COCOA GROWERS' BULLETIN

Number 50 **December 1996**

Contents

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EDITORIAL

The first issue of the Cocoa Growers' Bulletin was despatched in August 1963. There have been some delays in publication, but nevertheless 33 years later have reached issue Number 50 while maintaining the objectives of the publication. This provides an opportunity for looking forward to consider the future of world cocoa cultivation. There is one concern of over-riding importance.

Pests and diseases continue to devastate cocoa cultivation in nearly every cocoa producing area and more often than not, the farmers response is to apply agrochemicals (as insecticides or fungicides) in the hope that these will provide an effective control mechanism. An alternative approach to pesticide use known as Integrated Pest Management (IPM) was developed in the 1940s - 1960s. IPM attempts to tackle the entire agrosystem in which the crop and the pest are but two components. Different tactics are used in developing management systems that capitalise on natural biological factors with agrochemicals being only used as a last resort, with their dosage and application systems carefully adjusted to minimise harmful effects.

A successful IPM system should make use of all suitable tactics and techniques including pest and disease monitoring, development of insect and fungus resistant crops, cultural practices, maintenance of the pests natural enemies in the farmers fields, mass release of large numbers of these natural enemies and use of pest specific bacterial or fungal pathogens. Only as a last resort, would the minimal application of a chemical pesticide be considered*. Unfortunately, there have so far been almost no successful examples of successful IPM applications to cocoa cultivation.

The increased concern by environmentalists in particular and the public in general about the use of agrochemicals on any crop for human consumption puts an obligation on all of us in the world cocoa industry to minimise their use and develop methods of IPM The need is now urgent and requires a different approach to pest and disease control in cocoa. The research must start now!

* **adapted from Mengech,A.N., Saxena,K.N. and Gopolan,H.N.B. (1995) Integrated Pest Management in the Tropics : Current Statue and Future Prospects. John Wiley & Sons, Chichester, UK.**

ISSN 0045-7256 *R.A.LASS, EDITOR*

Cocoa Growers' Bulletin is published twice per annum by Cadbury Schweppes plc as an information service to cocoa growers, plantation staff, extension officers and research workers. It is distributed free with one copy being sent to each name on the current mailing list. Any correspondence including requests for names to be added to the mailing list should be sent to R.A.Lass, Editor, Cocoa Growers' Bulletin, Technical Development Department (V52), Cadbury Limited, P.O.Box 12, Bournville Lane, Bournville, Birmingham, B30 2LU, England.

REVIEW OF PRODUCTION, CONSUMPTION, STOCKS AND PRICES

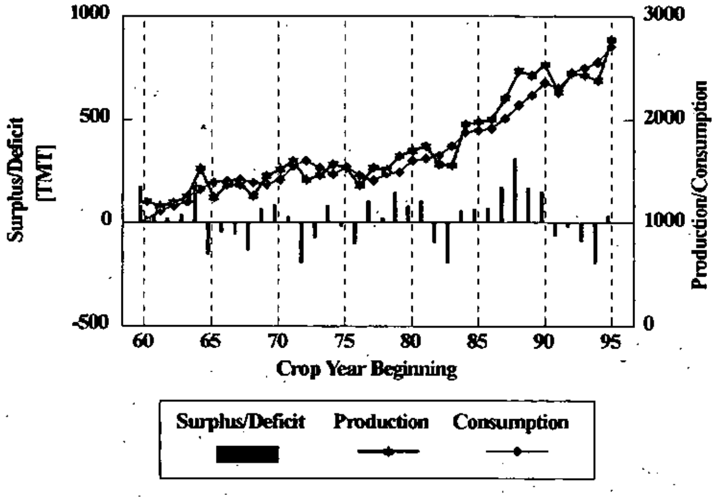
S.A.Wakeling

(October 1995 - September 1996)

PRODUCTION

E D & F Man Limited Cocoa Market Report No.356 reported that World production in 1995/96 would be 2,760 TMT ('000 tonnes), which would be 16.6% up on the 2,368 TMT in 1994/95. The bulk of the increase came from West Africa where production rose by 24.2% to a record 1,811 TMT and of this total 83.7% came from Ivory Coast and Ghana. The Ivory Coast was reported as having produced 1,125 TMT in 1995/96, a record high. Moreover, in Ghana the 1995/96 crop of 390 TMT was the highest for 20 years. Other than West Africa, the only other major increase over 1994/95 was from Indonesia whose 1995/96 crop of 290 TMT was up by 23.9%, though the 1994/95 crop of 234 TMT had been adversely affected by climatic factors. The two countries which showed a reverse over 1994/95 were Brazil and Malaysia. In Brazil the forecast of a 1995/96 crop of 219 TMT was down from 229 TMT in 1994/95 and compared to an average of 365 TMT over the period 1986/87 to 1990/91. It was due to a combination of witches' broom disease, poor farm husbandry and farm maintenance and a declining tree stock. In Malaysia the forecast of a 1995/96 crop of 105 TMT was down from a 1994/95 crop of 120 TMT. It is believed that the reduction from crops averaging 220 TMT in the late 1980s to the current levels of a little over 100 TMT has been due largely to a reduction in area, as growers move to oil palm and to a lesser extent due to lower yields as growers put less inputs into their cocoa because of low producer prices.

WORLD COCOA SUPPLY AND DEMAND



Source: **E D & F Man Limited, Cocoa Market Report No.356.**

WORLD COCOA PRODUCTION DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.356 (September 1996)

	1991/ 1992 **	1992/ 1993 **	1993/ 1994 **	1994/ 1995 **	1995/ 1996 (i)
Cameroon	108	99 *6*	95 *-7*	107 *9*	120
Ivory Coast	740 *17*	785	845 *10*	876 *41*	1125
Ghana	243	312	255	309 *2*	390
Nigeria	110	130	140 *5*	140 *10*	150
Others	31	30	30 *-1*	26 *-2*	26
Total Africa	**1232** *17*	**1356** *6*	**1365** *7*	**1458** *60*	**1811**
Brazil	301	305	276	229 *7*	219
Colombia	49	50	51	52 *2*	51
Ecuador	82	69	78	81 *4*	93
Mexico	51	51	39 *1*	43 *5*	35
Peru	11	11	11 *2*	12 *4*	12
Venezuela	15	16	18	16 *-2*	16
Others	10	12	12	12 *-1*	14
Total C. & S.America	**519**	**514**	**485** *3*	**445** *19*	**438**
Dominican Rep.	48	52	58 *-2*	55 *2*	55
Others	9	9	10 *1*	12 *2*	10
Total West Indies	**57**	**61**	**68** *-1*	**67** *4*	**65**
Indonesia	167	231	248	234 *-11*	290
Malaysia	217	219	204 *4*	120 *-25*	105
Papua New Guinea	41	39	31	20 *-6*	34
Others	18	20	19	15 *-4*	17
Total Asia & Oceania	**443**	**509**	**502** *4*	**398** *-46*	**446**
WORLD TOTAL	**2251** *17*	**2440** *6*	**2420** *13*	**2368** *37*	**2760**
% change in production from previous season	-10.7 *-0.2*	8.4 *-0.6*	-0.8 *0.3*	-2.1 *1.0*	16.6

(i) **Forecast.**

****** **Changes since the last edition of the Cocoa Growers' Bulletin.**

Note: **All figures in Thousand Metric Tonnes (TMT).**
Some figures may not add due to rounding.

WORLD COCOA CONSUMPTION DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.356 (September 1996)

	1991/ 1992 **	1992/ 1993 **	1993/ 1994 **	1994/ 1995 **	1995/ 1996 (i)
France	67	80	95	108 *-2*	112
Germany (Fed. Rep)	306	331 *20*	319 *15*	307 *29*	300
Italy	62	58	65	70 *3*	70
Netherlands	294	309	331	350 *-5*	377
United Kingdom	153	169	170	154 *-5*	183
Others	145	144	154 *-2*	147 *-11*	150
Total Western Europe	**1027**	**1091** *20*	**1134** *13*	**1136** *9*	**1192**
FSU/USSR	25	95	90	80	85
Other Eastern Europe	83	75	75 *3*	76 *2*	80
Total Eastern Europe	**108**	**170**	**165** *3*	**156** *2*	**165**
Ivory Coast	108	100	110	108 *-2*	120
Others	67	60 *-5*	71 *-12*	104 *18*	116
Total Africa	**175**	**160** *-5*	**181** *-12*	**212** *16*	**236**
Brazil	216	218	224	194 *-2*	205
United States	307	326	317	332 *-15*	353
Others	190	187	174 *2*	199 *15*	201
Total America	**713**	**731**	**715** *2*	**725** *-2*	**759**
Malaysia	87	99	103	100 *-4*	100
Others	187	192	191	223 *5*	250
Total Asia & Oceania	**274**	**291**	**294**	**323** *1*	**350**
WORLD TOTAL	**2297**	**2443** *16*	**2489** *6*	**2544** *18*	**2697**
% change in grindings from previous season	-2.0	6.4 *0.7*	1.9 *-0.4*	2.2 *0.5*	6.0

(i) Forecast.

****** Changes since the last edition of the Cocoa Growers' Bulletin.

Note: All figures in Thousand Metric Tonnes (TMT).
Some figures may not add due to rounding.

CONSUMPTION

E D & F Man Limited Cocoa Market Report No.356 reported that World cocoa consumption (as measured by World grind) would rise to 2,697 TMT, an increase of 6.0% on 1994/95, the highest annual growth rate since 1988/89. They reported that second quarter 1996 grinds of the five major grinding nations (USA, Brazil, the Netherlands, Germany and UK) had increased by over 12% on the second quarter of 1995. They believed that the small increase in the grindings of 2.2% in 1994/95 actually understated world cocoa consumption as it coincided with a significant reduction in cocoa butter stocks which had built up during the early 1990s. The strong grindings growth reflected good increases in many chocolate markets. For the period January to July 1996, chocolate production increased by 4% in the UK and by 11% in Germany. Much of the increase in Germany was to satisfy demand from Eastern Europe. In the USA chocolate shipments, for the first half of 1996, were 3% up on the first half of 1995 despite a 10% increase in the price of most chocolate products during December 1995.

STOCKS

E D & F Man Limited Cocoa Market Report No.356 reported that for the 1995/96 season there would be a small surplus of 36 TMT, after 4 years of deficit during which estimated world stocks had been run down from 1,449 TMT in 1990/91 to 1,061 TMT at the end of 1994/95. E.D. & F.Man Limited believe that another set of exceptionally large crops (as per 1995/96) would be needed to avoid returning to a deficit in 1996/97, particularly as the growth in grindings shows no signs of coming to an end.

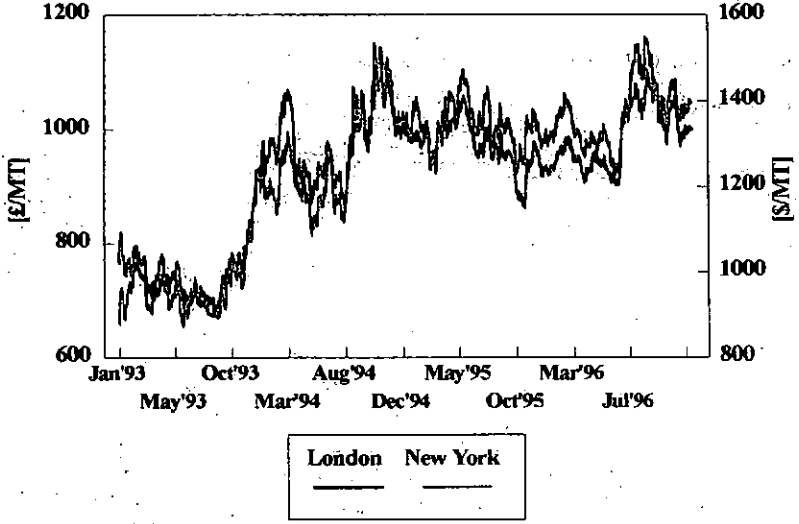
WORLD COCOA STOCK DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.356 (September 1996)

	1991/ 1992 **	1992/ 1993 **	1993/ 1994 **	1994/ 1995 **	1995/ 1996 (i)
Stock change	-69 *16*	-27 *-10*	-93 *7*	-200 *18*	-35
Closing stocks **(including buffer stock)**	1380 *41*	1353 *32*	1260 *39*	1061 *58*	1096
Stock/consumption ratio **(including buffer stock)**	0.60 *0.02*	0.55 *0.01*	0.51 *0.01*	0.42 *0.02*	0.41

(i) Forecast.
**** Changes since the last edition of the Cocoa Growers' Bulletin.**
Note: All figures in Thousand Metric Tonnes (TMT).
Some figures may not add due to rounding.

NEW YORK AND LONDON TERMINAL MARKETS - 2nd POSITION



Source: E D & F Man Limited, Cocoa Market Report No.356.

A REVIEW OF NIGERIAN RESEARCH ON COCOA SOILS 1940 TO 1990 AND PRESENT RESEARCH NEEDS

S.A.Ayanlaja*

INTRODUCTION

The paper reviews soil research on cocoa in Nigeria between 1940 and 1990. Before 1960, soil selection in Nigeria was based on purely visual observation and this resulted in establishment of some cocoa farms on substandard soils. Adequate data on soils to guide on the selection of good cocoa soils are now available and a more advanced land resource survey technique is being developed. Research on physical and water retention properties of soils revealed some physical properties that markedly affect cocoa growth and productivity.

Results of research on soil fertility and fertiliser application have been somewhat disappointing as most basic fertilisers either have no effect or negative effects on cocoa production under Nigerian conditions. However, continuous cultivation of cocoa leads to some organic matter depletion, and deterioration of soil physical and chemical properties and yield declines. Micronutrients, especially boron and zinc are known to increase cocoa yields by between 13% to 70%. The present extensive cultivation system of cocoa in Nigeria is inadequate, since soil productivity cannot be sustained under this farming system. There is therefore an urgent need to develop a method by which soil fertility and organic matter could be sustained. A viable and stable agroforestry system of cocoa cultivation should be devised with reliable soil water management arrangements.

Cocoa was first introduced into Nigeria around 1890 and the area planted to cocoa increased to 400,000 ha by 1940. The need to improve the cultivation management techniques for increased productivity was recognised, and the West African Cocoa Research Institute (WACRI) based in Ghana was established in 1944. When experiments there showed cocoa trees giving a yield response by fertilisers, the Ministry of Agriculture and Natural Resources (MANR) in Western Nigeria decided to start soil/fertilizer experiments in Western Nigeria in 1958 and an experimental station (to include cocoa) was established in Ibadan, Nigeria in 1962.

SITE SELECTION

The 400,000 ha established before 1940 by peasant farmers was with no technical support. A lot of Nigeria cocoa farms were planted before the establishment of the soil survey, characterisation and research unit in the Ministry of Agriculture and Natural Resources, which only came to being between 1951 and 1960 (Smyth and Montgomery, 1962). Soil suitability evaluation, before 1960, was based on visual observation on the basis that the soil must have been under forest or bush fallow for over 10 years and no reference was made to the physical condition of the surface or subsurface soils (Omotosho, 1975). Site selection was probably also sometimes only based on crude climatic measures, especially rainfall (Ali, 1969).

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Vine (1941), described five soil types in Nigeria based on texture, drainage and depth of the catena in the already existing cocoa belt. Smyth (1960) provided a guideline for soil selection for cocoa, based on visually observable criteria. Systematic soil research to identify the appropriate position of the catena that is most suitable for cocoa was only really started by Wessel in 1964. In this work of seven 0.1 hectare blocks, F_3 Amazon cocoa variety were planted on a strip 40 m wide down a slope in the forest of Gambari Experimental Station, Ibadan in 1964 and 1965. It was found that 3 years after planting, 80% of the cocoa planted at the lower portions of the catena died due to water logging during the wet season, while only 20% death was recorded for plantings at the top and upper slope portions of the catena. The results indicate the unsuitability of flood plains for cocoa cultivation, confirmed by Alvim (1967). Survival of cocoa in the top and upper slope portions depends on the amount of water held by the large volume of soil which can be tapped by the roots during the long dry season.

Egbe (1966), surveyed South Eastern Nigeria and based a suitability classification on the amount of rainfall in the area, soil pH and clay content in relation to water storage. Wessel (1969) gave a detailed description of the properties of cocoa soils across the whole of Southern Nigeria. He concluded that the best cocoa soils are formed on basalts.

Ayanlaja (1987), compared the soil physical and moisture retention properties of cocoa soils across the whole of Southern Nigeria with soil characteristics known to be suitable for cultivation of cocoa elsewhere and found that 44% to 55% of cocoa farms in Nigeria are sited on soils which are not particularly suited to cocoa Adequate data on soil particle analysis, depth, colour in relation to drainage, monthly rainfall and mean evapotranspiration in relation to soil moisture retention were presented to form a guide for site selections for successful cocoa cultivation.

Smyth (1988), described a land resource survey technique for land suitability classification for cocoa production.

STUDIES ON SOIL PHYSICAL PROPERTIES

The moisture release curve of clay and sandy soils in Nigeria was determined by Wessel and Adamolekun (1968). It was found that 86% of the available water was released in the PF range of 2.5 and 3.5 in the sandy soil as against 54% water released in the more clayey soil series. This explains the higher death toll of cocoa seedlings in sandy as opposed to clay soils. This is not unexpected. According to Babalola (1972), differences in soil moisture content were reflected in leaf area, root development, number and times of leaf flushing of cocoa seedlings. His work suggested that watering only once a month results in substantial leaf fall and consequent death of the seedlings.

Falade (1975) studied the interaction of bulk density (BD) and moisture supply on growth of an Amazon cocoa variety at four BD (1.13, 1.30, 1.43 and 1.79 g cm^{-3}) and 3 moisture supply levels in a factorial combination. The dry weights of both roots and shoots were found to increase to a maximum at BD of 1.35 g cm^{-3}, before decreasing with further increases in BD. The experiment also revealed that mechanical impedance in the sub-surface horizons caused cocoa seedlings to develop more lateral roots in the uncompacted surface layer. When surface layers have lost most of their water, this situation could result in death of the trees.

Ayanlaja (1987) found that water retention in the surface soils of nine cocoa farms in Southern Nigeria ranged between 8.7 and 35.6% at 0.3 bar and at 15 bar (field capacity) with a mean of 31.7%. When these figures are compared with 18% moisture content known to produce acceptable yield levels, it is obvious that some farms cannot support good cocoa growth.

SHADING AND INTERCROPPING ON SOIL PROPERTIES AND COCOA YIELD

One of the earliest experiments on the effect of shade on growth of cocoa was started in 1961 (Freeman and Wessel, 1961). Cocoa was planted under shade of tree cassava, plantain, pigeon pea. Sunn hemp (*Crotalaria juncea*) and two forms of artificial shade (palm frond tripod and plastic mulch) were included. Measurements taken of soil moisture just before the rains started in 1962, showed that soils under plastic mulch, palm frond, living shade and bare soil contained 11.3, 7.0, 3.6 and 4.0% soil moisture contents respectively. Consequently, the percentage of dead and leafless trees was highest (64%) in cocoa planted under living shade.

A 2^3 factorial trial involving presence or absence of N P K, Mg and shade with 4 replications on adult Amelonado cocoa was carried out at Ikom (S.E.Nigeria) in 1962. The trial results are given in Table 1.

TABLE 1 : EFFECT OF SHADE AND FERTILISER ON COCOA YIELD (KG/HA)

Treatment	Shade	No Shade
0	991	1233
N P	1157	1307
K Mg	1086	1172
N P K Mg	1157	1220

Intercropping cocoa with cassava, plantain and pawpaw showed that exchangeable K was lower in cocoa/plantain plots than in all other treatments (Egbe and Omotosho, 1971). Soil properties were better in the cocoa/kola intercropping arrangement in which a row of kola trees stand close and adjacent to two cocoa rows, than in arrangement where cocoa and kola rows alternate (Ekanade and Egbe, 1990).

SOIL FERTILITY, FERTILISER AND NUTRITION STUDIES

Kowal (1959), compared the soil contents of water, nitrate and organic matter under differently spaced cocoa and secondary forest and found that levels of soil organic matter and nutrients were higher, and soil physical conditions better, under forest than under cocoa. Cunningham (1962) also found that the level of nitrogen is much higher under forest than in cultivated lands. This indicates that the rate of nutrient removal under cocoa is greater than the rate of nutrient build up by litter decomposition.

Fertiliser trials in Nigeria were started by the Ministry of Agriculture and Natural Resources (MANR) in 1958, and involved mixtures of N P K and N P K Ca Mg fertilisers. Unfortunately, there were no conclusive results to these due to unsatisfactory experimental designs.

In collaboration with the Ministry of Agriculture and Natural Resources, the Cocoa Research Institute of Nigeria's (CRIN) started the Series I factorial fertiliser trials in 1962, and the Series II and III fertiliser experiments in 1964 and 1965 respectively.

TABLE 2: EFFECT OF FERTILISER ON YIELD (KG/HA) IN THE SERIES II EXPERIMENTS

	P_0	P_1	P_2	Mean
N_0	1195	1224	1249	1222.7
N_1	1102	1361	1560	1341.0
N_2	1224	1673	1816	1571.7
Means	**1173.7**	**1419.3**	**1542.3**	**–**

The Series I trials involved a $4^2 \times 2^3$ N P K Ca Mg factorial experiment at eight sites: Iddo, Aba-Agbo, Ayonrinde Ricket, Iroko, Akinyele, Balogun and Aiyetoro. All the sites were located in central western Nigeria with about the same rainfall (1,200 mm), on soils formed on basement complex (gneisses, granites, schists, quartzite and amphibole) rocks. It was found that the principal fertiliser effects were similar from year to year. By the sixth year (1968), Ca increased the yield at Akinyele, while it decreased it at Aiyetoro. There was no response to K and no significant interaction between N and K. Unfortunately, very low yields in two of the locations (Iddo and Iroko) somewhat invalidated the analysis. The yields of the series of experiments are low due to low rainfall which was also unevenly distributed (Egbe and Omotosho, 1971).

The Series II experiments involved a 3^3 N P K Mg factorial experiment. The experiment was located in 5 sites including Fidiwo, Oloba, Iwo, Ilesha and Fiditi. As in Series I, this experiment was carried out on 22 year old Amelonado cocoa trees. Six years of observation revealed significant effects of phosphorous. The response to K and Mg combinations were also significant, furthermore a significant interaction of N P was found at Oloba (Wessel and Adamolekun, 1968).

The Series III trials involved a 2 x 3 N P K factorial experiment at 4 locations: Oda, Oke-Irun, Ikole and Apomu. Six years observations show that P continually increased yield at Oda. There was no response to N and K and no interaction between elements were observed, (Wessel; 1962; 1963; 1966; 1969; Wessel and Adamolekun, 1968). The results are shown in Table 3.

Concurrent with the Series I, II and III experiments, CRIN also set up fertiliser trials at Araromi, Apoje, Ikom and Ibadan and a mulch and fertiliser trial was set up at Ibadan in 1962 by Wessel. Data showed that mulch (grass and banana leaves) greatly stimulated growth even after the twice yearly application of the mulch had been discontinued. N P fertiliser application was found to depress yield while other types and rates of fertilisers did not affect yield (Wessel and Adamolekun, 1968). It seems probable that the mulching treatment actually improved the moisture retention capacity of the soils.

TABLE 3: EFFECT OF FERTILISER ON DRY BEAN YIELD (KG/HA) IN THE SERIES III TRIALS

	N_0	N_1	P_0	P_1	K_0	K_1	SE	5% Sign Level
Oda	2144	1972	1818	2299	2079	2038	150.3	527
Oke-Irun	832	623	678	776	668	787	88.3	306
Ikole	1895	2114	2048	1960	2008	2001	121.8	418
Apomu	1136	1174	8877	1423	1290	1021	123.9	428
All sites	1427	1441	1316	1553	1463	1406	47.5	152

Source: Wessel and Adamolekun (1968).

A $2^2 \times 2^3$ N P K Mg factorials trial at Apoje (Basement complex soil), was planted in 1964. The results up to 1969 showed that only N P had any effect, producing a yield increase of only 2.3% (Wessel, 1969; Egbe and Omotosho, 1971). A 2^3 factorial experiment involving application N P K Mg, and shade with four replications was laid down at Abia and Ikom. The soils were deep, clayey, chocolate coloured and of volcanic origin. The effects of shade and N P treatments were found to be significant at 10% level, while application of $MgSO_4$ at 150 g per tree was found to depress yield (Wessel, 1962; 1969).

Generally, other fertiliser applications of major nutrients on young cocoa seedlings were found to be without effect or to slightly depress growth/yield (Egbe, 1968). However, Omotosho (1975) calculated the amount of the nutrients removed from soil and found that 38.97 kg of N, 6.29 kg of P, and 20.38 kg of K were removed by each tonne of harvested Amelonado cocoa. Based on this and the results of various fertiliser experiments, as well as fractionation, fixation and rate of N mineralisation experiments (Omotosho, 1965; 1970; 1971; 1975), he derived a fertiliser recommendation for Amelonado cocoa as follows: 136 kg N, 70 kg P_2O_5 and 58 kg K_2O per ha per annum and recognised the need to use higher fertiliser dosage for Amazon cocoa with incorporation of boron (Omotosho, 1975).

As early as 1961, micronutrient deficiency symptoms have been observed in Nigeria on seedlings in the nursery. To find the appropriate nursery soil where Zn and Fe deficiency will not constitute a constraint, soil from 4 sites was collected for a pot experiment. The treatment had 1.5 g Ca to induce Zn deficiency by raising pH, and 30 mg Fe with 30 mg Zn in addition to N P K Ca, and Mg. It was found that induced high pH (7.4) in soil samples having high % carbon (2.3) resulted to Zn deficiency in seedlings, while soil samples with lower pH and receiving Zn treatment produced healthy seedlings (Freeman, 1962).

In 1962, Wessel set up a nutrient spraying experiment to combat Zn deficiency. There were four treatments, Zn, Fe, Zn + Fe, and a control. Fe SO_4 and Zn SO_4 were applied as 1% solution at fortnightly intervals for 6 months. The results show that foliar Zn and Fe application had no effect on degree of Zn deficiency, as the average deficiency index remained virtually unchanged. However, deficiency symptoms were milder than the previous year.

Ojeniyi et.al., (1981) superimposed a boron experiment on half of 48 Amazon cocoa N K treated plots in four locations across Southern Nigeria. Boron was deficient in soil and leaves of untreated (12 year old) Amazon cocoa but boron treatment increased yield by between 13 and 70%. Application of N and K fertiliser reduced the impact of soil applied Boron.

Onianwa et.al., (1986) analysed forest mosses across the whole of Southern Nigeria for heavy metals and found 700 $^{u}gg^{-1}$ Cu, 30 $^{u}gg^{-1}$ Pb and 0.8 ^{u}gg-1 Cd. They suggested that the high Cu in plants was caused by the use of Cu based fungicide for *Phytophthora* control.

Ayanlaja (1983) analysed soils collected under cocoa farms across the whole of Southern Nigeria and found the surface soils to be high in Cu, Fe and Mn. The average 0.1 N HCl extractable micronutrients were recorded as : 10.27 ppm Cu, 400 ppm Mn and 20 ppm Fe).

Chude and Obigbesan (1983), obtained maximum dry matter yield in six month old Amazon and Amelonado cocoa varieties by applying 10 and 50 ppm Zn respectively. Cu contents of the cultivars were similar and root Cu decreased with increase in Zn supply. Fe was concentrated in the root and Mn in the leaves and Zn increased Mn supply to Amelonado cultivar.

PRESENT RESEARCH NEEDS

Despite the volume of soil research in cocoa in Nigeria, soil chemical and physical deterioration will still result in drastic yield reductions. The major cause of tree death in Nigeria has been low available water in the soil especially during the long dry season. Wessel (1964) reported 90% death of young trees during a dry season. Smith (1964), Alvim (1967), Ali (1969), Sale (1970), Babalola (1972), Hutcheon et.al., (1973), Falade (1975) and Ayanlaja (1987) all showed that growth, survival and yield of cocoa were greatly influenced by available soil water. Heavy rain does not always permit the incoming rainwater to infiltrate the soil adequately as 60% of rainwater is lost to runoff (Lal, 1974). Future research should survey the possibility of storage and re-use of runoff water for tree irrigation and systems of irrigation have been studied in some other cocoa growing areas because of their advantage in maintenance of soil water for sustained productivity (Oron et.al., 1983; Hillel, 1988; Orchard and Saltos, 1987; Khan et.al., 1988).

Cultivation of cocoa results in gradual depletion of soil organic matter and consequently to deterioration of soil chemical and physical properties, with concomitant yield reductions (Omotosho, 1965; Wessel, 1966; Omotosho, 1971; Are, 1971; Omotosho, 1975; Ayanlaja, 1983; Ayanlaja, 1987).

It has also been observed that mineral fertiliser application does not solve the problem instead, it may even aggravate it. N P K application has been observed to either have no effect or to bring about yield reduction (Wessel, 1965; Egbe and Omotosho, 1971). However micronutrient applications in Nigeria have resulted in between 13% to 70% yield increases (Ojeniyi et.al., 1981; Chude and Obigbesan, 1983).

Since cultivation of cocoa leads to organic matter depletion and soil deterioration in Nigeria, a farming system whereby organic matter is continually added to soil needs to be developed for cocoa. Shade or shelter tree species which improve soil productivity and yields and enhance cropping systems are needed. The central role played by the trees in shifting cultivation and bush/fallow rotation system is the provision of nutrient rich leaf litter which increases soil organic matter. An agro-forestry system currently known to be capable of sustaining soil fertility in the tropics is the alley farming system. This system involves the integration of other tree species, managed within the cropping system. Research has shown that the system is highly stable and sustainable. The trees act both as a nutrient pump and nutrient source, ensuring the constant injection of major and minor nutrients and their effective cycling within the system.

Trees, especially legumes, provide mulch and organic matter to maintain soil fertility (Kang and Wilson, 1987). Trees increase soil nutrients by nitrogen fixation, control erosion, and maintain high level of soil organic matter and so bring about improvement of soil structure, aggregation and water retention, (Sanginga et.al., 1989; Nair, 1985; Kang and Wilson, 1987; Kang and Duguma, 1985).

Development of an appropriate viable and stable agro-forestry system involves the selection of appropriate leguminous trees/shrubs, compatible with cocoa trees. Nutrient recycling under specific shrub/cocoa combinations, soil water, rate of pruning, the rate of decomposition of pruning, the nutrient profile of the pruning, all need be investigated to give an agro-forestry system for cocoa under which the soil productivity could be sustained and the gradual deterioration of soil properties halted. Similar systems are being developed in other cocoa growing parts of the world and the inventory of nutrient and nutrient profile in agroforestry system with various legume/cocoa combinations is indicating that productivity of the soil could be sustained under such a system (Alpizar et.al., 1986).

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THE COCOA BREEDING PROGRAMME IN GHANA : ACHIEVEMENTS AND PROSPECTS FOR THE FUTURE

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INTRODUCTION

The earliest cocoa planting materials were West African Amelonado and non-Amelonado selections described as 'Local-Trinitarios'. These had poor establishment capabilities, long generation time, and low yields but good commercial bean quality. The initial objective of the breeding programme was to improve these poor qualities while retaining physical bean quality. With the identification of Cocoa Swollen Shoot Virus disease (CSSV) in the late thirties and its subsequent development to epidemic proportions, breeding for CSSV resistant cocoa became an important breeding objective. These two objectives have subsequently dominated the breeding programmes at the Cocoa Research Institute of Ghana (CRIG). Breeding to improve establishmentability, long generation time and low yields, made significant progress with the development of hybrids between selected Upper Amazon types and crosses of West African Amelonado and local Trinitario types. Breeding for CSSV resistance has achieved very little mainly due to poor sources of strong resistance to the disease.

Breeding for resistance to the black pod disease has been undertaken in Ghana but this was not a primary objective, because losses due to the disease have not been substantial. Breeding achievement in this area is also limited due to lack of availability of sources of resistance. However, in recent years the losses which were being caused by the *P.palmivora* has been overtaken by *P.megakarya* which is highly virulent under the Ghanaian conditions. Total (ie. 100 percent) losses due to the disease are being recorded in some farms in Ghana and it is spreading to new areas steadily. Breeding for resistance to the disease has now become a major objective.

Most of the cocoa farms in Ghana are old and replanting is needed urgently. There are long periods of drought and this together with depletion of soils means that the replanting and establishment of new cocoa farms is extremely difficult. Planting materials with greater vigour are now needed.

The objectives of the present breeding programme at CRIG are:

i. breeding to improve yield;
ii. breeding to improve establishmentability;
iii. breeding for CSSV resistance; and
iv. breeding for *P.megakarya* resistance.

This paper discusses the strategies being adopted to achieve these objectives.

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Genetic Resources

The availability of suitable genetic variability in the germplasm is a pre-requisite for successful breeding programmes in a country where the species is not native. The germplasm collections at CRIG, Tafo mainly include local Amelonado and Trinitarios (Posnette, 1943) most of which are uniform, Posnette's 1944 Trinidad introductions (Posnette, 1948), materials from the 1952 Anglo-Colombian collection expedition (Chalmers, 1970) the introductions made by the British Research Team from 1969 to 1979 (Lockwood & Gyanfi, 1979) and in total recent germplasm obtained through the Cocoa Quarantine Facility at the University of Reading (Anon, 1991). These represent about 740 clones. Efforts are now being made to introduce more germplasm.

Information on the genetic diversity of the cocoa collection in Ghana is essential to the design of a coherent breeding strategy. For example, information on the degree the populations are genetically related can:

i. help decide what parents to use for making new genetic combinations;
ii. help in selecting parents for maximising heterotic responses; and
iii. help identify populations that should be maintained to preserve maximum genetic diversity in the germplasm.

Simple and accurate determination of genetic relationships based on comparisons throughout entire genomes is needed in order to use the information most effectively in cocoa improvement. Simple techniques for detecting polymorphisms in DNA sequences have been developed in a number of crop plants including cocoa (Russel et.al., 1993) and we intend to use such techniques for determining genetic relationships in our germplasm collection.

Three factors have limited the success of germplasm conservation in Ghana - bush fires, CSSV outbreaks and the age of trees. A number of measures are being taken to minimise these threats including duplication of the germplasm at two other sites miles apart and far removed from the CSSV endemic areas. A third site has been selected in the *P.megakarya* endemic area so that field evaluation of the clones for resistance to the disease could be carried out as well as conservation. Another strategy is to modify the treatment of CSSV infected trees in the germplasm collections, so that the number of trees removed per treatment is reduced, so that instead of removing the infected tree and all those in contact with it, only the infected tree is removed whilst the contact trees are coppiced and allowed to rejuvenate. New leaf flushes of the rejuvenated trees are assessed and only trees which then show disease symptoms are eliminated.

Breeding to Improve Yield and Establishment Potential

Historically breeders have paid a lot of attention to breeding for resistance to diseases, especially CSSV, the primary objectives of the CRIG breeding programme are now to increase the establishment potential and to maximise potential yield. Since stronger sources of resistance to the prevalent diseases (CSSV and black pod) are currently lacking, our strategy is to breed for varieties that will establish quickly and give the farmer adequate economic returns before destruction by CSSV.

Most of the cocoa farms in Ghana are old and need to be re-planted, the soils are impoverished due to overcropping and the dry seasons are generally becoming more severe than previously, making cocoa establishment ever more difficult. We are therefore seeking vegetative vigour in the pre-bearing phase as this leads to ease of establishment. Such varieties are being developed for areas which originally carried cocoa, but have become marginal due to overcropping and the changing pattern of the dry seasons. To achieve this, we are selecting for parents that are genetically distant to take advantage of heterosis.

In addition, most of our seed gardens planted in the late fifties are now old and need to be re-planted. Some of the parents such as T60/887, T79/501 and T85/799 could still be used, but the genetic base is narrow and new parents are needed to replace the inferior parents or to augment the superior parents. We have initiated what is being called the "alternative hybrids programme" to search for superior female parents from the non-Upper Amazon accessions in our germplasm.

Breeding for Cocoa Swollen Shoot Virus Disease Resistance

Lack of strong sources of resistance in current populations is the main limitation to breeding for resistance to the disease, though other factors such as poor screening procedures and lack of understanding of the genetics involved are also important limitations. Studies in virus detection and identification, mealybug-transmission efficiency as well as studies on host effects have been initiated together with virologists and biochemists. These will help in the development of reliable laboratory screening procedures for selection of resistant parents. To understand the genetics of diseases, mapping the cocoa genome and identifying molecular markers linked to genes controlling resistance to diseases is required, but will have to be undertaken in close collaboration with laboratories experienced in dealing with these advanced techniques. RAPD markers have been used to construct a low density genetic linkage map of cocoa and the anthocyanin biosynthetic locus has been placed in one of the linkage groups (Osei, 1993). It is likely that RAPD markers linked to important genes such as CSSV resistance genes could be identified and a programme has been initiated in collaboration with the Molecular Biology Laboratory at Pennsylvania State University funded by the American Cocoa Research Institute.

The cocoa swollen shoot virus is not found in the centre of diversify of the *Theobroma* species and so it is highly likely that cocoa is a recently acquired host of the virus while some forest trees indigenous to West Africa, such as *Ceiba pentandra*, are the original host plants. These trees are not killed by the virus. Future research in host plant resistance to the virus will have to identify the resistance mechanisms observed in these species and mimic them or alternatively find ways to duplicate or incorporate these mechanisms into cocoa. The availability of modern molecular techniques now makes these plausible alternatives for application cocoa in the not too distant future.

Recently we attempted to induce CSSV resistant mutants in cocoa by subjecting cocoa budwood to gamma rays (Adu-Ampomah & Owusu, 1993) and screening the budlings at MV4 and MV5 stages for CSSV resistance. Eight plants have been obtained while after persistent inoculations have shown no disease symptoms. Even though these plants appear to be chimeric, this indicates that resistance to the disease could be induced. Research in this area will be pursued.

Breeding for Black Pod Resistance

The lack of success in breeding for resistance to the disease caused on a global scale by either *P.palmivora* or *P.megakarya* is also seen in the programme. The problems are:

i. unreliable screening procedures;
ii. lack of strong resistance sources; and
iii. lack of understanding of the genetics of host pathogen interactions.

A similar approach to that being used to breed for CSSV resistance will be adopted, to include developing reliable laboratory screening procedures and the identification of RAPD markers linked to loci conferring resistance to the disease. In the case of *P.megakarya*, another breeding strategy being adopted is to develop for varieties with peak yields outside the rainy season during which time the *P.megakarya* infection is low or negligible.

Future Prospects

The cocoa breeding objective in Ghana will centre on maximising potential yield and maximising realisable yield in areas favourable for cocoa cultivation and marginal areas respectively. Robust varieties will be of special importance in Ghana where most farmers have low income. Attempts will be made to combine the attributes of different populations by selection among hybrids between them and assessing if maximum heterosis could be attained.

In breeding for resistance, novel methods that could induce variations in the desired direction, such as mutation breeding together with tissue culture and genetic transformation will have to be investigated. Methods that could speed up breeding programmes which have hitherto been slow should be devised and then be adopted Such methods could include the DNA based methodologies for mapping, such as restriction fragment length polymorphisms (RFLP) and random amplified polymorphic DNAs (RAPDs). This will require closer collaboration between research institutes in Ghana and advanced laboratories outside cocoa producing countries.

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ACKNOWLEDGEMENT

The author express grateful thanks to Mr J.N.Krofa for typing the manuscript. The paper is published with the permission of the Executive Director of Cocoa Research Institute of Ghana.

PERFORMANCE OF COCOA HYBRIDS UNDER TWO SHADE SYSTEMS AT CATIE, COSTA RICA

J.A.Morera*

INTRODUCTION

The cocoa crop in Central America and the Caribbean has been traditionally managed by farmers in different ways, under varying ecological systems. The natural habitat of cocoa is a lower storey tree in the lowland humid tropical forest where it grows associated with palms, small trees and bushes; for this reason cocoa has been traditionally established under shade and is considered as typically a shade-loving plant (Enriquez, 1985; Martinez and Enriquez, 1984).

Growing cocoa without shade may give rise to problems. Depending on the soil's natural fertility, increasing extraction of nutrients leads to a decrease in production and early tree senescence (Dominguez, 1985) unless nutrients are replaced with fertiliser. Complete elimination of shade in productive cocoa plantations leads to a rapid yield increase, but it also leads to early deterioration of the plantation due to disease and insect attacks, finally causing the death of the cocoa trees (Wood and Lass, 1985). Single species rarely have all the desirable characteristics required of the ideal shade tree for cocoa. However, those with the best qualities for a given locality should be selected (Jimenez, 1980a; Suarez, 1987; Santos and Vieria, 1982). The choice of shade species varies between regions and countries (Martinez and Enriquez, 1984). Vinha and Mattos (1982), provide a list of 131 native trees recommended for permanent shade for cocoa in the State of Bahia and the northern part of the State of Espirito Santo, Brazil. Some species recommended for permanent shade of cocoa are fruit trees such as *Citrus* spp., *Annona* spp., *Anarcardium occidentale* and *Calocarpum mammosum*; legume trees, mainly the genus *Gliricidia*, *Inga* and *Erythrina*; timber trees; *Cedrela toona* (red cedar) and *Cordia alliodora* (laurel); *Bactris gasipaes* and other species such as *Cocos nucifera*, and *Hevea brasiliensis* (Gutierrez and Soto, 1976; Jimenez, 1980b; Martinez and Enriquez, 1984).

Legumes have the advantage of incorporating nitrogen to the soil and some of them produce useful quantities of firewood (Gutierrez and Soto, 1976; Vinha and Mattos, 1982). The species *Erythrina poeppigiana* is easily reproduced through cuttings and seeds and annually incorporates nitrogen equivalent to 224 kg per ha of ammonium sulphate (Martinez and Enriquez, 1984). *C.alliodora* (laurel) is considered to be a promising shade tree due to its fast growth, straight trunk and an apparently deep root system. The crown gives high leaf production, is self pruning and the wood is used for construction of floors, ceilings, doors, windows and cabinets (Martinez and Enriquez, 1984).

Alpizar et.al., (1986) studied two agroforestry systems in Costa Rica: cocoa under laurel (*C.alliodora*) and cocoa under mountain immortelle (*E.poeppigiana*) or 'poro' as it is locally called.

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There were no differences as regards nitrogen, phosphorus and calcium accumulation between these systems, but potassium and magnesium production was higher under laurel shade as was total biomass production, though there was almost no difference in the aerial biomass production of cocoa under the two shade systems (Fassbender et. al., (1988).

Heuveldop et.al., (1988) also studied the above systems and showed that cocoa and wood production was slightly higher under *Erythrina* shade. Natural production of leaf litter under *E.poeppigiana* was 8.9 tonnes per ha per annum some 1.8 tonnes higher than under *C.alliodora*.

The study reported on here compares these two shade systems for cocoa hybrids, which was undertaken to evaluate the response on yield and other factors under the conditions existing at the Tropical Agricultural Research and Training Centre (CATIE), Costa Rica.

MATERIALS AND METHODS

The trial was planted in 1977 and is sited 602 metres above sea level, 83°38' West longitude and 9°53' North latitude. The annual average temperature is 21.5°C, with a average maximum of 26.5°C. Average annual rainfall is 2630 mm, with a relative humidity of 87% (Figures 1, 2, 3 and 4). The soil is of loamy texture and very deep and the pH oscillates between 5.0 and 6.0. The treatments to be compared are cocoa planted under poro (*E.poeppigiana*) and cocoa planted under laurel (*C.alliodora*) shade. The shade trees are planted at 6.0 x 6.0 m and the cocoa at 3.0 x 3.0 m in both cases.

Each plot comprised 32 trees of CATIE experimental hybrids of Catongo x Pound 12 cross. There were two guard rows of another cross to minimise interference between the plots and to provide pollen. The two treatments were managed the same, though poro was pruned twice per annum, a full prune in May at the start of the wet season with a partial prune in November. At planting, each tree was given 100 g of a 10-30-10 fertiliser and in later years four applications of 18-10-6-5 (to total 600 g per tree per annum) were applied. Unfortunately in later years, this fertiliser was not always available locally and so others were used, but always in equal amounts per plot.

Glyphosate was applied for weed control at planting, but after that the crop was maintained by manual weeding. From about 10-24 months, the plots also received regular rounds of formation pruning to establish a good shape to the tree.

From the time of appearance of the first pods (in 1979), harvests were made every two weeks and number of pods and dry beans were recorded. Unfortunately in 1981, only pod numbers were recorded for six months and so the amount of dry bean has had to be estimated.

When the first pods appeared, a biweekly record of cocoa production began which continued for 11 years. The number of infected pods with "marchitamiento prematuro" (cherelle wilt) and number of shoots* per tree were also recorded and the pod index for the hybrid and for the season was calculated. The data was analysed and mean difference was determined through the Duncan multiple range test.

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* Shoots being those from any plant part other than terminal, lateral or latent buds on stems.

FIGURE 1 : SUMMARY OF RAINFALL DATA (AVERAGE OF 54 YEARS DATA)

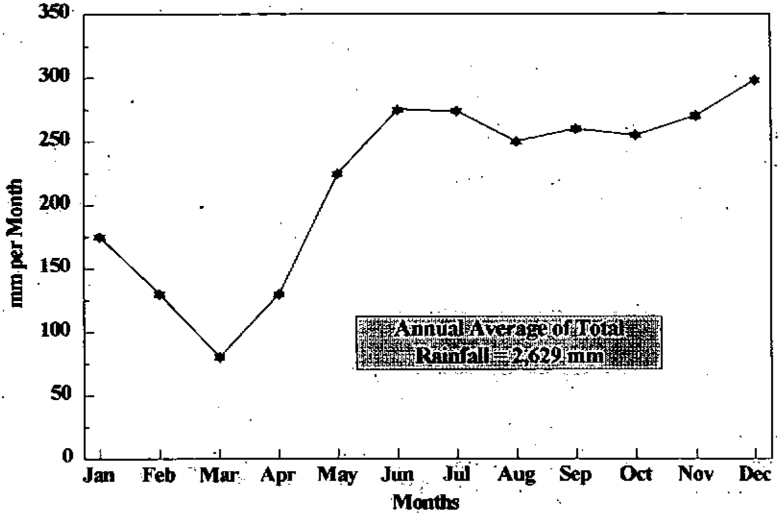
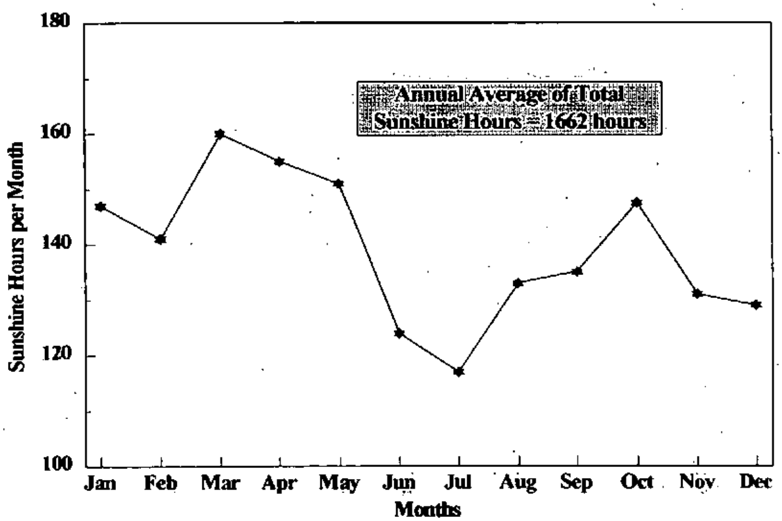


FIGURE 2 : SUMMARY OF SUNSHINE DATA (AVERAGE OF 37 YEARS DATA)



Source: Meteorological Station, CATIE.

FIGURE 3 : SUMMARY OF TEMPERATURE DATA (AVERAGE OF 37 YEARS DATA)

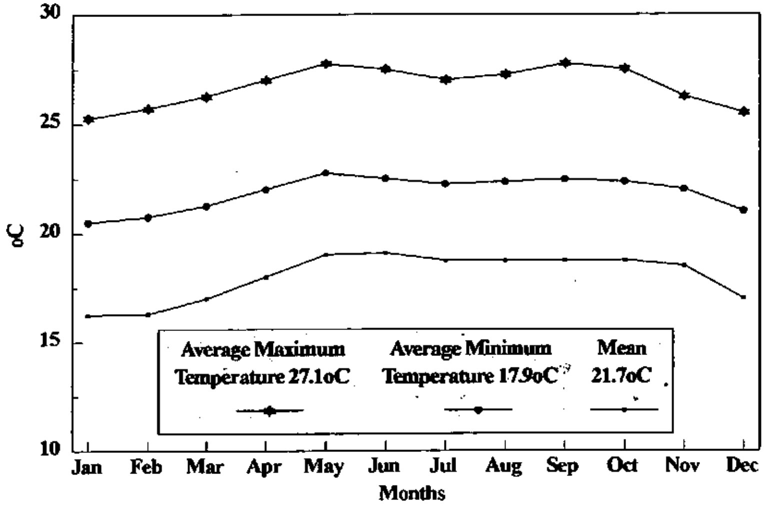
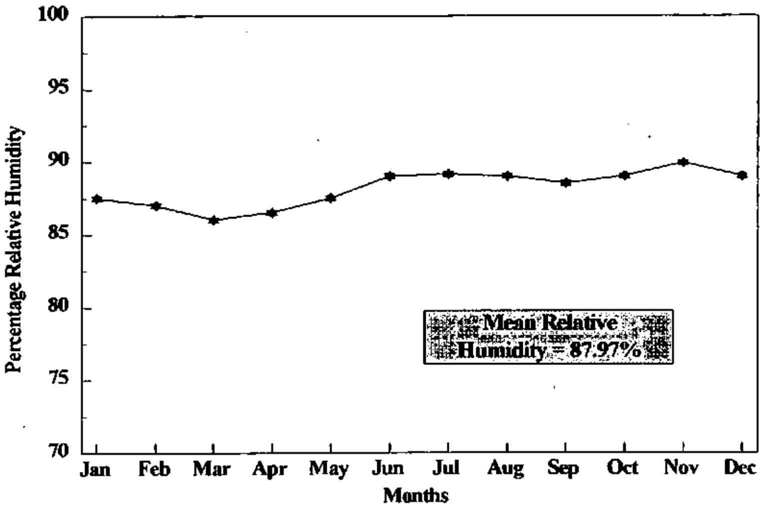


FIGURE 4 : SUMMARY OF RELATIVE HUMIDITY DATA (AVERAGE OF 37 YEARS DATA)



Source: **Meteorological Station, CATIE.**

RESULTS AND DISCUSSION

Data on pods infected with *Moniliophthora* and black pod were not studied because the experiment was not affected by these diseases. The experiment was located in an area relatively isolated from cocoa plantations, and so there were no inoculum sources. The analysis of the 11 years of results showed no overall statistical difference in total cocoa production between the shade treatments (Table 1). However, the statistical analysis for each year indicated that there were significant differences between treatments for some particular years.

TABLE 1 : ANNUAL AVERAGE AND VARIANCE COEFFICIENT (V.C.) FOR THE HYBRID CATONGO X POUND 12 UNDER TWO SHADE SYSTEMS (TURRIALBA, COSTA RICA)

Treatment (Shade)	Average Yield (kg/ha/an)	Pod / Tree		Shoots per Tree
		Healthy	Infected	
Cocoa under Laurel (*C.alliodora*)	742.1	16.71	5.61	14.29
Cocoa under Poro (*Erythrina*)	758.8	16.61	6.66	11.29
V.C. (%)	13.8	13.2	36.8	22.2

In 1979 (2 years after planting), yield for the hybrid was low. Under the laurel system, an adjusted yield of 97 kg per ha per annum of dry cocoa was obtained and 71.2 kg per ha per annum under poro (Figure 5). In 1980, production increased up to 421.3 kg per ha per annum under laurel shade and up to 477.4 kg per ha per annum under poro.

In 1985, yield was 469.4 kg per ha per annum and 422.2 kg per ha per annum under laurel and poro respectively, but this average is only for the first half of the year, since collection of data was interrupted during the second half due to lack of labour. It was expected that production in 1985 would have been between 700 and 900 kg per ha per annum in the light of the data from previous years.

In 1989, yields decreased under both systems, but especially so under poro shade where the yield was only 571.5 kg per ha per annum of dry cocoa. This was probably due to low fertilisation during the previous years and/or to inadequate management of poro shade.

During 1986 and 1988, yields remained over 900 kg per ha per annum. The years 1981, 1986 and 1989 presented significant statistical differences in yield between the two shade treatments. In 1981, production under poro shade was higher, but in 1986 and 1989, it was higher under laurel shade (Figure 5).

Irregular management of poro and inappropriate fertilisation, probably accounted for the higher production under laurel shade than with poro. During six of the eleven years, yields under the poro system were slightly higher than under laurel shade and this is reflected in the annual average where the difference is 10.7 kg per ha per annum higher with poro.

FIGURE 5 : YIELD OF DRY COCOA PER HECTARE FOR THE HYBRID CATONGO X POUND 12 EVALUATED UNDER THE TWO SHADE SYSTEMS (KG)

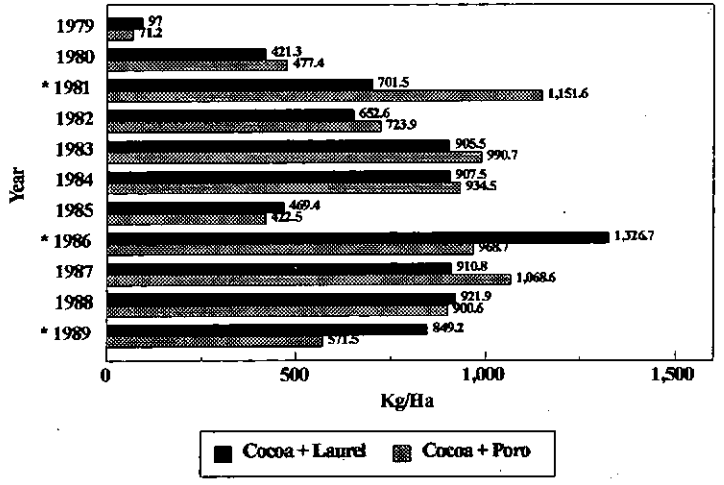
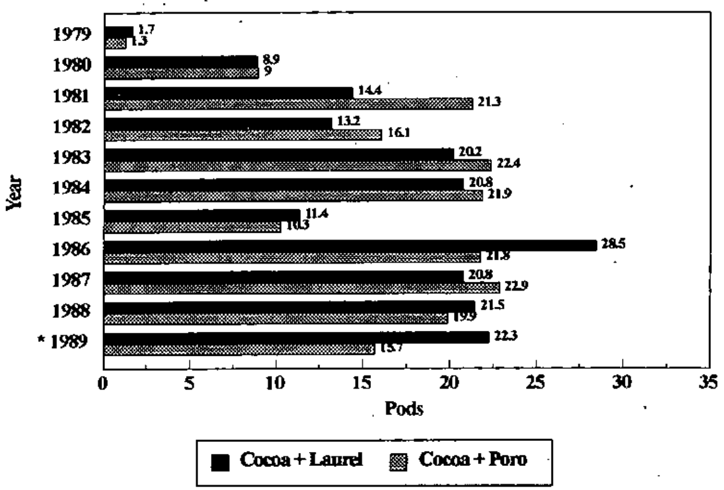


FIGURE 6 : AVERAGE NUMBER OF HEALTHY PODS PER COCOA TREE UNDER THE TWO SHADE SYSTEMS

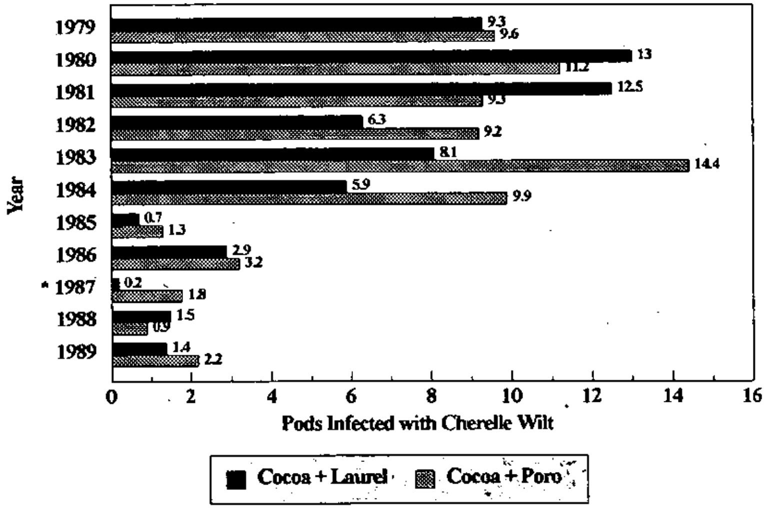


* Significant Statistical Difference at 5%.

Source: **CATIE, Turrialba, Costa Rica.**

Variation in number of healthy pods over the eleven years was similar to the variation in yield of dry cocoa (Figure 6). The variable-pods lost due to "marchitamiento prematuro" (cherelle wilt) only showed significant statistical difference in 1987. A higher number of pods was observed under poro shade; however, the values were relatively low in both systems in relation to other years (Figure 7). Cherelle wilt showed greater difference between years compared with the above.

FIGURE 7 : NUMBER OF PODS PER COCOA TREE LOST THROUGH CHERELLE WILT UNDER THE TWO SHADE SYSTEMS



* Significant Statistical Difference at 5%.

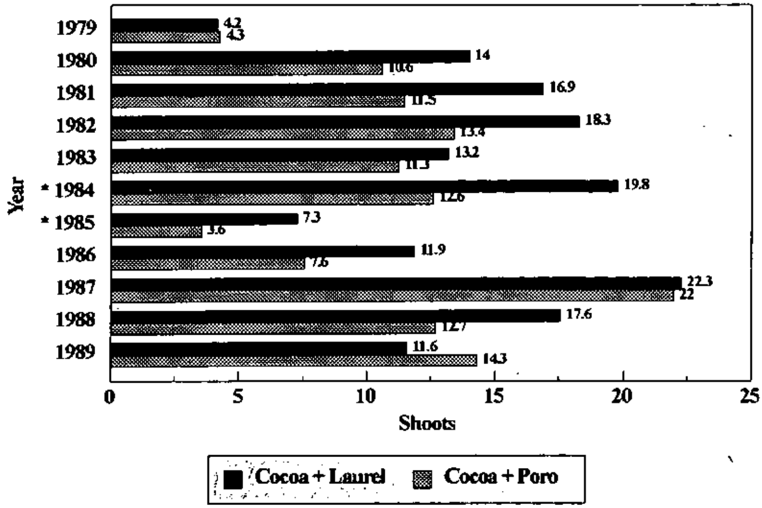
Source: **CATIE, Turrialba, Costa Rica.**

In the cocoa and laurel system, cherelle wilt varied from 13 pods lost per tree in 1980 down to 0.2 pods in 1987. The highest values were observed in the cocoa-poro system which was reflected in the averages. These variations can be explained based on the physiological condition of cocoa trees which was greatly influenced by environmental conditions. Climate differences brought on by non-standard fertilisation from one year to another may have caused the variations observed.

Losses from cherelle wilt were high during the first five years in production and lower in the following ones. This was perhaps because during the first years, the trees had not developed completely and did not have an adequate nutrient and water supply to support a great number of pods to maturity.

The highest average for number of shoots was observed under the laurel shade system with significant differences in 1984 and 1985 (Figure 8). The type of shade offered by poro trees with the resulting excessive shade due to inadequate pruning in some years, may have caused a decrease in light levels. As a result the stimulus to shoot production was lower under the poro system.

FIGURE 8 : NUMBER OF SHOOT PER COCOA TREE UNDER THE TWO SHADE SYSTEMS



* Significant Statistical Difference at 5%. .

Source: **CATIE, Turrialba, Costa Rica.**

There was little difference in the annual average of the Pod Index* between systems (Figure 9). Cocoa-laurel system presented the lowest pod index of 18.4 in 1979, and the highest of 31.2 in 1985. This means that for that year, 12.8 additional pods were required to obtain a kilogram of dry cocoa in 1985 as opposed to 1984. From a selection viewpoint, low indexes are appropriate. Variation from one year to another in the pod index was observed, which implies environmental and nutritional influences on pod size.

CONCLUSION

In general, these and other previously presented results suggest that the cocoa/poro shade system is slightly more effective for increasing yield of cocoa than the cocoa/laurel system. Irregular shade management of poro, climate differences and inappropriate fertilisation increased the production under laurel shade in 1986 and 1989.

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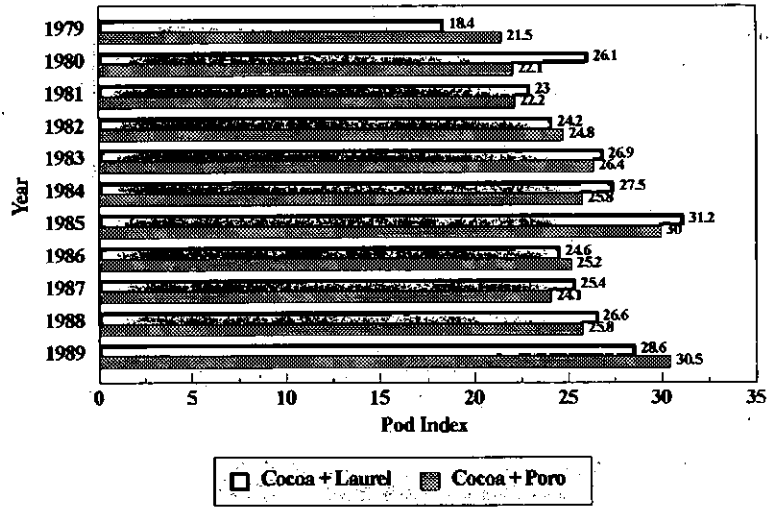
* Pod Index is defined as the number of fruits required to obtain 1 kg dry beans ie. 1000 divided by seed number times mean seed dry weight.

FIGURE 9: POD INDEX PER YEAR FOR THE HYBRID CATONGO X POUND 12 EVALUATED UNDER THE TWO SHADE SYSTEMS



Source: **CATIE, Turrialba, Costa Rica.**

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ACKNOWLEDGEMENTS

The author is grateful to Mr Eddie Salazar for help with the data collection.

SOME OBSERVATIONS ON THE COCOA INDUSTRY IN SARAWAK

H.S.Koo*

Judging from the impressive production and total cocoa export from Sarawak in the late 1980s, people would have been tempted to say then and there that Sarawak, a relatively new-comer to the cocoa scene, was another "Sabah" in the making. It not only has abundant land but infrastructure that was generally better than that existing in Sabah at the time. The soil and rainfall pattern are also somewhat similar.

Cocoa production in Sarawak peaked in 1990 when it exported 21,202 MT (Table 1). Since then, its production has steadily declined causing grave concern among the cocoa fraternity whilst, at the same time, threatening the very survival of the industry in the years to come. By the end of 1995, the cocoa production has declined by approximately 75% since 1990 and this figure is expected to decrease further at the end of 1996.

TABLE 1 : COCOA EXPORTS FROM SARAWAK AND MALAYSIA, 1988-1996 (JANUARY-SEPTEMBER)

Year	Cocoa Sarawak Exports (Tonnes)	Total Malaysian Export (Tonnes)
1988	18,415	189,387.0
1989	19,227	169,290.9
1990	21,202	162,617.8
1991	20,177	148,515.5
1992	15,915	125,439.5
1993	11,077	127,046.6
1994	7,243	83,078.5
1995	6,443	52,532.5
1996	3,159 (J/S)	36,618.1 (J/S)

Source: Department of Statistics, Malaysian Cocoa Monitor, MCB, Kuala Lumpur, 5(1), June 1996.

What has gone wrong with the cocoa plantation industry in Sarawak which, in the last three years has seen its total cocoa production reduced by these amounts? The answer was found on visits to some remaining cocoa growing areas around Kuching in 1994.

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The "best" quality cocoa used to come from Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) cocoa schemes from the areas shown in Table 2.

TABLE 2 : COCOA AREAS ON SALCRA SCHEMES

Kampong	Area (see Map)	Acre
Taee	Serian	985
Merang	Serian	435
Sabako	Lundu	616
Paku Layar	Spoak	1,461
Awik	Kalaka	374
Batang Air	Lubok Antu	958
Pantu	Lingga	457
Bajo	Lundu	567
	Total	**5,853**

Source: Sarawak Land Consolidation and Rehabilitation Authority (SALCRA) Office, Kuching.

Unfortunately, some of these schemes have been returned to the Dayaks (Bajo, Batang Air and Pantu) and the Malays due to difficulties in attracting workers to work on these schemes while other areas are being converted or are going to be converted into oil palm. Oil palm cultivation is less labour intensive and much more profitable.

Serian

Serian is situated approximately 60 kilometres from Kuching and is easily accessible by most forms of transport. It is an important cocoa growing area - in 1994 producing roughly 1,500 MT of dry cocoa per year.

On the way to Serian, there is a lot of totally abandoned cocoa plantation overgrown with weed and other forms of vegetation. It is obvious from the appearance that these farms have been neglected for quite some time. A number of cocoa plantations have been uprooted to give way to neat vegetable plots as well as new poultry farms. According to farmers, vegetables and poultry are giving them a better return than cocoa. This is certainly true when cocoa prices are below R$2,000/MT*. The Salcra scheme at Taee is being cleared for oil palm cultivation.

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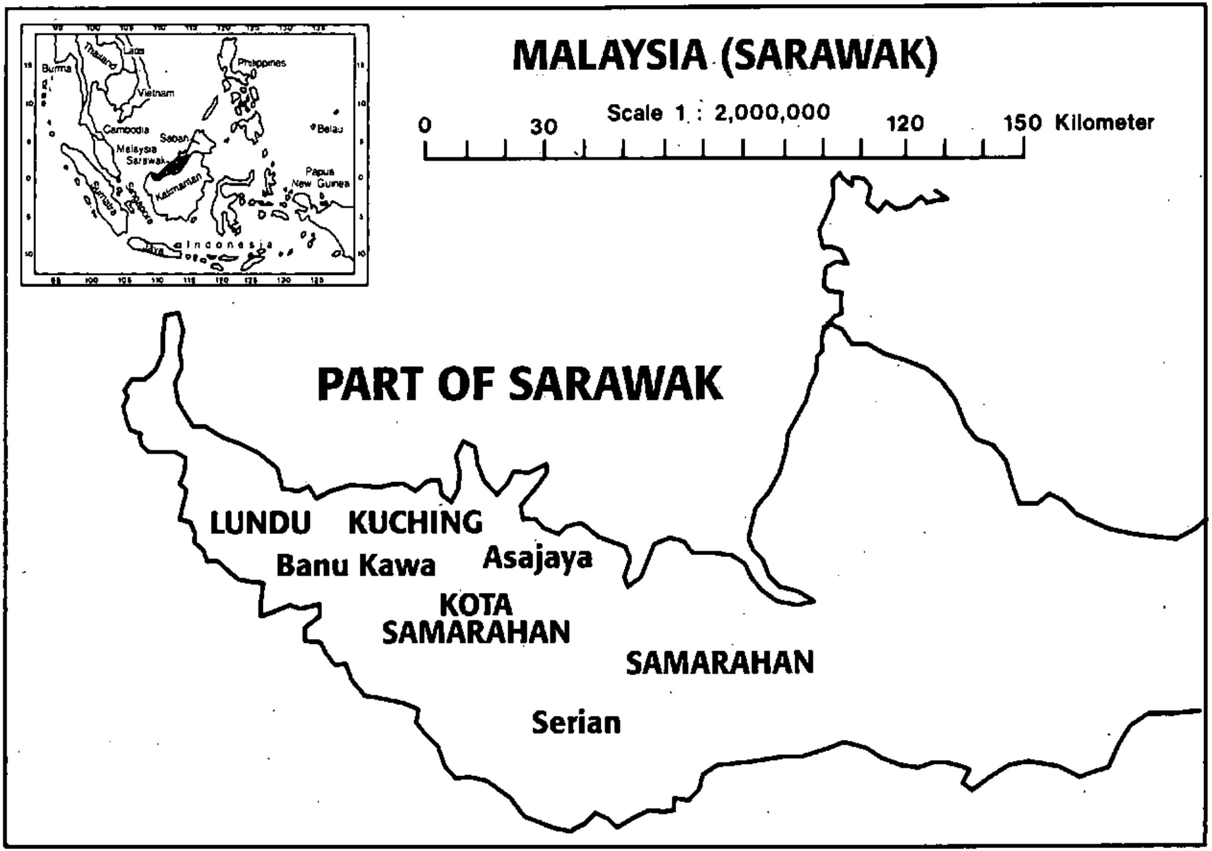
* In December 1996, the exchange rate R$2.5261 equivalent to US$1.00.


MALAYSIA (SARAWAK)
Scale 1 : 2,000,000
0 30 120 150 Kilometer
Burma
Thailand
Laos
Vietnam
Cambodia
Philippines
Sabah
Malaysia
Sarawak
Kalimantan
Sumatra
Singapore
Indonesia
Java
Belau
Papua New Guinea
PART OF SARAWAK
LUNDU
KUCHING
Banu Kawa
Asajaya
KOTA SAMARAHAN
SAMARAHAN
Serian

Approximately 45 kilometres along the Kuching-Serian road near Kampong Baru, some cocoa farms have been cleared for oil palm cultivation. Most of the farms are neglected and need to be rehabilitated. It is also evident that there had been little or no input into the plantations over the past few years due to depressed cocoa prices.

Matang

Situated approximately 12 kilometres from Kuching is Matang - an area that was once had about 2,000 acres of cocoa. Today, the cocoa plantations in Matang are in a pitiful state suffering from total neglect. This is a predominantly Chinese area where "absentee landlords" visit once a while.

What was once a cocoa and pepper plantation had now been totally changed with the completion of the bridge linking Kuching and Batu Kawa. Due to its close proximity to Kuching, the value of the land has sky-rocketed now that it is easily accessible. Already, 20,000 acres of former cocoa and rubber plantations have been ear-marked for future housing development. In the light of these changes, it is not too difficult to see why Sarawak's cocoa production declined so rapidly!

Kota Samarahan

In many ways, the neglect of the cocoa plantation is also seen in the Malay areas (Jais, Pandan and Eboi) and Dayak areas (Pinang, Entingan and Merenek). A number of plantation companies listed on the Kuala Lumpur Stock Exchange have already started planting oil palm in an extensive way in these areas.

The "hope" of a future for the Sarawak cocoa industry is in Asiajaya, reputed to be the not only the oldest cocoa growing area in Kuching but also the "best" maintained.

In sharp contrast to other areas, it is evident that these farmers (often of Chinese ethnic origin) have made some effort to take care of their plantations through pruning and general maintenance. These areas are around Jemukan, Semera, Sampun, Beliong, Moyan, Nonok (Asiajaya) and Tambirat, where cocoa is intercropped with coconut.

PROBLEMS AFFECTING THE COCOA INDUSTRY

Investment Return

The depressed price of cocoa over recent years have definitely taken its toll on the cocoa industry. This is particularly so in the Matang area where a lot of Chinese absentee landlords had planted cocoa as a form of investment.

With the current bullish oil palm price, it is not too hard to see why a lot of cocoa land has been converted. In the late 1980s, expansion in cocoa areas in Sarawak had taken place in Government schemes and in small-holdings reflecting the perceived profitability of investment in cocoa. In recent years, there has been a sharp fall in cocoa hectarage as a result of depressed cocoa prices. It is hard to convince people to plant cocoa in Sarawak when as the rate of return for oil palm is so much higher than cocoa, even if cocoa prices were to reach R$3,500/MT. Additionally, the production costs and management needs of cocoa are much higher.

Given the bright economic outlook for Malaysia and in particular Sarawak, private plantation companies, particularly those listed companies with their accumulated large amount of retained earnings, are likely to continue to expand further into oil palm.

Labour Shortage

Sarawak like Sabah is acutely short of labourers of all types, be it skilled or unskilled. Unlike Sabah, Sarawak is unable to tap the labour force from neighbouring Indonesia. Many of the local work force has been attracted by the lucrative offers not only from Peninsular Malaysia and Singapore but also from as far as Japan, Hong Kong and Taiwan. The vacuum left by these workers has to be filled by the indigenous groups who are mainly people close to the land. The high demand has also increased the wage rate both for skilled and unskilled labour. Attractive offers from the timber companies have lured a lot of young people away from the land, leading to the labour cost per day in Sarawak being almost double that in Sabah. The total neglect of cocoa, and other, farms in the Malay and Dayak villages testify to this fact.

Pest and Diseases

As a result of the neglect of the plantations, pests and diseases have become very serious as maintenance has been minimal. As a result, Vascular Streak Dieback infections and Cocoa Pod Borer attacks are seen in most cocoa farms visited. Pests such as rats and squirrels are also plentiful. One farmer reported to have shot as many as ninety squirrels in his cocoa farm in one week.

Urban Drift

It is an ironic twist of education that makes people, particularly the younger ones, leave their "village life style" for the brighter "city lights". A visit to Kuching, gives the impression that it is a booming city. As such, it is becoming more and more difficult to get people to stay on the land of their parents or ancestors. The booming Malaysian economy as well as that in other prosperous Asean regions, are drawing more and more labourers away from the farms.

In spite of these problems, there is hope for the cocoa industry as well as other agricultural produce facing similar threats. The Government is well aware of this problem, and through the agricultural department, is currently distributing free fertiliser to the farmers encouraging them to rehabilitate their crop. The Government is also looking into ways and means of increasing the basic pay so that it is commensurate with the rising cost of living in the State. It is hoped that cocoa prices can remain around the R$3,000/MT level because at this level, the farmer will show some interest in maintaining and rehabilitating his farm. At the depressed price of R$2,000/MT, the cocoa farmer, with so much stacked against him, doesn't stand a chance at all (Table 3).

TABLE 3 : AVERAGE MONTHLY COCOA PRICES IN KUCHING (SMC 1C GRADE)

	1992	1993	1994	1995	1996
January	2,604	1,939	2,564	2,988	2,530
February	2,252	1,925	2,527	3,128	2,475
March	2,050	1,832	2,619	3,062	2,392
April	1,761	1,844	2,355	2,837	2,591
May	1,592	1,788	2,524	2,779	2,659
June	1,504	1,777	2,694	2,716	2,492
July	1,798	1,990	2,948	2,538	2,203
August	1,920	1,998	2,965	2,620	2,197
September	1,867	2,397	2,758	2,675	2,092
October	1,876	2,510	2,741	2,662	2,185
November	1,940	2,669	2,816	2,763	2,252
December	1,898	2,773	2,639	2,639	2,318
Average	**1,922**	**2,119**	**2,693**	**2,785**	**2,366**

Source: **Malaysian Cocoa Board, Kota Kinabalu.**

A DESIGN FOR IMPROVED EFFICIENCY IN SOLAR DRYING OF COCOA

N.Hollywood*, S.Brown and B.Toreu*****

ABSTRACT

The construction of solar driers which utilise rocks painted black for solar collectors and clear polycarbonate sheeting for covers is described. These units have been demonstrated to have a high drying efficiency in virtually all weather conditions encountered in East New Britain. Cocoa loaded at the rate of 50 kg per square meter is typically dry within four days. Construction and performance of the driers is described. Smallholder adaptive trials regarding their use, along with 200 kg fermenting boxes, at thirty sites in East New Britain is also discussed.

INTRODUCTION

The solar driers described were developed during an Australian Government (AUSAID) funded project. In the early stages of this project, small box (200 - 250 kg) fermentations, for smallholder use were studied. Additionally, in fermentation and drying trials it was noted that sun drying was the most effective method of reducing acidity and improving the organoleptic characteristics of cocoa. However, during the drying trials, it was noted that under weather conditions prevalent in East New Britain, cocoa would not dry below a moisture content of 10% even after extended periods (two weeks) on a standard sun drying bed. This led to extremely frequent mould contamination of cocoa. The main type of drier employed by smallholders in Papua New Guinea is a wood fired kiln drier. The use of defective kiln driers has led to smoke contamination being one of the single largest complaints regarding PNG cocoa. These facts made it imperative that investigations into improving the efficiency of solar driers be conducted.

An examination of sorption isotherm values for cocoa demonstrated that at temperatures of 30°C and relative humidity of 75%, cocoa will tend to equilibrate at 10% moisture. These conditions and higher relative humidities are frequently encountered here and a moisture content of 10% corresponded with what we were finding in practice.

A review of cocoa drying literature demonstrated that although solar drying is employed in cocoa production, it generally consists of drying platforms with little attempt to improve efficiency or is used in combination with artificial means. One exception to this was a paper by Hammond (1977) in which solar collectors of corrugated iron with polythene plastic sheeting for covers was used to improve the drying efficiency of a standard sun drying bed in Brazil.

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A literature search of drying technologies in other food and timber industries however did provide several options for application to cocoa Very importantly, the review also revealed the fairly recent development of clear polycarbonate sheeting with high light transmitting properties, high durability and a twenty year lifespan (Palmer and Kleinschmidt, 1992). Previously, the material used on solar driers was UV resistant polythene plastic sheets which have a lower light transmitting ability and become opaque after six months use (personal observation).

Most of the options for solar drying came from a review by Bolin and Huxsol (1980) of methodologies for fruit drying. In this review, they discussed: (i) Black trays (simply by painting drying trays black more incident radiation is absorbed and fruit drying accelerated); (ii) Solar troughs (with half cylinder shaped reflector of chrome plated paper with the drying tray covering one half of the radius. Incident radiation is reflected to the drying tray); (iii) Solar heated Cabinet drier; (iv) Polytube drier and (v) Heat collector type drier (this type of drier uses heat collectors placed at the side to vent heated air through a drying tray).

For people considering the use of solar driers, this review could be referred to for consideration of methods suitable to their country. In the PNG situation, it was decided that the two most practical approaches would be the solar cabinet or drying bed with attached solar collectors type driers. Solar cabinets are probably impractical for the smallholder situation as they need air tight sealing, apart from openings in the top and bottom for ventilation of heated air up through successive layers of trays. However this type of drier could be suited to the plantation sector where more technical ability is available. Another drier type probably of use to the plantation sector is the solar kiln timber drier of Palmer and Kleinschmidt (1992).

The drying bed with solar collectors was therefore considered to be the most practical approach for the smallholder situation because of the relative simplicity of design. This basic design was therefore employed at CCRI and solar collectors of plywood, rocks and galvanised iron tested. Rocks painted black were found to be the most efficient due to their ability to continue radiating heat after dark and rocks were therefore employed as solar collectors in these driers.

MATERIALS AND METHODS

The size of the driers constructed was determined by acceptable loading rates and the quantity of beans to be dried. These units were meant for smallholder use with 200 - 250 kg fermentations being conducted. Experimentation with prototypes demonstrated that 50 kg per square meter was a safe bed loading rate and therefore, drying beds of 2 x 2 meters were used. Units, however, can be scaled up to the size required by a user.

The materials required for construction of this size unit were as follows: Seven polycarbonate sheets ("Suntuf polycarbonate, Greca wide, clear 4.2 x 1.27 meters" and twenty four 1500 type timber screws with washers obtained from SUNTUF, Unit 8/ 1 Dann Street, Capalaba, Queensland, Australia. The cost of these sheets is US$57 each. We understand that the polycarbonate is an Israeli product but do not have information on the manufacturer.), four sheets of 8 x 4 ft, 26 gauge flat iron, four x 4 litres of black paint, twelve x 5 meter 2" x 2" timber, five x 5 meter 4" x 2" timber, four x 5 meter 1" x 1" timber, four square meters of cocoa wire, 4 square meters of arc mesh, nails and polysealant as needed, black plastic sheeting, herbicide, three meters galvanised iron ridge capping and seven cubic meters of rocks to fill the solar collecting areas. Total cost of a drier this size was US$1140, including US$180 for purchase of rocks and delivery. This compares well to US$1430 for an equivalent sized wood fired kiln drier. When labour costs for fuel collection are considered and costs of maintenance, when the oven and chimneys of wood kin driers corrode in a couple of years, solar driers are a considerably cheaper alternative.

Prior to construction of a drier, the ground was cleared of vegetation and sprayed with herbicide. A compass was used to determine direction and the solar collecting wings arranged in a North - South direction for even heating during the day. The driers (Plate 1) were constructed by building a 2 x 2 meter drying bed suspended on four posts one meter above ground level. Timber beams were placed across the drying bed and arc mesh laid down followed by cocoa wire. The timber and arc mesh are to support the weight of a person if it is necessary to climb into the drier. A tent shaped roof was then constructed. The pitch of this roof was determined by the width of the bed and lengths of polycarbonate. Three sheets of polycarbonate were cut in half and used for the roof. This results in a roof 1.6 meters high, above the drying bed, at the apex and overhanging the drying bed by 0.5 meters at each end. A length of galvanised iron ridge capping was then fixed over the apex of the roof. The legs of the drying bed were then reinforced with cross beams of timber and flat iron nailed onto all sides. On the two sides with solar collectors to be attached, the flat iron had a 1.8 meter x 15 cm section cut out immediately below the drying bed. This was to allow ventilation from the solar collectors to under the drying bed.

PLATE 1: SOLAR DRIER WITH ROCKS PAINTED BLACK AS SOLAR COLLECTORS AND COLLECTOR COVERS AND ROOF OF CLEAR POLYCARBONATE

Of the remaining two sides, one was completely sealed with flat iron and the other had a door placed in it. The ground under the drying bed was lined with black plastic sheeting to prevent ground moisture entering. The door allowed use of this area under the drier as a storage area for cocoa post bagging. Wings for the solar collectors were then constructed. These were 4 meters in length rising from 10 cm above ground level to the height of the drying bed, forming a triangular shape (Plate 1). The framework was timber and sides covered with flat iron. Reinforcing beams of timber were also used across the width. The space inside the wings was then filled with approximately 3.5 cubic meters of rocks on each side after lining the ground with plastic sheeting. Painting of the rocks and flat iron surfaces was conducted by using a hand pump, pressurised knapsack herbicide sprayer with paint being diluted with mineral turpentine. After painting the rocks, polycarbonate sheets (two on each side) were then fastened to the top of the wings with the timber screws. Polyfiller was then run around all of the joins in timber, flat iron and polycarbonate in the wings. On completion of this sealing stage, the wings were tested for leakage by placing a smouldering piece of coconut husk in the wings. With proper sealing, smoke will only escape from under the drying bed.

RESULTS AND DISCUSSION

Typical results for sunny weather are presented in Figures 1 and 2 and results for extended, overcast and wet conditions are presented in Figures 3 and 4. Figure 1 demonstrates that in clear sunny conditions, temperatures approaching 60°C can be obtained during the middle of the day. After nightfall, at 18.00 hours, temperatures of at least 10°C above ambient were recorded until midnight due to radiation of heat from the mass of rocks. Similarly temperatures of 6°C above ambient were still occurring at dawn at 6.00 AM.

Figure 2 demonstrates the accelerated rate of drying occurring over that on a conventional drier with a moisture content of 8% being obtained by day 4 in comparison to 9% by day 7 on the conventional drier.

Figures 3 and 4 demonstrate the much reduced efficiency of the driers during wet overcast conditions, with drying to 7% moisture being obtained in six days. Despite overcast conditions, bed temperatures remained 5°C to 7°C above ambient and this was sufficient to produce drying in a short enough period to prevent mould contamination.

Since these driers have been developed (August 1995), one unit has been tested on a weekly basis at CCRI's Tavilo research station in an attempt to monitor it's performance under all weather conditions. During this time, only one batch of cocoa has had severe mould contamination but this was due to strong winds blowing rain sideways onto the drying bed. This can be remedied by attaching plastic sheeting over the ends of the drier. Thirty units have also been installed at smallholder sites in East New Britain Province during 1996. These sites are visited on a regular basis and samples collected for analysis. From approximately 500 samples collected to date, four have had some surface mould contamination which would probably not be enough to downgrade it from FAQ. It therefore appears that these driers are suitable for cocoa growers in East New Britain.

FIGURE 1 : A COMPARISON BETWEEN TEMPERATURES ENCOUNTERED IN SUN DRIERS WITH AND WITHOUT SOLAR COLLECTORS DURING THE COURSE OF A SUNNY DAY. ON THIS DAY, RAINFALL WAS ZERO, VERY LITTLE CLOUD COVER AND TOTAL SOLAR RADIATION OF 4.8056 (KWH/ SQUARE METER)

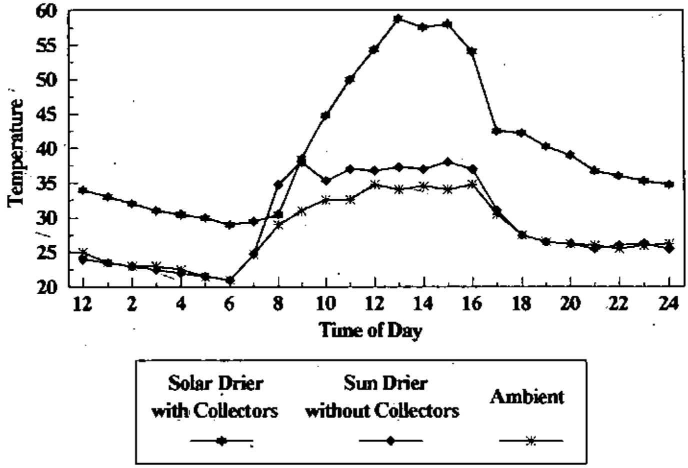


FIGURE 2 : THE RATE OF MOISTURE LOSS OF COCOA ON SUN DRIERS, WITH AND WITHOUT SOLAR COLLECTORS DURING SUNNY WEATHER. RAINFALL FOR SEVEN DAY PERIOD : 1, 0.2 mm; 2, 0 mm; 3, 0 mm; 4, 1.8 mm; 5, 0 mm; 6, 0 mm; 7, 0 mm

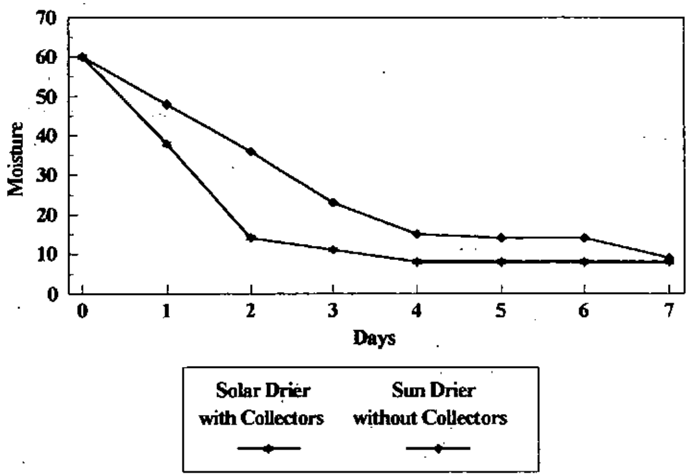


FIGURE 3 : A COMPARISON OF TEMPERATURES IN A SOLAR DRIER WITH AMBIENT TEMPERATURES DURING WET WEATHER. ON THIS DAY, RAINFALL WAS 24 mm WITH OVERCAST CONDITIONS ALL DAY AND TOTAL SOLAR RADIATION FOR THE DAY OF 1.1671 (KWH/SQUARE METER)

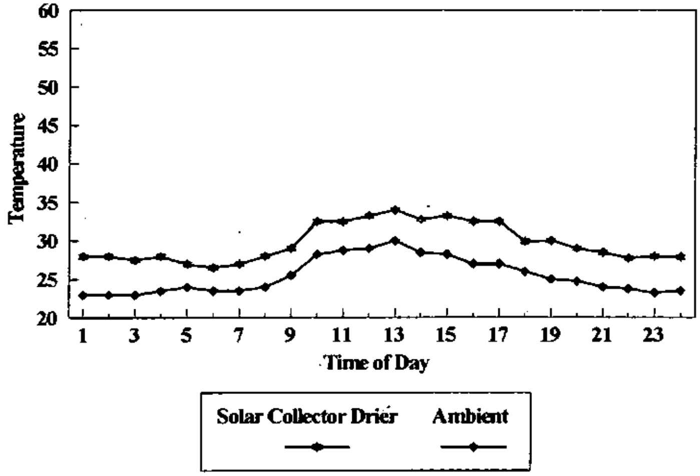
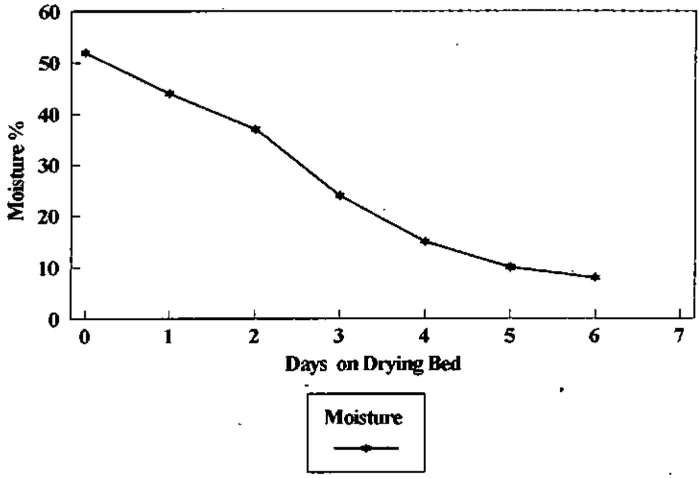


FIGURE 4 : RATE OF DRYING OF COCOA ON SOLAR DRIER IN WET CONDITIONS. THE RAINFALL FOR THE SEVEN DAYS WAS : 1, 3.2 mm; 2, 13 mm; 3, 5 mm; 5, 14 mm; 6, 24 mm



However, if we examine weather station records for other cocoa growing provinces in Papua New Guinea, the picture is not so clear. Table 1 demonstrates that East New Britain is the driest cocoa growing province in the country with some having an average 1,000 mm a year more rain. It is therefore difficult, at present, to recommend this methodology for the whole of PNG or for other countries which have higher rainfall than East New Britain. For this reason, we are applying for funding to expand the adaptive trials into some of the wettest provinces and two driers have recently been constructed in West New Britain.

TABLE 1 : AVERAGE ANNUAL RAINFALL OF VARIOUS COCOA GROWING REGIONS IN PAPUA NEW GUINEA. SOURCE (McALPINE, KEIG AND SHORT, 1975)

Weather Station	Province	Average Annual Rainfall
Hoskins	West New Britain	3,569 mm
Kerevat	East New Britain	2,500 mm
Kavieng	New Ireland	3,282 mm
Buka	Bouganville	3,408 mm
Alotau	Milne Bay	3,199 mm
Madang	Madang	3,558 mm

TABLE 2 : COMPARISON OF RAINFALL LEVELS IN DRIEST (ENBP) AND WETTEST (WNBP) COCOA GROWING REGIONS OF PNG DURING 1996

Month	East New Britain		West New Britain	
	Rainfall	No. of Rainy Days	Rainfall	No. of Rainy Days
January	79	14	610	21
February	108	19	641	22
March	307	22	632	27
April	266	20	368	21
May	211	25	163	21
June	113	19	125	20
July	83	18	128	19
August	42	22	135	19
September	252	19	140	13
October	151	19	140	20
November	200	25	217	22
December	252	26	430	26
TOTAL	**2064**	**248**	**3569**	**251**

It would therefore be wise to recommend to anyone considering using this methodology to check weather records. If conditions are wetter than East New Britain, the driers will need to be tested under local conditions before adoption. Trials are also underway at Tavilo research station to scale up these driers to a size capable of taking several tonnes of cocoa. Results of this trial will be presented in the future.

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Born in Australia in 1950; Obtained a BSc majoring in Microbiology from the University of Queensland in 1970 and completed an MSc in microbial metabolism in 1978; Was employed at Queensland University from 1971 till 1976 and joined Queensland Department of Primary Industries in 1978; Since joining the Department of Primary Industries has been involved in food technology with the latest involvement, since 1992, in Australian Government Aid Project (AUSAID), PNG Cocoa Quality Improvement Project at the PNG Cocoa and Coconut Research Institute.

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Cumulative Index
Cocoa Growers' Bulletin 33-50

Cumulative Indices by subject and by author for Cocoa Growers' Bulletin 33-50 have been prepared by Michelle Thomas and Tony Lass, Technical Development Department, Cadbury Limited. In every case, issue number precedes page number and as many cross references as possible have been included. For Cumulative Indices by subject and by author for earlier issues of the Bulletin 1-32, see Bulletin 33.

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The inside pages of Cocoa Growers' Bulletin
has been printed on recycled fibre
to assist in protecting the environment

Printed by Haines Clark & Co. Ltd.
Wellington House, 11 Merse Road, Redditch B98 9HL England.