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EDITORIAL

There are many millions of small farmers in West Africa whose livelihood depends on the successful and economic cultivation of cocoa. Their planting material and techniques of cultivation have hardly altered over the last 5 decades and for cocoa to continue to be an economically competitive crop for them improvements in planting material and technology are essential. On the other hand, there are an increasing number of large plantation companies growing substantial cocoa in the Far East. Both the technology and the planting material for these two diverse groups of cocoa growers are different and so research must be directed to the specific problems of each group. The large plantation companies in the Far East are now funding their own research and developing their own hybrids. However, research for the many millions of small growers must be conducted by governments and these small growers also need an efficient extension service to inform them of the recommendations arising from the research. Scarce resources in terms of money, manpower and equipment will continue to plague many research institutions in the countries where smallholders grow cocoa.

A 'network' system of coordinated research programmes could make better use of the scarce resources which are available. One of the disciplines which lends itself best to this 'network' approach is that of the collection, conservation, characterisation and evaluation of germplasm. The first three activities should be carried out by a small number of internationally funded centres while the evaluation should be carried out in a diversity of cocoa growing environments in all cocoa producing countries. Logically, the international centres should be funded by the larger international donors with some assistance from the host country in each case. The evaluation programmes would be funded by national governments with assistance from the international donors as appropriate.

The international cocoa community should review the historic situation and the future requirements for germplasm collection, conservation, characterisation and evaluation, allocate responsibilities and arrange for adequate funding for this 'network'. It is somewhat ironical that research on a crop giving a livelihood to many millions of smallholders is not considered to be an appropriate activity for funding by most donors who readily give to other research institutions within the CGIAR system. Is it not now time for this policy to be changed? Cocoa cannot be considered an industrial crop similar to rubber, oil-palm or sugar grown almost exclusively by large plantation companies.

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R.A. LASS, Editor

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REVIEW OF PRODUCTION AND CONSUMPTION
January 1986 - April 1987

A.B. Cook, Cadbury Limited

PRODUCTION

Since our last review, based on Gill and Duffus's March 1986 report, the production position has changed significantly. Even at that stage they were still underestimating by 19,000 tonnes what the world 1984/85 production had been. In addition the forecast that the 1985/86 crops would be lower than 1984/85 did not prove to be the case, with the Ivory Coast providing most of the additional tonnage.

Their forecast for 1986/87 shows a small decline compared with 1985/86, partly caused by Nigeria where the privatisation of the cocoa industry caused some of the early new crop tonnages to be exported in the previous crop year. In Brazil the total tonnage is expected to be similar to the previous year but this has been made up of a record main crop followed by an extremely disappointing Temporao. Production in Malaysia continues to expand rapidly and the recovery in Ghana continues, with increased production for the third consecutive year.

CONSUMPTION

After the dramatic recovery in consumption in 1984 and 1985, 1986 was rather disappointing, showing a small decline against 1985 in spite of the significantly lower cocoa prices from February 1986 onwards. Gill and Duffus have not published detailed country-by-country grinding estimates for 1987 in their new report but they do give a global figure of 1,868,000 tonnes for the 1986/87 season, an increase of 47,000 tonnes compared with their global figure for the 1985/86 season, thus showing a delayed response to the cheaper cocoa prices.

STOCKS

Gill and Duffus are now forecasting that world stocks at the end of September 1987 will be 709,000 tonnes, marginally higher than the September 1982 figure, which will be the highest level since 1965. Thus over the last 5 years we have seen a 2 year drop from 705,000 tonnes in 1982 to 388,000 tonnes in 1984 and a 3 year recovery back to the 1982 level.

INTERNATIONAL COCOA AGREEMENT

A new International Cocoa Agreement was agreed in outline in July 1986 but it was not until March 1987 that the detailed rules which would allow its Buffer Stock mechanism to operate were agreed. This ICA differs from the previous ones in that its support prices are denominated in Special Drawing Rights (SDR's), a weighted basket of the major international currencies. In an individual currency, therefore, the support prices vary as the currency rates change. The market price at the end of March 1987 was marginally

WORLD COCOA PRODUCTION AND GRINDINGS DATA

Reproduced from Gill and Duffus Market Report 325

Dated April 1987
(all figures in thousand metric tonnes)

Production	1983/4	1984/5	1985/6 (estimate)	1986/7 (forecast)
WORLD TOTAL	1517	1950	1961	1932
Africa	861	1080	1102	1065
S.America	463	655	606	582
W.Indies	52	53	54	50
Asia & Oceania	141	162	199	235
PRINCIPAL COUNTRIES				
Cameroon	108	120	118	125
Ghana	159	175	219	230
Equatorial Guinea	8	8	6	6
Ivory Coast	411	565	585	570
Nigeria	115	151	120	80
Brazil	302	412	376	372
Colombia	38	41	43	45
Ecuador	48	121	103	80
Mexico	35	42	40	40
Venezuela	16	15	18	18
Dominican Republic	39	39	40	36
Malaysia	80	93	125	150
Papua New Guinea	28	31	30	30

GRINDINGS	1984	1985	1986 (estimate)	1987*
WORLD TOTAL	1750	1830	1823	
Western Europe	663	686	683	
Eastern Europe & USSR	894	930	913	
N.America	231	226	223	
Central & S.America	355	394	383	
Australia & N.Zealand	11	7	6	
Asia	98	109	140	
Africa	161	164	158	
PRINCIPAL COUNTRIES				
United States	209	205	203	
Germany (FR)	194	207	201	
Netherlands	161	167	183	
USSR	150	160	150	
United Kingdom	90	91	89	
France	52	42	40	
Brazil	214	234	215	
Ivory Coast	85	90	90	

* forecast not included in Market Report 325

below the initial support level of 1600 SDR's and it was anticipated that the Buffer Stock Manager would be ready to start operating around the end of April.

PRICES

Prices fell sharply from January to June 1986 as it became progressively clearer that the 1985/86 production was significantly better than had been anticipated. There was a rally between July and September 1986 on a combination of reaction to the new Cocoa Agreement and initial concern about the coming 1986/87 crops. Since October prices have moved gradually lower as it has become clear that the crop outturn will be similar to the previous year and also significantly above the current consumption levels.

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

1986	January	£1855
	February	£1661
	March	£1530
	April	£1385
	May	£1421
	June	£1362
	July	£1480
	August	£1628
	September	£1587
	October	£1580
	November	£1515
	December	£1480
1987	January	£1400
	February	£1375
	March	£1350

Cocoa Growers' Bulletin No. 38 May 1987

COCOA BREEDING: PAST, PRESENT AND FUTURE

A.J. Kennedy+, G. Lockwood++, G. Mossu*,
N.W. Simmonds** and G.Y. Tan***

INTRODUCTION

The Cocoa Chocolate and Confectionery Alliance, in April 1986, brought together a small group of research workers concerned with plant breeding and genetics in general, but with a specific interest in cocoa. The aim of this meeting was to review the current state of cocoa breeding in various countries and to make recommendations on a broad front as to the future direction that cocoa breeding and germplasm utilisation should take.

The discussion group comprised Prof. N.W. Simmonds (University of Edinburgh) (Chairman), Dr. A.J.Kennedy (Cocoa Research Unit, UWI, Trinidad), Dr. G. Lockwood (Commonwealth Development Corporation), Dr. G.Mossu (Institut de Recherches du Cafe et du Cacao, France) and Dr. G.Y. Tan (Papua New Guinea). The meeting was held over two days and the following paper represents the version of the discussions reflecting the general views of the group. The initial draft was prepared by Dr. A.J. Kennedy.

OVERVIEW AND HISTORICAL BACKGROUND

Genetic Resources and Conservation

Cocoa is a crop of ancient origins that has become a commodity of major importance to the economies of many countries. From farmer to consumer is a chain of unusual complexity among agricultural products. Starting with the complex ecology of the cocoa farm, some degree of on-farm processing (fermenting, drying) and ending with the production of an array of consumables from confectionery to cosmetics. An account of the total activity associated with cocoa is to be found in Wood and Lass (1986).

Attempts to collect and conserve Theobroma cacao germplasm began early in the twentieth century. These early collections were based on phenotypic selection within local populations of Forastero, Criollo and Trinitario groups and can be regarded as 'land variety' collections. The work of Van Hall (1930) in Indonesia, Pound (1936) in Trinidad and Posnette (1943) in Ghana provide examples. These, and several similar programmes, led to the accumulation of numerous

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clonal selections. In the first instance, such collections were national but many have since been distributed to diverse sites. General accounts of the history, botany and breeding of cocoa can be found in Toxopeus (1969) and Cope (1976).

In the 1920s and 1930s witches' broom disease became a very serious problem in Trinidad, causing widespread devastation in the local Trinitario cocoa population. In response to this situation Pound mounted the first significant collecting expeditions for cocoa germplasm in 1938 and 1943. His only aim at that time was to find resistance to Crinipellis perniciosa, the causal fungus of witches' broom disease (Pound, 1938; Pound, 1943).

The Pound collection consisted of three distinct groups. From Peru he collected the Upper Amazon types consisting then of about 2500 seedlings derived from about 250 pods. These seedlings are grouped into five populations named after their collection sites:- Iquitos Mixed Calabacillo (IMC), Morona (MO), Nanay (NA), Parinari (PA) and Scavina (SCA). Pound's 1938 report indicates that the Parinaris were two distinct populations. In 1942-43, Pound collected budwood from eight of the parental trees of the seedling collection and 24 others which became known as the P (Peru or Pound) clones.

The third group of Pound's collections was from Ecuador where he selected 80 "Refractario" trees showing apparent resistance to witches' broom disease. From these 80, some 320 pods were collected. They were all selected on commercial haciendas and each subgroup was named after the estate from which it came. The Refractarios are a highly heterogeneous population which has received scant attention from breeders.

Many of the Pound accessions are maintained by the Cocoa Research Unit of the University of the West Indies, Trinidad. Kennedy (1984) lists those that are still extant in the International Cocoa Genebank, Trinidad.

Trinidad is also the source of two other collections from the centre of diversity of the crop. In 1952, an expedition jointly by the Cocoa Research Unit, Trinidad and the Colombian Government yielded the SPEC collection which contained also some wild Theobroma and Herrania species. Between 1968 and 1972 Chalmers collected cocoa from the Oriente region of Ecuador (Chalmers, 1972). Very few of these two collections survive in Trinidad (or elsewhere) and they were never systematically distributed.

A valuable collection of Criollo material is conserved in Costa Rica at the Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE), Turrialba. Because of the threat that they may become extinct, Criollos are considered by IBPGR to be of highest priority for immediate conservation.

The great value of the Pound collection has stimulated further collecting in the area considered to be the centre of diversity. The London Cocoa Trade Amazon Project has collected systematically in

Eastern Ecuador (Allen and Lass, 1983). Large scale collecting is also underway in Brazil and, recently, expeditions have collected samples in Mexico, Colombia and Venezuela.

IBPGR recognised the threat to wild cocoa posed by wide-scale clearing of forest in South and Central America and, consequently, designated cocoa as a priority crop for conservation (Anon, 1981). It is essential that the now widely based collections of cocoa be effectively distributed, evaluated and exploited by breeders. To this end, IBPGR nominated two "base collections": those at the Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad (CRU/UWI) and at the Centro Agronomico Tropical de Investigacion y Ensenanza, Turrialba, Costa Rica (CATIE).

The mobilisation of this germplasm depends not only on the genebanks but also on the existence of suitable plant quarantine facilities. At present, such facilities are sadly lacking. Although the Cocoa Research Unit, Trinidad operates a regional quarantine station in Barbados (for the Americas and Caribbean), the only internationally recognised quarantine is in the facilities maintained by the United States Department of Agriculture and the American Cocoa Research Institute in Miami, Florida, USA.

Breeding

Tree crops in general (and cocoa is no exception) have long generation times. In cocoa there can be a minimum of 5 years between generations but, more realistically, the interval is likely to be 8-10 years. Progress is, therefore, likely to be slow and response to changes in direction even slower. It is important, then, that breeders have clear objectives. Table 1 summarises cocoa breeding efforts and results in the major growing areas.

TABLE 1
Cocoa Breeding Worldwide

PLACE	PRODUCTION	BREEDING BEGUN (decade)	SEEDLINGS /CLONES PREFERRED	BENEFIT /IMPACT
Brazil	+++	1950	S	little
Other SA	++	1920	S	nil to some
Caribbean	+	1930	C	some
Ghana	++	1930	S	some
Cameroon	+	1950	S	substantial
Nigeria	+	1930	S	little
Ivory Coast	++++	1950	S	substantial
Indonesia	+	1920	S	some (?much)
Malaysia	+	1950	S & C	much
Papua New Guinea	+	1950	S	starting

From this table it is disappointingly apparent that breeding has had, broadly, little impact except in Cameroon, Ivory Coast and Malaysia.

The impact of breeding in these countries appears to have been greatest perhaps because they have only recently planted the greater part of their cocoa areas. Selection work was started in Ivory Coast in 1946 and Cameroon in 1949 by IRCC which led to hybrids showing precocity and high yield compared to the local varieties (Mossu, 1983). There are many and varied reasons for the weak impact of breeding but undoubtedly a major factor has been the narrow genetic base from which most programmes were developed. From Table 1 it can also be seen that cocoa is grown in two ways: as clonal plantings and as seedlings (derived, in principle if not always in practice, from known parents).

Two programmes serve to illustrate the development of the two main alternative routes. In Trinidad (and the Caribbean generally) clonal cocoa predominates. A breeding programme initiated by the Ministry of Agriculture in the 1930s and continued (unbroken) by W.E. Freeman into the 1980s has developed locally adapted TSH clones. The method of breeding was deliberately to restrict the genetic base to as few as four original parents (IMC 67, SCA 6, P 18 and ICS 1) and then, in successive generations of interbreeding, select outstanding individual trees to develop as clones. The objectives were clearly defined (and few): low pod index, resistance to black pod, resistance to witches' broom disease and, to a lesser extent, resistance to wilt disease (Ceratocystis fimbriata). The yield component of pod index was probably the major criterion in the early years, with disease testing becoming more important in later generations. However, since the genetic base was very narrow, progress within this population has come to a halt. The current TSH clones have a potential yield of well over 2 tonnes/ha (in Trinidad) and a pod index of 8-9 pods/kg of dry cocoa. Although, on the face of it, this was a successful programme, there has apparently been little impact on the Trinidad cocoa industry. There are many and complex socio-economic reasons for this which are beyond the scope of this article.

In Anglophone West Africa, cocoa breeding began a few years later than it did in Trinidad and with a different premise: namely that, in the then social, economic and agricultural circumstances, farmers would only plant seedlings. The first step was phenotypic selection of superior individuals on farms and experimental stations, with emphasis on yield and ability to withstand the onslaught of cocoa swollen shoot disease and attack by mirids (Distantiella theobroma and Sahlbergella singularis) (Posnette, 1943). However, in contrast to Trinidad the selections were evaluated as self-pollinated seedling progenies, with a view to eventual distribution of the best selections as clonal seed (Posnette, 1951). Nonetheless, many of the selections were propagated by Posnette and tested as clones (Glendinning, 1964). The progeny of one selection showed sufficient promise to justify establishment of a block of the clone in order to produce seed, but it was never distributed to farmers.

Effective resistance to the spread of swollen-shoot virus or to mirids was not found in the Ghanaian cocoa population of the 1930s so Posnette (1951) obtained more diverse material from Trinidad.

Among this material, seedlings of Upper Amazon origin proved to be particularly valuable and it is appropriate to trace their origin in detail. Pound's (1938) seedling material was quarantined in Barbados and transferred to Trinidad as budded plants, where it was established at Marper (*Marasmius perniciosus*) farm, which is nearly 65km from Imperial College (now University). The Professor of Botany at that time, E.E. Cheesman, took a sample of the budded plants as a demonstration for students and planted them at the College. When Posnette was obtaining his germplasm, travel within Trinidad was restricted by shortage of tyres, and he spent much of his time at the College where he studied compatibility relationships in Cheesman's sample of the Upper Amazon material (Posnette, 1945). In this way seed pods were obtained from crosses involving the Upper Amazon selections IMC 47, 60 and 76, NA 31, 32, 33 and 34 and PA 7 and 35 and these clones subsequently became important to breeders in West Africa and elsewhere.

In Ghana, heterosis was observed in outcrosses of Upper Amazon parents (Posnette, 1943) and its general occurrence was later confirmed in Trinidad (Montserrin, de Verteuil and Freeman, 1957). Exploitation of this heterosis is simple, it being sufficient to cross an Upper Amazon with a Trinitario, a Criollo or an unrelated Forastero. This relatively simple discovery of strong inter-population heterosis provides the basis for almost all modern cocoa breeding programmes (e.g. Toxopeus, 1972).

Nowadays, direct selections from the original Upper Amazon populations are commonly used for seed production, IMC 67, NA 32, NA 33, PA 7, SCA 6 and SCA 12 being particularly important. Elsewhere, selection procedures of varying degrees of sophistication have been adopted. In Trinidad, resistance to witches' broom disease determined the choice of SCA 6 and SCA 12 (Montserrin, de Verteuil and Freeman, 1957) and the outstanding vigour, precocity and yield potential of their hybrids have ensured adoption in a wide range of environments. IMC 67 was selected for resistance to Ceratocystis wilt. In Ghana, Upper Amazon parents were selected within the F1 seedlings introduction for precocity, high yield, bean size and compact growth habit (Knight & Rogers, 1955a). F_1 introductions are also used in Papua New Guinea, while an F_2 introduction from Ghana has been used in the Ivory Coast.

The second parent is often drawn from the local population. In Trinidad, ICS 1 and ICS 6 were used because of their promise as clones and, likewise, the United Fruit Company (UF) clones were adopted as parents in Costa Rica. The large-seeded and self-incompatible Trinitario selection W41 was used in Ghana, together with selected individuals obtained by self-pollination of Posnette's local selections. The Trinitario parents used in Papua New Guinea were derived in much the same way. In Brazil, selfings of Catongo (the SIC 800 and SIC 900 series) have been used. Often the rationale behind use of a 'Local' parent is an expectation that it will confer resistance to locally important pests and diseases, together with satisfactory bean size and quality, which may be deficient in the Upper Amazon material.

In all cases, the self-incompatibility of the Upper Amazon parents, the genetic basis for which has been described (Knight and Rogers, 1955b; Cope, 1962; Glendinning, 1966), has been used to allow seed production by natural pollination in biclonal seed gardens (Glendinning and Edwards, 1961).

The advance obtained from the first series of Upper Amazon hybrids was spectacular and their precocity was of paramount importance in new plantings. In West Africa they have permitted continued planting of the crop in areas where the traditional variety (Amelonado) would now be very difficult to establish. Resistance to Ceratocystis wilt in Trinidad from IMC 67 has been of particular value.

Many of the varieties in current use were selected out of a small number of original crosses. There were nine potential varieties in the original Ghanaian trials, of which seven were approved for commercial use (Lockwood, 1976). In Papua New Guinea, seven Upper Amazon and seven Trinitario parents were evaluated for general combining ability for yield, among which three of each were selected for production of commercial seed (Tan, 1981). Further progress might be expected from more rigorous selection of parents and evaluation of many more hybrids.

The emphasis of selection has been on correction of defects, mostly in relation to disease; but other characters have also been sought, notably drought resistance in Nigeria and larger beans in Malaysia. Many crosses have been made but the new hybrids do not differ greatly from the earlier ones and, in general, further major advances in yield and disease resistance remain to be secured. The over-emphasis on disease resistance has often been counter-productive. Such resistance as is found, because of the testing procedures, tends to be Vertical Resistance (VR). The search for immunity has all too often obscured from the breeder the existence of adequate polygenic, Horizontal Resistance (HR). The dangers of single gene immunity are well known (Van der Plank, 1984) and need no elaboration here. The insistence on high levels of disease resistance leads to the discard of genotypes with good yield potential long before this has been recognised. Nevertheless, during the past, much local resistance has been identified and maintained in breeding lines. Such resistance may not be successful away from its specific, local environment.

Breeding Objectives

All successful breeding programmes must have very clearly defined objectives, thus allowing definite strategies to be developed. The severe problems presented by diseases in all cocoa growing countries have, in the past, had major influences on objectives. All too often, resistance has been so dominant as to become the only objective. While the pressure to generate resistant varieties is understandable, the wisdom of such over-emphasis should surely be questioned. At times it seems that disease resistance has become an end in itself rather than a means to sustain high yield at acceptable production cost. Much of the work on resistance breeding has given disappointing results and it has been stated (Bartley, 1986) that progress has been made only with swollen-shoot virus. The vertical resistance to witches' broom disease has stood up only in Trinidad but has failed in South America where a different pathotype of the fungus exists. However, resistance to wilt disease which may be under the control of a single gene (Gardella, Enriquez and Saunders, 1981), appears to have stood up over a period of time, the experiment to investigate this having spanned 14 years. One undoubted cause for poor progress is the lack of sensitive and reliable methods for screening large numbers of progenies in breeding programmes. There is often concurrently an imperfect understanding of the nature of the interactions between pathogen and host and environment. The scale of effort required to apply screening methods to tree crops is illustrated by the swollen-shoot programme which was described by A.F. Posnette as probably the largest scale of screening ever applied to a tree crop at that time. In general, resources available to cocoa breeders and supporting facilities are seldom commensurate with the problems that they face.

In such circumstances reallocation of resources away from disease resistance would be likely to bring greater rewards.

From the point of view of the cocoa farmer, the main objective is unquestionably a high and stable yield of marketable product. The pathway to this yield may be examined in order to assist the breeder in setting objectives. Yield is the accumulated end product of the interactions between:

> variety - including bean size, shell content, shell thickness etc, (i.e. inherent potential), specific environment (i.e. site, climate), reproductive efficiency (i.e. pollination), general management, specific management

The inclusion of specific environment in the list emphasises the location specificity of breeding programmes. Selection may be even more specific in its aims so that, even within a single country, varieties will be adapted to particular areas depending on such factors as rainfall, altitude, soil type and distribution of disease. There is unlikely ever to be a single new 'wonder' variety that suits all locations.

Part of environment is the management system and here there is a general dichotomy between small-holders (SH) and large estates or plantations (ES). The differences between these systems require that the breeder develops varieties adapted to the appropriate system. Recognition of the importance of Genotype - Environment interaction is essential in selection of varieties for either SH or ES systems. SH systems tend towards low input management and, usually, to the planting of seedling varieties. Estates are geared to intensive systems where more technological input is possible (and economic), with a growing trend to clonal varieties. An exception to this latter generalisation is the Caribbean, where new plantings are almost exclusively clonal although the bulk of production is by small-holders.

The breeder needs to define the components of production that are to be improved. These factors are more or less amenable to selection and therefore improvement depends on the degree of variability in the breeding population. From the base populations available to breeders the following components of yield could be listed as being of major importance:

small trees adapted to high density planting
enough local disease resistance
precocity (to maximise economy)
heavy flowering (mainly on trunk)
self-compatibility (for ease of fruit setting)
high ovule number (to maximise bean production)
large pods (to maximise bean/pod ratio)
favourable partitioning between crop and production of vegetative dry matter

Quality factors are far more uncertain in definition. Flavour is an extremely complex character, having components in variety, fermentation, drying, roasting and general environment. Perhaps butter fat might be increased (or decreased) by breeding? The manufacturing industry needs to define for itself what, if any, quality factors need to be changed and, more importantly, the quantitative basis on which this may be done. The uncertainties of Cocoa definition and estimation of 'quality' are surely a deterrent to the breeder of cocoa (as they are in some other crops).

Figure 1 summarises the pathways that breeding has taken and shows a broad prospect for future development. Detailed tactics for future strategy are dealt with in a later section of this paper. Here again, stress is put on local programmes exploiting local genetic variation. The need to widen the genetic base of each local breeding scheme is evident.

GENETIC RESOURCES AND CONSERVATION

Existing Collections of Genetic Resources

The two major collections (in Costa Rica and Trinidad) hold a great deal of the known genetic resources. They are, at present, complementary rather than duplicative. Although a large representation of this material has passed through intermediate quarantine over the years, rather little has found its way into individual working collections. Many working collections in South American, African and Asian countries hold material that still has to be systematically evaluated and exploited. Some national collections in South and Central America hold material that has not been evaluated, exploited or distributed to the international collections and so is not generally available. However much basic description the genebank custodians are able to accumulate, it will always remain the responsibility of each breeder to evaluate genotypes for local adaptation and breeding potential within specific local breeding programmes. As the IBPGR has often observed, 'characterization' and 'evaluation' are quite distinct activities.

The international cocoa research community must organise itself in order to best utilise what material is already available. There is need to mobilise germplasm which is found only in national collections and to address the general problem of international quarantine for germplasm movement if the material already in genebanks is to be useful on a global scale. Distribution will, inevitably, be a continuing process and momentum will have to be maintained by a concerted and coordinated effort on the part of cocoa breeders and genebank managers.

FUTURE CONSERVATION PRIORITIES

Future Collections

The centre of diversity of cocoa has been partly explored but the main emphasis has been on the Ecuadorian sector of the area. The Peruvian and Peru/Ecuador border regions have so far been neglected. In recent years, extensive collections have been made from the whole of the areas of Brazil where cocoa grows wild.

The need to give high priority to Central American and Pacific coast land races (mainly Criollo) has been recognised by IBPGR (Anon, 1984). Criollo material is, on the whole, poorly conserved in genebanks and is fast disappearing because of changes in land use policies in Central America.

New collection effort must have an emphasis on conservation of genetic resources rather than collection of material of immediate use to breeders. This investment in collecting for use in future breeding programmes is of crucial importance.

Genebank Policy

The genetic resource centres have a major responsibility to accumulate, characterise, maintain and distribute germplasm in their care. Evaluation is the responsibility of the breeder, not of the genebank.

Both the recognised international centres for cocoa germplasm are able to offer an important facility for training in cocoa genetics, breeding and germplasm management. This role should not be underestimated since evaluation and exploitation in local programmes relies on knowledge and understanding for its success.

Since the genetic diversity is readily available only in these centres, new techniques are appropriately developed there too. Isozyme analysis will probably prove a valuable tool for description, characterisation and identification. This system is already being developed in Ivory Coast and Trinidad, with complementary work in progress in England and France.

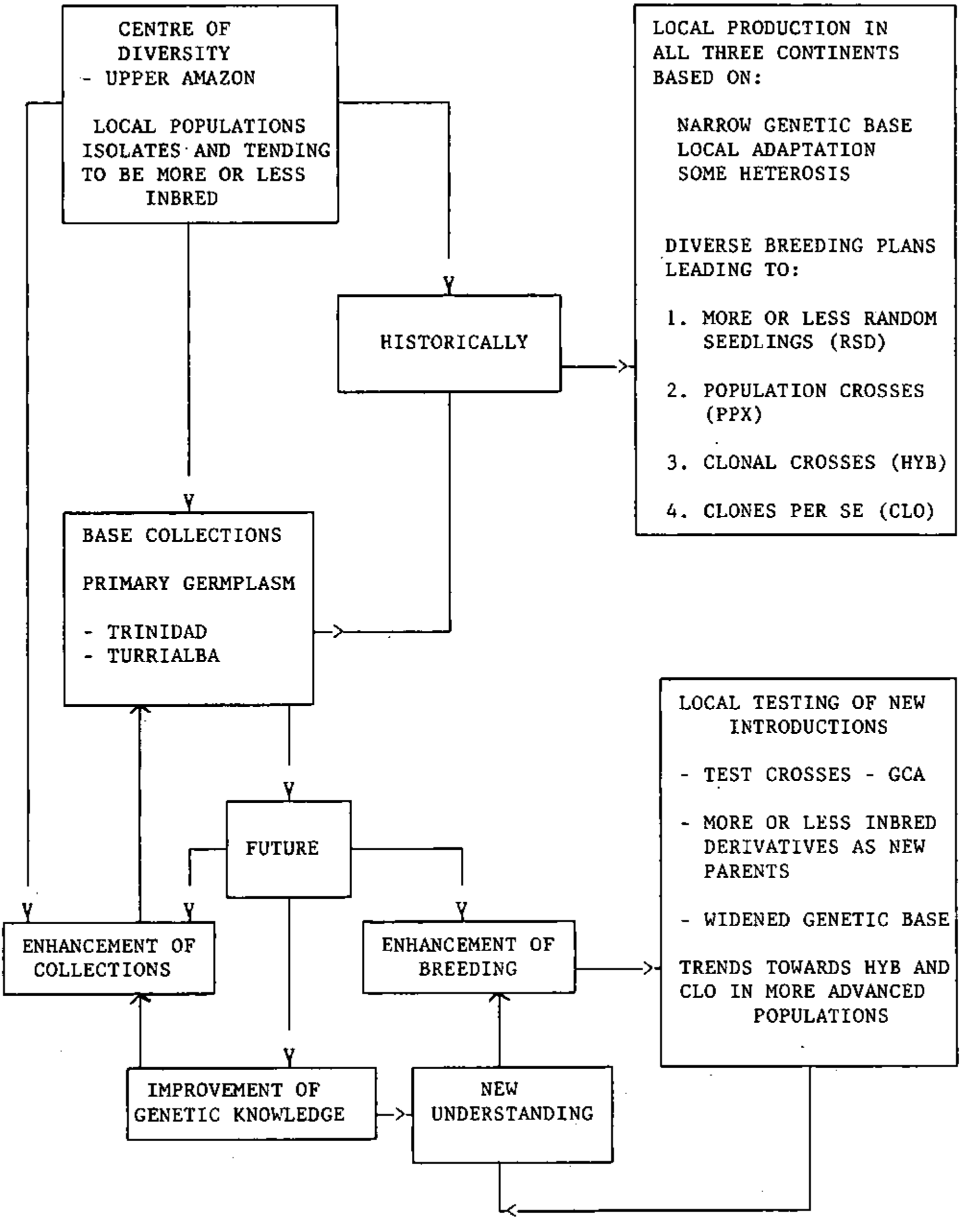
CENTRE OF DIVERSITY - UPPER AMAZON
LOCAL POPULATIONS ISOLATES AND TENDING TO BE MORE OR LESS INBRED
LOCAL PRODUCTION IN ALL THREE CONTINENTS BASED ON:
NARROW GENETIC BASE
LOCAL ADAPTATION
SOME HETEROSIS
DIVERSE BREEDING PLANS LEADING TO:
1. MORE OR LESS RANDOM SEEDLINGS (RSD)
2. POPULATION CROSSES (PPX)
3. CLONAL CROSSES (HYB)
4. CLONES PER SE (CLO)
HISTORICALLY
BASE COLLECTIONS
PRIMARY GERMPLASM
- TRINIDAD
- TURRIALBA
LOCAL TESTING OF NEW INTRODUCTIONS
- TEST CROSSES - GCA
- MORE OR LESS INBRED DERIVATIVES AS NEW PARENTS
- WIDENED GENETIC BASE
TRENDS TOWARDS HYB AND CLO IN MORE ADVANCED POPULATIONS
FUTURE
ENHANCEMENT OF COLLECTIONS
ENHANCEMENT OF BREEDING
IMPROVEMENT OF GENETIC KNOWLEDGE
NEW UNDERSTANDING

FIGURE 1

The development of efficient micropropagation is a vital need in cocoa genetic resource management. The crop has, so far, proved to be intractable to in vitro techniques. Only concerted and continuous effort will overcome the problems. A quick, cheap micropropagation technique would have great impact on the economics of germplasm multiplication and distribution.

In vitro techniques for collecting cocoa germplasm from the wild will also make a major contribution to genetic conservation (Withers, 1983).

Cocoa Quarantine

Following the discontinuation of the service of the Royal Botanic Gardens, Kew as a quarantine centre for cocoa, the USDA centre in Miami remains the only effective and recognised service. This leads to a severe restriction in the potential movement of cocoa germplasm.

A small, but internationally yet unrecognised, facility exists in Montpellier, France. A regional station is also operated by CRU, Trinidad in Barbados. A temporary facility has just been initiated at the University of Reading, UK. These stations, as at present structured, can have only limited influence on cocoa movement worldwide; the Barbados site is very valuable as an inward station for extending the ICG,T.

Administration of Genetic Resources

Historically, there has been no international policy for the administration and funding of international genebanks for cocoa. Funding has been on an ad hoc basis and usually of a very insecure nature. Tree crop genebanks are expensive to establish and maintain because of the land area they must occupy.

In the long term, it will be essential to establish a stable, funding source for the genebanks. Managements will then be relatively secure from individual government policies or single agency interests. Free access to germplasm may then become certain. The establishment of adequate quarantine facilities that are also secure in funding and independent in management will be an essential and complementary part of this mechanism. The global resources for cocoa may then be administered in an efficient manner, with orderly long term policy planning.

Biotechnology

The development of so called 'biotechnology' is gathering momentum for many crop species. Since the most recent developments in molecular biology and gene (or DNA) manipulation are expensive and may be irrelevant to cocoa, any policy to engage in this type of research must be considered very carefully. There is a clear distinction between the 'genetic engineering' techniques of DNA manipulation and the technology of micropropagation.

Since cocoa breeding technology in its present state cannot make use of the DNA technology, little or no emphasis should be placed on this. All of this advanced laboratory-based technology relies on the availability of efficient micropropagation/regeneration methods. These are currently totally lacking for cocoa.

Much more effort and support should be devoted to the development of routine rapid micropropagation methods. The success of these will have an immediate impact on genebank management, quarantine operations and germplasm distribution. In the longer term, they will enable future research to use such advanced DNA technology as should then be appropriate. The importance of micropropagation has been widely recognised. Unfortunately, most of the work has been done in temperate countries far distant from both the basic plant material and from the people and organisations who will need to use the technique. While recognising that there are technical reasons for this, there is clearly a need for substantial development in the tropics, whether in cocoa genebanks, breeding stations or international research institutes.

INTO THE NEXT CENTURY

General

There already exists enough conserved material to ensure that well organised breeding programmes will be able to make significant progress for many years. However, the material is at present sited only in genebanks (Turrialba and Trinidad). The first priority must, therefore , be to enhance the dissemination of these collections to local breeding programmes. Local programmes must then utilise material in a rational and systematic manner.

Each breeding programme will have its own objectives which must take into account local socio-economic factors. These will include the choice between clonal or seedling planting, specific environment and ma:.agement and marketing practices. The primary focus must be on yield, along with the development of disease resistance adequate for local needs. Immunity, if it involves (as it usually does) the use of vertical resistance (VR) is a mistaken objective. Resistance is best regarded, not as an objective *per se*, but as an aspect of yield, a protection against loss.

Breeding programmes should be designed, firstly to assess the available germplasm efficiently and then to utilise it in a way that gives maximum gain. The arbitrary basis of selection of the parents that are of global importance in variety production has been discussed already and the same principle applies to the broader choice of the population to be utilized. There is no reason to suppose that the IMC, MO, NA, PA or SCA populations that have already been widely used will be the best choices in all circumstances. In the short term (one or two generations), progress will ensue from evaluation of the much wider range of populations that are already available to breeders or which can be obtained from intermediate quarantine. It will then be possible to utilise the better ones more efficiently. These activities must be the responsibility of the local breeders; they cannot be undertaken by the custodians of genebanks. The major requirements are for the assessment of general combining abilities (GCA) of parents and then exploitation of specific combining ability (SCA), and local genotype-environment interactions.

A scheme that attempts to make best use of the available germplasm is outlined in Figure 2. The natural structure of present germplasm collections is one of more or less distinct populations. Each population is of a distinct geographical origin and separated from other populations by geographical isolation. Further, within each population there is some degree of inbreeding (in terms of common descent) because of the isolation. The upper portion of this figure (enclosed in a broken line) encapsulates, to a large extent, the present situation. In the West African breeding programmes there has been some exploitation of hybridisation between selected parents from the originally introduced (Amelonado) population and the much later introductions of populations from the Upper Amazon.

The generalised scheme presented here allows flexibility in the generation of clones (CLO) and hybrids (HYB), while simultaneously improving the population base. By keeping each population as a separate breeding unit, there is an inevitable degree of inbreeding as improvement by selection takes place. Heterozygosity is restored when hybrids are made, either at the clonal level (A_I x B_I - See Figure 2) or by population crosses [PPX(AxB)]. The restoration of heterozygosity exploits the heterosis thus generated. New populations must eventually be introduced into the scheme to provide for continuing progress but, given the breadth of the genetic base that exists in present genebanks, such new populations would probably be required only 20 years from now. However, the fact that they <u>will</u> be needed serves further to emphasize the need to establish a sound base for cocoa genetic resource management now. Twenty years is only half the productive life of many cocoa plantings.

FUTURE RESEARCH

Research Framework

A sound research basis is essential for the successful implementation of development programmes such as the improvement of a country's cocoa industry. The knowledge and understanding gained from research eventually leads to a continual development process. The results of research do not always have an immediate effect and in many instances the impact is felt only after an intermediate phase of application of primary results. Many of the research programmes concerning cocoa are by nature long term, none more so than breeding projects. It is for this reason that research programmes must have clear and realistic objectives and, given limited resources, priorities must be set. Although an attempt is made below to define general areas of research priority, in practice each institute will set detailed lists within its own framework of resources and problems.

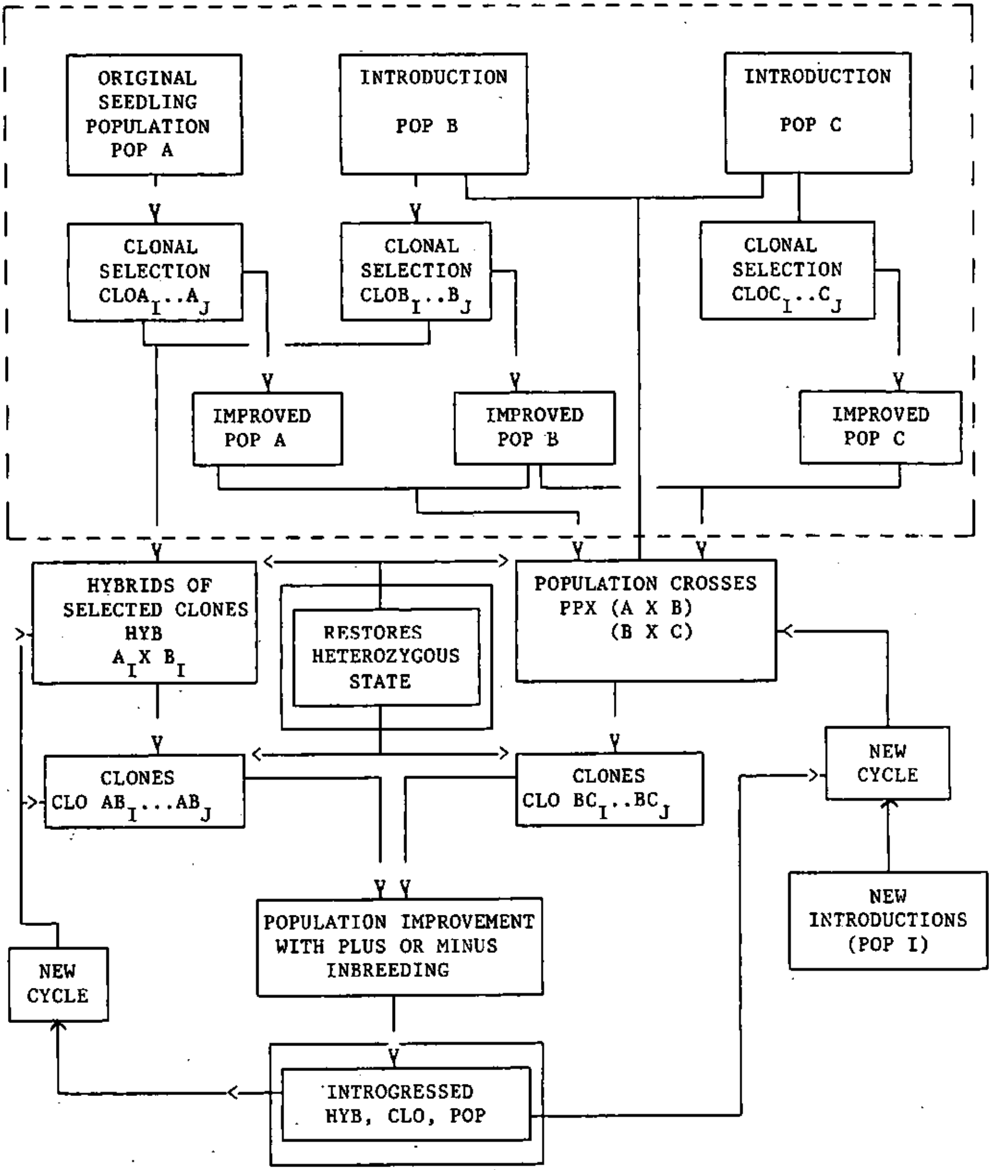
ORIGINAL SEEDLING POPULATION POP A
INTRODUCTION POP B
INTRODUCTION POP C
CLONAL SELECTION CLOA$_I$..A$_J$
CLONAL SELECTION CLOB$_I$..B$_J$
CLONAL SELECTION CLOC$_I$..C$_J$
IMPROVED POP A
IMPROVED POP B
IMPROVED POP C
HYBRIDS OF SELECTED CLONES HYB A$_I$X B$_I$
RESTORES HETEROZYGOUS STATE
POPULATION CROSSES PPX (A X B) (B X C)
CLONES CLO AB$_I$...AB$_J$
CLONES CLO BC$_I$..BC$_J$
NEW CYCLE
NEW INTRODUCTIONS (POP I)
POPULATION IMPROVEMENT WITH PLUS OR MINUS INBREEDING
NEW CYCLE
INTROGRESSED HYB, CLO, POP

FIGURE 2

Research Priorities

The basis of yield needs to be understood in a more fundamental way. The yield of any given tree is a complex interaction of several components. The potential is related to ovule number and pollination efficiency. Work by IRCC in Ivory Coast has clearly shown some of the relationships that exist between these parameters (de Reffye et al, 1979; Mossu et al, 1981). The physiological capability of the tree, with its origin in the genotype of the tree, is important in the ability of the plant to set and hold any given yield capacity. A basic knowledge of the physiology of partition of resources within the tree, as between vegetative growth and pod production, and within the fruit between the various components of the pod and beans will be essential for sustained improvement from breeding.

Biometrical knowledge of systems to evaluate breeding potential is, in general, poor. The study by quantitative genetics of important characters is in its infancy and much more research effort must be directed to improving this field of knowledge. Experimentation on this topic requires substantial resources since it involves large and prolonged field trials. Biochemical methods of characterisation, such as isozyme typing, need to be developed into standardised techniques. These will allow evaluation of genetic variation within and between populations. Much of present description relies entirely on gross morphological characters, too many of which are environmentally 'plastic'.

The need for and urgency of rapid micropropagation techniques has been stressed earlier.

RESEARCH ORGANISATION

It has been pointed out above that cocoa breeding must, of its nature, be a highly dispersed operation with many locally supported stations serving small-holders, farmers and estates. Appropriate breeding methods must be used to produce varieties (seedling or clonal) that meet the needs of their customers. Since many problems are local (eg. environmental stresses, diseases), these local breeding programmes will have to maintain at least some associated research capability, though not at any very fundamental level. Financially they will have to be locally supported, either directly by the cocoa producers or, less directly, by government agencies with some responsibility for publicly supported research. Clearly such stations are necessary and the work they do is essential. However, they can hardly be expected to attack the fundamental longer term research needs mentioned earlier.

For long term research, implying substantial commitments with few visible short-term returns, an international organisation with secure long-term support is essential. There exists the nucleus of such a system in the Trinidad genebank mentioned several times in the preceding sections. Opinions will vary widely as to the extent to which such a genebank should become a generalised cocoa research centre with greatly widened research responsibilities in crop physiology, biometrical genetics, biochemical taxonomy, biotechnology etc (all in addition to its fundamental maintenance, documentation and distribution of germplasm functions).

Probably, there is no 'ideal' structure and what will in practice emerge is likely to have substantial economic and historical components that are essentially random in nature. With regard to the Trinidad genebank, it seems clear that, whatever extra research responsibilities might be assigned to it, any serious international effort must involve something more, namely one or more other centres with securely supported long term research programmes, (such as possibly the CATIE centre in Costa Rica).

Not the least important of the tasks of the international elements (however they may develop) would be to act as communications nodes between each other and with the dispersed local breeding programmes. One of the more important developments in tropical agricultural research in the past two decades has been to move away from the single 'International Centre' idea towards a system based on 'networking'. The concept behind networking is to generate an effective means of coordinating dispersed research activities. Such networks of institutes encourage the flow of information and ideas, minimise wasteful duplication of effort and coordinate the disbursement of funds in a controlled and effective manner. A possible outline of this structure is presented in Figure 3.

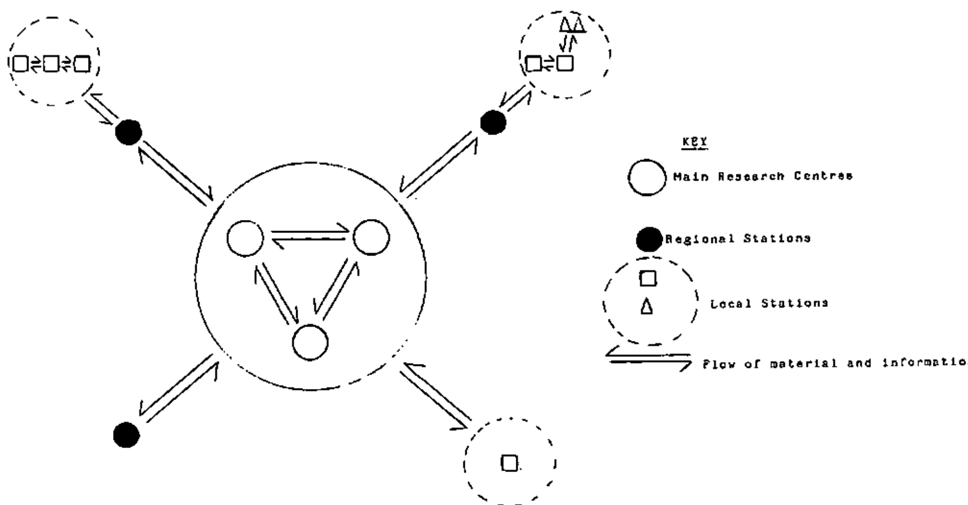

FIGURE 3: Representation of a research network

Modern technology and communication make the development of research networks feasible; they must increasingly become the basic structure for tropical agricultural research. For a crop such as cocoa the time is overdue when serious consideration has to be given to effectively utilising resources.

REFERENCES

Allen, J.B. & Lass, R.A. (1983) London Cocoa Trade Amazon Project. Final Report Phase I, Cocoa Growers' Bulletin, 34,

Anon (1987) Genetic Resources of Cocoa. Report of First Meeting of Cacao Working Group, IBPGR, Rome, AGP/IBPGR/80/56.

Anon (1987) Report of the Second Meeting of the Cacao Working Group, IBPGR, Rome, AGPG/IBPGR/83/126.

Bartley, B.G.D. (1986) Cacao, *Theobroma cacao* In Breeding for Durable Resistance in Perennial Crops, FAO, Rome FAO Pl. Prod. Prot. Paper, 70 p.25-42.

Chalmers, W.S. (1972) The Conservation of wild cocoa populations: the Plant Breeder's most urgent work. Proc. IV Internat. Cocoa Res. Conf., Trinidad, 1972, p.114-118.

Cope, F.W. (1962) The mechanism of pollen incompatibility in *Theobroma cacao* L. Heredity 17, p.157-182.

Cope, F.W. (1976) Cacao. *Theobroma cacao* (Sterculiacae). In Evolution of Crop Plants (Ed. N.W. Simmonds), Longman, London and New York, p.285-289.

Gardella, D.S., Enriquez, G.A. & Saunders, J.L. (1982) Inheritance of clonal resistance to *Ceratocysti fimbriata* in cacao hybrids. Proc. 8th Internat. Cocoa Res. Conf., Cartagena, Colombia, 1981, p.695-702.

Glendinning, D.R. (1964) A study of clonal cocoa varieties Hort. Res. 4, p.89-97.

Glendinning, D.R. (1966) The incompatibility alleles of cocoa Cocoa Research Institute (Ghana Academy of Sciences) Report for the period 1st October 1963 - 31st March 1965, p.75-86.

Glendinning, D.R. & Edwards, D.F. (1961) The development and production of new W.A.C.R.I. hybrid varieties. Report of the Cocoa Conference 1961 CCCA, London.

Kennedy, A.J. (1984) The International Cocoa Genebank, Trinidad: its role in future cocoa research and development. Proc. 9th Internat. Cocoa Res. Conf., Lome, Togo, 1984, p.63-67.

Knight, R. & Rogers, H.H. (1955a) Recent introductions to West Africa of *Theobroma cacao* and related species A review of the first ten years. Emp. J. exp. Agric. 23, 113-125.

Knight, R. & Rogers, H.H. (1955b) Incompatibility in *Theobroma cacao* L.. Heredity 9, 69-77.

Lockwood, G. (1976) A comparison of the growth and yield during a 20 year period of Amelonado and Upper Amazon hybrid cocoa in Ghana. Euphytica 23, 647-658.

Montserrin, B.G., de Verteuil, L.L. & Freeman, W.E. (1957) A note on cocoa hybridisation in Trinidad with reference to clonal selections and hybrid seed. Caribbean Comm. Public Exch. Serv., No. 33.

Mossu, G., Paulin, D. & Reffye Ph.de (1981) Etude des conditions se floraison et de pollinsation sur les rendements du cacaoyer, Proc. 8th Internat. Cocoa Res. Conf, Cartagena, Colombia, 1981, 37-44.

Mossu, G. (1983) La selection Cacaoyer dans les pays francophones s'Afrique, Etat actuel des Travaux et perspectives d'avenir. Document IRCC, Paris.

Posnette, A.F. (1943) Cocoa selection in the Gold Coast. Trop. Agric., Trinidad, 22, 184-187.

Posnette, A.F. (1945) Incompatability in Amazon cocoa. Trop. Agric., Trinidad, 22, 184-187.
Posnette, A.F. (1951) Progeny trials with cocoa in the Gold Coast. Emp. J. exp. Agr. 19, 242-251.
Pound, F.J. (1936) The completion of selection. Fifth Annual Report on Cocoa Research, 7-16, Port of Spain 1936.
Pound, F.J. (1938) Cacao and Witch-Broom Disease of South America. Port of Spain, p.58.
Pound, F.J. (1938) Cacao and Witch-broom disease, Port of Spain, 16pp.
Reffye, Ph. de, Parvais, J.P., Mossu, G. & Lucas, P. (1979) Influene des modalites de la pollinsation sur la recolte du cacaoyer. Proc. 7th. Internat. Cocoa Res. Conf., Douala, Cameroun, 1979, p.545-552.
Tan, G.Y. (1981) Breeding for disease resistance to vascular streak-dieback canker and black pod in hybrid cocoa. Proc. 8th Internat. Cocoa Res. Conf. Cartagena, Colombia, 1981, p.731-734.
Toxopeus, H. (1969) Cacao Theobroma cacao L.., In Outlines of Perennial Crop Breeding in the Tropics, (Eds. Ferwerda and Wit). Veenman, Wageningen, p.79-109.
Toxopeus, H. (1972) Cocoa breeding: a consequence of mating system, heterosis and population structure. Cocoa and Coconuts in Malaysia, 3-12, Kuala Lumpur : Incorporated Society of Planters.
Van Hall, C.J.J.J. (1930) Trinidad and Java cocoa. Selection research work on cocoa in Trinidad and Java. Trop. Agric., Trinidad, 7, 9-12.
Van der Plank, J.E. (1984) Disease Resistance in Plants (2nd Edition) Academic Press, London and New York.
Withers, L.A. (1984) Working Group on Cocoa, IBPGR (1984). Report of the second meeting, Arlington Va. USA IBPGR, Rome.
Wood, G.A.R. & Lass, R.A. (1986) Cocoa 4th Edition. Longman Group Limited, London.

COCOA IN FIJI

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HISTORICAL

The cocoa industry in Fiji dates back to the 1880's when Criollo and Trinitario types were introduced from Trinidad or Ceylon (Sri Lanka). By 1909 there were 150 hectares of cocoa growing and 5 tonnes of dried beans were exported, but thereafter the cultivation area and production declined so that by 1936 there were no exports of cocoa from Fiji (Vernon, 1979). After a period of very little interest in cocoa cultivation, there was a resurgence of interest in the 1950's and the area under the crop expanded to over 1000 hectares by the mid 1960's, with a peak production of 61 tonnes in 1963. Unfortunately, the planting material used was the seeds collected from the remnant survivors of the 1880 - 1930 Trinitario plantings and the very high susceptibility of this material to stem canker and black pod disease caused by *Phytophthora palmivora* almost devasted the cocoa industry until 1965.

Since 1965, the Governmental policy has been to plant only Amelonado material introduced from Sabah, Malaysia in 1958, mainly because of its greater tolerance to stem canker and black pod. Amelonado has adapted well to the agroecological conditions in Fiji and given high sustained yields of 2 tonnes of dry beans per hectare per year in research conditions and in trials under farmers' field conditions (Martin, 1985).

PRESENT INDUSTRY

At present there are 4,375 hectares of mainly Amelonado cocoa growing in Fiji, of which 1,180 are bearing (Anon, 1985c). The location of the cocoa growing areas is shown in Figure 1. The total production for 1985 was 225 tonnes of dry beans which was a drop of nine per cent from the 246 tonnes produced in 1984. This drop in production was mainly due to the devastating effects of two cyclones, Eric and Nigel, that struck the main island of Viti Levu in January 1985, causing losses estimated at approximately 100 tonnes of dry beans (Anon, 1985c). These figures indicate that the cocoa industry is relatively small at present, but major developmental efforts with a view to expanding the crop area to 7,000 hectares to produce well over 1000 tonnes per year by 1990, are planned for the period 1986-1990, under the Government Development Plan 9 (Anon, 1985a).

Cocoa is grown under a variety of management models. The most common is the 1-3 hectare farm operated by an individual household. Of the thousand growers covered in a survey in 1985, around 70 per cent were classified as smallholders. A further 10 per cent worked in informal co-operative groups. The smallholder sector of the industry which is generally characterised by low yields and minimum supervision accounted for an estimated 82 per cent of the production in 1984. In recent years there has been an increasing interest in larger, higher input estate units which operate through a loan from Government budgetary allocation for cocoa development. The first such estate of 200 hectares was established at Matasawalevu in Macuata Province in 1979. This involved farmers grouping together to form a single production unit as a formal co-operative association and under the supervision of a residential Agricultural Officer. The other significant estate type plantings are Uluisaivou in Ra Province, Waimaro in Tailevu Province and Lovoni on Avalau Island covering 102, 50 and 32 hectares respectively (Anon, 1985b). The encouraging success of the Matasawalevu project has resulted in plans to duplicate this model in a number of locations during the Development Plan 9 period of 1986-1990 (Anon, 1985a).

CLIMATE AND SOIL

Fiji Islands lying between 16° and 19° latitude appear to be very close to the lower limits for profitable cocoa cultivation. However, the maritime climate modifies temperatures extremes and makes the growing of cocoa feasible to an elevation of about 250 metres above sea level in a fairly wide area of the Central Division, North Eastern parts of Western Division, and Northern Division, and larger outer islands such as Taveuni, Koro, Rotuma, Ovalau, Gau and Kadavu (see Figure 1). The total rainfall of the cocoa growing areas range from about 2400 mm per year in drier parts of Tailevu and Naitasiri Provinces. The main limiting factor is the rainfall during the peak pod ripening period of February to April, which results in excessive black pod losses, which are common in areas like Naitasiri and parts of Tailevu (Vernon, 1976). Recent experience in Ra, Macuata and Bua Provinces indicate that moisture stress during June to August may be more of a limiting factor during the pre-bearing stages of young cocoa than previously envisaged. This could however be overcome by the use of proper shade for establishing cocoa.

Cyclones are a common occurrence in Fiji. In the recent past cyclones Fay (in 1978), Meli (in 1979), Tia (in 1980), Oscar (in 1983), Eric and Nigel (in 1985) and Martin (in 1986) caused considerable damage to cocoa in various parts of the country.

Cocoa grows best on flat to gently sloping land where the soil is deep, well drained and fertile to moderately fertile, slight to moderately acid and light textured. The main soils on which cocoa is grown in Fiji are Humic latosols and related Colluvial soils, recent Alluvium, Red Yellow Podsolic soils, Latosolic soils, Nigrescent soils and Coastal sands.

AGRONOMIC PRACTICES

Amelonado is the only recommended variety at present. Establishment is mainly by selective thinning of natural forests and to a lesser extent under coconut. Temporary shade crops such as banana, taro, cassava and yaqona (Piper methysticum) are grown particularly when cocoa is planted under coconut.

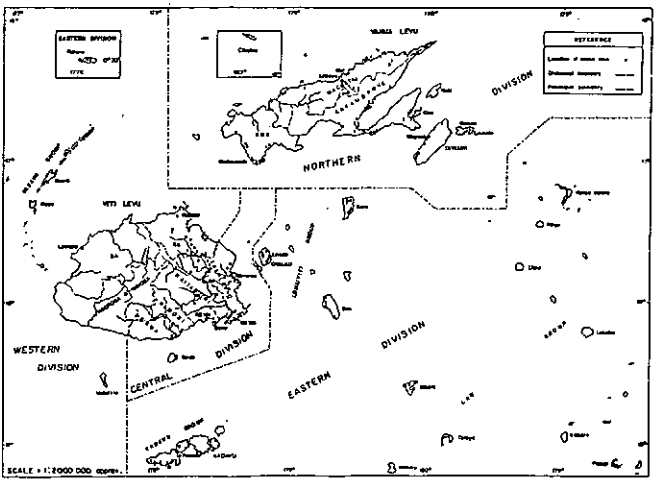

Figure 1: Map of Fiji Islands showing the location of cocoa growing areas

Permanent shade trees, Gliricidia maculata and Erythrina lithosperma are grown in situations where the forest is excessively thin. The policy is to depend more on shade and less on fertiliser application as the latter is costly and not commonly used on cocoa in Fiji.

Planting is directly into the ground with three seeds at stake and thinning the stand to two and one plant per stake at three months and at jorquetting respectively. Spacing is 2.5 x 2.5m on the square system of planting. The control of weeds in young cocoa is mainly by manual weeding, three rounds during the first year and two during the second and third years. Pruning method recommended is Discretionary pruning (Martin and Prasad, 1983), which is recommended where two to three basal chupons are allowed to grow in addition to the main stem while restricting the tree height to the first jorquette. As most of the of the plantings are newly cleared virgin bush where the soil is fertile, no fertiliser application is necessary. However, for cocoa on poorer soils and those grown under coconut a 13:13:21 NPK fertiliser mixture at the rate of 45,90 and 180 kg per hectare per year is recommended during the first, second and third year and thereafter respectively. The harvesting season starts from early April and lasts till mid-December with a major peak in May/June and a minor peak in September, these peaks varying slightly with the climatic conditions of the region. Harvesting is by sharp knives usually at fortnightly intervals.

PESTS AND DISEASES

During the past few years stem borers (Xyleborus fijianus, Pterolophia lateripicta, Araecerus greenwoodi) and ring bark borer (Oopsis brunneocaudatus) have become significant pests of young and bearing cocoa respectively. Stem borers can be controlled by the application of Furadan on the soil surface and ring bark borer by painting the affected stems with Lannate.

Black pod caused by P.palmivora is the only major disease of cocoa at present. The control measures include removal and burying of infected pods, regular harvesting and field sanitation. Low volume spraying of Perenox at fortnightly intervals during the cropping season is carried out in areas where the losses are high.

PROCESSING AND MARKETING

Ripe pods are broken with a wooden mallet and beans are scooped out. Fermentation is carried out in wooden boxes which are of different sizes depending on the quantity of beans to be fermented, but are typically 0.9 x 0.9 x 9.8m holding about 0.5 tonnes of wet beans. On the floor of the boxes there are 15 mm holes, 10-15 cm apart for drainage of sweatings and entry of air. The arrangement of boxes is usually in a row or in tiers, the latter facilitating the turning of beans. A typical box fermentation lasts for six days during which the beans are turned twice, after two and four days.

The most common method of drying is the use of a wood fired Samoan Flue Dryer. The drying process lasts for three days during which the moisture content of the beans is reduced from 55 per cent to 6-7 per cent for safe storage. The first day of drying, during which the temperature is slowly increased from 45°C to 55°C makes the beans skin dry and helps to ensure that the beans are well separated and not cluttered together. In the second and third days a constant temperature is maintained to reduce moisture to 7 per cent. Between the second and third days the beans are rested overnight to permit diffusion of the moisture and normalisation of moisture in the beans. Heat with the temperature not exceeding 70°C at any stage is applied the following morning. The beans are frequently raked, using a paddle, to promote uniform drying.

Marketing is the responsibility of the National Marketing Authority (NMA), which is a Government statutory agency. NMA purchases the dry beans at five grading points distributed in the cocoa growing regions. Depending on the grade, farmers receive F$1700, 100, 625 (US$1441, $847, US$530 approximately) for grade I, II and III respectively. Most of Fiji's cocoa production has been sold to United Kingdom and Europe with a small quantity sold to Australia.

RESEARCH AND EXTENSION

A considerable amount of Fiji's agricultural research resources over the last 20 years has been devoted to cocoa. At present cocoa ranks third after sugar cane and rice in research priority. A vigorous research programme is in progress at three research stations and at outstation sites. The main emphasis is on breeding varieties which are high yielding and more black pod tolerant than the currently recommended Amelonado, and on deriving optimum cultural practices such as spacing, pruning, fertiliser application, weed control and control practices for stem and ring bark borers and black pod. This programme is being implemented by a team of three professional and six technical staff.

The extension services provide technical advice to growers on selection of sites, crop husbandry and processing. In estate type projects, direct farm management services and supervision are also provided. The other Government incentives to cocoa farmers include the supply of free seed pods at the farm gate, and subsidies on the cost of construction of fermentary/dryer and fencing, and on purchase of herbicides, insecticides and fertiliser.

FUTURE PROSPECTS

Despite the research and extension efforts of the Government the national average yield of 1984, a year of no disastrous cyclones, was as low as 321 kg per hectare (Anon, 1985c). However, recent research and extension trials in Fiji have shown that Amelonado could yield 2 tonnes of dry beans per hectare (Martin, 1985). The lower national average yield could be attributed to the faulty selection of sites, both climatically and edaphically and the neglect or poor management of the crop resulting in low production and heavy losses due to black pod. The Government is currently placing greater emphasis on proper selection of new areas for planting and on training the extension field staff and farms on cocoa production and processing with the hope of improving the standard of crop management and processing, thereby establishing cocoa as a viable industry in Fiji.

REFERENCES

Anon (1985a) Fiji's Ninth Development Plan, 1986-1990. Central Planning Office, Suva, Fiji, 191 p.

Anon (1985b) Cocoa Profile : A programme for future development of Cocoa Industry. Agricultural Commodity Committee, Suva, Fiji, 52p.

Anon (1985c) Annual Report for the Extension Division, 1985. Ministry of Primary Industries, Suva, Fiji, 28 p.

Martin, M.P.L.D. (1985) Performance of Amelonado and hybrid cocoa in Fiji. Fiji Agricultural Journal 47, (2).

Martin, M.P.L.D. and Prasad, G. (1983) Effects of pruning on Amelonado cocoa in Fiji. Fiji Agricultural Journal, 45, (1) 7-12.

Vernon, A.J. (1976) Location factors in cocoa cultivation in Fiji. Fiji Agricultural Journal, 38 (1) 33-40.

Vernon, A.J. (1979) History of cocoa in Fiji. Dept.of Agriculture, Suva, Fiji, 4p.

INTERPRETING THE EPIDEMIOLOGY OF COCOA WITCHES' BROOM FOR BETTER DISEASE MANAGEMENT IN RONDONIA, BRAZIL

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Cocoa is a native Amazonian plant attacked by several locally endemic pathogens, including Witches' broom. The causal agent, Crinipellis perniciosa (Stahel) Singer, is distributed over a large area of mainland South America and some islands in the Caribbean. This area covers a range of climates and altitudes that produce different disease intensities, and it has already been noted that Crinipellis causes unusually high pod losses in Rondonia relative to vegetative infection (Evans, 1981). The disease is not yet found in Bahia, Brazil, and there is concern about the potential losses were the disease to appear there. As a result of these two problems, the Cocoa, Chocolate and Confectionery Alliance, London, commissioned an intensive study of the conditions in Rondonia with the cooperation of the Commissao Executiva do Plano da Lavoura Cacaueira (CEPLAC) of Brazil. This article will examine some of the possible explanations for the high pod losses and how the crop should be managed to reduce these losses.

HISTORY

Rondonia is situated in the western Brazilian Amazon in the transitional region between high gallery forest and the savannahs of central Brazil. Until the end of the 1960's, this area was dominated by extraction from forest trees (rubber and Brazil nuts) and mineral resources (gold and tin prospectors). The construction of the Cuiaba to Porto Velho road in the early seventies changed the situation by improving access to Rondonia for movement of people and local produce. The population of the state has increased from 111,000 in 1970 to nearly 700,000 in 1983 (Coy, 1986). The estimate for new arrivals in 1985 is close to 200,000. Migration was slower until 1978, when several colonisation projects were opened up in new areas of forest. Land was divided into lots of 100 or 50 hectares which were given to one family. Forests were cleared and a range of crops, annual, perennial and cattle pasture, have been planted.

Perennial crops such as cocoa, coffee, rubber and black pepper are seen by many planners as holding great promise for producing sustainable yields in Amazonia. All four crops are affected by important diseases that raise some doubt about their future in large-scale cultivation. However, these cash crops provide a significant income for the region and are preferable to annual crops due to better cycling of nutrients within agroecosystems.

Farmers were encouraged to plant cocoa by a government scheme, and loans were available for financing of 10 or 20 hectare areas.

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There was a surge in cocoa planting in 1977/78 coincident with the peak in world prices (Figure 1) and the area under cocoa increased from less than 5,000 hectares in 1976 to more than 30,000 in 1980.

Seed material was provided of varieties from Bahia, some of which had had sufficient time in Belem and in other countries exposed to Witches' broom to show their susceptibility. As has already been discussed (Rudgard, 1986), farmers were not aware of the disease potential and were slow to start phytosanitary pruning if they did so at all. By 1982 when the world price fell below £900 per metric tonne the epidemic was out of control in many plantations leading some farmers to abandon their cocoa (Fearnside, 1985). There followed a struggle to control the infestation, aided by a massive campaign of publicity and training by CEPLAC. Seeds of the more susceptible varieties ceased to be distributed to farmers from 1981 onwards when seed gardens in Rondonia started to be used. These factors combined with increased cocoa prices in 1984/85 have enabled farmers to prune properly, and production from Rondonia continues to rise (area 25,000 tonnes in 1985 from about 50,000 hectares). The outlook for effective control may not be so assured if prices continue to fall in 1986/87 with sanitation being such a costly, labour-inefficient process.

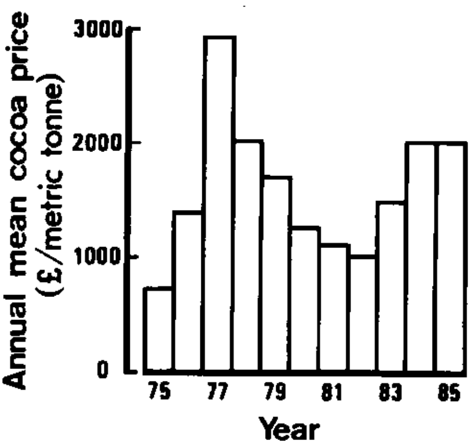

FIGURE 1: Changes in the annual mean price of Ghana cocoa

CLIMATE AND DISEASE CYCLE IN RONDONIA

The average annual rainfall is about 2000 mm (80 inches) spread through nine months, September - May. There is a distinct dry season when little or no rain falls between the beginning of June and the end of August. Cloud cover is more intense in the wet season, humidity and night-time temperatures are higher and daytime temperatures lower. Cocoa responds to such a climate by producing one main wet season crop set around November and harvested in May/June, and a small unpredictable dry season crop set in May and harvested in October/November. There are three and sometimes four flushes of shoot growth at distinct times in the wet season.

The fungus is perfectly adapted to the climate and growth of cocoa in Rondonia as could be expected of an endemic pathogen. There is only one complete disease cycle per year due to the long incubation period and the interval between broom death and production of the basidiocarps (Figure 2). Dead brooms required a considerable time of apparently correct conditions before they began to fruit at the start of the rains. This induction period varied in length, and basidiocarp production was induced on different brooms any time from October to December. Dead brooms in their first year produced their first basidiocarps later than second year brooms. The latter were normally less important because brooms tended to fall off trees and/or rotted after one season. Up to half of all basidiocarps produced formed on the dead leaves attached to necrotic brooms.

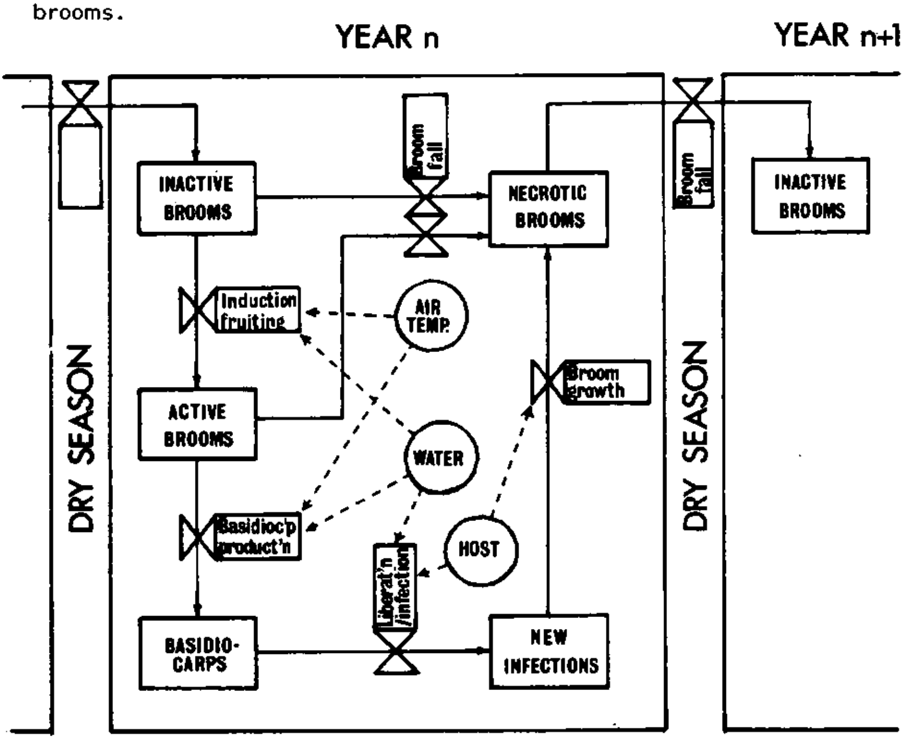

FIGURE 2: Annual cycle of vegetative infection of cocoa by witches' broom disease

Once fruiting was induced basidiocarps formed in flushes throughout the wet season, although at any one time only a small proportion of brooms were fruiting. An average of up to 20 basidiocarps per wet season were formed on each active broom depending on climatic variations, and over 80 per cent of necrotic canopy brooms produced basidiocarps. Broom activity was controlled by periods of wetness derived from rain. Basidiocarp production was nil or insignificant when wetness was less than 4 hours or more than 20 hours per day. Alternating periods of wet and dry promoted fructification provided air temperatures stayed within the range of 20-30°C. Spores released at night from basidiocarps infected growing tissues of the tree. There were normally two flushes of shoot growth between January and April which were exposed to spores in conditions favourable for infection. Brooms formed in a flush cycle after shoot infection, expanded for 3 weeks and then gradually became brown and necrotic. Basidiocarps were never produced in the same wet season in which a broom was formed.

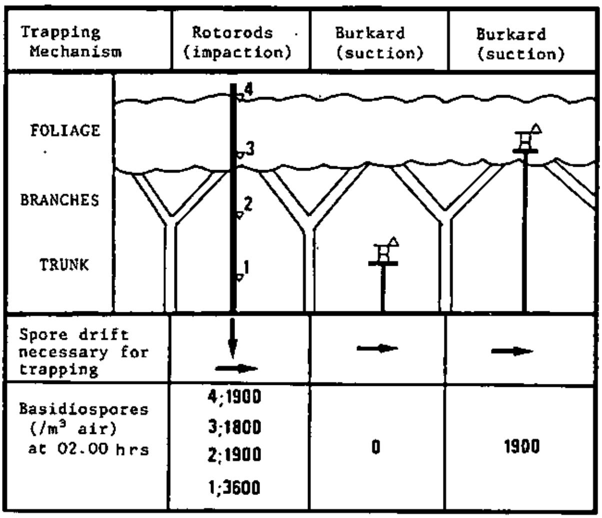

FIGURE 3: Comparison between number of basidiospores caught by two types of spore-traps at various heights above the ground in cocoa canopy at 02:00 on 28th February 1986

DISEASE SPREAD IN TIME AND SPACE

Few researchers have attempted to trap basidiospores, but all report a peak of spore release between midnight and 02.00 hours. In Rondonia a volumetric suction trap (Burkard) placed at canopy height caught nearly 2,000 spores/m^3 of air sampled at 02.00 hours, whereas one at 1.5m caught none at all (Figure 3). Rotorod traps placed at various heights caught between 1500 and 4000 spores/m^3, catching more near the ground, by sweeping the air with thin rotating pairs of sticky rods. From these results it would seem that there may have been some lateral movement of spores within the foliage because Burkard traps catch only blown spores. There can have been almost no lateral movement of spores below the canopy, and most simply settled out of the still air. The time taken for such spores to sediment out in still air from a height of 4m would be about 20 minutes (Gregory, 1961). Germination of spores and penetration of the shoot/pod takes approximately 3 hours (Khonje, 1984) and requires surface moisture. On the trees studied pods wet by rain after 12.00h on one day stayed wet until an average of 09.30 hours the following morning. Definition of the length of a wetness period was less important than establishing whether basidiospore release and infection could have taken place during the period. With an average of 4 days with rain every week in the critical months, pods may have been exposed to up to 50 infection periods in the first twelve weeks of their development in which they were susceptible. The two factors controlling the amount of infection were number of spores (or basidiocarps) and numbers of wetness periods suitable for infection. Temperature in Rondonia was not limiting for most of a normal wet season.

Shoots are smaller targets and susceptible for less time (about 3 weeks) than pods (12 weeks). Thus, 80 and 95 per cent of pods and 15 and 32 per cent of shoots were infected in 1984 and 1985 respectively. The final fraction that became infected was the cumulative total of gradual losses over a number of weeks. The mean loss per week determines the final total and if infection rates are the same per week for pods and shoots, more pods will be lost overall as they are susceptible for longer (Figure 4).

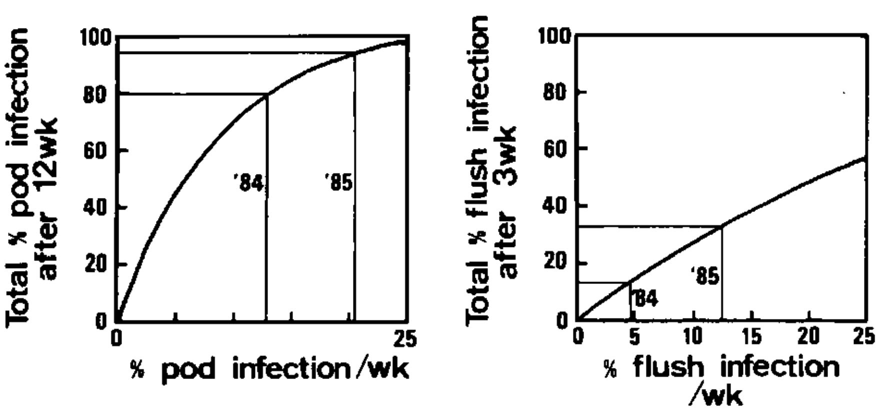

FIGURE 4: Increasing total cumulative infection of groups of pods and flush shoots in relation to mean weekly infection over the whole susceptible period of 12 weeks for pods and 3 weeks for shoots

Mean rates of infection were 4.5 and 12.5 per cent per week for shoots and 12.5 and 21.0 per cent per week for pods in 1984 and 1985 respectively. Thus pods were two or three times more likely to be infected than shoots on exposure to the same conditions within a specified period. Serious pod losses would result from any infection rate higher than 2 per cent per week.

The epidemic of vegetative infection developed over several years and was distinct from the infection of fruit by each year's broom population. Necrotic and often mummified pods seldom produced basidiocarps and hardly contributed to the reinfection of the tree. Numbers of new brooms did not only depend on external factors, as flush intensity affected the number of growing shoots available for infection. In 1984, when basidiocarp production was low, wetness periods few in number, and flushing reduced, the disease hardly progressed ($x_1 - x_0$, Figure 5). In contrast the climatic conditions in 1985 provided a greater number of infection periods and increased basidiocarp production. Flushing was more intense and this combination of factors resulted in a three-fold increase in the number of vegetative brooms (x_2-x_1). Yet only a third of all flushes were infected even when conditions were very much more favourable in 1985.

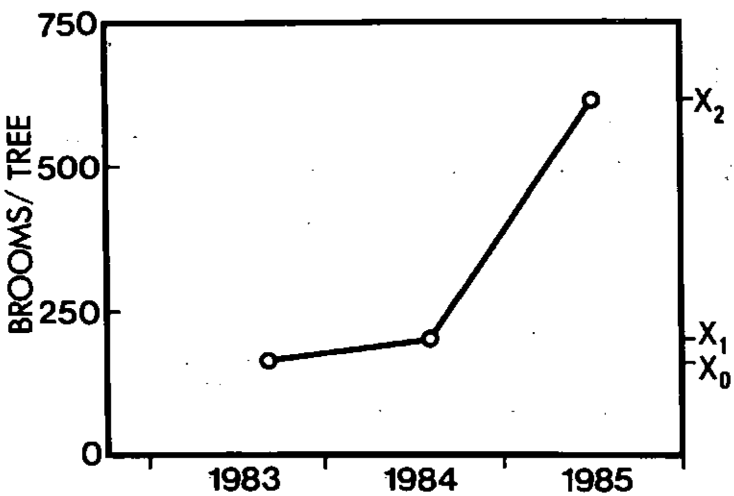

FIGURE 5: Increase in mean numbers of vegetative brooms per tree from 1983 to 1985 in a research site in Ouro Preto, Rondonia

Disease dispersal from a point source was examined using growing seedlings as trap plants placed at given distances from a central group of suspended brooms. The nearest plantation of cocoa was 500m away through a belt of forest. A third of all plants directly below the brooms became infected (Figure 6). There was almost no lateral spread from the central source, indeed no difference in per cent infection between plants 2m away and plants 50m away. Dispersal of spores was minimal and the background infection very low. There was enough infection to cause a few brooms to form that would provide secondary inoculum for the following wet season. Thus an infected plantation in Rondonia would probably only cause some canopy infection in a neighbouring cocoa farm, from which the epidemic would then build up within that new plantation. From work in Trinidad, Holliday (1954) reached a similar conclusion regarding short and long-distance disease dispersal.

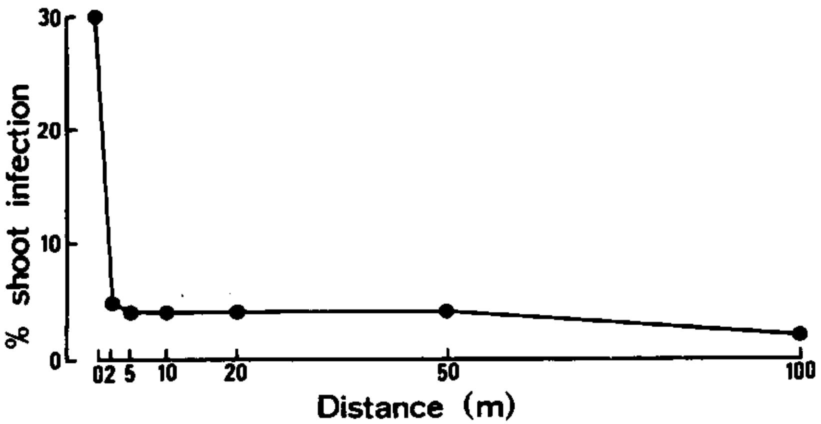

FIGURE 6: Disease gradient on growing seedlings placed at different distances from a point source of inoculum containing 1,500 detached brooms suspended 2m above the ground

INDIRECT DISEASE LOSSES

Flower cushions may themselves become infected. Full symptom expression did not occur on all cushions fungus penetrated and in some cases the infection died out without invading all the tissues. Intensity of flowering was an important factor determining amounts of infection and also appearance of symptoms as has been shown in Trinidad (Holliday, 1956). Symptoms normally occurred in a sequence that terminated in the production of one or more brooms.

By the last stage of invasion of the cushion, necrosis often resulted in the loss of all meristematic tissue and no more pods could be produced on it. There was a finite population of cushions on a mature tree, and most pods were produced on the trunk and main branches to 3m above the ground in well-formed cocoa. Gradual loss of these cushions by infection and necrosis diminished reproduction of the trees by reducing flowerering. The destruction of cushions resulted in indirect losses in production.

Such losses were difficult to quantify, especially where the cushion was not completely killed and some flowering still occurred. Cocoa plantations in Rondonia are not more than 15 years old, and most are less than nine years old. Cushion infection has only become a problem where vegetative canopy infection has been allowed to increase. This can occur in plantings as young as seven years old, where several hundred cushions on each tree have produced brooms and parthenocarpic fruit called chirimoyas. These brooms contributed inoculum to the epidemic, although there was some evidence that wetness periods were longer than for high canopy brooms and fructification was less intense. The only infected pods associated with infected cushions were "chirimoyas" and "carrot" (Dale, 1946) shaped pods. Invasion of developing pods by systemic growth of mycelium through the peduncle seemed unlikely.

DISEASE MANAGEMENT IN RONDONIA

Pod losses are the economic effect of this disease and control measures are aimed at reducing such losses. Witches' broom is endemic on wild cocoa trees which grow at a very low density in normal forest. Basidiospore dispersal is likely to be inefficient in the forest, whereas in a plantation it is extremely efficient. Surface wetness on pods was more often the limiting factor than spore concentrations in Rondonia once infection was established in a field. With 2000 spores/m^3 of air during each suitable infection period, basidiocarp numbers would need to be greatly reduced before there would be insufficient spores to cause serious losses. An average rate of pod infection of 5 per cent loss per week would give a total loss for the season of 40 per cent.

Since no infection occurred during the period May - November the inclusion of fruits harvested in this period would reduce the proportion of fruit lost to the disease. There were some periods in both 1983/84 and 1984/85 when nearly all available pods were infected, but mean losses over the whole wet season harvest were lower. Weeks with high disease potential were concentrated in January - March when the main wet season crop was developing and at its most vulnerable. This may have been part of the explanation for such high overall pod losses. In March/April 1984 and January/February 1985, 50 per cent of the wet season crop became infected in five weeks containing 17 and 15 infection periods respectively. It is not possible to compare Rondonia with other cocoa regions without precisely comparable information on climate, host growth etc. However the high losses recorded in Rondonia were due to a combination of the following factors:

1. Concentration of developing crop into the mid wet season.

2. Rainfall in afternoon or early evening for an average 3 days per week in wet season.

3. Temperature in ideal range throughout wet season (20° - 30°C).

4. High productivity (basidiocarps) of brooms in canopy.

Broom removal for sanitation of plantations is the only control method used in Rondonia and it aims to reduce the source of inoculum. However, it is essential that phytosanitation is started before the disease becomes severe. Data from developing epidemics of pod disease have shown that the third and fourth years are critical in the establishment of witches' broom in Rondonian cocoa (Rudgard, 1986). Thus the early initiation of broom removal is necessary if costs of disease control are to be minimised. However, where witches' broom is already established the cost-benefit of pruning has been difficult to estimate without any idea of the relationship between different amounts of pruning and the associated reduction in pod loss. From work completed in a heavily infected plantation a model for estimating pod loss was derived using numbers of wetness periods and basidiocarps (Rudgard and Butler, 1987). It was possible to extrapolate from this model what effect artificial reduction of inoculum would have. In most years 50 per cent broom removal would have hardly any effect because number of wetness periods would still be the factor controlling infection. Over 95 per cent of brooms would have to be removed in order to reduce basidiocarp production to such a level that disease incidence on pods would be halved. A separate topic not within the scope of this CEPLAC/IICA/CCCA Project concerned the effect of tree height on pruning efficiency. This has been examined in some detail by scientists in Belem and their results indicated that canopy height should be kept below 4m (Andebrhan, 1985). The time taken to prune each tree would be thereby reduced without affecting total yield.

Sanitation was an expensive and often unprofitable exercise when there were large numbers of cushion brooms, and drastic pruning was often necessary to recuperate such cocoa (Rodrigues and Silva, 1986). However cushion disease was seldom serious where canopy infection was kept under control. Thus phytosanitary pruning of vegetative brooms is also a means of avoiding the more serious long-term increases in cushion infection.

Pruned brooms continued to produce basidiocarps if left on the ground. Their productivity was lower than brooms in the canopy and their basidiocarps survived for less time. They were wetted by throughfall from the canopy during rainstorms and were saturated with water for longer periods than brooms still attached in trees. Too much water in brooms inhibited fructification and sparse canopies allowed greater air movement and exposure to sunlight that dried out brooms in less time. Where canopies were dense, brooms in leaf litter on the ground often did not dry out for days at a time.

Management of cocoa canopies should aim to keep gaps in foliage as small as possible if brooms are to be left on the ground after pruning. It has been claimed that such a practice would increase infection of pods by increasing periods of surface wetness caused by condensation (Barros, 1981). Condensation is a separate phenomenon related to the mass of the pod and rising air temperatures between 06.00 hours and 09.30 hours (Butler, 1980). Such moisture on pods would not be associated with basidiospore release as brooms would be dry, and its duration would hardly be affected by canopy density.

Once broom numbers fall below a critical level, basidiocarp production would be sporadic because of the patterns in fructification. Constant efficient pruning keeps down infection of pods because spores are only produced from the previous year's brooms. Relaxation of phytosanitation would result in the formation of vegetative brooms during the first year, and an increase in pod infection in the following year. Experience has shown that cultural control is possible in Rondonia despite such an efficient pathogen system. Further work needs to be done with the pod loss model in order to calculate cost benefits.

SUMMARY OF CURRENT RECOMMENDATIONS FOR DISEASE MANAGEMENT

(developed by staff and co-operators of Phytopathology Division, CEPLAC, Belem)

1. Structure of cocoa canopy
   a. Trees <u>must</u> be kept less than 4m tall.
   b. Foliage canopy <u>must</u> be intact with as few gaps as possible;

2. Pruning of brooms
   a. Phytosanitary pruning must be begun when a plantation is not more than 3 years old;
   b. One main pruning in the dry season <u>must</u> be completed before the first large wet season flush, removing at least 95 per cent of all brooms;
   c. A second pruning should be completed by mid-December;
   d. Pruned brooms:
      i) may be left on the ground IF foliage canopy is intact;
      ii) must be covered with leaf litter (or banana leaves) or be removed from plantation IF canopy is sparse.

ACKNOWLEDGEMENTS

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REFERENCES

Andebrhan, T. (1985) Relationship between the position of pods and other tissues and infection by C.perniciosa. In: Informe Tecnico, CEPLAC/DEPEA, 1984, 56, 56-59.

Barros, O. (1981) Cacao. Manual de Asistencia Tecnica No.23, p.215 Instituto Colombiano de Agropecuario.

Butler, D.R. (1980) Dew and thermal lag: measurement and an estimate of wetness duration on cocoa pods. Quarterly Journal of the Royal Meteorological Society, 106, 539-549.

Coy, M. (1986) Realidade atropela os planos do Polonoroeste. Pau Brasil, 11, 63-73.

Dale, W.T. (1946) Witches' broom disease investigations XII: Further studies on the infection of cacao pods, Tropical Agriculture, Trinidad, 23, 217-221.

Evans, H.C. (1981) Witches' broom disease - a case study. Cocoa Growers' Bulletin, 32, 5-19.

Fearnside, P.M. (1985) Agriculture in Amazonia. In: Amazonia (Ed. by G.J. Prance & T..E. Lovejoy), pp.393-418. Pergamon Press, New York.

Gregory, P.H. (1956) Microbiology of the atmosphere. Leonard Hill, UK.

Holliday, P. (1954) Control of Witches' broom disease of cacao in Trinidad. Tropical Agriculture, Trinidad, 31, 312-317.

Holliday, P. (1956) Further observations on the susceptibility of Imperial College Selections to Witches' broom disease. Report Cacao Research of the Imperial College of Tropical Agriculture, Trinidad, 1955-1956, 48-53.

Khonje, P.T. (1984) Effects of environmental factors on an isolate of Crinipellis perniciosa (Stahel) Singer, the cause of witches' broom disease of cocoa (Theobroma cacao L.). MSc Thesis, University of Reading.

Rodrigues, C.H. & Silva, J.A. (1986) Effect of pollarding in the recuperation of heavily infected farms. In: Informe Tecnico, CEPLAC/DEPEA, 1985, 94-96.

Rudgard, S.A. (1986) Witches' broom disease of cocoa in Rondonia, Brazil: pod losses. Tropical Pest Management, 32, 24-26.

Rudgard, S.A. & Butler, D.R. (1987) Witches' broom disease on cocoa in Rondonia, Brazil: pod infection in relation to pod susceptibility, wetness, inoculum and phytosanitation. Plant Pathology, (In Press).

FORTY EIGHT YEARS OF COCOA RESEARCH AT THE COCOA RESEARCH INSTITUTE OF GHANA

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The series of Gold Coast Department of Agriculture Bulletins dating from 1926 to 1938 contain many reports on topics ranging from yield and diseases to quality and storage of commercial cocoa beans, by such notable workers as H.A. Dade, G.S. Cotterell and R.H. Bunting, all of the former British Colonial Research Service. The studies were carried out at the Department's stations at Asuansi, Aburi, Kpeve and Kumasi where other important crops were also studied. The last of these Bulletins (Wright, 1938) described the establishment of the Cocoa Research Station at Tafo. In the history of cocoa research, the Tafo station was second only to the Cocoa Research Scheme of Trinidad.

By 1930 Ghana had been the world's largest cocoa producer for 20 years already and the industry was plagued by insect pest and disease problems. Production was declining in the Eastern Region because of cocoa swollen shoot virus (CSSV). It was against this background that the Agricultural Adviser to the British Minister of State for the Colonies, Sir Frank Stockdale, recommended in 1935 the setting up of the Tafo Research Station to investigate problems of pests and diseases in order to maintain production in the Eastern Region. A similar visit to Ghana and Nigeria by the Agricultural Adviser to the Colonial Office, Dr. H.A. Tempany in 1943 led to the establishment at Tafo of the expanded West African Cocoa Research Institute (WACRI) in 1944, with O.J. Voelcker as its first Director and a sub-station at Ibadan, Nigeria. The history and early programmes of both the Cocoa Research Station and WACRI have been well documented (Greenwood, 1943; and Voelcker, 1946, 1948a, 1948b). As we approach the fiftieth year of its establishment it is considered necessary to bring the account up to date. This paper, therefore, describes the activities and achievements of the Institute from 1938 up to the present time.

After the independence of Ghana (1957) and Nigeria (1960), WACRI was dissolved, giving birth to the Cocoa Research Institute of Ghana (CRIG) and the Cocoa Research Institute of Nigeria (CRIN). In Ghana, CRIG was adminstered by the National Research Council, later the Ghana Academy of Sciences and the Council for Scientific and Industrial Research (CSIR). It is a characteristic feature of the Institute's chequered history that when CSIR celebrated its Silver Jubilee in 1984 CRIG had already left the CSIR. CRIG was brought under the administrative control of the Ministry of Cocoa Affairs in 1976 so that it could function effectively within the cocoa industry. Since 1979 CRIG has been part of the Ghana Cocoa Marketing Board (now Ghana Cocoa Board), following the abolition of the Ministry. But despite all these changes in the Institute's history it has continued to fulfil its role in research alongside several cocoa research centres in other parts of the world.

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STAFF

The early research staff were almost exclusively expatriate (British) scientists serving with the Colonial Research Service or the Gold Coast Department of Agriculture; and a cadre of British scientists, some of whom are now internationally well known, is the corner stone of a long tradition spanning almost five decades. Four scientists, including A.F. Posnette and M. Greenwood, of the Central Cocoa Research Station at Tafo were absorbed by WACRI at its inception. The total number of British research scientists in 1944 was fifteen. In order to attract Africans with the aptitude for research a scholarship scheme for training at home or abroad was instituted.

RESEARCH PROGRAMMES, 1938-1962

In the early years, research was concentrated on the bionomics of the cocoa mirids, Sahlbergella singularis Hag. and Distantiella theobroma Dist., their predators and food-plants, and on the cocoa swollen shoot virus disease, its strains, insect vectors, alternative hosts and control.

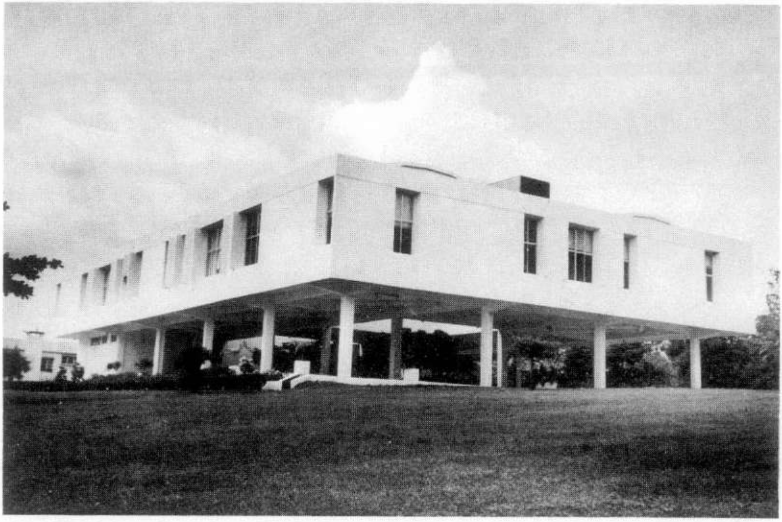

FIGURE 1: The Library Block at CRIG

COCOA SWOLLEN SHOOT VIRUS

The outbreak of CSSV in the Eastern Region of Ghana was first reported in 1936. As far back as 1930 its presence had been evident, but described as an 'extensive dieback' disease which was believed to be caused by deteriorated environment, poor soils and drought. But in 1936 W.F. Steven considered it to be an infectious disease and introduced cutting out as a control measure, using the presence of swellings for diagnosis. Dr. A.F. Posnette arrived in the then Gold Coast in 1937 and became involved in the setting up of the Central Cocoa Research Station at Tafo in 1938, as its first plant breeder, to breed for resistance to the pests and diseases. By graft transmission he soon demonstrated the virus nature of the 'die-back' disease. The graft experiments also produced conspicuous mosaic leaf symptoms which were more reliable for field detection of the disease than stem swellings. In a rapid series of elegant experiments. Dr. A. F. Posnette made many important discoveries about the vector and transmission of the virus, as well as the strains, symptoms, host range and epidemiology of the disease and he pioneered attempts to control swollen shoot disease by cutting out infected trees (Posnette, 1943). The eradication programme began in 1943 and has continued with interruptions for fifty years becoming the most ambitious of its type ever undertaken. Furthermore, in collaboration with J.McA. Todd, Posnette identified resistance and tolerance of virus infection among breeding materials. Posnette became better known as a pathologist than as a plant breeder, although he initiated an important breeding and selection programme which was to be pursued more extensively in later years, as discussed below.

Much attention was devoted to the study of the host range or natural hosts of CSSV. In a string of publications on this subject (Posnette, Robertson and Todd, 1950; Todd, 1951; Tinsley and Wharton, 1958 postulated that Ceiba pentandra, Cola cordifolia, Cola chlamydantha and C. gigantea, were the original hosts of CSSV and that the virus moved into cocoa when the latter was introduced into Ghana. In a later study of the pattern of distribution of the tree in West Africa, however, Tinsley (1971) has concluded that there is no convincing evidence for incriminating the wild indigenous trees as the original source of CSSV. He has suggested that CSSV came originally from South America.

ENTOMOLOGICAL RESEARCH

Collaborative entomological studies by Strickland and Cornwell on the insects associated with the CSSV disease were made (Strickland, 1951a, 1951b; Cornwell, 1956, 1958, 1960). These investigators pioneered studies on the taxonomy, ecology and bionomics of the mealybug vectors and their attendant ants. Their studies showed Planococcoides njalensis to be the most important vector of CSSV. P. njalensis was found to be protected by Crematogasterine and Oecophylla ants with the former building protective tents over the mealybug colonies. Anagyrus spp. and some Cecidomyiid midges were found to parasitise on mealybugs (Figure 2b).

The first entomologists also studied the population dynamics, ecology, biology and control of the major mirid pests, Sahlbergella singularis (Figure 2a) and Distantiella theobroma. Mirid attack on both young and mature cocoa resulted in die-back of the shoots. In young shoots the mechanical damage caused by the feeding, together with release of toxic saliva, caused necrosis and death. S.H. Crowdy (Crowdy, 1947) showed that mirid damage was usually followed by fungal infection, causing a chronic die-back condition. It was discovered also that when canopies were broken by fallen trees the improved light conditions favoured growth of flush shoots, which attracted mirids. 'Capsid pockets' were more numerous and most destructive from September to March.

By 1944 a simple but effective chemical control method had been devised for protecting young cocoa. It consisted of painting with one per cent aqueous DDT suspension the branching points of the young trees where the insects were found to rest in the heat of the day (Anon, 1950). In 1956 field control trials with Endrin, Aldrin, Dieldrin, gamma-BHC and Heptachlor were initiated in conjunction with the Department of Agriculture using the 'Motoblo' mist-sprayer.

In 1956 a large scale mirid control programme based on WACRI recommendations using Gammalin 20, (Lindane) was undertaken by the Ministry of Agriculture, financed by the Cocoa Marketing Board. In this scheme each gang of five operators was able to cover about 30 acres a day spraying the chemical with motorised mist-blowers. Farms were sprayed four successive months in a year, beginning from August with 280g a.i./ha for the first two months and 70g a.i./ha for the subsequent two months (Gordon, 1976). In 1960 a peak sale to farmers of 1.4 million litres of Gammalin 20 was made. There were spectacular increases in yield, and Ghana's peak production in 1965 of 520,000 tonnes was attributed to the 'saturation spraying' campaign of the early 1960s.

Control of mealybugs met with no success, however. Studies on the biological control of mealybugs with a few locally found parasitic insects and moulds, or with about one million exotic parasitic insects were of no avail.

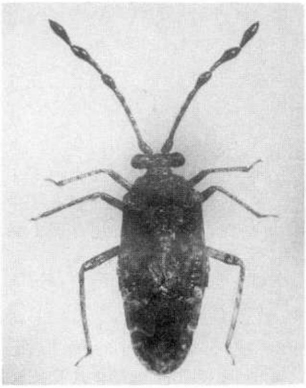

FIGURE 2a: Cocoa capsid, Sahlbergella singularis
FIGURE 2b: Mealybugs on cocoa pod.

Contact insecticides were found to be ineffective due to the protective tents built over the mealybugs by attendant ants, whilst systemic insecticides which were found to be effective were too toxic for safe use where food crops such as cocoyams were grown amongst the cocoa (Anon, 1950; Hanna, Heatherington and Judenko, 1952; Nicol, 1953; Thorold, 1975).

BLACK POD DISEASE

The black pod disease caused by Phytophthora palmivora was also common in the early days of WACRI and received considerable attention in the early 1940s. It was soon confirmed that, as shown earlier by H.A. Dade, disease incidence increased in cool, very humid weather; also the disease spreads from pod stalks into the wood of the tree. As a control, frequent harvesting of ripe pods, removal of infected pods from the trees and shade manipulation were recommended (Anon, 1950).

COCOA AGRONOMY AND SOILS

From the late 1930s onwards, the centre of cocoa production was shifting to the Ashanti and Western Regions where new farms were being planted to cocoa under shade provided by forest trees. Re-establishment of cocoa in the Eastern Region was made difficult by (i) prevalence of mirids which attacked and destroyed young cocoa and (ii) the degenerated environment resulting from food farming and loss of shade trees; and (iii) loss of soil fertility. Re-establishment of cocoa received immediate attention at WACRI. The use of temporary shade for young cocoa, permanent shade on older cocoa, shade density and shade management were studied. So also were planting seeds at stake and planting of seedlings from nurseries. A procedure for planting cocoa under these conditions, described in the Institute booklet, 'WACRI and the Cocoa Farmer', consisted of leaving the land to be replanted to fallow in order to regenerate the soil, clearing and preparing the land for replanting, but leaving seedlings of forest trees for permanent shade; planting plantain, banana and cocoyam to provide temporary shade and planting cocoa seeds at stake in straight lines 1.5m apart. Shade was provided by regenerated bush on either side of the planted rows. Shade reduction was then effected so that it was neither too much nor too little. It had been established already that too much shade reduced growth and yield. It was considered better to use local forest trees for shade than to use a single species of a tree not native to West Africa (Anon, 1950).

A method of propagation by rooted cuttings was successfully developed in the early stages using 0.5 per cent Beta-indoylbutyric acid. This enabled good plant parents to be propagated in large numbers from single leaf cuttings. The 'clonal trees' bore pods several years earlier than seedlings, and when left untrained had a low spreading habit.

COCOA POLLINATION

For a long time the agents of cocoa flower polliantion proved elusive because of their small size and the difficulty of trapping them. it is now established that Ceratopogonid midges are the chief agents of pollination. Serious studies on pollination were prompted by Voelcker's (Voelcker, 1937, 1938) discovery in Trinidad of self-incompatibility in cocoa. In the Gold Coast the presence on pollinated flowers of clusters of pollen grains and of fine hairs or bristles on the style and pollen clusters served as evidence implicating Ceratopogonid midges as the agents of pollination (Posnette, 1950; Posnette and Entwistle, 1957).

These were identified as Forcipomyia ingrant Carter, F. ashantii, and Lasiohelea litoraurea. Posnette (Posnette, 1950) used two characters, albinoism and axil spot, to determine the incidence and extent of cross pollination. He showed with both methods that cross-pollination accounted for 18-43 per cent of the total number of pods and that pollen was seldom carried more than two rows of trees. These findings were in agreement with those of Voelcker (Voelcker, 1937, 1940) and were useful for the designing of bi-clonal plots for production of clonal seed for distribution to farmers.

BREEDING AND SELECTION

Until the late 1940s the yellow podded Amelonado cocoa formed about 95 per cent of the cocoa cultivated in Ghana. It is a genetically uniform Forastero. The rest consisted of trees restricted to Trinitario or Criollo origin, often with elongated pods and red pigmentation.

While in Trinidad in 1943 and 1944, Posnette despatched 121 pods of cocoa and its allies with a view to broadening the genetic base for breeding of resistance to swollen shoot disease and the mirids. Some of the pods were obtained by crossing seedling trees collected by F J Pound in the area of the headwaters of the River Amazon. After a period of quarantine in Accra, seedlings from these pods were planted out at WACRI, Tafo in 1945. By 1948, the precocity and overall superior performance of the introduced upper Amazon cocoa types were generally acknowledged.

With this observation, the 1948 Commission of Enquiry into CSSV recommended that the best of the new selections should be multiplied by open pollination. After a careful assessment of vigour, precocity, yield and flavour, a total of ten of the new types were released as 'Mixed Amazons' in September 1954. Multiplication plots or Seed Gardens of the F_2 generation (from open pollination) were set out, for the production of F_3 open pollinated seeds for distribution to farmers.

THE IMPACT OF WACRI IN THE EARLY YEARS

With their early bearing and high yielding properties, the Mixed Amazons quickly became very popular with farmers, a success story which must be counted among the greatest achievements of the Institute. The Ghanaian peasant has a shrewd sense of judgement and appraisal that is sometimes witty, humorous and/or cynical. He was quick to christen the scourge of cocoa farms by mirids as "Go Back To The Oil Palm" ("San konu wo abe"). The early - bearing Mixed Amazons were christened: "Never too late for the Aged Farmer". With its far reaching research findings and recommendations, and the policy of opening its doors to a flood of farmers, teachers and students from both Ghana and Nigeria, WACRI soon made a gigantic impact on the farmer and the public as a whole, whilst being shielded by the Government and the Department of Agriculture from the effects of the unpopular recommendations of cutting out cocoa trees affected by CSSV.

THE POST INDEPENDENCE ERA

After the political independence of the British West African territories, the dissolution of WACRI in October 1962 and the formation of CRIG, 12 expatriate research staff resigned, leaving only 7 professional scientific staff and 25 vacancies. Of the 7 there were 3 Ghanaians and one Canadian. Canada was the first to provide technical assistance in 1963 with 2 entomologists and 2 technicians to work on the mirid problem which had taken on a most serious dimension. In 1963/64 three British scientists also arrived on technical aid. These expatriate staff headed the various scientific divisions, but under the first Ghanaian director, Mr. S.T. Quansah, who served from 1963 to 1965. A slow process of recruitment and training of Ghanaian staff was then begun. By 1970, out of the 16 research scientists on the station 11 were Ghanaians and another Ghanaian, Dr. E.J.A. Asomaning, was Director.

THE BRITISH RESEARCH TEAM

By the early sixties more than 140 million cocoa trees had been cut out under the government CSSV control programme, which had begun in 1946. But the vigour with which the programme was started could not be maintained due to hostility from farmers despite generous compensation for cutting out and replanting. The programme was abandoned altogether in 1962 when the Cocoa Division of the Ministry of Agriculture was disbanded. The swollen shoot epidemic subsequently increased, and in 1967 the Cocoa Division was re-established. Since then the cutting out of diseased trees has been carried out on a rather limited scale. This situation, coupled with the ease of re-infection of small areas of replanted cocoa close to infected trees, has made control of the disease by cutting out ineffective. In 1969 the search for resistant or tolerant types of cocoa, which Posnette initiated in the mid-1940's, was taken up in earnest with the establishment of a British Research Team, sponsored by the British Overseas Development Administration.

In 1964 the popular WACRI Series II or 'Tafo Hybrid' cocoa which were crosses made by R. Knight and H.H. Rogers between selected Upper Amazon parents from Posnette's 1944 introductions with

Amelonado and local Trinitario selections were released to farmers (Glendinning and Martinson, 1966; Martinson and Lockwood, 1974). Large scale seed production was facilitated by mass hand pollination in the seed gardens (Edwards, 1973). The Amazon parents of the Series II hybrids together with later introductions were the main source of material for selection for resistance to the swollen shoot disease.

The British Research Team began work by screening these types of cocoa and their crosses for resistance and/or tolerance. The screening methods were essentially those developed by Posnette, (Posnette, 1947) and consisted of starving mealybug nymphs collected from the field, feeding them on cocoa seedlings infected with CSSV (for virus acquisition), then transferring them to cocoa beans for 24 hours before planting the beans in seed boxes. After one month had elapsed, infection could be readily detected in the form of mosaic leaf symptoms (Kenten and Legg, 1970). Seeds of many different cocoa hybrids were compared and promising materials selected. The method was refined by use of manual inoculation with a partially purified preparation of CSSV, but inoculum could not be produced on a large enough scale. Hybrids showing a fair measure of resistance have been identified (Legg and Lockwood, 1981) and could be used to advantage (Legg, 1981). Lockwood (Lockwood, 1981) has concluded that there is little or no practical prospect of breeding stronger sources of resistance from available genotypes. However, in the tolerance trials, hybrids selected on the basis of laboratory tests proved to be sensitive in the field (Legg, Kenten and Lockwood, 1980).

The Team introduced a substantial number of cocoa clones from the Latin American and Caribbean Regions and CRIG now has one of the most comprehensive cocoa germplasm collections in the world.

After the British Research Team's departure more sensitive methods of detecting CSSV infection were developed as a tool for epidemiological studies and for further screening for resistance and tolerance. A new method of extraction and purification of the virus developed recently has enabled production of antiserum and the development of ISEM and ELISA (Adomako et al. 1983; Sagemann et al, 1983).

THE INTERNATIONAL CAPSID RESEARCH TEAM

Mirid resistance to Lindane was discovered in 1961 in the Eastern Region and had spread to Ashanti and the Western Region by 1963. Three experts Dr. R.A.E. Galley of Shell Co., UK., Prof. A.W.A. Brown, University of Western Ontario, and Dr.J. Marshall of Canada Department of Agriculture Research Station, Penticton, visited Tafo in 1963 and confirmed the occurrence of resistance. Following these reports the International Office of Cocoa and Chocolate (IOCC) arranged a visit by Dr. F.P.W. Winteringham in 1964 to study and advise on the situation. He subsequently recommended the sponsorship of a team of scientists to study and solve the problem. An International Capsid Research Team consequently arrived at Tafo in 1965 and worked for the next 6 years in Ghana and in Nigeria (Collingwood, 1972). This was funded by members of IOCC which groups together the world's manufacturers of cocoa and chocolate.

Marchart studied alternative insecticides and found propoxur (Baygon, Unden) and Orthobux, both carbamate insecticides, to be effective as replacements for Gammalin. Unfortunately, Baygon of low persistence because of wash-off from frequent rains and high evaporation and the residual effect was low (Marchart, 1970). Unden has subsequently been used on large scale since 1979.

The International Capsid Research Team also produced a wealth of data from detailed studies of specific aspects of the mirid problem, such as distribution and abundance of mealybugs, integrated biological and chemical control of pests, as well as resistance of cocoa varieties to mirid attack.

OTHER ENTOMOLOGICAL STUDIES

The economic effect, biology and control of Bathycoelia thalassina, a minor pest of cocoa, were studied in great depth by a number of authors (Gerard, 1964, 1965, Lodos, 1967 Owusu-Manu, 1975, 1976. T.Kaufmann (1973, 1975) conducted extensive studies into the pollination of cocoa. The work on the ecology of mealybugs pioneered by A.H. Strickland and P.B. Cornwell was taken up and greatly extended by M.Bigger and C.A.M. Campbell of the British Research Team (Bigger, 1976, 1981; Campbell, 1983). The later work showed tha Planococcus citri had replaced Planococcoides njalensis as the dominant mealybug species and that P. citri together with other mobile species may now be the more important vector of CSSV.

INCOMPATIBILITY

The genetics of incompatibility in Upper Amazon cocoa was worked out by R.H. Knight and H.H. Rogers who identified a series of 5 S-alleles which showed dominance and co-dominance and a sporophytic incompatibility reaction (Knight and Rogers, 1955a, 1955b). Using Knight and Roger's data, Glendinning (Glendinning, 1967) was able to demonstrate the occurrence of at least 16 S-alleles.

CYTOLOGICAL STUDIES: POLYPLOIDY AND INTERSPECIES CROSSES

Attempts to develop tetraploid cocoa were initiated at the Institute by Knight (Knight, 1957) as a means of improving the fertility of interspecies hybrids in Theobroma, and possibly developing the resulting polyploids as varieties. Work on the cytology and fertility of tetraploids was continued by Martinson (Martinson, 1975), and showed that improved fertility may be attained through careful selection of the tetraploid cocoa.

The hybrid between T. cacao and T. grandiflora (Knight and Rogers, 1955b; Martinson, 1966) was obtained which may have potentially useful genes for resistance to CSSV. Although the hybrid flowered, there was no fruit set. A successful F_1 backcross onto cocoa was obtained and this is currently being assessed for disease (CSSV) resistance. Flowering trees of the hybrid between T. cacao and T. angustifolim were obtained by G.Lockwood but they proved to be sterile.

BLACK POD RESEARCH

Efforts similar to the CSSV resistance programme have been expanded by J.D. Amponsah and A. Asare-Nyako over the past 15 years. These workers developed methods for selection for resistance to Phytophthora palmivora and selected material for field trials (Amponsah and Asare-Nyako, 1973).

Intensive epidemiological studies have also been conducted (Turner and Asomaning, 1962; Asare-Nyako and Dakwa, 1974; Dakwa, 1974; Asomaning, 1976) whilst the biology of the fungus has received considerable attention. The importance of invertebrates as vectors of the fungus was reported by Evans (Evans, 1973). Two chromosome types have now been identified, the most prevalent one in Ghana being the S type. Studies of chemical control have shown (Asare-Nyako, 1974) that it is economic to spray with copper.

SHADE MANAGEMENT, ECOPHYSIOLOGY AND FERTILISER STUDIES

The question of shade/light requirements has been intensively studied since the mid-forties. In the first shade and manurial experiment in Ghana shade removal was found to trigger much higher yield response in Amelonado cocoa (by 85%) than application of fertiliser per se (45.5%) (Cunningham and Lamb 1959; Cunningham, Smith and Hurd, 1961; Cunningham and Arnold, 1962). In three years the combination of shade removal and fertiliser application raised yield to just over 3,461 kg dry cocoa beans/ha and showed for the first time the high potential yield of Amelonado cocoa. The results also showed that under no-shade conditions if yield exceeded 2,241 kg/ha there was high uptake and a concomitant depletion of potassium. There was, therefore, need to increase the rate of potassium application when yield exceeded 2,241 kg/ha (Cunningham and Arnold, 1962).

After this experience with Amelonado the discovery by D K Acquaye, R W Smith and R G Lockard (Acquaye et al, 1965) of potassium deficiency in the precocious Amazon cocoa variety grown under no shade conditions came as no surprise. This problem has been studied on a long-term basis by Y. Ahenkorah and co-workers (Ahenkorah, 1966; Ahenkorah, Akrofi and Adri, 1974; Ahenkorah and Akrofi, 1977). Potassium is now an important component of standard fertiliser formulations for unshaded and/or high yielding cocoa. Physiological studies on the combined shade management and fertiliser trials was confirmed (Greenwood and Posnette, 1950) by the finding that cocoa flowers and flushes more frequently and intensively under no shade than under shade conditions (Hurd and Cunningham, 1961; Asomaning, Kwakwa and Hutcheon, 1971;

Bonaparte, Ampofo and Mensah, 1973). Recent studies of the seasonal free sugar levels, (Owusu, Adomako and Hutcheon, 1978) showed that the peaks of flowering and flushing coincided with those of free sugar levels. They also established a direct relationship between sunshine hours and free sugar levels. From this they have concluded that light is always limiting in shaded cocoa and have proposed that carbohydrate status is a triggering factor in flowering and flushing.

COCOA FERMENTATION AND QUALITY

Cocoa quality depends on the genetic type of the trees and can easily be ruined by careless fermentation. Research in the field of fermentation and quality has yielded a most fruitful result and is one of the most important achievements of the Institute. A policy of low cost technology has encouraged use of banana and plantain leaves for fermentation in heaps on the ground, whilst concern for uniformly fermented beans led to the discovery that aeration must be improved by turning larger heaps every 2 days over the period of 6 days (Knapp, 1934). Detailed studies carried out by (Howat, Powell and Wood 1957), and by Rohan and co-workers concerned uniformity of fermentation. Recognition of the importance of aeration led to the development of the 'Rohan Tray' method of fermentation.

The cheapest way of drying cocoa is in the sun, and the extended period of 10 to 12 days improves the quality of the final product (Adomako, 1983). A series of experiments, (Rohan, 1958; Rohan and Stewart, 1967) elucidated the formation of chocolate flavour precursors such as amino acids, peptides and sugars during fermentation and drying, and reaction of these precursors by Maillard-type reactions to form aroma compounds during roasting. With dynamic extension work and good quality control measures enforced by government, Ghana's cocoa, processed in small batches on many thousands of individual peasant farms, soon came to symbolise the best in quality, and has remained so.

COCOA BY-PRODUCTS

Interest in cocoa by-products and wastes utilisation was shown right from the beginning of the Institute's history. During the war, when shipment of cocoa was held up and supplies of basic needs had dwindled, short courses on the preparation of various products in Tafo and Kumasi were organised for 5,000 participants and a pamphlet was issued entitled "Household Uses for Cocoa" (Greenwood, 1942, 1943). After the war, due to availability of alternative supplies, the subject of cocoa by-products utilisation was neglected. Utilisation of husk and sweatings for animal feed and soap, alcohol, pectin and fertiliser production has been investigated at the laboratory and pilot-scale levels (Adomako, 1985).

LIAISON WITH OTHER ORGANISATIONS

From the beginning, the Institute maintained close links with institutions engaged in cocoa research in Trinidad, Brazil, Costa

Rica, and South East Asia. It has also carried out collaborative studies with the International Atomic Energy Agency (IAEA) in pesticide residues in cocoa and efficent use of fertiliser. A new research project with the Ghana Atomic Energy Agency concerns mutation breeding. It maintains close contact with the East Malling Research Station and the Rothamsted Experimental Station, from where many research scientists have been loaned to the Institute in the past. Between 1977 and 1980 the Institute collaborated with Harrisons and Crosfield Sdn Bhd., Malaysia and a British scientific team sponsored by the Cocoa, Chocolate and Confectionery Alliance in investigations into the causes of acidity in cocoa beans, and with Professor Bohle Biehl of the University of Braunschweig, West Germany, on ultra-structural and biochemical changes in cocoa during fermentation.

PRESENT SCOPE OF RESEARCH

As stated elsewhere the reason for bringing the Cocoa Research Institute under the Ghana Cocoa Board was to facilitate an effective link in the responsibilities. A significant development in the work of the Institute, therefore, was the broadening of the scope of research to include coffee and kola, both beverage crops (the former also marketed by the Board). Following this expansion, in 1975, the Institute established a sub-station at Afosu in the Eastern Region. At the suggestion of the former Director, Dr E J A Asomaning, the Board also supported the idea of CRIG adding shea nut and some lesser known oil tree crops to its schedule, thus making CRIG a veritable "BEVERAGE AND OIL TREE CROPS RESEARCH INSTITUTE". A sub-station was established at Bole in the North in 1976 solely for shea nut research.

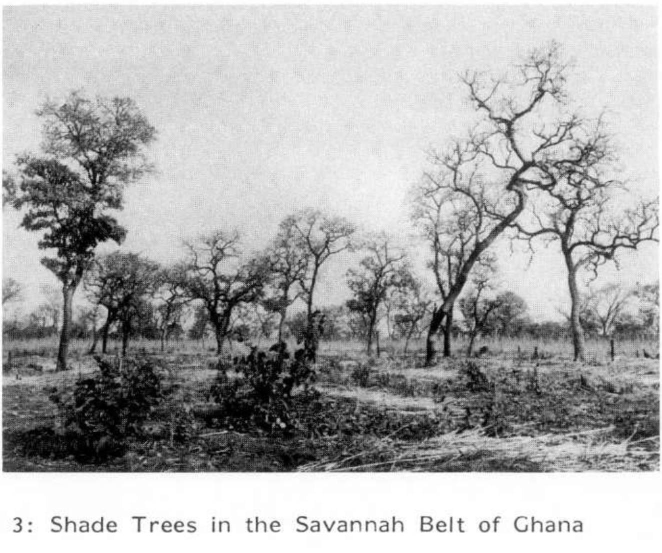

FIGURE 3: Shade Trees in the Savannah Belt of Ghana

A joint 3-year programme with the Virus Diseases Research Institute of the Federal Biological Research Centre for Agriculture and Forestry, Braunschweig (West Germany) on CSSV has just been completed. In Ghana close collaboration has been maintained with some Research Institutes and the Universities by providing part time teaching staff, and in joint research projects.

Shea trees are endemic in the savannah belt of Ghana (Figure 3) and the nuts have been collected from the wild trees and exported for the past 50 years. Locally shea butter is eaten in large quantities and used as a cosmetic. It is used abroad as a cocoa butter substitute and for the manufacture of margarine. An even more highly valued fat is that of Pentadesma butyracea (Table 1). The tree grows wild in the southermost part of the Savannah belt in the Brong Ahafo Region of Ghana. Its fat resembles cocoa and shea butter in its physical characteristics, and is also used as a cocoa butter substitute. Investigations into the soils, agronomy, ecophysiology, breeding, insect pests and diseases of these crops have been initiated.

TABLE 1: Physical and chemical characteristics and fatty acid composition of tallow (*Pentadesma butyracea*) fat, shea butter and cocoa butter.

Characteristics	Tallow Fat	Shea Butter	Cocoa Butter
Fat content of seeds	50.0	52.1	53.4
Ash content	2.1	3.2	2.8
Melting point (complete fusion) (°C)	39.0- 39.5	38.0- 39.5	34.34
Slip point (°C)	37.5- 38.2	36.7- 37.4	33.3 - 33.5
Iodine number	47.3	64.2	36.1
Acid number	8.3	13.4	1.8
FFA	4.2	6.8	0.9
Saponification number	188.0-194.0	179.6-190.0	190.6 - 195.0
Unsaponifiable matter (%)	1.5 - 1.8	7.3- 9.0	0.1 - 0.3
Solidification point (°C)	27.0 - 28.6	26.5-30.0	28.0 - 28.6

Component fatty acids (% of total)

Fats	Myristic	Palmitic	Palmitoleic	Stearic	Oleio	Linolenic	Linolenic	Degree of unsaturation
Tallow Fat	Nil	3.1	0.2	45.5	50.5	0.4	Nil	0.51
Shea Butter	Nil	4.8	Nil	45.9	40.8	6.9	1.6	0.59
Cocoa Butter	0.2	26.8	0.3	36.1	31.1	3.2	1.2	0.42

[Source: Adomako, 1977]

CONCLUSIONS AND FUTURE RESEARCH

The last expatriate permanent staff on loan from the Royal Netherlands Government left the Institute in 1982, but rarely is the Institute to be found without one expatriate group or another working on a specific project. It has been, and remains, a truly international research centre.

As amply shown in the history of the Institute, financial support has been provided and multidisciplinary teams have been formed to solve specific problems when they have arisen. For example, the establishment of WACRI itself to investigate urgently the swollen shoot and capsid epidemics, the International Capsid Research Team to study mirid resistance and alternative insecticides, and the British Research Team charged with breeding for resistance to CSSV. Two conditions are necessary for success in research; qualified staff and funds. When industry shows interest and ability to utilise research findings a healthy relationship exists between industry and research. But there is the danger of industry not being able to utilise research or not being able to fund specific problem-oriented research. This naturally leads to decline or failure of the industry. It is hoped that the cocoa industry at both the local and international levels will continue to support the work of the Institute. Especially, it is hoped that the resources of Ghana will be able to provide necessary funds and impetus for solving specific problems through research, be it on cocoa, coffee, kola or shea nut.

The causes of the decline of the cocoa industry in Ghana during the past decade have been summarised as:

1. Inferior producer price resulting in a switch by farmers to alternative more profitable food crops;
2. Scarcity of new plantings with a high percentage of cocoa tree stock being too old;
3. Shortage of labour due to rural-urban migration;
4. Lack of suitable incentives to prospective young farmers.

The labour problem may be the most important; and it may be seen to have started with mass education soon after independence. The peasant farmer whose labour force used to consist of his wife and children progressively found himself destitute, with his children drifting to the urban centres to seek white collar jobs, or taking to the distributive trade which became lucrative in recent years. While it can be said that answers to production problems are forthcoming from a vast store of technical and scientific research information, it is less certain how to solve the problem of decline brought about by such socio-economic factors.

The cocoa rehabilitation strategy of the government for the immediate future is to concentrate its efforts (extension services, insecticide supply, seed supply, spraying facilities, etc) on the parts of the cocoa belt which are still not badly affected by CSSV. For these areas, the use of cocoa hybrids showing an appreciable level of CSSV resistance will be beneficial. As detailed elsewhere

(Martinson, 1985), breeding and selection for drought resistance, and research into the establishment of cocoa in exposed and marginal areas are among the priority areas for research in the next decade.

The practice of using forest trees for permanent shade achieved a smooth integration of cocoa production and silviculture (Adomako, 1983. Years ago, when contiguous cocoa farms spanned vast areas, journeys around the cocoa growing regions were made through veritable forests which were not only an important source of timber but served to maintain the ecology of the countryside also. However, during the past decade the loss of farmer interest in cocoa has led to neglect and cutting down of cocoa to grow oil palm and food crops. These crops do not require shade.

As a result many of the forest trees have been felled and vast areas of forests have been denuded.

Deforestation affects many parts of the Eastern Region, Ashanti and Brong-Ahafo. But the situation is particularly serious in Brong-Ahafo and the northern parts of Ashanti which are close to the dry savannah belt and are threatened with acridity. The shattering effect of the decline of cocoa cultivation on the environment has not as yet received the attention it deserves, but it demonstrates clearly some environmental and socio-economic benefits of cocoa cultivation.

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REFERENCES

Acquaye, D.K., Smith, R.W. and Lockard, R.G. (1965) J. Hort. Sci. 40, 100.

Adomako, D. (1977) J. Sci. Fd. Agri. 28, 384-386.

Adomako, D. (1983) Outlook on Agriculture 12, 83-89.

Adomako, D. (1985). Proc. 9th Internat. Cocoa Res. Conf. Lome, Togo, 1984, 437-4.

Adomako, D., Paul, H.L., Lesemann, D.E., and Owusu, G.K. (1983) Ann. Appl. Biol 103, 281-284.

Ahenkorah, Y. (1966) Rep. Cocoa Res. Inst. Ghana, 1963-1965, 102.

Ahenkorah, Y., Akrofi, G.S. and Adri, A.K. (1974) J. Hort. Sci. 49, 43-51.

Ahenkorah, Y. and Akrofi, G.S. (1977). Proc. 5th Internat. Cocoa Res. Conf. Ibadan, Nigeria 1975, 291-301.

Amponsah, J.D. and Asare-Nyako, A. (1973) Can. - ORSTOM, Ser. Biol 20, 47-50.

Anon, (1950) West Africa Cacao Res. Inst. (WACRI), 1944-49, Tafo, Gold Coast, W.A.C.R.I., 31 p.

Asare-Nyako, A. (1974). Ghana Jnl. Agric. Sci. 7, 17-23.

Asare-Nyako, A. and Dakwa, J.T. (1974). In Phytophthora Disease of Cocoa, P.H. Gregory (ed.) Longman, London, 125-129.

Asomaning, E.J.A. (1976) In "Cocoa Production" (J. Simmons, Ed.) Praeger Publishers, New York, 413 p.

Asomaning, E.J.A., Kwakwa, R.S. and Hutcheon, W.V. (1971). Ghana J. Sci. 4., 47-64.

Bigger, M. (1975) Exp. Agric. 11, 193-99.
Bigger, M. (1981). Bull. ent. Res. 71, 435-448.
Bonaparte, E.E.N.A., Ampofo, S.T. and Mensah, J.Y. (1973) Rep. Cocoa Res. Inst. Ghana, 1971-72, 30-34.
Campbell, C.A.M. (1983) Bull. ent. Res. 73, 137-151.
Collingwood, C.A. (1972) PANS, 18, 46-55.
Cornwell, P.B. (1956) Bull. ent. Res., 47, 137-166.
Cornwell, P.B. (1958) Bull. ent. Res., 49, 613-630.
Cornwell, P.B. (1960) Bull. ent. Res., 51, 175-201.
Crowdy, S.H. (1947) Ann. appl. Biol. 34, 45-59.
Cunningham, R.K. and Lamb, J. (1959) J. Hort. Sci. 34, 14-22.
Cunningham, R.K. and Arnold, P.W. (1962) J. Sci. Fd. Agric. 13, 213-221.
Cunningham, R.K., Smith, R.W. and Hurd, R.G. (1961) J. Hort. Sci., 36, 116-125.
Dakwa, J.T. (1974) Turrialba 24, 367-372.
Edwards, D.F. (1973) Rep. Cocoa Res. Inst. Ghana, 1971-72, 163-170.
Evans, H.C. (1973) Ann. appl. Biol. 75, 331-343.
Gerard, B.M. (1964) Proc. Conf. Mirids and other cocoa pests, 1964, 101-110.
Gerard, B.M. (1965a) Nature, 207, 881.
Glendinning, D.R. (1967) Nature, 213, 206.
Glendinning, D.R. and Martinson, V.A. (1966) Rep. Cocoa Res. Inst. Ghana 1963-65, 52-56.
Gordon, J. (1976) In "Cocoa Production" (J. Simmons Ed.), Praeger Publishers, New York, 413p.
Greenwood, M. (1942) Household uses for cocoa. Gold Coast Dept of Agric., Tafo.
Greenwood, M. (1943) Rep. Central Cocoa Res. Station, Tafo, 1938-1942, 45.
Greenwood, M. and Posnette, A.F. (1959) J. Hort. Sci. 5, 164-174.
Hanna, A.D., Heatherington, W. and Judenko, E. (1952) Nature, 169, 334-335.
Howat, G.R., Powell, B.D. and Wood, G.A.R. (1957) Trop. Agric. 34, 249.
Hurd, R.G. and Cunningham, R.K. (1961) J. Hort. Sci. 36, 126-137.
Kaufmann, T. (1973) J. Kansas Entomol. Soc. 46, 285-293.
Kaufmann, T. (1975) Proc. 4th Conf. W. Afr. Cocoa Entomol., 77-80.
Kenten, R.H. and Legg, J.T. (1970) Ann. appl. Biol. 65, 419-424.
Knapp, A.W. (1934) J. Soc. Chem. Ind. 53, 151.
Knight, R. (1957) J. Hort. Sci. 32, 1.
Knight, R. and Rogers, H.H. (1955a) Heredity 9, 69-77.
Knight, R. and Rogers, H.H. (1955b) Empire J. exp. Agric. 23, 115-125.
Legg, J.T. (1981). The Cocoa Swollen Shoot Research Project at the Cocoa Research Institute, Tafo, Ghana, 1969-78. Technical Report Vol. 1. 160 pp.
Legg. J.T., Kenten, R.H. and Lockwood, G. (1980) Ann. appl. Biol 95, 197-207.
Legg, J.T. and Lockwood, G. (1981) Ann. appl. Biol. 97, 75-89.
Lockwood, G. (1981) Ann. appl. Biol. 98, 131.
Lodos, N. (1961) Bull. ent. Res. 57, 289-299.
Marchart, R. (1970) In Nuclear Techniques for Studying Pesticide Residue Problems, IAEA, Vienna, STI/PUB/252, 1-10.
Martinson, V.A. (1975) Genetics 45, 341.

Martinson, V.A. (1985) Proc. 9th Internat. Cocoa Res. Conf. Lome, Togo, 1984 11-14.
Martinson, V.A. and Lockwood, G. (1974) Proc. Internationaler Kongreb Uber Kakao und Schokoladeforschung, Munchen, 1974, 85-91.
Nicol, J. (1953) Proc. W. Afr. Internat. Cocoa Res. Conf. Tafo, Gold Coast, 1953, 18-20.
Owusu, J.K., Adomako, D. and Hutcheon, W.V. (1978) Physiol. Plant. 44, 43-47.
Owusu-Manu, E. (1975) Proc. 4th Conf. W.Afr. Cocoa Entomol., 1974, Univ. Ghana, Legon, 3-9.
Owusu-Manu, E. (1976) Biol. J. Linnaean Soc. 8, 217-244.
Posnette, A.F. (1943) Trop. Agric. (Trin.), 20, 116-123.
Posnette, A.F. (1947) Nature, 159, 500.
Posnette, A.F. (1950) J. Hort. Sci. 25, 155-163.
Posnette, A.F. and Entwistle, H.M. (1957) Rep. Cocoa Conf. London, 66-68.
Posnette, A.F., Robertson, N.F. and Todd, J. McA. (1950) Ann. appl. Biol. 37, 229-40.
Rohan, T.A. (1958) J. Sci. Fd. Agric. 9, 542-551.
Rohan, T.A. and Stewart, T. (1967) J. Fd. Sci. 32, 395-398.
Sagemann, W., Paul, H.L., Adomako, D. and Owusu, G.K. (1983) Phytopath Z. 106, 281-284.
Strickland, A.H. (1951a) Bull. ent. Res. 42, 65-103.
Strickland, A.H. (1951b) Bull. ent. Res. 42, 725-748.
Thorold, C.A. (1975) Diseases of cocoa. Clarendon Press, Oxford.
Tinsley, T.W. and Wharton, A.L. (1958) Ann. appl. Biol, 46, 1-6.
Todd, J. McA. (1951) Nature, 167, 952-953.
Turner, P.D. and Asomaning, E.J.A. (1962) Trop. Agric. (Trin.). 39, 339-343.
Voelcker, O.J. (1937) Imp. Coll. Trop. Agric. 6th Ann. Rep., 1936, 2-5.
Voelcker, O.J. (1938) Imp. Coll. Trop. Agric. 7th Ann. Rep., 9-14.
Voelcker, O.J. (1946) Trop. Agric. 17, 184-186.
Voelcker, O.J. (1948a) Nature, 161, 117-119.
Voelcker, O.J. (1948b) Emp. J. exp. Agric. 16, 241-248.
Wright, J. (1938). Dept. Agric. Gold Coast. Yearbook, Bull. No. 36, 36 pp.

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Born 1945 in Bedford, United Kingdom. Obtained BSc (Horticulture) MSc and PhD from Wye College. Joined the UK Overseas Development Administration on graduating in 1967 and was breeder in the British Research Team at the Cocoa Research Institute in Ghana from 1969 to 1978. On completion of the Ghana work, bred field beans at the Plant Breeding Institute, Cambridge until joining Commonwealth Development Corporation in 1984.

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Born in 1944 in France. Obtained the Diplome d'Etude Approfondie (D.E.A.) in Applied Genetics at University of Paris in 1969. Joined the same year in the Institut de Recherches du Cafe et du Cacao as cocoa breeder in the experimental station of N'koemvone in Cameroon, until 1977. Joined the IRCC Ivory Coast as Chief of cocoa genetics laboratory at Bingerville until 1983. Designated as an assistant of IRCC General Manager in Paris, in charge of cocoa technical matters.

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MAY 1986

20th Annual Report 1984. Research Dept., United Plantations Berhad, Teluk Anson, Perak, Malaysia - 126p.; Mar 1985. This annual report gives an account of the activities of the United Plantation Research Department (Malaysia) for the year 1984. The research activities are grouped in the following fields: (1) oil palm breeding and selection, cultural practices, nutrition and Pome (Palm Oil Mill Effluent); (2) coconuts, breeding and selection, cultural practices, nutrition; (3) cacao, breeding and selection, cultural practices, nutrition and crop protection. The report also includes a chapter on production and advisory activities. Rainfall and sunshine records are presented.

Record of an egg parasite of cacao pod-borer in Indonesia.

NAGARAJA, H., WORDOJO, S. and REYES, T.M. Cocoa Investors, Hagonoy, Davao del Sur, Philippines - Planter (Malaysia) v. 61(715)p. 469-472; Oct 1985. Trichogrammatoidea spp. (Hymenoptera, Trichogrammatidae), egg parasites of the cacao podborer (Conopomorpha cramerella) in Indonesia. The Trichogrammatoidea sp. from Indonesia (recorded in the island of Halmahera) is morphologically indistinguishable from T.cojuangcoi from the Philippines and Sabah. This parasite, which appeared to exert fairly high parasitism was isolated, bred and released against C.cramerella at the Christensen farm in Davao del Sur, Philippines.

Residiual effects of shade species during establishment on the yield of cocoa.

MARTIN, M.P.L.D., PRATAP, R. and PRASAD, G. Research Div., Ministry of Primary Industries, Suva, Fiji - Fiji Agricultural Journal (Fiji) v. 46(1) p. 17-20; Jan 1984. A field experiment was conducted at the Dobuilevu Research Station, Viti Levu in Fiji, from 1974 to 1982, to study the residual effects of the temporary and ground shade crops, banana, cassava and taro, and a permanent shade tree sp. Terminalia ivorensis, during establishment on the yield of cacao. Cacao shaded by banana gave appreciably greater actual and potential yield each from bearing until the termination of the experiment (1977-1982). The mean actual and potential yields for the 6-year period of cacao shaded by banana were 40, 35 and 32%, and 42, 40 and 34% greater than those shaded by terminalia, taro and cassava, respectively. The reasons for the superiority of banana as a temporary and ground shade crop for young cacao are discussed.

JUNE 1986

[Influence of cacao fermentation time on the production of pyrazines in chocolate] Influence du temps de fermentation du cacao sur la production des pyrazines du chocolat.

BAREL, M., LEON, D. and VINCENT, J.C. Institut de Recherches du Cafe et du Cacao (IRCC), Montpellier, France - Cafe, Cacao, The (France) v. 29(4) p. 277-286; Oct 1985. The free amino acids, monosaccharides and other aroma precursors of pyrazines, which represent 25% of the compounds in the aromatic fraction of chocolate, are produced during fermentation. The effect of fermentation time on the presence of pyrazines, first, on green cacao and then on roasted cacao was studied. The UPA x Amelonado hybrids used for this study came from Bingerville in the Ivory Coast. The concentration of tetramethylpyrazine in green cacao reached its maximum on the 7th day of fermentation. In the case of roasted cacao, the changes in the 9 principal nitrogenous basic compounds (including 5 pyrazines) revealed show the link between the production of pyrazines by roasting and fermentation time. For the Ivory Coast hybrids investigated, the fermentation time giving the maximum concentration of pyrazines was obtained on the 6th day.

[Some data on the in vitro vegetative propagation of cultivated trees Quelques donnees sur la multiplication vegetative in vitro des cacaoyers cultives.

DUFOUR, N. and DUBLIN, P. CIRAD, Montpellier, France - Cafe, Cacao, The (France) v. 29(4) p. 235-244; Oct 1985. The influence of physical and chemical factors on in vitro production of stems of primary explants taken from 4 to 5 cm long orthotropous fragments (including 1 of 2 nodes) of 8 to 10 month old Amelonado cacao was studied. In addition, rooting tests on first generation stems, separated from or with their primary explants were studied. Results show that it is possible to obtain rooted microcuttings from orthotropous stem fragments and that, after transfer to normal cultivation conditions, these produce well-developed seedlings suitable for planting out in the field.

[The soil diagnosis method to calculate the fertilizer requirements of the cocoa tree] La methode du diagnostic sol pour calculer les besoins en engrais des cacaoyers.
JADIN, P. and SNOECK, J. Agronomy Dept., Institut de Recherches du Cafe et du Cacao (IRCC), Montpellier, France - Cafe, Cacao, The (France) v. 29(4) p. 255-272; Oct 1985. A soil diagnosis method, developed by IRCC's Ivory Coast agronomic research stations is presented. The method is based on analyses of different types of soils in which nutrient balances, nutrient levels and soil pH were correlated with vigor and yield of cacao plantations. The assumptions made from these analyses were tested in pot and field trials. This method has made it possible to estimate the fertilizer needs of a plantation. Calculations were made with a computer programme. Some examples of fertilizer rates and application times are presented.

[Integral utilization of wastes from cacao enterprises] Aproveitamento integral dos recursos da empresa cacaueira. Commisssao Executiva do Plano de Lavoura Cacaueira (CEPLAC), Itabuna, Bahia, Brazil - 48 p. 1984. The cacao fruit can have many uses in smallholders' households. After field processing of the fruit, that is the separation of the beans from the pods, the husks or empty pods are fed to cattle, thus furnishing milk or meat and manure, which in turn furnishes, through bio-digestion, sludge and biogas. The beans are surrounded with a sweet pulp, which is used for making jellies, vinegar, alcohol and juices. In this way 30 000 kg fresh beans could give 2800 1 of jelly, 2800 1 of vinegar, 300 1 of alcohol, 5100 1 of juice and 10 200 1 of nectar. The different processing methods, accompanied with appropriate drawings, are discussed.

JUNE 1986

Combination of cacao with other plantation crops: an agroforestry system in Southeast Bahia, Brazil. ALVIM, R. and Nair, P.K.R. CEPEC, Itabuna, Brazil - Agroforestry Systems (Netherlands) v. 4(1) p. 3-15 1986. Brazil accounts for about 20% of the world production of cacao, and about 95% of cacao produced in Brazil is from the southeastern part of Bahia State. Traditionally, cacao is grown in monoculture (though under the shade of various other species). But various crop combinations involving cacao have recently been undertaken by the farmers with encouragement from Brazilian government. As a part of the crop diversification programme in the traditional cacao growing areas and their surroundings, extensive areas are being planted to other plantation crops, mainly clove, Eugenia caryophyllata (Syzygium aromaticum), and rubber and, to some extend, coconut too. Crop combinations have been adopted in some of these new plantings and cacao is an important component of most of such combinations. Whereas several other crops are combined with clove trees, cacao is usually the only species grown with mature rubber trees. Young rubber trees are, however, interplanted with a number of other species. Productive coconut areas are found mostly in sandy soils along the coast so that there is little intercropping. However, scattered farms are found where coconuts are underplanted with guarana, black pepper, cacao, cashew, etc. as done commonly in other parts of Northeast Brazil. The paper presents some data on the performance of some of the combinations involving cacao and other plantation crops based on field survey, and discusses the potentials and constraints of extending the system to more areas in the region.

Cocoa. WOOD, G.A.R. and LASS, R.A. - Longman, New York (USA) 4. ed., 639 p. 1985. ISBN 0-582-46352-1. The 4th edition of this book has been completely re-written and considerably enlarged to cover all aspects of cacao production in greater detail than before. In 17 chapters, aspects like history, botany and environment; crop planting, propagation and establishment; shading and nutrition, maintenance and rehabilitation; labour use; diseases and pests; post-harvest operations and quality and marketing, production and consumption are dealt with.

Study on suitability of cocoa soil in

relation to root density of cocoa. JAKRO, A.A. Institute of Agriculture, Timbank, Sabah, Malaysia - Planter (Malaysia) v. 62(718) p. 3-8; Jan 1986. The effects of physical and chemical properties of the soil at Timbang, Menggaris, Sabah, Malaysia, on root distribution of cacao were studied. The root density increased with soil depth. The top layer (0 - 20 cm) contained 66% of the total roots. Lower soil depths (40-60, 60-80 and 80-100 cm) were found to have an inferior aeration and poor drainage. Soil pH, exchangeable K and Mg, cation exchange capacity and base saturation were considered good, while organic matter content and exchangeable Ca were below the satisfactory level.

AUGUST 1986

Aspects of woodpecker damage to cacao in the Dominican Republic.
MITCHELL, B. and BRUGGERS, R.L. San Francisco de Macoris, Dominican Republic - Tropical Pest Management (UK) v. 31(2) p. 148-152: Apr 1985. The Hispaniolan woodpecker, Melanerpes striatus, damages cacao by piercing the pod and eating the pulp surrounding the developing seeds. Piercing of the pod permits invasion by insects and micro-organisms. Pod damage was assessed at 3.7% in 1981 and 3.5% in 1982, close to the 4% estimate of the Ministry of Agriculture of the Dominican Republic. Preliminary attempts to protect cacao pods using chemical repellents and colour cues were inconclusive. None the less, additional crop protection work, as well as changes in agricultural production practices, may ultimately provide sufficient aid to offset losses.

[Effects of cultivation practices on the production of the cacao tree in the lowlands of Amazonia]. Eifeitos de praticas culturais sobre a producao de cacaueiros em varzea amazonica.
NASCIMENTO, J.C., ALMEIDA, L.C. de and ALVIM, P. de T. Empresa Brasileira de Pesquisa. Revista Theobroma (Brazil) v. 14(3) p. 175-180; Jul 1984. The influence of cultural practices, such as clump thinning, maintenance pruning, and elimination of excessive shade on the productivity of the subspontaneous cacao in the higher lowlands on the margin of the Amazon River in the State of Amazonas, was measured. At the same time the effect of rainfall and the water table level on the physiological process of leaf fall and flushing of the trees was studied. The results show that leaf fall and flushing reach a peak in August when the flooding subsides, uncovering the lowlands. There was an increase of 83% in production due to improved cultural practices.

[Compatibility in different pollination systems of cocoa] Kompatibilitas dalam sistem perkawinan yang berbeda pada coklat.
CAPITUPULU, L.A. - Buletin Balai Penelitian Perkebunan Medan (Indonesia) v. 15(1) p. 3, 5-12; Mar 1984. To study the self-incompatibility and cross-compatibility in cacao the rate of the fruit setting was measured after self-pollination and related and unrelated cross-pollination. Artificial pollination was carried out on mature, 1 and a half to 2 and a half year old trees. As compared with cross-pollination, self pollination resulted in lower fruit setting rates and a higher "cherelle wilt". Self pollination of secondary clones in a polyclonal garden (144 clones) showed that nearly 10% of the clones were self-compatible. Ten primary clones of IMC, Pa, Pound, and UF selections were self-compatible and cross-compatible with unrelated populations. Cross-pollination in related parents resulted in low fruit setting or compatibility; some combinations were cross-incompatible. Reciprocal crosses showed differences between clones used as male or as female parents for fruit setting. The lower fruit setting in related parent crosses, suggested that a mixture of hybrid varieties would produce higher setting and pod production than a monohybrid stand.

[Limitation of the "cut test" in assuring the flavour quality of exported cacao beans] Limitacao da "prova de corte" no controle de qualidade do cacau comercial.
LOPEZ, A.S. CEPEC, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) v. 14(3) p. 199-207; Jul 1984. The role of the "cut test" in the determination of the cacao quality and its limitation are discussed. This procedure, recommended by FAO and adopted by many countries is to assure, among other factors, that fermentation has been adequate. Results obtained from classified cacao fermented by seven different methods were analysed. Suggestions for improving the test are given and their effects on the quality

of Brazilian cacao, especially with respect to its acidity, are discussed.

[Laboratory and field evaluation of fungicides against cacao moniliasis] Evaluacion en laboratorio y campo de fungicidas para el combate de la moniliasis del cacao.
MURILLO, D. and GONZALEZ, L.C. Agronomia Costarricense (Costa Rica) v. 8(2 p. 83-89; Sep 1984. The efficacy of 20 fungicides for the control of Phytophthora palmivora or Monilia roreri and other Monilia spp. were tested in vitro. Measurements were made in the inhibition of M. roreri conidia on water agar by each fungicide at 1 and 10 ppm. Readings at 1 ppm were erratic. At 10 ppm the most active fungicides were captafol, Omadine. (1-hydroxy-1-H-pyridine-2-thione) copper, Omadine zinc, Omadine sodium and chlorothalonil; the latter showed no significant difference ($P<0.05$) with triphenyl-tin-acetate (TTA, fentin acetate), dichlozoline, carbendazim, mancozeb, cuprous oxide, propoconazole, methylthiophanate and oxycarboxin. Captafol, clorothalonil, TTA and cuprous oxide were chosen for the field test. Field tests were run on the highly susceptible cacao clone "UF-29". All fungicides significantly reduced incidence of moniliasis with regard to controls (which reached 93% incidence); chlorothalonil treatment showed a 31% incidence; cuprous oxide 42%; TTA 51%, and captafol 74%. Persistence on the pods, after 2 weeks and 63.1 mm rainfall, was estimated as zero, 36, 55 and 92% captafol, chlorothalonil, TTA cuprous oxide, respectively.

[Indices to evaluate reactions of cacao cultivars to Phytophthora spp.] Indices para avaliar a reacao de cultivares de cacau a Phytophthora spp.
LUZ, E.D.M.N. and YAMADA, M.M. CEPEC, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) - v. 14(3) p. 181-188; Jul 1984. A grading system is proposed to measure the reaction of cultivars and hybrid progenies of cacao when inoculated with Phytophthora spp. The indices vary for each species according to its virulence to the cacao plant. The diameter of the lesions caused by P.capsici are one half and one third of those caused by P.palmivora and P. citrophthora respectively. The index scale complies with the proportions which are obtained generally when pods are inoculated and has to be applied to the mean of the diameters of the lesions obtained 9 days after the inoculation. In all tests highly susceptible cultivars were included as standards.

[Chemical control of Selenothrips rubrocinctus, pest of cacao in the Altamira region, Para, Brazil] Controle quimico de Selenothrips rubrocinctus praga do cacaueiro na regiao de Altamira, Para, Brasil.
MENDES, A.C. de B., BICELLI, C.R.L. and SILVA, G.J. de J. CEPLAC, Belem, Para, Brazil - Revista Theobroma (Brazil) v. 14(3) p. 189-192; Jul 1984. The cacao thrips Selenothrips rubrocinctus is a major pest of cacao in Para, Brazil. The insecticides Unden (propoxur) at 160 g a.i./ha, gamma HCH at 240 g a.i./ha, Folithion (fenitrothion), Malix (endolsufan) at 240g a.i./ha, carbaryl (Carvin) at 1200 g/ha and trichlorphon (Dipterex) were tested on the nymphal population of the cacao thrips. All the insecticides tested, with the exception of fenitrothion and trichlorphon showed an efficiency of more than 90% for the period of 14 days. Carbaryl, endosulfan and gamma HCH had a residual effect up to 21 days after application.

[Occurrence of Halisdota sp. (Lepidoptera: Arctidae) and its parasites on cacao trees in Southern Bahia, Brazil and evaluation of insecticides for their control] Ocurrencia de Halisdota sp. (Lepidoptera: Arctidae) e seus parasitoides em cacauais do Sul da Bahia e avaliacao de inseticidas para o seu controle.
FERRAZ, E.C.A., and ABREU, J.M. de CEPEC, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) v. 14(3) p. 193-197 Jul 1984. Outbreaks of Halisdota sp. on cacao trees, grown under the shade of Trema micrantha, are recorded for the first time. Field trials were carried out to evaluate the efficacy of carbaryl (at 360g and 540 g a.i./ha) and trichlorphon (250, 500 and 750 g a.i/ha), sprayed at 80 l/ha of spray liquid, with the addition of a sticking agent. Provisionally trichlorphon (Dipterex 50 ec) can be recommended for application at the rate of 500 ml a.i./ha. The presence of 2 parasites of Halisidota sp., viz Leschenaultia leucophrys and Lespesia affinis was observed in the field.

[A pseudo pest in the Mariendal cacao estate in North Sumatra] Hama semu

pada tanaman coklat kebun Mariendal di Sumatera Utara.
PARNATA, Y. - Buletin Balai Penelitian Perkebunan Medan (Indonesia) v. 15(3) p. 83-84, 93-96 1984. Severe damage of the exocarp of cacao pods caused by the membracid insect Leptocentrus vicarius was reported from a cacao estate in North Sumatra. The symptoms resembled canker lesions. Close observations showed that this bug was tended by the ant Anaplolepis longipes usually on the Gliricidia shade tree. At a sudden change in this environment, depriving them of much of their food, the bugs were lodged on cacao pods. The damage gradually decreased corresponding to the return to the natural balance. Because the seeds were not affected active control was not carried out.

[Testing of bulk cacao varieties in North Sumatra for growth vigour and earliness of fruiting] Pengujian beberapa varitas coklat lindak di Sumatera Utara ditinjau dari segi pertumbuhan dan kecepatan pembuahan.
ANWAR, S. and SURTIYATA, S. Buletin Balai Penelitian Perkebunan Medan (Indonesia) v. 15(2) p. 43, 45-52; Jun 1984. In 1973 bulk cacao varieties (Upper Amazon Hybrids) were introduced in North Sumatra. When adapted to local agro-ecological conditions bulk cacao is a vast and easy growing, early and highly productive crop. Six newly evolved Indonesian varieties have been tested on these qualities. Initial observations showed that PTP VI Sintetik No 2 and PTP VI Improved F_2 had more vigour and greater percentage of flowering and fruiting than the other tested varieties which were: PTP VI Sintetik No 1 and No 3, F_1 Eks Jember and PTP Improved F3.

[The effect of liming, based on soil exchangeable aluminium, on the growth of cacao seedlings] Pengaruh pemberian kapur berdasarkan aluminium tukar tanah terhadap pertumbuhan bibit tanaman coklat.
SUGIJONO and PANJAITAN, A. - Buletin Balai Penelitian Perkebunan Medan (Indonesia) v. 15(2) p. 43, 53-62 1984. An experiment was conducted to test the effects of liming on the growth of cacao seedlings. It was carried out under greenhouse conditions, using a yellow podzolic soil. The experiment indicated that liming treatment caused a significant increase on the plant growth and the dry matter production. The significant effect was due to improved chemical properties of the soil especially the soil exchangeable Al which is neutralised to a level nontoxic for the plant growth; the increased soil pH, and the increased Ca content. The optimum dosage of liming for the growth of the cacao seedlings was 1.5 x me exchangeable AL/100 g soil which was equivalent to 22.5 g $CaCO_3$/10 kg soil. The addition of lime in that dosage increased root weight and plant crown dry matter production to 231% and 169% respectively over the control.

[Quality requirements of cacao beans for the manufacture of consumption chocolate] Mutu biji coklat dan persyaratan yang dikehendak pabrikan.
HARUN, A. and ALAMSYAH, T.S. - Buletin Balai Penelitian Perkebunan Medan (Indonesia) v. 15(1) p. 4, 19-30; Mar 1984. For the production of good quality consumption chocolate, manufacturers seek dry and good quality cacao beans with the ability to develop a good strong chocolate flavour after processing, free from off-flavours, particularly smoke, mould and excessive acidity, bitterness and astringency. The average weight of cacao beans should be at least 1.0 gram, well fermented and thoroughly dried, with a moisture content between 6-7%, free from harmful bacteria, insect damage, foreign matters and pesticide residues.

SEPTEMBER 1986

[The influence of seed weight on development and vigour of cacao seedlings] Influencia do peso da semente no desenvolvimento e vigor de mudas de cacau.
FRAZAO,, D.A.C., COSTA, J.D. and Coral, F.J. The influence of the weight of cacao seed on seedling development and vigour was studied under nursery conditions. Seeds were classified into 3 groups, viz. light (0.9 to 1.3g) medium (1.4 - 1.8g) & heavy (1.9 - 2.3g). It was shown that heavy seeds gave stronger seedlings.

Competition between Corcyra cephalonica and Ephestia cuatella in cocoa beans.
ALLOTEY, J. and KUMAR, R. Dept. of Zoology, University of Ghana, Legon, Ghana - Insect Science and its Application (Kenya) v. 6(5) p.627-632

1985. Competition between Corcyra cephalonica and Ephestia cautella was studied in broken cacao beans using the 2 species alone, introduced after each other or together. Both species of moths cannot co-exist for an extended period and in competition E.cautella becomes extinct. The results offer an explanation of recent evidence that C.cephalonica is rapidly becoming the most important pest of stored cacao beans in Ghana today.

Cocoa production: present constraints and priorities for research.
LASS, R.A. and WOOD, G.A.R. (Eds). World Bank Technical Paper (USA) No.39, 103 p.1985. This technical paper reviews the more important biological factors in cacao production and takes a pragmatic view of how necessary improvements may be realised in the world's major cacao producing area with emphasis on problems that have, or may be expected to have, a major impact on production at the farm level. Subjects are presented in 10 chapters: (1) introduction; (2) cultivation; (3) agronomy and physiology; (4) selection and breeding; (5) propagation; (6) diseases; (7) insect & other pests; (8) pesticide application; (9) fermentation, drying & quality & (10) labour requirements.

OCTOBER 1986

The influence of harvesting, fermentation and drying on cocoa flavour quality.
LEWIS, J.F. and LEE, M.T. Planter (Malaysia) v. 62(721) p.134-141; Apr 1986. The flavour of Malaysian cacao can be made to resemble that of cacao from Ghana by changes in harvesting and processing, like: (1) allowing the pods to ripen before harvesting; (2) storing pods for about 10 days before splitting; (3) using a shallow bean depth (38 cm) during fermentation and (4) shorter fermentation periods (5 days) with fewer "turns" (one after 48h). (Malaysian cocoa standard and its implication on Sabah cocoa quality.
LEE, M.T. Cocoa Research Station, Department of Agriculture, Quoin Hill, Sabah, Malaysia - Planter (Malaysia) v.62(72) p.142-153; Apr 1986. The specifications for Standard Malaysian Cacao (SMC) beans, the procedures of grading and the possible effect on the physical quality of Sabah cacao beans are highlighted. SMC is classified into 6 grades according to the level of defective beans, insect damage and germinated beans. The best grade is SMC-I-A. The general quality of Sabah beans is good, but a considerable improvement of shell content, bean size uniformity of shell content is needed. The latter 2 parameters can be achieved by grading.

Determination of cadmium, lead, copper and arsenic in raw cocoa, semi-finished and finished chocolate products.
LEE, C.K. and LOW, K.S. Chemistry Dept., Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia - Pertanika (Malaysia) v. 8(2) p.243-248; Aug 1985. The levels of Cd, Pb, Cu and As were determined in 2 batches of raw cacao and semi-finished and finished chocolate products. The suitability of the method of dry ashing followed by analaysis by inductively coupled plasma emission spectrometry of these metals is also evaluated. It appeared that the analysis method used in the present study was suitable. The levels of Cd, Pb, Cu and As in raw cacao appeared high. Metal contents of locally produced chocolates are within acceptable levels, except for As which bordered on the limit. No contamination of metals during the manufacturing process was observed.

NOVEMBER 1986

[Chemical characterisation of cacao beans with a 'smokey' taste] Caracterisation chimique des feves a gout de 'fume'.
GUYOT, B., GUEULE, D. and MORCRETTE, I. IRCC, Montpellier, France - Cafe, Cacao, The (France) v. 30(2) p.113-120; Apr 1986. The 'smokey' taste of cacao beans is a defect which may have 2 origins: drying and storage. The development of an analytical, non-subjective method based on the qualitative and quantitative determination of phenolic compounds was undertaken to supplement the organoleptic tests used until then for the settlement of commercial disputes. Two types of bean samples were used: experimental samples, 'smoked' under control and commercial samples taken from contaminated batches. The samples were subjected to organoleptic tests and to analytical methods in which the volatile compounds of the beans were steam extracted. The phenolic compounds were identified by combination of gas chromatography and

mass spectrometry. Among the 7 additional phenolic compounds detected in the cacao with a 'smokey' taste 3-ethyl phenol and 3,4-dimethy phenol together accounted for 99% of the intensity of the 'smokey' taste.

[Various farmers' reactions to the project for the renovation of coffee and cacao plantations in Togo] La diversite de reponses paysannes au projet de renovation de la cafeiere et de la cacaoyere Togolaises.
RUF, T. Cahiers de la Recherche-Developpement (France) no.8, p.35-45; Oct 1985. The process of retrospective evaluation of a development project should be broader than a simple economic comparison between a reference point and a post-project situation. The process here proposed for the renovation of the coffee and cacao plantations exemplifies the intention of carrying out studies in order to understand the farmers' various answers to outside intervention. This implies considering successively how the plantation economy has structured the rural society before the project; how the project plan of action has been set up; and what results have been obtained, and interpreted by those in charge of the project.

[Heterogenous farmer structures: reactions to price changes. The case of rice and cacao in Ivory Coast] Structres paysannes heterogenes: reponses aux prix diversifies. Cas du riz et du cacao en Cote d'Ivoire.
RUF, F. IRAT, CIRAD, Montpellier, France - Cahiers de la Recherche-Developpement (France) no.8 p.6-9; Oct 1985. In Ivory Coast, coffee production is declining whereas cacao plantations are expanding. Rice output is decreasing since 1980. All this is due to the impact of producer prices upon the producers' economic choices and decisions as to production systems. Long term growth rate of cacao demand is estimated at 2% per annum while supply levels increase by 4 to 6%. Low producer prices for rice and import subsidies cause an artificial change in consumption patterns.

Studies on the feeding value of agro-industrial by-products. 3/ Digestibility of cocoa-pod and cocoa-pod-based diets by ruminants.

SMITH,, O.B. and ADEGBOLA, A.A. University of Ife, Ife, Nigeria - Animal Feed Science and Technology (Netherlands) v. 13(3-4)p.249-254; Dec 1985. Digestion studies with cattle and sheep were carried out to determine the effect of graded dietary cacao pod levels of 0,20,40% in cattle, and 0,15,30,45,60 and 75% in sheep, on nutrient digestibilities. Sheep digested only 23% dry matter (DM) and 51% crude protein (CP) of the pod. For ether extract (EE), digestibility was similar ($P>0.05$) across treatments. Pod dietary levels of 30% and above depressed ($P<0.05$) nutrient digestibilities. At the lowest dietary level of 15%, however, nutrient digestibilities were similar ($P>0.05$) to those of the control diet. A similar trend was observed in cattle in which test animals fed on diets containing 20 and 40% pod digested less ($P<0.05$) DM, CP and acid detergent fibre (ADF) than the controls. Highly negative correlations ($P<0.05$) were obtained between nutrient digestibilities and dietary levels of pod. The latter explained over 90% of the variations observed in nutrient digestibilities, except for EE for which an R^2 value of 0.48 was obtained. The results indicate that the addition of pod to grain-based ruminant diets at levels of 30% and above, may significantly depress diet digestibility. Low level performance may, however, be obtained in ruminants fed such diets containing up to 45% pod, since at this level, more than 50% of essential nutrients were digested.

DECEMBER 1986

Witches' broom disease of cocoa in Rondonia, Brazil: pod losses.
RUDGARD, S.A. Tropical Pest Management (UK) v. 32(1) p.24-26; Jan 1986. Pod losses caused by Witches' broom disease, Crinipellis perniciosa, passed 50% in cacao plantings in their 6th year in Rondonia, Brazil where no control was applied. It is recommended that pruning should be initiated in the 4th year after planting. Recovery of fermentable seeds from diseased fruits was minimal, and pod losses could be used to estimate yield loss. Monthly losses had to be calculated by comparing actual harvests with predictions based on previous fruit set. Manipulation of harvest time by manual pollination may create difficulties with pod weight/size and unpredictability of fruit wilt.

21st Annual Report 1985. Research Dept., United Plantations Berhad,

Teluk Intan, Malaysia - 116p. 1986.
In the annual report of the Research Department of United Plantations Berhad over the year 1985, experiments are reported in oil palm, coconut and cacao. For each crop, field experiments were conducted concerning breeding and selection, cultural practices and nutrition. The weed Nephrolepis bisserata did not have any significant effect on the performance of oil palms on peat. Naphthalene balls inserted into the frond axils, gave outstanding protection to coconut heavily infested with the rhinoceros beetle (Oryctes rhinoceros). Plantvax (oxycarboxin) reduced white thread blight (Marasmium scandens) incidence in cacao by 60.3%. Vitavax (carboxin) appeared to be effective for long term control of pink disease (Corticium salmonicolor) in cacao.

[CEPLAC report on cacao research 1983] CEPLAC Informe de pesquisas de 1983. CEPLAC, Ilheus, Bahia, Brazil - 497 p.1985. The research report for 1983 of the "Comissao Executiva do Plano da Lavoura Cacaueira" (CEPLAC) is presented. Activities during that period were devoted, amongst others, to breeding, developing plant protection measures, quality aspects, production systems, soil conservation, research of the natural resources, crop diversification, including rubber, pastures, fruit plants and spices, such as pepper, and development of methods for the control of Witches' broom disease caused by Crinipellis perniciosa (syn. Marasmiu perniciosa).

JANUARY 1987

[Tolerance of cacao hybrids to aluminium]. Tolerancia de cultivares hibridas de cacau a aluminio.
SANTANA, M.B.M., YAMADA, M.M. & SANTANA, C.J.L. de Divisao de Geociencias, Centro CEPEC, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) v 15(1) p. 9-18 Jan 1985. The tolerance of 5 cultivars of cacao to A1 was tested using nutrient solutions with different A; levels. Solutions were replaced every 2 weeks and their pH was adjusted to 4.0-4.2. The plants were collected at 110 days and their foliar area, dry matter production and P, K, Ca, Mg and Al contents of roots and aerial parts were measured. Cultivar SIC 831 x Sca 6 followed by SIC 831 x IMC 67 showed highest tolerance.
Chemical plant growth regulators in tropical plantation crops.
SETH, A.K. (ASPAC/FFTC) no.234, 15 p; Mar 1986. Three examples of present and future use of growth regulators in tropical plantation crops are reviewed. In tropical plantation crops ethephon is in common use stimulating latex flow in rubber trees; there is potential for the use of auxins on palm oil trees delaying fruit abscission to increase oil yield, and growth retardants have a wide application in limiting vegetative shoot growth giving effective chemical pruning. In nursery management, plant growth regulators will have an important role in controlling seedling size and seedling response to water stress.

A note on the qualitative damage caused to cocoa pods by Sahlbergella singularis.
OJO, A. CRIN, Ibadan, Nigeria - Turrialba (IICA) v 35(1)p.87-88; Jan 1985. The damage caused to cacao pods by the mirid Sahlbergella singularis was studied. Pod weight and husk weight were significantly reduced at damage levels (0, 25, 50 and 100% of the pod surface covered by mirid lesions) for bean weight, pod length, pod width, total bean number/pod and deformed bean number/pod.

Cocoa waste and its utilization.
NAMBUDIRI,E.S. & SHIVASHANKAR, S. Central Food Technological Research Inst., Mysore, Karnataka, India - Indian Cocoa, Arecanut & Spices Journal (India) v. 8(3) p.78-80; Jan 1985. Composition of raw cacao material and possible products from wastes are tabulated and discussed. These wastes are pod husk, mucilage, bean shell and germ.

[Effect of different levels of supplementation on weight gain of confined young bulls fed with fresh cacao pod husks] Efeito de diferentes niveis de suplementacao sobre o ganho de peso de novilhos confinados alimentados com casca fresca do fruto do cacaueiro.

LLAMOSAS, C.A., PEREIRA, J.M. & SOARES, M.S. CEPEC, Itabuna, Bahia, Brazil - Revista Theobroma (Brazil) v. 15(1) p.27-34; Jan 1985.
The effect of the supplementary feeding of a mixture of concentrates on the live weight gain of young bulls fed with fresh cacao pod husks was studied. Three levels of the mixture

were added to the husks, fed ad libitum to 21 young bulls confined for finishing. The average dry matter consumption from the bulk fraction did not differ among treatments. The bulk portions in the rations of treatments 1, 2 and 3 were 82.0, 77.6 and 71.4 per cent of dry matter respectively. There was no significant difference between treatments of live weight gain. The tendency of this parameter shows treatment 2 to be the most efficient.

FEBRUARY 1987

Incidence of cocoa black pod disease in Dakshina Kannada District (Karnataka), a major cocoa growing area in India.
MOHANAN, R.C. Regional Station, Central Plantation Crops Research Inst, Vittal, Karnataka, India - Indian Cocao, Arecanut & Spices Journal (India) v.(4) p.91-92; Apr 1985. Black pod disease of cacao, caused by Phytophthora palmivora is the most important cacao disease in India. A preliminary study has been undertaken to evaluate the incidence of this disease in 5 cacao-arecanut mixed gardens in Dakshina Kannada district, Karnataka. The lowest disease incidence recorded was 12.93% and the highest 29.78%. Incidence varied significantly from garden to garden. Disease incidence on nearly mature pods was 22.83% to 40.84%. It is concluded that losses from black pod must be very high and need more attention.

Standardisation of seed propagation in cocoa.
KESHAVACHANDRAN, R. and NAIR, P.Ç.S. Kerala Agricultural Univ., Trichur, Kerala, India - Indian Cocao, Arecanut and Spices Journal (India) v. 9(1) p.1-4; Jul 1985. Large, medium and small sized mature Forastero cacao pods collected monthly from Dec-Apr were cut into 3 equal portions (pedical, middle and distal). Sound seeds from each group were sown in polythene bags of 3 sizes (23 x 15, 25 x 18 or 30 x 20 cm) filled with potting mixture of soil, sand and farmyard manure of the ratio 1:1:1 or 1:1:2. Characters of pods in different months, vegetative growth, root growth and seedlings dry weight at 30, 60 or 90 day intervals are discussed as well as shoot and root growth of seedlings in bags and filling mixture. It is indicated that large and medium sized pods weighing > 350g with not less than 409 cc volume and harvested during Feb-Apr were desirable for raising seedlings in the nursery. The largest bags and 1:1:2 potting mixture were most suitable for raising seedlings.

The control of cocoa swollen shoot disease in Ghana: an evaluation of eradication procedures.
THRESH, J.M. and OWUSU, G.K. East Malling Research Station, Maidstone, Kent, UK - Crop Protection (UK) v. 5(1) p.41-51; Feb 1986. The effectiveness of the eradication measures that have been, or could be used to control cacao swollen shoot virus in Ghana is discussed. Removing only trees found with symptoms is shown to be an inefficient method of control unless outbreaks are very small. It is more effective to remove not only those trees with symptoms but also all apparently healthy trees adjacent to them. More drastic measures are justified in dealing with large outbreaks, and where these are numerous, the most effective procedure is to clear whole areas and replant in large compact blocks. There is little evidence to justify coppicing trees around treated outbreaks; routine eradication measures could be made more effective if a suitable insecticide was introduced for controlling mealybug vectors. More information is required on the performance of resistant varieties and other aspects before definite recommendations can be made on the most appropriate treatment and replanting practices in the different areas.

MARCH 1987

Effect of palm oil sludge cake on early growth of newly planted oil palm, rubber and cocoa in the field.
TECH, K.C., CHAN, W.H. and OOI, L.H. Agronomic Research Unit, Applied Agricultural Research, Buloh, Selangor, Malaysia - Planter (Malaysia) v. 62(726) p.368-382; Sep 1986. The properties of palm oil sludge cake indicate that it could be beneficial for promoting growth of immature oil palm, rubber and cacao in the field. Experiments were started at the end of 1982 to study surface application of the sludge cake as well as incorporating it into planting holes at the time of field planting. The results indicate that the sludge cake can be used as a supplement to inorganic fertilizers to improve early growth for cacao, oil palms and rubber. High

rates of application should be avoided; the suggested rates of sludge cake for the crops are: rubber and oil palm, 1-2 kg/planting hole; cacao, 0.25-0.5 kg/planning hole. As the effect of sludge cake was mainly nutritional, its use as a surface dressing will probably be limited to poor areas where nutrition is a problem and areas where frequent application with inorganic fertilizers is necessary.

Modelling agroforestry systems of cacao with laurel (Cordia alliodra) and poro (Erythrina poeppigiana) in Costa Rica. Inventory of organic matter and nutrients.
ALPIZAR, L., FASSBENDER, H.W. and HEUVELDOP, J. University of Costa Rica, San Jose, Costa Rica - Agroforestry Systems (Netherlands) v. 4(3) p.175-189 1986. Based on research conducted in Costa Rica, models have been developed for agroforestry systems of cacao under laurel and under poro, grown on a clay loam soil. Organic matter and nutrients (N, P, K, Ca and Mg) were analysed in soil, litter and plant parts (leaves, branches, trunks and roots). The model for the organic matter and nutrient cycles for both systems is discussed. A considerable part of the elements retained by E.poeppigiana in branches and leaves are put in circulation by pruning. Cacao in both systems presents no notable differences in N, P and Ca accumulation. Cacao accumulates more K and Mg under C.alliodora than under E.poeppigiana. In both systems the elements are accumulated in the following order: N > Ca > K > Mg > P. E.poeppigiana only slightly exceeds C.alliodora in reserves of N and Ca.

APRIL 1987

No abstracts.

MAY 1987

Twenty years' results from a shade and fertiliser trial on Amazon cocoa (Theobroma cacao) in Ghana.
AHENKORAH, Y., HALM, B.J. & APPIAH, M.R. Cocoa Research Inst. of Ghana, New Tafo-Akim, Ghana - Experimental Agriculture (UK) v.23(1) p.31-39.
The effects of 3 shade densities, NPK fertilizers and fertilizer-pest/disease relationship on Amazon cacao in Ghana over a 20-year period are reported. Yields, equivalent to the mean yield from the unfertilized plots, were achieved in about 3, 4 and 6 years in fertilized plots under the no-shade (S_0), medium-shade (S_1) and heavy-shade (S_2) treatments, respectively. There were 3 growth phases, each characterised by a different yield trend. No appreciable changes in the exchangeable Ca and Mg were observed during the experiments, but K dropped to 68% from its initial value while the available P of the unfertilized plots and the S_0 plots fell by 38%. Fertilizer recommendations for P and K should take account of overhead shade. The effect of N application was often negative. No direct relationship was observed between fertilizer treatment and the incidence of pest/blackpod/swollen shoot virus (SSV) disease of cacao. SSV infection was greatest under S_0. Cacao farms in Ghana cannot maintain high yields (above 1000 kg dry cacao/ha) beyond 15 years of intensive cropping.

[Effect of the size of explants and growth regulators on the development of the tissues of Theobroma cacao L. var.amelonado, cultivated in vitro]
Influence de la taille des explantats et des reulateurs de croissance sur le developpement des tissues de Theobroma cacao L., var. amelonado cultives in vitro.
LEGRAND, B. and MISSISSO, E. Ecole des Sciences, Universite du Benin, Lome, Togo - Cafe, Cacao, The (France) v. 30(4) p.239-246.
A technique for sterlizing explants taken from othrotropous suckers of cacao (var. Amelonado) is described. Explants require a minimum size below which growth regulators are necessary to induce rooting and bud bursting. In the medium used, no callus formation occurred except when seatin was present. Zeatin promotes a spectacular elongation of buds. IAA (indole acetic acid) only slightly promoted leaf development, while these leaves rapidly dropped. IBA (indole butyric acid) alone or together with IAA substantially promoted leaf development. However, bud growth was not continuous. This dormancy could not be disrupted.

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