavour.

An inexpensive rectangular flat bed dryer made by Sin Heng Trading Co., Muar was used for all tests. Agitation was via a paddle wheel which moved up and down the bed controlled by relays and a timer. The dryer dimention was 3.0m x 6.0m. A clean, odour free supply of hot air was achieved by passing fresh ambient air through a gas/gas heat exchanger. The heat was generated by a KNS wood fired burner. The drying temperature was regulated by quenching the hot air with ambient air.

All the beans used in these tests were from pods which had been stored for 9 days. The fermentation treatment used was that which had previously been shown to the optimum and most reproducible, namely five full days fermentation (about 120 hours) with one turn after 48 hours (F120/T48). Sub-samples of about 35kg were obtained from each test and sun dried as described above. A second sub-sample from each test was dried at 60°C in a ventilated oven. In these tests the size of ferments varied up to four times that of previous tests though the bean depth was always maintained at 0.42m.

PHYSICAL AND CHEMICAL MEASUREMENTS

Throughout all drying tests a number of physical and chemical parameters were monitored:

- a 'rapid moisture content' of the beans was determined by weighing 200 beans immediately after fermentation. From experimental observations, it was assumed that these had a moisture content of 53 per cent. Monitoring the weight of subsequent samples of 200 beans during drying, allowed the approximate bean moisture content to be followed with time;

- an 'oven moisture content' was determined by drying 20 beans in a ventilated oven at 105°C overnight. The value obtained for the beans immediately after fermentation, when available, was used to correct the rapid moisture content results and achieve a better approximation;

- the titratable acidity of cotyledons was monitored by homogenising 10g of cotyledons in 200ml of distilled water, filtering and then titrating a 25ml aliquot to pH 8.0 with 0.01m NaOH. The value obtained was corrected for the moisture content of the cotyledons and reported as mMoles of NaOH per 100g dry cotyledons;

- cotyledon pH was determined on the 25 ml aliquot used to measure the titratable acidity;

- the physical examination of 50 beans was performed by cutting these as in a normal cut test and recording the percentage showing the following:

    - fully brown cotyledons;
    - bleached cotyledons (1);
    - the presence of mechanically free liquid;
    - partly brown/partly purple cotyledons.

Other observations on the general appearance and handling characteristics of the beans were also recorded:

- process conditions were recorded using type K temperature probes and meters, vane type anemometers and hand held humidity probes;

- flavour development was followed throughout drying by taking samples from the drying test, completing their drying to less than 8 per cent moisture in a ventilated oven at 55°C and making them into chocolate for flavour testing.

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(1) The term bleached was used to describe cotyledons showing some white colouration of the exposed cut surface.

FLAVOUR ANALYSIS

All bean samples from these tests were made into dark chocolates in Malaysia and again in the UK. The intensities of certain flavour attributes defined as being relevant to chocolates of this type were measured using the method of quantitative descriptive analysis (Stone, Sidel, Oliver, Woolsey & Singleton, 1974).

To obtain objective flavour data which could be analysed in a statistical manner, a taste panel consisting of screened, selected and trained panelists was established at Sime Darby Plantations, Ebor Laboratories in Malaysia. Two other expert taste panels also participated in the work; the Cadbury Limited panel, Bournville, UK and the Cadbury Schweppes Group Research, Reading, UK. Both of these panels tasted chocolates made in the UK from the same samples of test beans.

In considering the flavour attributes most relevant to describing dark chocolates of the type produced, each panel independently defined and used a slightly different set of flavour attributes. However, certain attributes were common to all three panels. These were chocolate; acid; citrus; bitter; astringent and brown fruit. Other attributes found to be significant in differentiating samples were ribes; liquorice and off-flavours.

For control purposes a dark chocolate made from factory processed liquor was included in some comparisons. This liquor was made from commercial Ghana beans. Taste panel results were analysed using a statistical software package designed specifically for the analysis of sensory data using analysis of variance.

RESULTS AND DISCUSSION

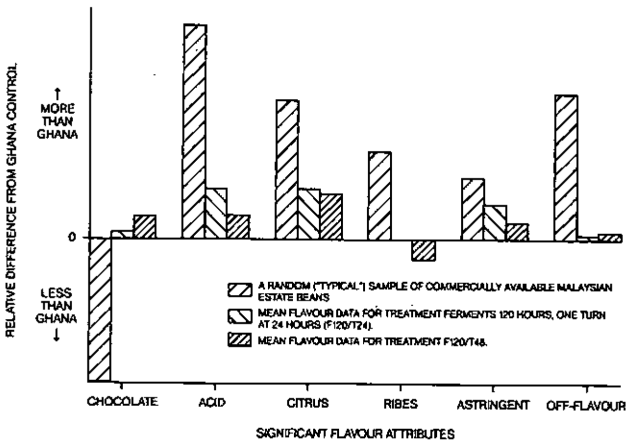
The main conclusiond drawn from this work are based on the flavour of the beans produced. Because of the 'bulking' aspect of West African cocoas described in the Introduction, it was not expected to match the flavour of the Ghana control chocolate from single fermentation test samples. The Ghana control chocolate was inserted into flavour comparisons to indicate the direction of changes rather than magnitudes. For this reason trends in the intensities of flavour attributes should be regarded as being more significant than absolute values.

THE INFLUENCE OF FERMENTATION REGIME ON FLAVOUR

The flavour attributes of the sun dried products of these fermentation treatments showed the potential to improve the flavour of Malaysian cocoa and bring it closer to that of the Ghana control. Much of the flavour improvement achieved in this set of tests, as will be shown, resulted from use of 9 day pod storage and sun drying. However, in addition there were also significant flavour differences between different fermentation treatments. Of the treatments considered, only treatments F120/T24 and F120/T48 consistently produced beans which were neither significantly different from the Ghana control nor between replicate tests. Both of these treatments involved 120 hours fermentation and a single turn. Figure 1 compares the sun dried products from these two treatments with a Malaysian estate sample and the Ghana control. The improvement in the chocolate, acid, bitter and astringent attributes are evident as is the large reduction in the level of off-flavour. Of the two treatments F120/T48 was consistently closer to the Ghana control and was therefore selected as the most appropriate fermentation treatment and was used in all subsequent tests.

It is noteworthy that this fermentation treatment was also selected by Lewis & Lee (1985) and is reported by Duncan (1986) to be among the most commonly practised treatments in Ghana.

Figure 1. Flavour attributes of selected better fermentation treatments in comparison with a random ("typical") sample of Malaysian estate beans, relative to the Ghana control.



0 represents the base line for the Ghana control sample.

THE INFLUENCE OF POD STORAGE ON FLAVOUR

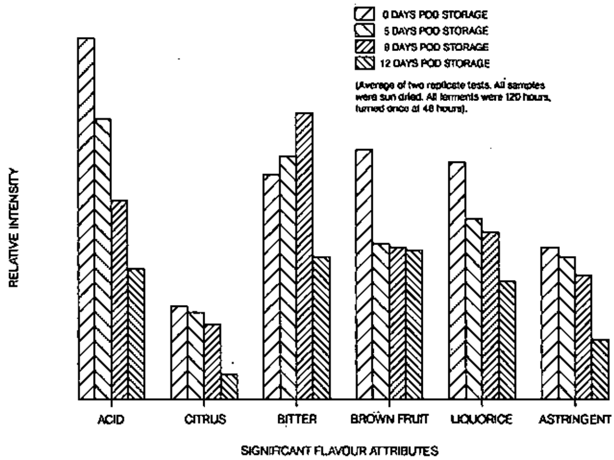
Pod storage was significant in reducing the acid, citrus, bitter, brown fruit, liquorice and astringent attributes, with 12 day pod storage giving the greatest flavour improvement (see Figure 2). In addition, chocolate flavour also improved with increased length of pod storage.

The flavour improvement caused by 12 day pod storage relative to a Malaysian cocoa and the Ghana control is demonstrated in Figure 3. Differences between the beans from 12 day stored pods and the Ghana control were not significant for the attributes considered, while both of these samples were significantly different from the Malaysian cocoa for all the attributes shown.

THE INFLUENCE OF DRYING ON FLAVOUR

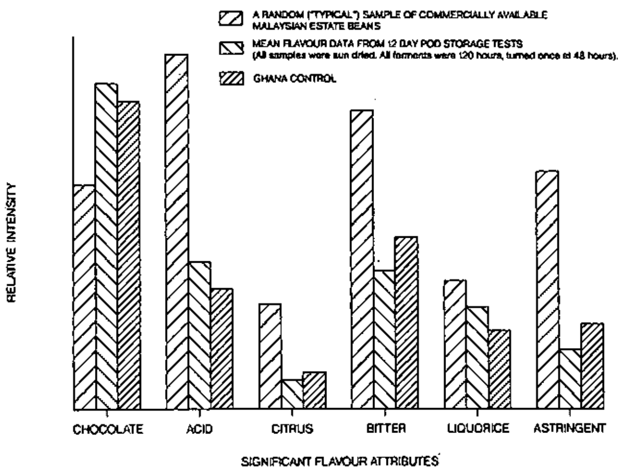
Irrespective of fermentation treatment, sun drying resulted in cocoa of significantly different flavour from that obtained by current Malaysian hot air drying methods. The major differences as shown in Figure 4, were associated with the chocolate, acid, citrus, bitter and astringent attributes. For the sun dried beans the intensities of these attributes were all a good deal closer to that of the Ghana control.

Figure 2. Flavour characteristics resulting from different periods of storage of cocoa pods before splitting to commence fermentation.



The rate of the flavour development during sun drying was studied, and results of the kind shown in Figure 5 were obtained. These imply that the flavour improvements provided by sun drying are largely complete after about 70 to 90 hours drying. The degree of flavour improvement from sun drying did vary for specific attributes between tests. However, although not always significant for the same attributes between tests, for any particular test there was always an improvement observed.

Figure 3. The flavour characteristics of beans from pods stored for 12 days before splitting, relative to a random ("typical") Malaysian estate bean sample and the Ghana control sample.



As indicated in Figure 6, 70 to 90 hours sun drying also coincided with:

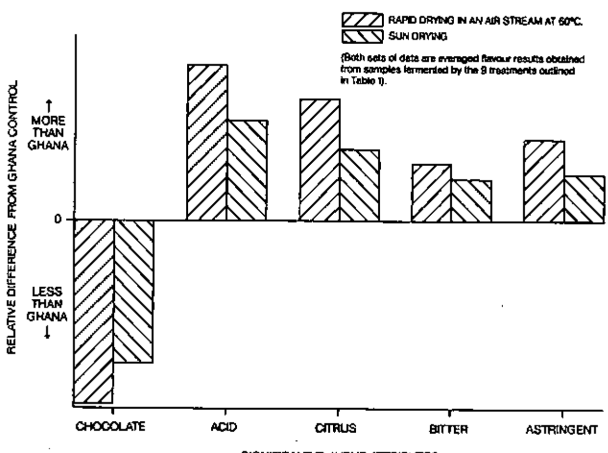
- about 20 per cent moisture content;
- loss of bleaching from the cotyledons;
- loss of mechanically free liquid from the cotyledons;
- the cotyledon reaching its final titratable acidity value;
- the level of fully brown and partly brown/purple beans present reaching their final levels.

It was also the point at which the drying rate changed, becoming much slower as moisture closely associated with the cotyledon itself was being removed.

With drying in a 60°C air-stream all of these changes occurred much earlier in the drying process and complete drying to 7.5 per cent moisture was achieved within 48 hours. When the bean moisture content was between 35 and 40 per cent the shells became dry to the touch, although there was still mechanically free liquid associated with the cotyledons.

Titratable acidity was found to correlate well with flavour acidity. For hot air dried beans it was typically between 30 and 40mMoles NaOH per 100g of dry nib which was about 50 per cent higher than that for sun dried beans. Loss of bleaching in beans drying in a 60°C air-stream was also rapid and occurred at higher moisture contents. The final level of fully brown beans was 60 to 70 per cent compared to 30 to 40 per cent in the sun dried cocoa.

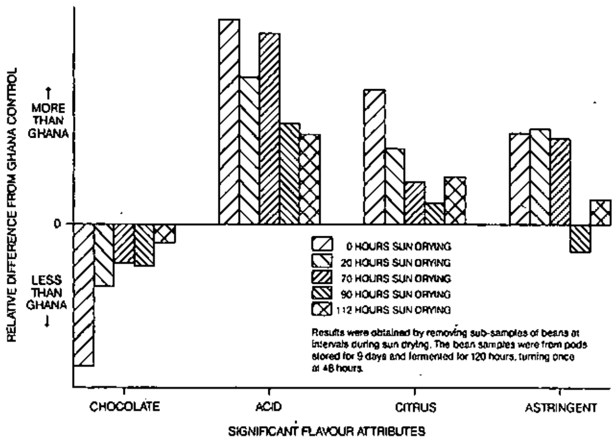
Figure 4. Comparison of the average flavour fermentation resulting from sun and hot air drying of beans at 60°C.



0 represents the base line for the Ghana control sample.

These data suggest that acid removal from beans during drying, and the resultant flavour improvement, are related to the diffusion of free liquid out of the cotyledon. During sun drying, moisture evaporation from the shell is replenished by the free liquid from the cotyledons. This free liquid contains dissolved acids (pH = 3.2), and is thus the mechanism by which acids are removed from the cotyledons. This process of acid removal continues until the free liquid is exhausted. The shell then dehydrates and drying of the cotyledon itself commences. Drying in 60°C air-stream, the shell is in contact with a hot dry gas and apparently loses moisture faster than it can be replenished by the diffusion of liquid from the cotyledon. As a result the shell dehydrates much more quickly than during sun drying and evaporation continues from inside the bean while there is still residual free liquid. The acids dissolved in the residual free liquid thus remain within the cotyledon resulting in a higher final cotyledon titratable acidity.

Figure 5. Typical flavour changes occurring during sun drying as indicated from the assessment of samples subjected to sun drying for various periods followed by rapid drying in a ventilated oven at 60°C.



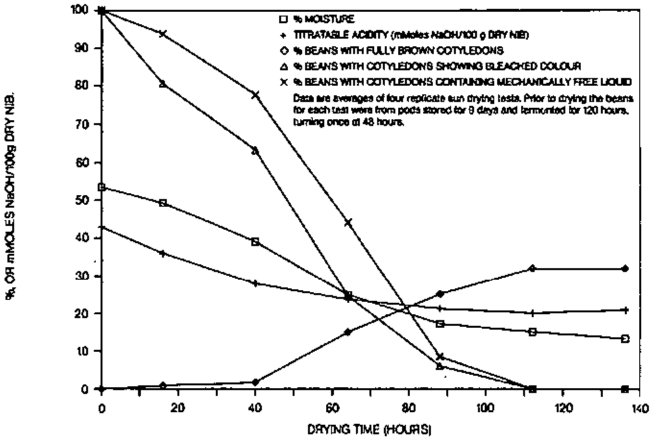
0 represents the base line for the Ghana control sample.

After fermentation the cotyledons have a bleached appearance. The more rapid loss of this bleaching and the higher level of browning which occurs during hot air drying (compared with sun drying), suggest that air penetration of the cotyledon is also inhibited by the moist shell. The different drying processes allowed air penetration of the cotyledon at different moisture contents, causing the differences in colouration between sun and hot air dried beans. The cut test colouration achieved by sun drying was typical of West African cocoa having 30 to 40 per cent fully brown beans and 60 to 70 per cent partly brown/partly purple. Hot air dried beans contained more than 60 per cent fully brown beans, which is typical of commercial Malaysian cocoa.

THE DEVELOPMENT OF AN IMPROVED ARTIFICIAL DRYING PROCESS

These data imply that the lowest acidity will result from drying conditions which balance the rate of evaporation of liquid from the surface of the bean with its rate of diffusion from the cotyledon. When drying rates were too slow the beans began to putrefy, and when too fast, titratable acidities were high and the flavour did not differ from that obtained by the current hot air drying regime.

Figure 6. Physical and chemical changes recorded during sun drying of cocoa beans as indicated by analysis of samples drawn at intervals.



On average, cocoa beans drying in the sun lost about 1 per cent of available moisture per hour during the first 70 to 90 hours, with bean temperatures rising from about 30°C to 45°C as drying proceeded. This drying rate was achieved using a flat bed dryer, by continuously blowing ambient air through the bean bed at an off-bed rate of about 0.3m/s. Due to the heating effect of the fan the actual temperature of the drying gas was about 1.5°C above the local ambient temperature, which varied between 25°C and 32°C and from 100 per cent to 60 per cent relative humidity. This small heating effect resulted in a slight lowering of the relative humidity of the drying gas which was sufficient to maintain drying even when ambient conditions during rain were at 100 per cent relative humidity. When beans achieved 20 per cent moisture, the drying temperature was raised to 60°C and reduction to 7.5 per cent moisture was completed in about 12 hours.

Artificial drying tests using these conditions, as shown in Table 2, produced a reduction in titratable acidity similar to that observed during the sun drying tests. Attempts to raise the drying temperature to 35°C produced a drying rate which appeared to exceed the rate of liquid diffusion from the cotyledon and resulted in higher titratable acidity, equivalent to the 60°C drying process (see Table 2).

These test beans showed improved flavour compared with beans dried at 60°C. In particular as shown in Figure 7, the test beans showed a significant reduction in acid, citrus, bitter, brown fruit and liquorice attributes and an improvement in the chocolate attribute. The flavour attributes for sun dried beans were still closer to the Ghana control than were the test beans. However, relative to the flavour of beans dried at 60°C, the difference between the sun dried and test dried samples was small.

TABLE 2: Recorded titratable acidities of cocoa beans in tests of various drying procedures

	Titratable acidity (mMoles NaOH/100g dry cotyledon) after treatment in indicated replicate				
Treatment/stage	1	2	3	4	5
Wet bean*	42.4	37.2	45.1	43.5	39.0
60°C drying**	31.8	30.3	36.3	-	32.2
Ambient air drying+	24.7	21.8	23.8	24.6	-
35°C air stream drying@	-	-	-	-	31.7
Sun drying	23.4	-	21.4	22.2	19.7

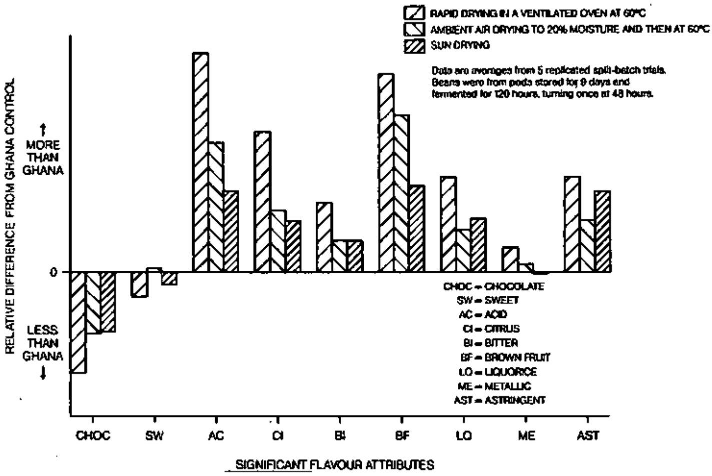
* beans immediately after fermentation, before drying. Batches split for the different drying treatment comparisons

** in a ventilated over at 60°C, to simulate "conventional" hot air steam drying

\+ test conditions - ambient air blowing until 20% moisture, followed by 60°C drying until 7.5% moisture

@ as above, except first stage in 35°C air stream

Figure 7. Effect of initial slow drying in ambient air ("simulated sun drying") on the flavour of Malaysian cocoa beans in comparison with rapid drying in air at 60°C, and with sun drying, relative to a Ghana control sample.



0 represents the base line for the Ghana control sample.

CONCLUSIONS AND PRACTICAL CONSIDERATIONS OF FERMENTARY AND DRYER DESIGN, TO IMPLEMENT THE SIME-CADBURY PROCESS

The results of this project demonstrate that the flavour of Malaysian cocoa, and therefore its quality as perceived by cocoa and chocolate manufacturers, can be improved to the point that beans with a flavour similar to West African cocoa beans can be produced in Malaysia. The processing steps required to achieve this flavour improvement involve:

- post harvest pod storage of 9 to 12 days;
- fermentation periods of about 120 hours;
- a single turn after about 48 hours fermentation;
- fermentation bean depths of about 40 cm;
- beans surfaces covered during fermentation;
- drying by blowing ambient air until 20 per cent moisture and then air at 60°C.

Except for drying, the time elements in the above procedures should not be treated as aboslutes but as target objectives, since they were derived from tests performed within the normal operating constraints of a large estate. Further, as indicated by Duncan (1986) it is likely that optimum flavour will result from 'bulking' of cocoas processed around these conditions, rather than by exactly achieving them every time.

The adoption of these processing methods and the subsequent flavour improvement should widen the market for Malaysian cocoa, and help to address the current price discount. However, all of these new processing methods are very different from current Malaysian estate practices, and the adoption of some will present practical problems on certain estates. During this project attempts were made to address some of the perceived difficulties. Besides the improvement in quality provided by these processing conditions, and the economic implications, other benefits in terms of method of operation, material handling and bean recovery were identified. Some of these advantages and disadvantages are considered below.

POD STORAGE

Storing pods for up to 12 days probably represents the largest deviation from current practice and will present the most problems. Theft and rodent damage are probably the largest drawbacks with storing pods in the field. If storing pods in the field is not practical or acceptable, the concept of a central pod storage and splitting area has to be considered. By correct design for material handling such a facility can be contemplated.

Increased harvesting costs will result from collecting pods rather than wet beans, and, in the absence of an alternative use for them, involve the need to send pod husks back to the field. These costs can be minimised by reorganisation of labour and the use of purpose designed collection equipment. They may be further off-set by new opportunities and financial incentives which result from bringing pods into a central area. These include:

- the opportunity to control the quality of pods harvested;
- the possibility of central pod insecticide treatment to control pod pests, mainly the cocoa pod borer;
- improved field sanitation and reduction of pest breeding opportunities;
- better recycling of the nutrients in pod husks, by more even re-distribution, possibly with reduced bulk after composting;
- the possibility of smoothing production peaks by flexibility in pod storage durations while maintaining regular harvesting schedules;
- the financial incentive to develop a practical and efficient pod breaker;
- the possibility of mechanising all wet bean handling;
- the incentive to find alternative "value added" uses for pod husks.

FERMENTATION

The indicated fermentation regime is simpler than current practice, requiring less material handling, and thus there is less opportunity for bean damage and losses to occur. Involving only one turn, it lends itself to single level fermentary design requiring less space, fewer fermentation boxes and less labour.

DRYING

The proposed drying process achieves 80 per cent of the required drying duty with ambient air and thus at much reduced energy cost. This first stage takes about 80 hours. Since shells do not strongly dehyrdrate, they do not become brittle and so are less vulnerable to mechanical damage during this period. The second drying stage, taking beans from 20 per cent moisture to 7.5 per cent using air heated to 60°C, is achieved within 15 hours.

Other material handling problems associated with drying wet beans were dealt with by limiting dryer loadings during the first stage to 0.13 tonnes per square metre. This gave an average bean depth of about 12cm and very even drying. this low bed loading and the longer total drying time during the first stage means that more drying area will be required for this process than for current dryers. However, since only the second stage requires a heat source, this stage would best be performed in a unit separate from the first. With this arrangement, and allowing for loading and discharge, a second stage dryer could handle the output from five ambient air blowers of the same dimensions. Since the first stage dryers are only blowing ambient air, they do not require burners, heat exchangers or hot air ducting. They can therefore be of relatively cheap construction.

The absence of hot dryer surfaces during the early stages of drying when the beans are wet and sticky, eliminated burn-on and bean clumping. This and the omission of agitation for the first 12 hours elimianted smearing and blinding or blocking of the holes in the dryer bed. As a result, during these tests, no cleaning of the dryer bed was necessary despite continuous use over a three week period, and bean damage from the action of the dryer was insignificant. Other observations suggest that using a flat bed dryer under these conditions, with correct agitator design and set up, bean damage during drying could be virtually eliminated. This type of flat bed dryer also lends itself to mechanical discharge which could be directly onto a conveyor feeding either the second stage dryer or a bean grader/bagger.

RECOMMENDATIONS AND FUTURE DEVELOPMENTS

The processing methods described, if adopted in their entirety, will produce a product which is superior in flavour to that of current Malaysian estate cocoa and quite similar to West African cocoa. The work described was based upon kilogramme bean samples taken from tests batches of sizes of up to 0.5 tonnes of dry bean equivalent. As described in the Introduction, the flavour of West African cocoa is not produced by any individual farmer but by 'bulking' the produce of many farmers. It is anticipated that this bulking effect will be achieved during the practical implementation of these recommendations and by the scale up that it involves. To evaluate this more fully and to assess the practical and economic implications of this novel processing method, Sime Darby Plantations are in the process of constructing a new purpose built facility on Devon Estate, Melaka. This facility will aim at developing all of the above findings. It is anticipated that the practical experiences from the operation of this new factory will be reported in the literature in due course.

ACKNOWLEDGEMENT

The authors are grateful to Mr K.S. Rajah, manager of Merlimau estate and his staff and staff at Ebor Laboratories for their cooperation and assistance.

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Stone, H.J, Sidel, S., Oliver, A. Woolsey & R.C. Singleton (1974) Sensory evaluation by quantitative descriptive analysis. Food technol. 28 (11) p.24-32.

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COCOA ABSTRACTS ARE REPRINTED FROM 'ABSTRACTS ON TROPICAL AGRICULTURE' PUBLISHED BY THE ROYAL TROPICAL INSTITUTE, AMSTERDAM

NOVEMBER 1988

Effects of temperature on growth and water relations of cocoa (Theobroma cocoa var. Comum) seedlings.
GOMES, A.R.S. and KOZLOWSKI, T.T. Department of Forestry, University of Wisconsin, Madison, Wisconsin, USA - Plant and Soil (Netherlands) v. 103(1) p.3-11 1987.
In growth chamber experiments in Wisconsin, USA, it was found that growth of 55-day-old cacao var. Comum seedlings varied with temperature regimes, various plant parts, growth parameters, and time of harvesting. Over a 60-day period the optimal day-temperature regimes were near 33.3°C for dry weight increase and relative growth rates of seedlings and leaves; 30.5°C for increase in leaf area, height growth, and leaf abscission; 22.2°C for dry weight increase of stems or roots, stem diameter growth and root-shoot ratio. The rates of increase in dry weight of stems or roots as well as root-shoot ratios declined progressively at temperatures above 22.2°C. Partitioning of dry matter was affected by temperature regime, with proportionally more photosynthate retained by shoots and less translocated to roots at high temperatures. The progressive decrease in the root-shoot ratio at temperatures above 22.2°C may decrease drought tolerance of seedlings because roots will be less capable of absorbing enough water to replace transpirational losses. This was shown by more negative shoot water potentials at high temperatures.

DECEMBER 1988

Report for the period 1982/83-1984/85 Cocoa Research Inst., Tafo, Ghana - Annual Report - Cocoa Research Institute p.242 1986.
In this report of the Cocoa Research Institute in Ghana the progress made in research and development during the period 1982/83 to 1984/85 is reported, with emphasis on agronomy, entomology, plant breeding, plant pathology, plant physiology and biochemistry, and soil science.

22nd Report 1986. Research Dept., United Plantations Berhad, Teluk Intam, Perak, Malaysia, p.111 1987.
The results of experiments with oil palm, coconuts and cocoa, covering the fields of breeding and selection, cultural practices and nutrition, over the year 1986 are presented. In the Dura improvement programme, the highest oil yielders produced 47.7 and 48.9 kg oil/palm/tree/year. Productivity trials were conducted using Elaeis oleifera from Colombia. In the section of coconut and dwarf breeding and selection, trials were made using tall and dwarf types. Urea, at the rate of 2.4. kg/palm/year depressed nut yield by around 6% whereas KCL increased the oil and albumen content of the nut. In cocoa, besides breeding and selection, budding versus cutting was examined. In addition the results of some trials in the field of crop protection were reported.

Management of the cocoa pod borer.
OOI, P.A.C., CHAN, L.G., CHONG, K.K., HAI, T.C., MAMAT, M.D.J. TUCK, H.C. and SOON, L.G. - Malaysian Plant Protection Society, Kuala Lumpur p.201; 1987.
The cacao pod borer, Conopomorpha cramerella (CPB, syn. Acrocercops cramerella) is to date a most serious pest of cacao in the Oriental Region of the world. From the Sulawesi region in the 1860's the CPB was seen to have spread in a westerly arc. CPB is also known to attack fruits of several fruit trees. Late in 1980, CPB was attacking about 5000 ha of cacao in the Tawau region of Malaysia. Biology, extent and severity of damage (biological) control measures of, and host plant resistance to, CPB are discussed in detail.

The palm civet: a pest of cocoa.
BHAT, S.K., SUJATHA, A. and THOMAS, K.G. Central Plantation Crops Research Inst., Kasaragod, Kerala, India - Indian Cocoa, Arecanut and Spices Journal v.10 (3) p.63-66; Jan. 1987.
In 2 districts of Karnataka and 12 districts of Kerala, India, a total of 944 cocoa farmers were contacted during 1985-86 to determine the prevalence of the palm civet (Paradoxurus hermaphroditus). The pest was present in 29.24% of the fields. A trial on 4 farms showed that civets in cocoa could easily be controlled by baiting with 0.5g carbofuran granules placed in longitudinal slits in ripe bananas, which were tied in pairs to 5 or 6 tree trunks/ha.

Effect of metabolites of Aspergillus niger and Trichoderma viride on development and structure of radicle of cocoa seedlings.
ODAMTTEN, G.T. and CLERK, G.C. Department of Botany, University of Ghana, Legon, Ghana - Plant and Soil (Netherlands) v. 106(2) p.285-288; Feb. 1988.
In Ghana, trials were conducted to study the effects of Aspergillus niger and Trichoderma viride, which inhibit the vegetative growth and sporangial formation of Phytophthora palmivora on the development of radicles and the growth of seedlings of cocoa. Both the volume and concentration of filtrate of A. niger and T. viride influenced the development of the radicles of cocoa seedlings. Radicles placed in petri dishes containing filter paper moistened with 20 and 30 ml of undiluted filtrate and filtrate dilutions of 1 : 1 and 1 : 2 failed to develop lateral roots and eventually died. The culture filtrate of A. niger was more repressive than that of T. viride. Radicles in the same volume of filtrate (20 and 30 ml) of higher dilutions (1:5 and 1:10) developed lateral roots and survived. Radicals placed in less volume ($\leq$ 10ml) survived and produced lateral roots irrespective of concentration of filtrates. Development of the radicles and roots in the control was consistently better than in filtrate solutions of either A. niger or T. viride. The hypocotyls of seedlings under the influence of metabolites of A. niger showed greater cambial activity and formed xylem vessels and tracheids with larger lumina.

JANUARY 1989

On the identity of a lymantriid defoliator of cashew and cocoa in South India.
RAMASESHIAH, G. and BALI, R. Hebbal Agricultural Farm Post, CAB International Inst. of Biological Control, Bangalore, Karnataka, India - Current Science (India) v. 56(22) p.1191-1192; Nov. 1987.
In Tamil Nadu and Karnataka, India, large numbers of destructive lymantriid larvae were collected from cashew and cocoa and reared in the laboratory. The moths were identified as Lymantria ampla. Figures of a gravid female and a male moth from south India which had been identified as Lymantria obfuscata agreed with L. ampla. Neonatal larvae of L. obfuscata from Kashmir failed to develop on cashew leaves in the laboratory. The male and female genitalia of L. obfuscata and of the moth from cashew in the south of India differed significantly and the parasite complex of L. obfuscata was found to be different. In the light of these observations the record of L. obfuscata on cashew and cocoa in the south of India is erroneous.

[Natural drying of cacao beans using a solar dryer] Secagem natural de cacau em estufa solar.
PASSOS, F.J.V. and FREIRE, E.S. CEPLAC, Itabuna, Bahia, Brazil, 10p. Undated.
The efficacy of a solar dryer for cocoa beans is discussed. Its drying capacity varies between 35 to 65 kg of beans/m^2, in 7 to 12 days, depending on the hours of sunshine. This solar dryer could also be used for drying other produce, such as coffee beans and Capsicum peppers. The commonly applied sun-drying method, using removable coverings, has a capacity of 30 kg beans/m^2 in 10 days and is more labour intensive. The construction of the solar dryer is explained, using drawings.

FEBRUARY 1989

Cocoa production technology in Ghana: an application of the translog production function.
GYIMAH BREMPONG, K., AKAAH, I.P. and DADZIE, K.O. Social Sciences Div., New Coll. of the Univ. of South Florida, Sarasota, Florida, USA - Eastern Africa Economic Review (Kenya) v. 3(1) p.15-20. July 1987.
Cross section data from cocoa farming in Ghana in 1988 were used to determine whether cocoa production technology in Ghana exhibited constant returns to scale; whether the inputs, land and labour, were separable, and whether the production function was of the Cobb-Douglas functional form. The calculated returns to scale was 0.9284, indicating that cocoa farming in Ghana exhibited decreasing returns to scale. The inputs were not separable in the production function and above all, the production technology was not of the Cobb-Douglas functional form.

Physical and chemical composition of Indian cocoa beans.
MALINI, E., PURANIK, J. SHIVASHANKAR, S. and NAMBUDIRI, E.S. Central Food Technological Research Inst., Mysore, Karnataka, India - Journal of Food Science and

Technology (India) v. 24(2) Mar. 1987.
The quality of cured cocoa beans from Kottayam (Kerala), Puttur and Sakaleshpur (Karnataka) and Chundale (Tamil Nadu) in India was studied. The following ranges of variation were found: weight per bean 0.78-0.89 g, violet beans 0-24%, salty beans 0-5%, insect damaged and fungus infested beans 0-20%, whitish beans 0-20%, rejects 0-32.5%, nibs 82.7-85.9%, shell 14.1-15.2%, moisture 4.33-6.10%, total ash 2.97-3.14%, water insoluble ash 1.48-1.91%, alkalinity of water soluble titrable acidity 2.17-2.88, volatile acidity 0.92-1.16, total sugar content 0.96-1.00%, lactic acid 0.27-0.57%, citric acid 0.56-0.88%, tannins 2.05-2.72%, theobromine 1.32-2.04% and fat 48.30-52.63%.

MARCH 1989

The Cocoa industry in Malaysia: a summary of research findings.
SENFTLEBEN, W. Institute of Southeast Asian Studies, Singapore, Singapore - Philippine Geographical Journal (Philippines) v.31(3-4) p.119-127; Jul. 1987.
Malaysia is currently the World's sixth largest producer of cocoa beans. In 1985, Malaysia produced around 100,000T of dry beans. The growth rate is remarkable. In 1965, a total of 2940 ha was planted, but in 1984 an area of 241,000 ha was covered by cocoa. The overwhelming part of cocoa is grown on medium-sized plantations. Historical development, the role of cocoa in the entire economy and in the regional economy, the shade regime, governmental policy, the activities of the Malaysian Cocoa Research and Development Board, the taxation of cocoa, cocoa smallholdings the rehabilitation of cocoa beans, the promotion of policy, production costs and the outlook for the planting of cocoa are discussed. In contrast to other countries growers have been largely spared from devastating pests and diseases.

Litter production and nutrient cycling in coffee or cocoa plantations with shade trees.
BEER, J. Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), Turrialba, Costa Rica - Agroforestry Systems (Netherlands) v. 7(2) p.103-114; 1988.
The relative importance of N fixation, organic material inputs and nutrient inputs in litterfall, as justifications for including shade trees in plantations of coffee or cocoa, is discussed. According to existing data, N fixation by leguminous shade trees does not exceed 60 kg N/ha/year. However, these trees contribute 5000-10000 kg organic material/ha/year. Comparisons were made between the leguminous shade tree Erythrina poeppigiana and the non-leguminous timber tree Cordia alliodora. The former, when pruned 2 or 3 times/year, could return to the litter layer the same amount of nutrients that were applied to coffee plantions via organic fertilizers, even at the highest recommended rates for Costa Rica of 270 kg N, 60 kg P, 150 kg K/ha/year. The annual nutirent returned in this litterfall represents 90-100% of the nutrient store in above-ground biomass of E. poeppigiana, and hence the consequences of competition with the crop should not be a serious limitation. In the case of C. alliodora, which is not pruned, nutrient storage in the tree stems, especially of K, is a potential limiting factor to both crop and tree productivity. It was concluded that, in fertilized plantations of cocoa and coffee, litter productivity is a more important shade tree characteristic than N fixation.

Soil suitability and management implications of soil taxonomy with special reference to tree crop cultivation.
PARAMANANTHAN, S. Department of Soil Sciences, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - Pertanika (Malaysia) v. 10(2) p.125-134.
Information on categories of soil classification (orders, sub-orders, great groups, sub-groups, families and series) is followed by a discussion of soil suitability and management interpretations using soil taxonomy for perennial crops, namely, rubber, oil palm, cocoa and coconut moisture. Factors limiting crop grwoth include climate, topography, moisture, physical and chemical soil properties. Each of these factors can further be subdivided into different land characteristics. Excepting topography, most of the other limiting factors can be evaluated using the family category. Moreover, various management requirements to alleviate these limitations can be ascertained.

[Spatial study of production in a cocoa plantation using the regionalized

variables method]. Etude spatiale de la production d'une cacaoyere suivant la methode des varaibles regionalisees.
CILAS, C. and LECOUSTRE, R. IRCC Kpalime, Togo - Cafe Cacao, The (France) v. 32(4) p.299-310; Oct. 1988.
The application of recent statistical methods which permit the description and structural analysis of a spatial variable are presented. The production of a cocoa plantation in Togo was investigated. Maps of the plot under study are presented together with different semi-variograms providing information on the spatial structure of heterogeneity. In this particular example, examination of the different semi-variograms revealed the existence of oriented structures within the plot. Mapping, associated with the application of smoothing algorithms may provide a useful tool in selection.

APRIL 1989

Control of Phytophthora palmivora on cocoa and durian seedlings.
CHAN, L.G. and LIM, T.K. Department of Plant Protection, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - Journal of Plant Protection in the Tropics (Malaysia). V.4 (1) p.9-13; June 1987.
In Malaysia, a trial was conducted to evaluate the acyalanine compounds metalaxyl-mancozeb (Ridomil MZ) and benalaxyl-mancozeb (Galben MZ), and the acyalanine derivatives cyprofuram (Vinicur) and milfuram (RE 20615) compared with fosetyl (Aliette), etridiazole (Terrazole), propamocarb (Previcur N) and captafol (Difolatan) for their prophylactic and therapeutic efficacy as a foliar spray and soil drench against Phytophthora palmivora on cocoa and durian seedlings. The metalaxyl-mancozeb mixture exhibited its superiority over the other chemicals in both protective and curative foliar spray and soil drench. It was followed by cyprofuram, fosetyl and milfuram order of descending overall effeciveness. Captafol was next in efficacy when used as a spray, followed by etriadazole as a soil drench. Benalaxyl-mancozeb was comparatively less efficacious, while propamocarb was the least efficacious while propamocarb was the least effective both as a drench or foliar spray.

The effect of biocide treatment on the storage and associated fungi of cocoa seeds.
HOR, Y.L. Faculty of Agriculture, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - Seed Science and Technology (Switzerland). V, 16(1) p.261-272. 1988.
In Malaysia, the efficacy of 9 fungicides to control fungi in stored cocoa seed was evaluated. After the fungicide treatment the seed was stored up to 28 weeks in an air-conditioned room (22 $\pm$ 2°C; 55% relative humidity). After storage of 2 weeks all untreated seeds were infected by storage fungi and germination was reduced to only 3%. With fungicide treatment, germination of approximately 80% was maintained for 12 to 18 weeks. The best treatment was 0.2% (w/w) of an equal benlate-thiram mixture applied as a dust or soak. Periodic retreatment at 6 weeks interval was not advantageous. The most damaging fungi was species of Penicillium (P. cyclopium and P. citrinum), Aspergilus (A. flavus and A. niger) and Botryodiplodia theobromae, Rhizopus arrhizus and Paecilomyces variotii were less destructive.

MAY 1989

[Research results in coffee and cocoa]. Institut de Recherches du Cafe et du Cacao (IRCC), CIRAD, Paris, France. p.56; 1988.
This publication contains 2 articles, one dealing with polyphenols in the beans of cocoa and the other with the growth and harvest of Robusta coffee. The article on cultivation and harvest of Robusta coffee gives detailed data on land preparation, selection of planting material, planting density, fertilizer management, irrigation, control of pests and diseases and weeding.

JUNE 1989

23rd Annual Report 1987. Research Dept., United Plantations Berhad, Teluk Intan, Perak, Malaysia. pp. 109; Feb. 1988.
The results of experiments in oil palm, cocoa and coconut at the United Plantations, Malaysia are presented. Data are supplied on breeding and selection, cultural practices, plant nutrition, tissue culture and crop protection.

Cocoa Growing in India.
ABRAHAM, C.S., THOMAS, K.G. and VELAPPAN, E. Directorate of Cocoa, Arecanut and Spices, Calicut, Kerala, India - Indian Cocoa, Arecanut and

Spices Journal (India) v. 11(1) p.1-9; July 1987.
Though cocoa was introduced into commercial production in India in the early 1960's, its large-scale cultivation started in the early 1970's. The major cocoa growing states are Kerala, Karnataka and Tamil Nadu. The area under cocoa is about 22000 ha. The estimated cocoa beans production during 1985-86 was about 8000t. Various aspects of cocoa growing in India are discussed: habitat, varieties, climate and soils, shade, (cultivation planting material, planting, manuring and irrigation, training and pruning, insect pests and diseases and harvesting), fermentation and drying, storage of dried beans and economics of cultivation of cocoa as an intercrop under irrigated conditions.

Pollination biology of Theobroma and Herrania (Sterculiaceae). 2. Analyses of floral oils.
ERICKSON, B.I., YOUNG, A.M., STRAND, M.A. and ERICKSON, E.H. Department of Entomology, University of Wisconsin, Madison, Wisconsin, USA - Insect Science and its Application (Kenya) v. 8(3) p.301-310; 1987.
In Costa Rica, the composition of the floral fragrance oils of Theobroma cacao, Theobroma mammosum, Theobroma simiarum and Herrania cuatrecasana were studied. Between 58 and 78 floral volatiles per species are listed. The major components were 1-pentadecane, n-pentadecane, n-pentadecane, n-pentadecane and other hydrocarbons for T. cacao; isoeugenol and an array of linalool oxides for T. mammosum; and n-tricosane and other saturated hydrocarbons for T.mammosum. The volatiles of T. simiarum included terpenoids as citral, geraniol, nerol and citronellol. H. cuatrecasana contained unusual volatiles such as : iridomyrmecin, guaiol and other azulenic deratives. The composition of the floral fragrance, as measured for T. cacao, varied considerably during the day. The role of the floral fragrance as a pollinator attractant is discussed.

Notes on distribution of ant-Homoptera interaction on selected crop plants.
ADENUGA, A.O. and ADEBOYEKU, K. Department of Plant Science, University of Ife, Ife, Nigeria. Insect Science and its Application (Kenya) v. 8(2) p.239-243; 1987.
In Nigeria, the seasonal abundance of homopterans and their tending ants was surveyed on cocoa, mango and pigeon pea. About 50% of the ant species examined tend more than 1 Homoptera species. The ant-Homoptera association observed and the damage caused by the homoptera is briefly described. The populations of the ants tend to synchronize with the population of the Homopterans which they tend during the season.

Pollination biology of Theobroma and Herrania (Sterculiaceae). 1. Floral biology.
YOUNG, A.M., ERICKSON, E.H. STRAND, M.A. AND ERICKSON, B.J. Invertebrate Zoology Section, Milwaukee Public Museum, Milwaukee, Wisconsin, USA - Insect Science and its application (Kenya) v. 8(2) p.151-164; 1987.
The floral characteristics related to pollination were studied in Theobroma cacao, Theobroma simiarum, Theobroma speciosum, Theobroma mammosum and Herrania cuatrecasana in Costa Rica. The stigmata and style receptivety, assessed by H_2O_2 tests, were high throughout the morning and early afternoon in T.cacao. Bagged flowers resulted in no fruit-set. When petal ligules were removed there was no change in the rates of flower abortion. Both Theobroma and Herrania flowers possessed ultraviolet light reflectance/absorbance patterns which may play a role in pollinator attraction. The uptake of neutral red stain in T. cacao and T. simiarum showed scattered glandular activity on petals and sepals, perhaps indicating the location of nectaries or other secretory organs. Conspicuous glandular trichomes on the ovary, on the lower third of the style, and in a conspicuous basal ring between petals and sepals (most pronounced and colourful in species other than T. cacao) may be sources of both floral attractant and reward.

[New data on the induction and development of somatic embryos of cacao]. Donnees nouvelles, sur l'induction et le developpement d'embryons somatiques chez Theobroma cacao L.
DUHEM, K. MERCIER, N. LE and BOXUS, PH. Station des Cultures Fruitieres et Maraicheres, Gembloux, Belgium - Cafe, Cacao, The (France) v. 33(1) p.9-14; Jan 1989.
In Belgium, zygotic embryos of cocoa (var. Trinitario x Upper amazon) were grown in darkness on 2 culture media; Murashige/Skoog (MS) + naphthalene

acetic acid)(10.75 μM) and MS + benzyl amino purine (4.42 μM) and MS + benzyl amino purine (4.42 μM) + indole acetic acid (0.57 μM) + gibberellic acid (0.029 μM). Somatic embryogenesis regeneration was obtained on both media, but only from immature zygotic embryos. Plantlets with leaves and roots were obtained from somatic embryos on media with various concentration of zeatin or 2-isopentenyl adenine, after the cotyledons had been removed. The percentage of plantlets obtained from somatic embryos was considerably improved by reducing the mineral salt concentration in the media as well as by adding activated charcoal to the growth medium. The gaseous exchange between the inside of the culture vessels and the external environment was important for obtaining plantlets from somatic embryos.

[Large-scale cocoa seed preparation]. Preparation des semences de cacaoyer en grandes quantites.
DURIS, D. Institut de Recherches du Cafe et du Cacao (IRCC), Abidjan, Ivory Coast - Cafe Cacao, The (France) v. 33(1) p.15-26; Jan. 1989.
In order to meet the demand for the large amounts of cocoa seeds required for implementing agricultural projects, IRCC (Ivory Coast) attempted to formulate a seed preparation technique, since the existing solutions did not comply with the economic, technical and plant protection constraints which rules out transporting pods. The aim was to conserve the viability of the beans removed from the pods at rates of around 75 to 80% for 2 or 3 weeks. By removing the mucilage with enzymes and coating the seed, the germination rate can be maintained at about 80% during storage. When seeds were packed in polystyrene boxes with inert material, the relative humidity was kept at 100%, the beans were protected from low temperatures and the CO_2 and O_2 rates were maintained at acceptable levels. No fermentation or mould was found in the boxes for the storage periods involved. The results obtained for consignments to Sao Tome and Vanuatu were very encouraging since germination rates of arond 85% recorded for strorage periods ranging from 15 to 21 days.

JULY 1989

[The effect of methods of application of indole butyric acid on budding of caca] Pengaruh pemakaian asam indol butrik pada okulasi tanaman kakao.
SUBRONTO and CHAIRANI, M. - Buletin Perkebunan (Indonesia) v. 18(3) p.98; Sep; 1987.
In Indonesia, the effect of brushing and spraying indole butyric acid (IBA) at levels of 0, 100 and 1000 ppm on the success rate of budding and on the growth of cocoa buds was studied. Upper Amazon hybrid rootstocks were budded with Pa 35. Observations carried out up to 2 weeks after growth of the buds were similar for both application methods. The addition of IBA at 100 ppm increased the length and diameter of the new shoots and the width of the leaves. However, the addition of IBA did not significantly increase the success rate of budding.

[The cocoa industry in Malaysia] Die Kakaowirtschaft und Kakaopolitik in Malaysia.
SENFTLEBEN, W. Institute of Southeast Asian Studies, Singapore, Singapore - Mitteilungen des Instituts fur Asienkunde Hamburg (Germany F.R.).
The cocoa industry in Malaysia is described. Attention is paid to: historical development; cocoa as a plantation crop; the role of cocoa in the economy; the shade regime; cocoa pests and diseases; goverment policy towards cocoa; cocoa smallholdings; marketing cocoa beans; linkage effects of the cocoa industry; cocoa promotion policy; employment; and production costs. Malaysia is currently the world's 6th larger producer of cocoa beans. In 1985 Malaysia produced about 100,000t of dry cocoa beans out of a total world production of 1,802 million tonnes. Until 1990 it is envisaged that another 80,000 ha of cocoa will be added to the already existing 285,000 ha.

Comparative drought tolerance of cocoa accessions.
BALASIMHA, D., RAJAGOPAL, V., DANIEL, E.V., NAIR, R.V. and BHAGAVAN, S. Regional Station, Central Plantation Crops Research Inst., Vittal, Karnataka, India - Tropical Agriculture (Trinidad and Tobago) v. 65 (3) p.271-274. July 1988.
In Karnataka, India, a study was conducted to gain information on the relative importance of several attributes of drought tolerance in cocoa cacessions, in terms of crop adaptation and yield stability. The

water relation components, stomatal behaviour and biochemical parameters were determined in 14 cocoa accessions. Based on the parametric relationships with drought tolerance, the rank sums of these accessions lead to the selection of NC 23, NC 29, NC 31, NC 39 and NC 42. These drought tolerant accessions had an effective stomatal regulation resulting in a decreased transpiration rate under water stress. Although a decrease in osmotic potential and nitrate reductase activity and an increase in soluble sugar were noticed in response to stress, there was no relationship with respect to drought tolerance. The stomatal diffusive resistance was neatively correlated with transpiration. The cocoa accessions with the higher drought tolerance characteristics and higher yield potential under drought stress should be useful basal material for selective breeding.

Some entomopathogenic fungi isolated from Conopomorpha cramerella.
LIM, T.K., RITA, M., OOI, P.A.C. and CHIN, C.I. Department of Plant Protection, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - Planter (Malaysia) v. 64(753) p.548-554; Dec. 1988.
In Selangor, Malaysia, 4 entomopathogenic fungi were isolated from pupae of Conopomorpha cramerella. Two strains of Paecilomyces fumosoroseus were isolated, one from cocoa collected in Sua Betong, Negri Sembilan, and one from rambutan collected in Serdang, Selangor. Beauveria bassiana was isolated from rambutan collected in Serdang, Selangor, and Paecilomyces lilacinus from namnam (Cynometra cauliflora) collected in Sri Lanka.

[The effect of pre-cropping on soil fertility in an area intended for cocoa cultivation]. Pengaruh 'pre-cropping' terhadap kesuburan tanah pada areal pertanaman kakao.
LUBIS, S. and PANJAITAN, A. - Buletin Perkebunan (Indonesia) v.18(4) p.153-154, 167-176,; Dec. 1987.
In an experiment in North Sumatra, Indonesia, the effect of 3 crops on the physical and chemical properties of the soil was studied. Soya bean, groundnut and maize were grown during the period of shade establishment for cocoa. Analyses of the soil at a depth of 0-20cm and 20-40 cm taken before and after growing seasons showed fluctuations in the pH and in the C, N, available P and exchangeable K, Mg and Ca contents. Accordingly, agronomic practices such as manuring and the types and rotation of crops planted in areas intended for cocoa cultivation need adjustments.

[The effect of stumping and bending of rootstocks and the use of growth regulators on budding of cocoa]. Pengaruh zat tumbuh pada mata tunas okulasi dengan pemotongan dan pelengkungan batang bawah pada tanaman coklat.
SUBRONTO and HUTOMA, T. - Buletin Perkebunan (Indonesia) v.18(1) p.3, 29-33; April 1977.
In an experiment in Indonesia, the effect of stumping and bending of rootstocks and the application of growth regulators on budding of cocoa was studied. The different growth regulators tested were indole butyric acid and Ethrel 48 PGR (epephon) (both at 100 and 1000 ppm), and kinetin and giberellic acid (both at 100 and 500 ppm). Cocoa (var. ICS 60) was budded on Upper Amazon seedling rootstocks. Observations during the first 6 weeks after budding showed that bending the buds produced considerably longer and thicker shoots and more leaves than stumping. The application of growth regulators at the highest concentration produced a significant higher success rate as compared with the untreated control. The results also indicated a higher success rate with bending. No interaction was found between the 2 types of treatment.

[The relation between the seed position in the pod and the early growth of seedlings of cocoa]. Uji keturunan hibrida poliklonal kakao kebun benih Simirik di pembibitan.
LUBIS, S. and NAPITUPULU, L.A. - Buletin Perkebunan (Indonesia) v. 18(4) p.154; 177-185; Dec. 1987.
In North Sumatra, Indonesia, an experiment was carried out with cocoa to study the relation between the seed position in the pod and the growth of seedlings during the first 6 months. One progeny of Trinitario cocoa, 4 of Forastero Amazon cocoa and a control (var. No. 3) were tested. The seeds were removed from either the centre or the tip and base of the pod. The results showed that the position of the seed gave no significant differences in the growth of the seedlings. The control showed a weaker growth than the progenies of Trinitario and Forastero

Amazon cocoa.

AUGUST 1989

[Control of leaf-cutting ants in cocoa plantations]. Controle das formigas cortadeiras em plantios de cacau.
ABREU, J.M. DE and DELABIE, J.H.C. Divisao de Zoologia, Centro de Pesquisas do Cacau, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) v. 16(4) p.199-211; Oct. 1986.
Information on the geographical distribution and the economic importance of the leaf-cutting ants belonging to the genera Atta and Acromyrmex, in cocoa-producing countries of South and Central America is presented. In addition, economic losses caused by these ants are presented. Several methods of control have been used or evaluated; however, in Brazil chemical control is limited to 2 chlorinated baits. New insecticides for chemical control as well as the management of predatory or repellent ants for biological control need to be evaluated.

[The installation, modification and operation of a traditional tubular oven dryer with heat exchanger in the cocoa region of Bahia, Brazil]. Instalacao, modificacao, orientacao e operacao do conjunto fornalha-trocador de calor do 'secador tubular' tradicional da regiao cacaueira da Bahia.
CUNHA, J. and MCDONALD, C.R. Centro de Pesquisas do Cacau, Ilheus, Bahia, Brazil - Boletim Tecnico - Centro de Pesquisas do Cacau (Brazil) No. 144, 22p. 1986.
During many years, the very complicated common tubular dryer was the only competitor of the sun drying of cocoa beans in Bahia (Brazil). Sun drying is a very slow process, covering a period of 10 days on average. A new tubular oven with heat exchanger was developed, which avoids the production of smoked beans. Comprehensive explanations and many technical drawings are provided.

[Stratification of cocoa growers in Bahia, Brazil]. Estratificacao de produtores.
GASPARETTO, A., MONTEIRO, A. AND TOURINHO, M.M. Pontifica Univ. Catolica do Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil p.28 1987. Reprint from Fespi No. 8 Jul-Dec 1987.
In Brazil, stratification by grouping of cocoa growers residing in the state of Bahia, on the basis of 4 classes of production volume, had been made over a period of 2 years. The average price paid to the cocoa growers, price fluctuations and alternatives for the method used for grouping, are discussed.

Effect of Cladobotryum antibiotic on the major pathogens of cocoa in Brazil.
BASTOS, C.N., NEILL, S.J. AND HORGAN, R. Divisao de Fitopatologia, Comissao Executiva do Plano da Lavoura Cacaueira (CEPLAC), Belem, Para, Brazil - Revista Theobroma (Brazil) v. 16(4) p.213-221.
An antifungal antibiotic was isolated from the culture filtrate of Cladobotryum amazonense a hyperparasite of Crinipellis perniciosa, the causal agent of the witches' broom disease of cocoa. The compound was isolated and purified by extraction with butanol followed by chromatography on Sephadex LH-20, paper and with HPLC. Tests undertaken in vitro with purified antiobiotic showed and inhibitory effect on the mycelial growth of C. perniciosa and Phytophthora palmivora. This compound also was considerably toxic to sporangia and basidiospores of P. palmivora and C. perniciosa, respectively. This in vitro activity of the fungitoxic compound is merely an indication of the possible usefulness in the control of the witches' broom pathogen.

[Antibiotic action of metabolites from Penicillium citrinum on Phytophthora palmivora]. Acao antibiotica de metabiolitos de Penicillium citrinum sobre Phytophthora palmivora.
BASTOS, C.N. Divisao de Fitopatologia, Comissao Executiva do Plano da Lavoura Cacaueira (CEPLAC), Belem, Para Brazil - Revista Theobroma (Brazil) v. 17(1) p.31-37.
Strains of the fungus Penicillium citrinum were detected in Para, Brazil, as a contaminant in cultures of Phytophthora palmivora, an agent of the black pod disease of cocoa. Preliminary observation showed that the strain P. citrinum has a great antagonistc effect on P. palmivora. Laboratory tests carried out with the partially purified antibiotic showed that the active ingredient was considerably toxic to P. palmivora to both mycelial growth in vitro and on lesion formation capacity in vivo.

[Controle of Phytophthora bark canker of cocoa using metalaxyl]. Control del cancer del tronco (Phytophthora spp.) del cocoa con metalaxyl.

ARDILA, N. AND CUBILLOS, G. Compania Nacional de Chocolates, Bucaramanga, Colombia - Cacaotero Colombiano (Colombia) v.10(34) p.32-36.
In Colombia, an investigation was performed on the bark canker (BC) of cocoa, which is caused by Phytophthora spp. and has been reported in many parts of the cocoa areas of the country. Traditionally, the control of BC has been achieved by excision of the diseased tissue, but this method has been replaced by scraping away the bark cover and around the canker patches, followed by painting with a 0.25% Ridomil (metalaxyl) suspension. The curative treatments with Ridomil, proved to be effective, and small lesions were able to recover quickly.

[Chemical control of the Mexican mite in cocoa]. Controle quimico do acaro mexicano Tetranychus mexicanus (McGregor, 1950) em mudas de cacaueiro.
NAKAYAMA, E., ABREU, J.M. DE AND FERRAZ, E.C. De A. Divisao de Zoologia, Centro de Pesquisas do Cacau, Itabuna, Bahia, Brazil - Revisto Theobroma (Brazil) v. 17(1) p.9-16; Jan 1987.
In Bahia, Brazil research was carried out on the mite, Tetranychus mexicanus, which frequently occurs on cocoa under nursery and greenhouse conditions. A greenhouse trial was conducted to study the efficacay of 7 pesticides. The treatments included fenopropathrin at 15 g, cyhexatin at 25g, propargite at 34 g, methamidophos at 36 g, avermectin at 0.5 and 0.63 g, binapacryl at 32 and 40g and bromopropylate at 15 g.a./100 l water. Living mites and larvae were counted at 1, 3, 8, 12, 14 and 19 days after treatment of the young cocoa seedlings. With the exception of bromopropylate, all the compounds tested attained an average efficacay of >80% during the 19-day-evaluation period.

Pulp preconditioning: a new approach towards quality improvement of Malaysian cocoa beans.
SAID, M., MEYER, B. AND BIEHL, B Cocoa/Coconut Research Division, Malaysian Agricultural Research and Development Inst. (MARDI), Serdang, Selangor, Malaysia - Perak Planters' Association Journal (Malaysia) 1986.
Malaysian cocoa bean quality is affected by a residual acidity. Pulp reconditioning prior to fermentation in order to reduce anaerobic alcoholic fermentation was found successful in increasing the flavour potential and reducing the acid content of beans. The pulp quality as ensured through pod storage and bean spreading prior to fermentation. The various processing stages are extensively discussed.

[Butter content of cocoa varieties of the CATIE collection at Turrialba, Costa Rica]. Contenido de grasa en las semilla de clones e hibridos de cacao Theobroma cacao L., del Catie, Turrialba, Costa Rica.
LOPEZ, B.,O., AND ENRIQUEZ, G.A. Centro Agronomica Tropical de Investigacion y Ensenanza (CATIE), Turrialba, Costa Rica - Cacaotero Colombiano (Colombia) v.10 (34) p.23-31; June 1987.
In Costa Rica, a study was done to examine the butter content of 43 varieties of cocoa, selected in Mexico, Peru and Costa Rica. Cocoa beans contain a high percentage (40-60%) butter. The Mexican varieties usually showed higher percentages (48.8%) as compared with the varieties selected in Costa Rica (47.7%). To study the hereditary transmission of the butter characters, genetic analyses were done of the varieties: POUND 7, SCA 6, UF 613 and UF 676. Hybrids such as UF 613 x UF 676 and POUND 7 x UF 613 showed the highest butter content.

[Conservation of cacao seed viability. 4. Effects of fungicides and seed pelleting]. Conservacao da viabilidade da semente de cacau. 4. Efeitos de fungicidas e peletizacao.
FIGUEIREDO, S.F.L., Revista Theobroma (Brazil) v. 16(4) p.177-188; Oct 1986.
In Brazil, a comparison was made between the efficiency of 7 fungicides and the pelleting technique in conserving the viability of cocoa seeds. Seeds from ripe fruits were used and in all treatments stored in polyethylene bags at 25 ± 1°C. Seeds without tegument (membrane) showed a higher germination percentage than those with tegument. Obviously, increasing the storage period reduced the germination rate. The best results were obtained with the fungicide Neantina (phenylmercuric acetate) which kept seeds viable for up to 100 days of storage, followed by Benlate (benomyl) which preserved them to 70 days. There were no significant differences between treatments with the fungicides Arasan (thiram), Cupravit Azul (copper oxychloride) and Nitrosan [2-(thiocyanomethyl thio) benzothiazole]. The poorest results were obtained with Polyran. Several storage fungi were found in all treatments during different storage periods. It is

concluded that fungi were responsible for seed deterioration when stored. Pelletized seeds remained viable for only 20 days and this method was not meant to be recommended for preservation of (cacao) seed viability.

[Bamboo (Bambusa vulgaris) as shelterbelt
for young cacao trees shaded by bananas in Bahia, Brazil]. Bambu (Bambusa vulgaris) como protecao lateral de cacaueiros jovens sombreados com bananeiras (Musa sapientum L.) no Reconcavo da Bahia, Brasil.
PINHO SOUZA, A.F. DE AND MULLER, M.W. Estacao Experimental Sosthenes de Miranda, Centro de Pesquisas do Cacau, Santo Amaro, Bahia, Brazil, Revista Theobroma (Brazil) v.17(1) p1-8; Jan 1987.
In Bahia, Brazil, the mechanical damage caused to young cocoa plants by high wind speeds was studied. This wind damage made farmers use windbreaks. For its wide availability, easy propagation and canopy structure, bamboo has been used for this purpose. However, the bamboo roots caused the death of young cocoa plants and decreased banana tree growth which was used as temporary shade. In an attempt to avoid these damages trenches of 20, 40 and 60 cm depth were set between the bamboo row and the cocoa and banana tree area. The penetration of the bamboo roots in the cocoa and the banana tree area was limited by the trenches. This effect increased with the depth of the trench. The results indicated that bamboo could be a suitable plant as cocoa windbreak since the negative effect caused by its roots can be avoided, with trenches of 60 cm deep.

SEPTEMBER 1989

Annual Report 1985/86. Cocoa Research Inst., Tafo, Ghana 129, p.1987.
Research activities on cocoa and coffee on the Cocoa Research Institute in Ghana conducted in the year 1985/86 are reviewed. The activities include investigations on cocoa rehabilitation, shading of cocoa, weed control in coffee by means of herbicides, and, for both crops, the control of pests and diseases, varietal improvement and fertilization. Attention is paid to plant physiology and biochemistry, as well as soil science items such as soil fertility related to shade and cocoa nutrition.

Present status of witches' broom disease of cocoa in Trinidad.
LAKER, H.A., SREENIVASAN, T.N. AND KUMAR, D.R. Cocoa Research Unit, University of the West Indies, St Augustine, Trinidad & Tobago - Tropical Pest Management (UK) v.34(3) p.318-323; Jul 1988.
A survey was conducted of 21 estates and cocoa germplasm collections at locations representative of the cocoa growing areas of Trinidad to determine the current status of witches' broom disease of cocoa on the island. The disease caused by Crinipellis perniciosa was prevalent at all the sites investigated. However, its incidence was considerably less than that reported in the 1940s and 1950s. The widespread cultivation of resistant cocoa genotypes appeared to be the dominant factor responsible for the reduced disease level. It is also observed that recommended management practices such as fertilizer application, regular weeding and shade regulation, all conductive to vigorous tree growth, were neglected on most estates. Consequently, the heavily shaded crop does not flush or flower so intensely as to provide an abundant supply of susceptible tissues for the pathogen which only attacks meristematic tissues.

[Cost of application of malathion for the control of insect pests of cocoa]. Custo de aplicacao de malathion no controle de pragas do cacaueiro.
ABREU, J.M. DE AND MONTEIRO, A.
Divisao de Zoologia, Centro de Pesquisas do Cacau, Itabuna, Bahia, Brazil - Boletim Tecnico - Centro de Pesquisas do Cacau (Brazil) no.141, 10 p.1986.
In Bahia, Brazil, an experiment was carried out to evaluate the cost of malathion application. Three methods of application, dusting, spraying and thermal fogging, were tested. The experiment was conducted in 12 ha planted with cocoa hybrids; 3 x 3m spacing, shaded with Erythrina sp., with a 24 x 24m spacing, and with 1 tree in the intersection of the diagonals. Malathion was applied at the rate of 300 g.a.i./ha in all formulations. Cost estimates were calculated on the basis of equipment depreciation, interests on capital loans, repairs, replacement of spare parts and other expenses. Results showed that the cost of spraying was 71.34, dusting 81.38 and thermal fogging 83.92 units/ha.

Annual Report of the Cocoa Research Institute of Nigeria 1986.
Cocoa Research Inst. of Nigeria, Ibadan, Nigeria 90p. 1987.
The annual report of the Cocoa Research Institute of Nigeria summarizes and evaluates all the activities developed over 1986, covering the field of cocoa, among which the most important are: herbicide and pesticide trials, fertilizer application and crop improvement through breeding activities. Other research programmes concerning crops such as kola, cashew, tea and coffee are also presented. In the kola programme the improvement of kola production propagation, processing and storage of nuts are studied. The cashew programme covers the improvement of establishing and management of plantations and plant protection measures. Research activities concerning tea include improvement of crop production and crop protection. The farming systems programme deals with the performance of tree crops in crop mixtures. The crop (waste) utilization programme, a wine project and improvement of thermo-resistant properties of chocolate production are studied.

OCTOBER 1989

Cocoa and Coconuts: progress and outlook.
PUSHPARAJAH, E. (Ed) & CHEW POH SOON (Ed). Incorporated Society of Planters, Kuala Lumpur (Malaysia) 980p. 1986.
A report on the International Conference on Cocoa and Coconuts is given and 80 papers presented at the conference are included. The papers are concerned with plant breeding and selection, plant physiology, plantation management, plant diseases, insect pests, fertilizer management, processing, marketing and by-products of coconut and cacoa.

[Cocoa warty pod disease in the Ivory Coast] La maladie verruqueuse des cabosses du cacaoyer en Cote d'Ivoire.
KEBE, B.I. & THOUVENEL, J.C. Institut de Recherches du Cafe et du Cacao (IRCC), Abidjan, Ivory Coast - Cafe, Cacao, The (France) v. 33(2) p. 83-99.
Wart pod disease, a new cocoa disease in the Ivory Coast, produces blister swellings on small discoloured spots on the surface of the pods. These swellings do not interfere with the normal development of the pods, but rot appears on the ripening pods. The work in the Ivory Coast has dealt with the development of the disease, epidemiological study, damage assessment and research into the primary cause. Botryodiplodia theobromae, the agent of the wart rot, is not the primary cause of the appearance of the disease, nor is any other pathogen, and mineral deficiency is not considered to be the cause of the disease. The results obtained with field trials indicate that an insect might cause wart pod disease, however, the insect or insects involved remain to be identified.

NOVEMBER 1989

A model of cocoa replanting and new planting in Bahia, 1966-85.
TRIVEDI, P.K. - Policy, Planning & Research Working Papers (World Bank) no.92, 50p; Sep 1988.
An analysis was made of new planting and replanting of cocoa in Bahia, Brazil, during the period 1966-85. Specifications for new planting and replanting derived from a cost-of-adjustment model were estimated. The results show that new planting and replanting activities are correlated to fluctuations in the price of cocoa. New planting was positively correlated to the cocoa price whereas replanting was, in the short-run, negatively correlated. At increasing prices the productivity and profitability of marginal plantings improved, which in turn reduced the incentive for uprooting and replanting. The results of the analysis further provides information on the efficacy of policies, the role of interest subsidies for the rehabilitation of the cocoa sector, and on the prospects for future expansion of this sector in Bahia.

[Characteristics of litter and its relation with the top soil fertility in cocoa plantations]. Caracteristicas do manto detritico e sua relacao com a fertilidade da camada superficial do solo em plantacoes de cacau.
LEITE, J. DE O. Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil - Revista Brasileira de Ciencia do Solo (Brazil) v.11(1) p.45-49; Jan 1987.
In Bahia, Brazil, research was done on the use of litter which consists of organic matter (plant residues), of macro- and microorganisms and thin roots of cocoa trees and shade trees which cover the top soil of cocoa plantations. The dry matter and the

chemical composition of the litter were measured and the relationship to A 11 horizon fertility was studied. Four cocoa plantations were involved: the first and second without shade trees, the third under Erythrina fusca shade and the fourth under native shade trees, on a red-yellow podsolic soil. The following results were obtained (a) a quantity of litter dry matter of 11.6 t/ha on average, (b) a variation of the contents and reservoirs of Ca, N, Mg, K and P in the litter and in the top soil according to the type of cocoa planting and the quantity of litter dry matter, and (c) a close relationship between the chemical composition of the litter and of the top soil, the Mg content having a particular position because of its correlation with Ca, N and P in the litter and in the top soil.

Studies on the feeding value of agro-industrial by-products: strategies for improving the utilisation of cocoa-pod-based diets by ruminants.
SMITH, O.B., OSAFO, E.L.K. & ADEGBOLA, A.A.A. Department of Animal Science, University of Ife, Ife, Nigeria - Animal Feed Science & Technology (Netherlands) v.20(3) p.189-201; Jun 1988.
In Nigeria, forage supplementation and chemical treatment, both potentially capable of improving cocoa-pod utilization by ruminants, were evaluated. Supplementation with Gliricidia sepium at 1.0% yielded no positive results. Feed intake, growth rate and feed/gain for control and test cattle were similar. Chemical treatment using solution of cocoa-pod ash (CPA) was more successful. Rumen degradability of cocoa-pods treated with CPA, equivalent in alkalinity to 2 (P_2), 4 (P_4), 6 (P_6) and 8 (P_8) g NaOH per 100g, was improved with the DM, acid detergent fibre (ADF) and neutral detergent fibre (NDF) disappearance rates of samples respectively. The digestibility of DM in cocoa-pod-based diets treated with either NaOH or CPA of equivalent alkalinity being similar. The degradability of DM, ADF and NDF increased from 25, 12 and 7% (control) to 55, 44 and 45% for P_6- and 55,46 and 42% for P_8-treated samples, based diets increased from 45 (untreated) to 55% (P_8 treated) in sheep and to 60% in goats. Nevertheless, treatment with P_8 reduced daily feed intake. Feed intake was, however, normal for diets containing P_6-treated cocoa-pods for sheep and goats. The concentration of CPA for treating cocoa-pod should, therefore, not be greater than the P_6 level.

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