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Editorial

In the last issue dated December 1976 our usual review of production and consumption reported the rapid rise in the price of cocoa that took place during 1976. Everyone knows how that rise has continued and prices have reached levels that were undreamt of a few years ago. These prices reflect the fall in production during the past year and high prices will be with us until production increases and/or consumption falls. This is the month in which predictions about the forthcoming West African crops are made with some confidence and the market will respond to those predictions. By the time this issue reaches many of its readers these predictions will have had their effect and there will be further data on consumption to influence prices.

It would be churlish to begrudge producers the high returns that some of them are getting – most of the farmers in West Africa benefit not at all from high prices – but at the same time it would be foolish to ignore the effect of high prices on consumption.

The effect may well be more far reaching than usual as the pattern of consumption may be altered as well as the quantity of beans ground. There is clear evidence of a considerable change in cocoa consumption when the prices of products are examined.

For many years the ratio of the price of cocoa butter to beans was 2·2 to 1 while cocoa cake (10–12% fat) sold at 0·5 times the price of beans. The prices of cake and butter must add up to 2·5 times the price of beans to cover material costs alone or to 2·6–2·7 times for processing to be remunerative. These ratios have altered drastically during the past 18 months, and today butter can be bought at the same price as beans or even slightly below while cake is being sold at 1·5 times the price of beans. This fall in the demand for cocoa butter and increase in demand for cake indicates a profound change in consumption pattern. The precise nature of that change is hard to discover and it is equally difficult to predict whether the change will be reversed when cocoa prices fall as they must.

G. A. R. Wood
August 1977

Review of Production and Consumption

Production

At this late stage in the production year it is unlikely that the final crop outturns will be significantly different from the forecast figures. The latest forecast of 1976/77 world total production is 1,370,000 tonnes, which is 140,000 tonnes down on the estimated 1975/76 figure of 1,510,000 tonnes, and will be the lowest world total production figure since 1968/69.

This decline is almost entirely accounted for by sharp declines in production in Ghana, Nigeria and Cameroon. Brazil will have produced slightly less than in the three previous years, but this will still be substantially more than was produced in any year prior to 1973/74. Ivory Coast, alone among the West African producers, will have produced approximately the same as in the two previous years.

Consumption

World consumption for 1977 is forecast by Gill and Duffus at 1,382,000 tonnes. This would be 128,000 tonnes below the 1976 estimate.

More significant, perhaps, is that this will be 184,000 tonnes (or 11·7%) below the 1972 figure and this is a measure of the extent to which the world industry has been hit by poor production and high prices over the last four years. One important fact is that it is forecast that between 1976 and 1977 consumption in the U.S.S.R. will have fallen from 140,000 tonnes to 100,000 tonnes, which will be the first time that the industry in the U.S.S.R. has reacted in any significant way to high cocoa prices.

Stocks

Gill and Duffus forecast that stocks at the end of the 1976/77 season will be 377,000 tonnes or 3·2 months usage. This will be 45,000 tonnes lower than the estimated figure for the end of the 1975/76 season but, due to the fall in consumption, only represents a fall of 0·2 months usage.

Prices

Month end prices for nearby Ghana shipment cocoa have been:

1976	July	£1325/tonne
	August	£1590/tonne
	September	£1720/tonne
	October	£1970/tonne
	November	£1970/tonne
	December	£2105/tonne
1977	January	£2495/tonne
	February	£2670/tonne
	March	£2400/tonne
	April	£2520/tonne
	May	£3050/tonne
	June	£3285/tonne

Prices rose throughout the latter half of 1976 as it became increasingly apparent how small the crops in Ghana, Nigeria and Cameroon were going to be. The continuation of the rise through the first half of 1977 was principally attributable to uncertainty in the market as to the extent that consumption would fall as a result of the very high price levels. At the time of writing there is evidence that consumption really is dropping significantly, and as a result there are signs that the market may have reached its peak.

WORLD COCOA PRODUCTION AND GRINDING DATA

Reproduced from Gill & Duffus Market Report
Dated 1st July 1977

(Thousand Metric Tons)

Production

	1974/75	1975/66 (Estimate)	1976/77 (Forecast)
Africa	1,009	1,001	875
America	439	406	384
West Indies	41	42	46
Asia and Oceania	57	61	65
World Total	1,546	1,510	1,370
Principal Countries			
Ghana	377	397	325
Nigeria	214	216	175
Ivory Coast	242	231	235
Cameroon	118	96	82
Equatorial Guinea	12	12	10
Brazil	273	258	237
Ecuador	78	63	68
Dominican Republic	27	30	30
Venezuela	19	15	17
Colombia	25	26	27
Mexico	32	33	25
New Guinea	33	32	34
Malaysia	13	17	19

Grindings

	1975	1976 (Estimate)	1977 (Forecast)
Western Europe	505	525	484
Eastern Europe and U.S.S.R.	277	270	216
North America	219	238	211
Central and South America	209	239	254
Australia and New Zealand	18	20	18
Asia	62	65	54
Africa	156	153	145
World Total	1,446	1,510	1,382
Principal Countries			
United States	208	225	200
Germany (Federal Republic)	139	141	135
Netherlands	119	127	120
United Kingdom	73	83	72
U.S.S.R.	150	140	100
France	34	36	32

Reflections on Yields from Hybrid Cocoa Varieties in Ghana

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In Ghana, Upper Amazon × Amelonado hybrids (4, 5, 6, 8) have been adopted for use in replanting schemes in the belief that they are superior to Amelonado. In a study on trends in cocoa production, the International Cocoa Organisation deduced that at maturity (15–19 years), the maximum sustained yield of Amelonado was 443 kg/ha whereas hybrids would give 841 kg/ha after seven years. The latter figure was taken from the 1970 report on the Eastern Region Cocoa Project, prepared by the International Bank for Reconstruction and Development; but the IBRD did not describe how the figure was derived. There is no published yield data from hybrids on farms and in trials yields vary by a factor of two or more depending on:

Season.
Site.
The assumptions made in calculating the yields.
The estimates of pod values used.

The purpose of this article is to discuss how best to arrive at accurate yield figures in cocoa variety trials and to attempt to quantify the yield advantage of hybrids over Amelonado.

Trials with Hybrid Varieties

In the present article, "the hybrids" refers to the new varieties developed in Ghana during the fifties (6). The 8th Progeny Trial Area (P.T.A.) at Tafo (9) was planted in 1952 at 2·4 m square spacing with 36 tree plots; the trial included eight plots of Amelonado, four of Amelonado × Amazon hybrids and eight of local-Trinitario × Amazon hybrids. In the trial the better hybrids consistently outyielded Amelonado, although blackpod losses were lower on the Amelonado. Once the trial was mature the yields of all the genetic types fluctuated together and there was no evidence that the yields of the hybrids reached a peak and then declined relative to Amelonado in the later years. The 9th P.T.A., also at Tafo, was planted in 1954 in thinned forest, the spacing was 3·05 m square and there were five replicates. The Series III experiment (4) was planted at Tafo in 1963 in plot D13 on clear felled land with ten replicates of fifteen Amazon hybrids in twenty tree plots and a spacing of 3·05 m square. Over the last five years two Series II hybrids, which were included as controls, were slightly lower in net yield than the average for the whole trial. Three Series II trials were planted in 1956, each included eight hybrid progenies and 36 tree plots at 2·4 m spacings, with four replicates at Apedwa and Asikuma and three replicates at Pankese, but with no perimeter guard trees. During 1975 a large swollen-shoot outbreak was cut out of the Apedwa trial, but otherwise the trails were intact. The Apedwa Series II trial is adjacent to a 4·86 ha plot of Amelonado which was planted in 1954 at 1·52 m spacing and thinned once by eye. Between 1970 and 1976 shade levels over the trial and the Amelonado were comparable. The 13th and 14th P.T.A.s (11), mainly with inter-Amazon hybrids, were planted at Apedwa in 1974 under thinned forest shade in dense bush which had previously carried scattered cocoa. Amelonado was planted throughout the trial areas for simultaneous calibration.

*On secondment on technical assistance from UK Ministry of Overseas Development.

Establishment Ability

A number of experiments in Ghana have compared the performance of hybrids and Amelonado under experimental conditions. The earliest of these was the Trinidad Introductions plot at Tafo, where it was quickly apparent that Pound's Upper Amazon selections were easier to establish, faster growing and earlier into bearing than Amelonado. Later trials have consistently reproduced this result. For example, the 13th and 14th P.T.A.s experienced two protracted dry seasons and mortality in the Amelonado was several tmes greater than in the hybrids which were under test:

	% Mortality by March, 1976	
	Amelonado	*Hybrids*
13th P.T.A.	27·9	8·9
14th P.T.A.	21·3	4·0

When considering results from experiments with hybrids and Amelonado it should be borne in mind that in one trial area it is difficult to find a combination of management methods which perfectly suit the two types. Normally the Amelonado has been grown at a closer spacing and shade levels have favoured the hybrids. More important, the trials were usually on old cocoa land, which was clear-felled in advance and replanted while the temporary shade remained sparse. Under such conditions the hybrids have an even greater advantage, whereas if the plantings had followed the traditional practice of thinning old forest land, the difference might have been less marked. From this it follows that in older cocoa growing areas of Ghana replantings should always be made with the new vigorous types. After swollen-shoot control farms are often exposed and the soil degraded and under such conditions Amelonado can be very difficult to re-establish.

Yield Estimation in Trials

Use of different methods of calculating yields from trials can lead to markedly divergent results, the main variables being:

Estimates of pod sizes.

Allowances for possible interaction between progenies.

Whether or not adjustments are made for spoilt pods.

It is not normally the practice in trials to separately ferment and dry all the cocoa obtained from each treatment at every harvest. Instead, for each treatment estimates are made of "pod values" (sometimes referred to as "pod indices") the numbers of pods required to yield a unit of dry cocoa. From these values and the numbers of pods harvested from each treatment an estimate of dry bean yield is obtained. Bean sizes and bean numbers vary markedly between progenies as well as through the season (Table 1), suggesting that accurate yield estimation requires determination of pod values for each progeny at every harvest, which is now the regular practice with cocoa breeding trials on the station at Tafo (10).

TABLE 1

Pod and bean characters in the 8th P.T.A. 1974/75

	Conversion ratio	*Pod value in kg*	*Bean weight in gm*
Range between progenies (mean over season)	35·81–44·97	17·93–34·98	0·89–1·43
Range within progenies (through the season)			
Amelonado	29·09–40·81	19·61–25·02	1·07–1·32
WAE 5	32·39–43·42	19·98–25·73	1·19–1·26
WE 3	30·65–40·12	31·22–39·57	0·81–0·98

Having estimated the dry weight of cocoa, corrections are sometimes made to allow for possible encroachment of one treatment onto another (7). However, most progeny trials with cocoa are concerned with assessment of the progenies for farmers' use as a mixture, so this consideration does not necessarily apply (12). But if an experiment does not have perimeter guard rows, there is a stronger case for the use of core plot data, because trees adjacent to empty areas exploit the space and thus occupy more land than their nominal spacing would indicate. Sometimes additional adjustments are made for pods which are lost to disease, squirrel damage, insect attack, etc., these lead to estimates of "potential" yields. The effect of this and the use of whole and core plots on the Apedwa Series II trial, which has no guard trees, are shown in Table 2.

TABLE 2

Yields from the Series II Trial at Apedwa in kg dry cocoa/hectare

	Whole plots		*Core plots*	
	potential	*net*	*potential*	*net*
1971/72	1117	622	974	521
1972/73	1038	712	917	615
1973/74	683	465	606	402
1974/75	553	337	480	266
1975/76	938	776	828	680

+FGKA.

It would seem preferable if net yields from breeding trials were most widely quoted, since the farmer is interested in the return from the cocoa he actually sells at the buying station and not in what has been lost. Moreover, the difference between actual and potential yields is not always clearly understood particularly by readers who are unfamiliar with the problems inherent in estimation of yields from progeny trials with cocoa but who may wish to use published data for other purposes. There is a natural tendency to quote potential yields because the figures are often large, but, as the Apedwa data shows, this can be misleading.

Yields obtained from Variety Trials

Yields and levels of blackpod losses in some of the breeding experiments are shown in Tables 3 and 4. Blackpod losses were estimated from the diseased pods which were harvested when unripe as well as those from which some useable cocoa was obtained. Pods which ripened prematurely and contained no useable cocoa were excluded from the total of diseased pods, except at Asikuma from 1970–74. The yields were calculated as above, except in the Series II trials where they were derived from the wet weights of cocoa recorded and the wet to dry weight conversion ratios determined at Tafo during the same season. In calculating the yields from the Apedwa Amelonado plot a pod value of 26/kg was assumed. All of the data from the Tafo and Asikuma experiments and the Apedwa Series II trial were collected by plant breeding staff. Over the last five years the Pankese experiment and the Apedwa Amelonado were visited regularly and there is no cause to doubt the reliability of the yield estimates.

TABLE 3

Blackpod losses (%) and net yields (kg/ha, whole plots) from selected progenies

Year	Progeny*	9th P.T.A.**		Trial Apedwa		Asikuma		Pankese***	
		Disease	Yield	Disease	Yield	Disease	Yield	Disease	Yield
1972/73	F	9·5	733	14·1	931	26·2	539	17·8	1051
	H	17·2	721	21·4	820	24·1	546	30·7	1112
1973/74	F	6·2	378	12·3	646	34·3	398	12·0	513
	H	13·9	945	28·4	893	38·7	452	40·7	553
1974/75	F	10·3	711	12·3	525	13·0	777	22·7	933
	H	11·0	821	28·4	361	12·4	671	45·8	825
1975/76	F	4·2	721	8·0	791	17·2	945	12·4	1487
	H	9·1	908	12·4	726	15·1	1172	20·6	1068

*F=WE6 (T85/799×T79/501)., H=WAE11 (S84: E10/4/90×T85/799)

**Replicates 3–5 only

***Replicates 1–3 only.

TABLE 4

Pod disease losses (%) and net yields of dry cocoa from whole plots (kg/ha)

Trial Area	1971/72		1972/73		1973/74		1974/75		1975/76	
	Disease	Yield	Disease	Yield	Disease	Yield	Disease	Yield	Disease	Yield
8th P.T.A. at Tafo										
Amelonado	14·6	670	9·0	860	13·2	707	16·9	669	9·3	708
Amelonado × Amazon hybrid	12·0	1110	10·9	1627	14·1	1309	23·1	1167	10·6	1713
Local-Trinitario × Amazon hybrids	16·3	911	14·2	1153	20·7	838	31·2	670	14·5	1111
Series III Trial at Tafo	23·0	379	22·3	440	23·9	501	24·7	541	15·0	702
Series II Trial at Apedwa	31·3	622	24·9	712	21·2	465	34·1	336	12·4	776
Amelonado plot at Apedwa	22·9	355	7·4	569	7·2	459	7·9	527	2·3	449
Series II Trial at Asikuma	32·8	597	28·9	525	41·1	389	17·7	506	21·6	937
Series II Trial at Pankese	18·3	1068	30·0	919	29·4	488	43·9	721	22·6	1121

The results from one year of a single progeny trial take no account of site-to-site and year-to-year fluctuations in blackpod losses and yield and thus cannot be equated to possible returns on farms. The fluctuations can be large, as can be shown from the yields of two of our better hybrids grown at four sites and compared over four seasons (Table 3).

In the 8th P.T.A. (Table 4) the better hybrids have continued to heavily outyield the Amelonado, thus the mean yield of the hybrids over the last five years was 1114 kg/ha (weighted for the differing replication of the progenies) which is 54% higher than the Amelonado mean of 723 kg/ha. However, 1971/72 was the only season in the life of the trial when the losses from blackpod disease have been higher on the Amelonado than on the Amelonado × Amazon hybrids and it may be significant that the year was one in which early setting on self-compatible progenies at Tafo and Apedwa was very high. The Amelonado trees cropped unusually early during the blackpod epidemic, whereas, the largely self-incompatible hybrids cropped later and thus avoided infection. In more normal years Amelonado has a consistent advantage over hybrids for blackpod losses and it seems certain that this difference would be sharply accentuated if farmers harvest hybrids as irregularly as they do Amelonado. Supporting evidence for this view comes from the Apedwa plots where blackpod losses on the hybrids were much higher than on Amelonado.

A detailed assessment of the Series III trial (8) showed that net yields have been very low; seven years after planting only 442 kg/ha and from the eighth to thirteenth year after planting an average of 513 kg/ha. In most years about half the pods did not yield fermentable cocoa, either because they were rotten following fungal infection (mainly blackpods) or the beans were caked. The latter is attributed to attack by *Bathycoelia thalassina*. Edwards (3), suggested that the low yields in the Series III trial and other plant breeding plots at Tafo were partially consequent upon exposure of the soil in the very early stages. As it is likely that many farm plantings with hybrids will be under similar conditions and not in newly cleared forest, the Series III rather than 8th P.T.A. yield levels may be a more reliable gauge of possible farmers' yields, under conditions comparable to those on the station at Tafo.

In the three Series II trials, losses from pod diseases have been serious even in years of normal rainfall and have been very high in wetter years (e.g. Pankese in 1974/75). Only in exceptionally dry years (Apedwa in 1975/76), were pod disease losses acceptably low. The marked increase in yield at Asikuma in 1975/76 is largely attributed to a lower level of infestation with *B. thalassina*.

The results from the Apedwa Amelonado plot are of particular interest because there are so few mature trials in which hybrids and Amelonado were compared, but it must be stressed that the comparison between this plot and the Series II trial has no statistical validity. The mean yield from the Amelonado over the last five years was 472 kg/ha, close to the ICO figure of 443 kg/ha whereas in the Series II trial the mean yield was 582 kg/ha, 23% higher than the Amelonado, but blackpod losses were also much higher.

The Yield Potential from Hybrids on Farms

In all the trials the management practices followed those of local farmers thus all the plots were grown under shade and except for a single dressing on the 8th P.T.A. no fertilizers were used. Harvesting was done at three week intervals and routine capsid sprays were applied according to current recommendations and so the management was nearer to that of the best rather than the average farmer. All the trials were in good vegetative condition between 1970 and 1976 yet the yields must be judged disappointing, except for the 8th P.T.A. and the Pankese trial in some years.

Much thought has been given to the difficulties of interpreting results from formal progeny trials in terms of farmers' plantings (e.g. 1). It is generally accepted that for net yield and losses from blackpod disease different types of planting material would tend to rank in the same order when growing in trials or on farms under similar ecological conditions with similar management practices. Ideally all new progenies should be tested under a wide range of conditions by planting on cocoa stations and farms throughout the cocoa growing areas. The information gained would lead to reliable recommendations of varieties for particular areas and knowledge of the yields to be expected. In practice this is not possible because of the amount of work involved and new progenies are tested at very few sites. Under similar conditions it seems reasonable to expect that average yields will be higher in trials than on farms because often the latter are less well managed. The trials reported here are very small areas among Ghana's huge acreage and even allowing for the difficulties of extrapolating from trials to farms any conclusions must be tentative. Some early high yields from trials with hybrids lead to the hope that under farmers' management they would be markedly higher yielding than Amelonado and it is perhaps forgotten that Amelonado can be extremely high yielding with the appropriate management (2). As illustrated above there is now increasing recognition that blackpod disease is likely to be a more serious problem on the present hybrids than on Amelonado, furthermore most new plantings will be on old cocoa land under less than ideal conditions. The hybrids have a conclusive advantage over Amelonado in easier establishment and earlier bearing and in addition they are likely to prove to be higher yielding. The IBRD yield estimate for hybrids is 90% higher than the ICO figure for Amelonado and would seem too high, because in well managed trials hybrids are not consistently yielding 841 kg/ha and even in the 8th P.T.A. the advantage of the hybrids over Amelonado is much less than 90%. The 8th P.T.A. and the data from Apedwa suggest that an advantage of 25–50% is more likely, which, if the ICO yield estimate for Amelonado is accepted, leads to projected yields from hybrids in the range of 550–650 kg/ha, which are regularly achieved in the trials. This estimate can be more than a working hypothesis pending collection of yield data from farms planted with hybrids because the results from trials show that yields from hybrids vary widely both from site-to-site and from year-to-year and depend heavily on regular harvesting to minimise blackpod losses.

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Recent Research on Insect Pollination of Cocoa*

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The cocoa crop is ultimately limited by the amount of pollination and fruit setting which occurs. Generally, less than 5% of the total number of flowers produced are pollinated, but observations suggest that, in some areas, the final fruit yield may be greatly increased under certain conditions (14, 15, 19, 31). However, in spite of the importance of pollination and the activity of the pollinating agencies in crop production, research efforts in this area have been very restricted.

The recent reviews by Free (4) and Entwistle (3) summarised most of the pollination investigations carried out prior to 1968, but since then, research on cocoa pollination has gained a new impetus especially in Costa Rica, Brazil and West Africa. This paper will concentrate on resuts of these more recent studies.

The Pollinating Agents

The idea held by earlier workers, that wind pollination was the only, or at least the principal means of pollination, was shown to be incorrect by the experiments of Harland (5), Billes (1) and Soetardi (18), but it was only in 1941 that Billes was able to show that cocoa pollination was carried out chiefly by small, biting, female flies of the genus *Forcipomyia*, family Ceratopogonidae. Even today, their small size (0·5 to 2·0 mm long) and quick movements make observations on these insects a difficult undertaking. These difficulties are compounded by a lack of easily recognisable adult characters which makes identification difficult and laborious, even for specialist taxonomists. The best morphological characters for separating the different species are, in fact, found in the larvae and pupae.

Much of the recent research on cocoa pollination has concentrated on the actual identity of the pollinators (29). Although more than 75 species of ceratopogonids in 10 genera have been found frequenting cocoa flowers, only about 50% have actually been observed pollinating (29). Other Microdiptera frequenting cocoa flowers include the Cecidomyiidae, Chironomidae, Drosophilidae, Psychodidae and Sphaeroceridae. Cecidomyiids are the most important numerically but the contribution by these insects to total pollination seems to be minimal. However, preliminary observations (8, 15) suggest that cecidomyiids and drosophilids may sometimes be important pollinators in Ghana and the Cameroons respectively.

The genus *Forcipomyia* contains the greatest number of known pollinators and is now divided into 16 subgenera (Wirth, pers. comm.), a great increase over the original six subgenera proposed by Saunders (17). The most important subgenera are *Euprojoannisia* (formerly known as *Proforcipomyia* and *Euforcipomyia*), *Thyridomyia* and *Forcipomyia*. Their relative importance in different cocoa-growing areas of the world is shown in Table 1.

*This paper was presented during the XV International Congress of Entomology held in Washington, D.C., U.S.A. from August 19 to 27, 1976.

TABLE 1

Diptera observed pollinating cocoa throughout the world and their known breeding sites.

Taxon	*No. of Pollinating Species observed*				
	Africa	*East Indies*	*Central America and West Indies*	*South America*	*Known Breeding Sites*
CERATOPOGONIDAE					
Forcipomyia (Forcipomyia) spp.	12	—	2	—	Rotten cocoa pods; rot holes in trees; cocoa leaf litter; rotten banana trunk.
F. (Euprojoannisia) spp.	3	1	6	4	Cocoa leaf litter; rotten banana stem and bracts; rot holes in trees.
F. (Thyridomyia) spp.	—	—	2	—	?
F. (Microhelea) sp.	1?	—	—	—	Rotten cocoa pods. Rotten banana leaves.
F. (Warmkea) sp.	—	—	2	—	Probably waterholding plants of some sort.
F. (Lasiohelea) sp.	—	1	—	—	?
Dasyhelea sp.	—	—	1	—	?
Culicoides sp.	1	—	—	—	?
Stilobezzia spp.	2	—	—	—	Rotting wood.
Atrichopogon sp.	1	—	—	—	?
CECIDOMYIIDAE	1	—	—	—	Organic debris in soil.
DROSOPHILIDAE					
Drosophila sp.	1	—	—	—	?
Total	22	2	13	4	

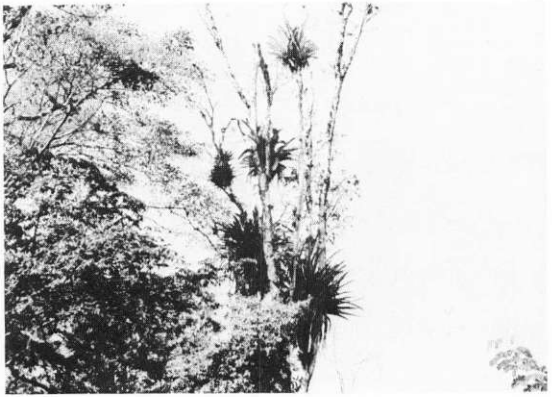
The species of Diptera observed frequenting cocoa flowers, their pollinating activity and breeding places have been recently reviewed (29). There has been little success in locating the breeding sites of the cocoa flower Diptera, especially of pollinators, until fairly recently. The immature stages of the Ceratopogonidae generally breed in moist, rotting organic substrates, and in cocoa plantations the most important sites seem to be cocoa leaf-litter, rotten cocoa pod husks, rotten banana stems and epiphytic bromeliads (28, 29, 30, 31) (Fig. 1). Although no known pollinator has yet been found in epiphytic bromeliads, this substrate may probably be one of their most prolific breeding sites (29).

Kaufmann (9, 10, 11, 12) has attempted to demonstrate the pollinating ability of some ceratopogonid species and also of a cecidomyiid (8) by cage experiments in which the species to be tested was enclosed in a mesh cage containing cocoa flowers. Winder (29) has suggested that such experiments may be misleading as to actual pollinating potential in the field, since such factors as the number of flowers available per midge, cage size, and the physiological state, fed or unfed, of the flies, were not taken into account. The only satisfactory way to discover whether a particular species is a pollinator or not, is by careful field observations and collection, as was done by Soria (19) in Costa Rica.

A

B

C



D

Fig. 1. Forcipomyia spp. breeding sites in cocoa plantations, Brazil: (A) Cocoa leaf litter; (B) Empty cocoa pods; (C) Rotting banana trunk; (D) Epiphytic bromeliads on shade tree.

Many other insects frequent cocoa flowers, chiefly ants, aphids, thrips and and coccids, but the cross-pollinating activity of these groups seems very doubtful, although some setting may occur on self-compatible trees. Kaufmann (7) showed that the psyllid, *Tyora tessmanni* Aulmann pollinated flowers under laboratory conditions, but the large number present during the February to April flowering period in West Africa, when virtually no setting occurs, indicates that this species is probably not important under field conditions. Microscopic examination of various species of ants, coccids, cicadellids and the aphid, *Toxoptera aurantii* B. de Fonsc., found in flowers during May and June in Bahia State, when most setting occurs, showed that no specimens carried pollen grains (Winder, unpublished observations). In Costa Rica, the thrips *Frankliniella parvula* Hood probably complements *Forcipomyia* pollination during the dry season (6, 19).

Vello and Magalhaes (26) showed that the presence of the "cacarema" ant, *Azteca chartifex spiriti* Forel, may increase total effective pollination on cocoa trees in Bahia, not through its own acitivity but perhaps by attracting ceratopogonid pollinators. However, further experiments are needed to substantiate these results owing to the small number of trees observed per treatment and the absence of any treatment replication. Soria (20) has reviewed the evidence on the pollinating activity of the stingless Meliponine bees in cocoa and came to the conclusion that this was usually accidental. Recently, Kaufmann (13) has stressed the importance of the halictid bee, *Lasioglossum* sp. in pollinating canopy level flowers in Ghana. However, the low viability of pollen grains carried by the meliponine bee *Trigona jaty* Smith in Costa Rica (6), suggests that the pollinating efficiency of *Lasioglossum* may not be as high as expected.

Ecology of Ceratopogonid Pollinators

The complete life-cycle of *Forcipomyia,* from egg to adult, lasts approximately 28 days at 24°C (Fig. 2). Adults live 1–12 days under laboratory conditions (6, 21, 24, 25). One of the most important objectives in rearing through different species of *Forcipomyia* is the value of the immature stages in identifying different species.

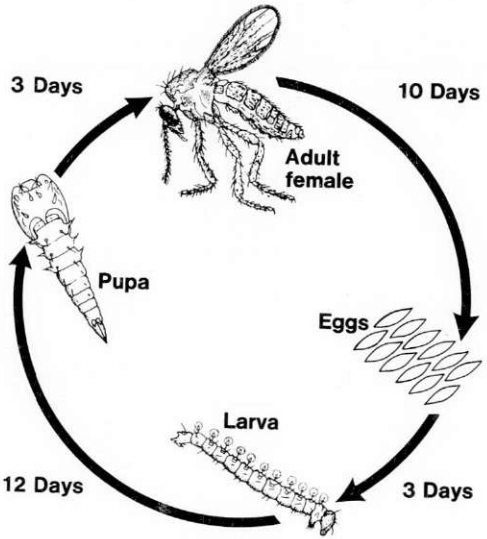


Fig. 2. Life cycle of Forcipomyia spp.

Pollinating activity by the female ceratopogonid midges seems to occur mainly in the early morning, before 9 a.m., with a further activity peak in the mid-afternoon (3, 28); any collecting should be done at this time. Pollinators are affected by climate: rainy, overcast conditions inhibit pollinating activity whereas sunny weather enhances it (3, 6, 19, 28). They seem to have distinct preferences for certain trees in a plantation, which produce more fruit than their neighbours but over a period of time relative attraction changes so that unattractive trees become attractive and vice versa (6, 19). The reason for this behaviour is not known. Why more female than male ceratopogonids visit cocoa flowers is uncertain, although several hypotheses have been put forward. In fact, both males and females pollinate flowers (6, 9, 10, 11, 12), although male pollination seems to account for only a very small part of the total. Since midges are attracted equally to "comun" flowers with red guide lines and "catongo" flowers, with no red guide lines, flower colour would not appear to be the main attraction stimulant (19). Downes (2) found that females of a species in the ceratopogonid genus, *Atrichopogon*, fed on pollen grains inside the honeysuckle flower, where they apparently obtained their protein for egg maturation; female ceratopogonids may visit cocoa flowers for the same reason. Certainly, flower visiting is a common activity for female ceratopogonids throughout the world (2, 29) but the ratio of pollinating Diptera to cocoa flowers varies from 1:7122 in Brazil to 1:316 in Costa Rica (29). Cocoa flowers pollinated by *Forcipomyia* characteristically carry a large and compact mass of pollen on the tip of the stigma (Fig. 3).

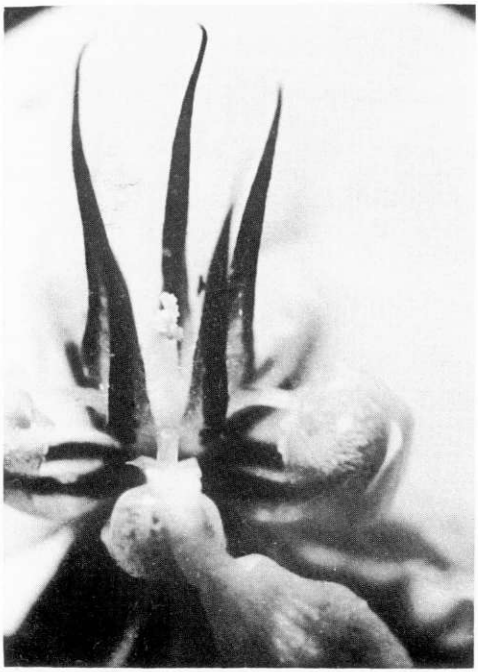


Fig. 3. Cocoa flower pollinated by Forcipomyia sp. Note the large and compact mass of pollen on the tip of the stigma.

Knowledge of the flight behaviour of pollinators is important when setting up a cocoa seed garden. Observations indicate that the flies traverse quite long distances (16). Suction trap studies in Bahia with traps set above and below the crown of shaded cocoa showed that five to seven times as many *F.* (*Euprojoannisia*) spp. and *F.* (*Forcipomyia*) spp. adults were present above as below the crown. This suggests that wind currents are probably very important in determining the distribution of adult ceratopogonid populations.

Seasonal Abundance of Ceratopogonids

Very little research has been done on the seasonal abundance of ceratopogonids and pollinators in cocoa plantations. Preliminary results from a two-year (1969–1971) emergence trap study in Bahia, of cocoa leaf-litter diptera in areas treated and untreated with BHC 1%, suggested a positive relationship between soil moisture and ceratopogonid populations. High populations were correlated with excess soil moisture and low populations with a deficit (31). The ceratopogonids in this study comprised more than 30 species in 9 subgenera of *Forcipomyia* and 5 other genera of ceratopogonids, including pollinating species from the subgenus *Euprojoannisia* (Winder and Wirth, unpublished observations).

A one-year study (1973) in Bahia, of the aerial populations of *F* (*Euprojoannisia*) spp. and *F.* (*Forcipomyia*) spp. in shaded cocoa, using insect suction traps 2 m above ground, showed that the largest numbers of both subgenera occurred from May to July (23). The soil moisture excess in this period was characterised by "advectional" rainfall, i.e., a little rainfall in short periods, whereas the soil water excess from November to January was characterised by "convectional" rainfall, where abundant rain fell in a very short time (23). This latter rainfall pattern may not provide the continuous wet conditions necessary for ceratopogonid egg and larval development. The probable importance of rainfall in ceratopogonid abundance in cocoa in Java was pointed out by Soetardi (18) and by Entwistle (3) for Ghana, where the dry, hot northerly wind or "harmattan" dries out breeding places, resulting in no pollination despite heavy flowering.

Effect of Insecticides

Although experiments showed that the use of wide-spectrum insecticides such as BHC, DDT and Dieldrin did not have a noticeable effect on pollination rates (3), the experimental planning was often deficient. The main problem in interpreting results has been the small size of the treatment areas, allowing immigration and emigration, and the absence of treatment replications (Table 2).

An experiment to measure the effects of three different treatments, mineral oil, lime and copper oxide solution, compared with a control, on the dipterous populations of cocoa pod heaps in Bahia was undertaken in 1971 (31). Preliminary results indicate that both lime and copper oxide treated pod heaps do not differ significantly in the number of ceratopogonids produced per unit weight (30 per kilo) from the control. However, the mineral oil teatment produced a mean of only 20 ceratopogonds per kilo of empty cocoa pod husk (Winder and Wirth, unpublished observations). When identification of all the insects collected is completed it will be apparent whether the treatments affected species diversity.

TABLE 2

Investigations on the effects of insecticides on cocoa pollinators.

Country/Authority	*Insecticides Tested*	*Area Treated*	*Comments*
Ecuador (14)	Carbaryl Malathion	approx. 300 m^2 (0·03 ha)	No measurable effect on fruit set. No Replications (D. F. Edwards pers. comm.)
Java (27)	Endrin	3300 m^2 (0·3 ha)	Mo measurable effect on fruit set. No replications.
Brazil (22)	BHC Carbaryl Methyl Parathion	(a) 625 m^2 (0·06 ha) (b) 2500 m^2 (0·25 ha)	Only % mortality on *Forcipomyia* spp. measured. Populations had recovered to original levels after 1 week. No replications.

Our present knowledge of the pollinator breeding sites indicates that they are generally well-protected from the immediate action of insecticides although the long term effect of residues may have serious consequences (3, 24, 28, 30). There is, therefore still a need for properly designed experiments on the effects of insecticides on pollinators and pollination rates. The possible side-effects of insecticides may, of course, be diminished by applying low concentrations and dosages of narrow spectrum insecticides during times when pollination rates are normally low.

Increasing Natural Pollination

Assuming that natural pollination of cocoa is a limiting factor in cocoa production in a particular area, fruit set might theoretically be increased through the manipulation of pollinator populations. Although only Microdiptera and especially certain *Forcipomyia* species are morphologically adapted to pollinate cocoa, this fly-flower association is not symbiotic as stated by Soria (19) since the tree depends on the fly but the fly does not seem to depend on the tree. This hypothesis is supported by the preliminary field data from emergence traps which suggests that there are many more potential pollinators present than pollinations effected.

A hectare of Bahian cocoa produces an average of 450 kilos, approximately 15,000 fruits, assuming that each fruit has 30 grams of beans. Also, assuming that each female fly only carries out one effective pollination, then only 15,000 pollinators would be needed during the year, a very small percentage of the total number available (28, 31). As already stated, ceratopogonids visit the flowers of many plants, and many species are also haematophagous, i.e., sucking the blood of other insects and small mammals. Therefore, visiting cocoa flowers seems to account for only a small portion of the activities of a pollinator species. Even if the number of pollinators could be increased for a particular area then, there would not necessarily be an associated increase in pollination rates. However, it may be advantageous to increase populations at specific times of the year when natural pollinator populations and pollination rates are low (28).

Pollinators are difficult to rear in the laboratory and the most economical approach would be to increase the number of natural breeding sites or perhaps, even provide artificial ones. Cultivation practices such as the non-removal of epiphytic bromeliads (28) and the amassing of empty cocoa pods into heaps may prove beneficial. However, a more detailed knowledge of the breeding sites is necessary for any scheme of this nature to be successful.

ACKNOWLEDGEMENTS

I wish to thank Dr. S. Soria, CEPEC, CEPLAC, for providing figures 2 and 3.

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The Transport of Cocoa Beans in Containers

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Cadbury Schweppes Limited

Ten years ago we published an article (1) on the bulk handling of raw cocoa which mentioned an experiment with the use of containers for transporting cocoa beans. During the past five years many further trials have been conducted and certain conclusions have been reached. Problems affecting quality arise in this method of transport and, while possible solutions are in sight, no final answer to them has been found. Nevertheless it seems right to review the situation at this stage as containerisation is becoming well established as a standard means of transport for many goods and products.

Trials with Standard and Insulated Containers

All the trials with which we have been concerned have stemmed from West Africa because the largest traffic in cocoa is between West Africa and Europe and also because containerisation of other cargo on this route has been expanding rapidly.

The first trials were conducted in 1972/73 season using standard 20 foot (6050 mm) containers lined with plywood and partly painted internally with anti-condensation paint, which can absorb some moisture.

These trials showed clearly that the fall in temperature between West Africa and Europe which occurs during part of the main shipping season leads to condensation inside the container which is a hazard to quality. The top layer of bags receives some of the moisture which condenses on the roof and sides, commonly known as sweat damage, and this can raise the moisture content of beans in those bags to a level at which mould will develop. Moisture determinations revealed a slight movement of moisture from the lower levels to the top layer. At the experimental level using only a few containers the movement of moisture does little or no harm as the cocoa can be handled quickly and the beans processed without delay. However, large numbers of containers in a shipment could not be handled in this way and the movement of moisture would be an unacceptable hazard to quality.

Trials with Bulk Containers

Apart from the quality problem we found that it takes nearly twice as long to unload a 20 foot container as it does to off-load the same quantity of cocoa, about 15 tons, from a standard truck. There is therefore, a financial disadvantage in dealing with bagged cocoa in containers.

This disadvantage might be overcome by transporting the beans loose in a container. This would require modification to the container as well as facilities for loading and unloading in country of origin and receiving factory respectively. A few experiments were arranged with temporary modifications to a container, which held about 16 tons of beans loaded through roof hatches. In these trials moisture uptake was much worse than with bags, the top 2–3″ of beans having moisture contents well over 8%, some samples reaching 15–20%. Cut tests showed that mould had developed internally in some of the damp beans.

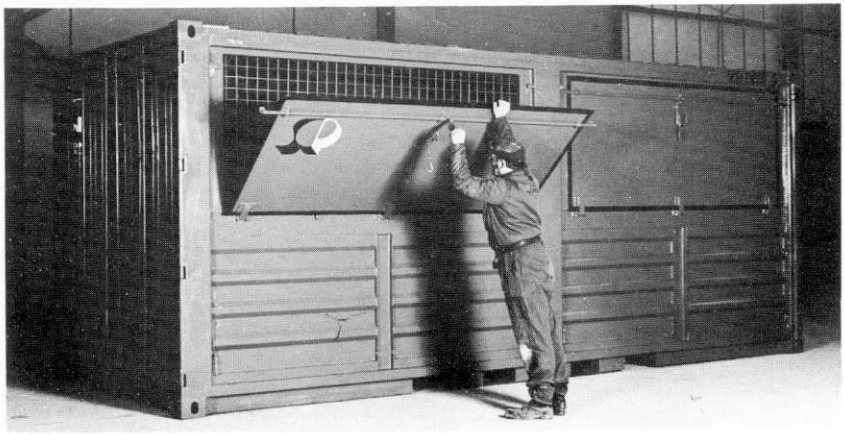

Fig. 4 Open sided container with flaps — designed by Sea Containers Ltd

Attempts were made to overcome the condensation problem by enclosing the beans in a polythene bag but this measure was unsuccessful. No further attempts have been made to transport cocoa beans in bulk.

Measures to reduce the hazard to quality

In order to avoid the effects of moisture movement, it is necessary to either prevent moisture being given off by the beans or to absorb it or to remove the damp air. All three approaches have been tried.

1. Trials with polythene liners in jute bags

Polythene liners inside standard jute bags would prevent moisture being given off by the beans and would prevent any condensation from reaching the beans. In 1975/76 several shipments were arranged from Ghana and Nigeria using standard steel containers loaded with bags. In some containers all the bags had polythene liners, in others only 50% of the bags and in some all the bags were unlined. Some containers were loaded on deck, some in the hold. On arrival in U.K. some loads were discharged immediately, other loads were put into store. When the containers were opened those in which all the bags had polythene liners were practically free from condensation while the other containers showed considerable condensation. This showed that the condensation which occurs without polythene liners arises largely from moisture given off by the beans and only to a small extent from moisture in the air within the container. There was no sign of condensation within the polythene lined bags. All the cocoa in polythene lined bags wherever it was stowed and whether held in store or not was of satisfactory quality. Thus these trials showed that polythene liners would prevent the hazard to quality arising from condensation.

There are obvious practical difficulties in the use of polythene liners for the West African crops. Their use would involve considerable changes in the way cocoa is handled so that their use in West Africa would be confined to special circumstances. The same difficulty may not apply in other countries and the use of polythene liners where cocoa is to be shipped in standard containers and the journey will involve a considerable drop in temperature would safeguard quality. It must be stressed that the beans must be thoroughly dry – moisture content not more than 6·5% – if polythene liners are used.

At the receiving end polythene liners make the opening and emptying of bags rather more difficult and their use may be unpopular on that account.

2. Trials with silica gel

Rowntree Mackintosh have conducted two trials using standard containers and varying quantities of silica gel to absorb the moisture given off by the cocoa.

Dehydrated silica gel was supplied in 5 kg bags and amounts varying from 5 to 40 bags, i.e., 25 to 200 kg, were placed in each of nine containers, mostly on top of the bags. There was evidence that the amount of condensation was reduced but not even the larger amounts prevented it entirely.

3. Trials with ventilated containers

(a) Container designed by East Asiatic Co. Limited. This container consisted of a standard box container with false side walls open to the interior at top and bottom. There was a ventilation grid running along the bottom of each side wall and four ventilators at the top of each side. Thus air could move between side walls, and if not obstructed, up through main chamber of the container. A trial was arranged with three containers, two loaded with bags, one in bulk, from Apapa, Nigeria to Antwerp in January – February 1976. There was considerable condensation in these containers when opened for examination and it was concluded that the ventilation had not been effective. However, it is understood that considerable modifications have been made to the design of this container in order to improve the ventilation; further trials will be arranged.

(b) Sea Containers Limited designed a new type of container which had two steel mesh panels in the upper half of both sides which could be closed by hinged flaps (Fig. 1). With the flaps closed the containers can be used for normal goods. For transporting cocoa the flaps would be opened during the voyage and closed after off-loading to prevent rain damage between ship and destination. Three trials were arranged early in 1977 between Nigeria and U.K. All gave satisfactory results but in only one trial was the weather really cold enough in U.K. to test this method. The method is dependent on the ship's hold being adequately ventilated and in these trials only the experimental containers were loaded, all the others were empty. Therefore, these trials have not given conclusive proof that these special containers are effective but all the evidence indicates that they will prove suitable for the transport of cocoa.

General Conclusions

The work that has been done on containerisation of cocoa beans has shown:

1. Standard containers are unsuitable when a considerable drop in temperature occurs.
2. The effects of a fall in temperature can be avoided if the cocoa is packed in polythene-lined bags.
3. Condensation can be prevented by using well ventilated containers.

It should be emphasised that the difficulties arising from condensation will only occur where there is an appreciable fall in temperature. No difficulties arise where the fall is slight or non-existent.

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Notes on Contributors

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CSIRO: Commonwealth Scientific and Industrial Research Organisation, Australia.

Cocoa Abstracts

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

July 1976

Gnosh, B. N.; Cunha, J. (Gulf Western Advanced Development & Engineering Centre, Swarthmore, Pennsylvania, USA). **Effect of season on sun drying of cocoa beans in Brazil.** Turrialba (IICA) v. 25(4) p. 396–403; October 1975.
The sun drying of cocoa beans after fermentation is carried out on a flat, horizontal platform. An average of 10 days is needed to sun dry a batch of beans, with a minimum and maximum recorded value of 5 and 12 days, respectively. An extraction of 84% of the bean moisture is needed to produce a dry sample. An average of 55 hours of sunshine and 69 platform-open hours is necessary to dry a batch; on the average the platform is kept open for 7 hours a day. The initial bean moisture content had only a marginal effect on the number of days needed to dry a batch. The dry stage, as judged by the operator, was found to vary from 7% to just over 10% in moisture content, which is somewhat higher than the maximum recommended value of 8%. The use of a portable, easy-to-operate moisture meter, is likely to produce more consistent results.

Omotoso, T. I. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Amounts of nutrients removed from the soil in harvested Amelonado and F_3 Amazon cacao during a year.** Turrialba (IICA) v. 25(4) p. 425–428; October 1975.
In the case of cacao it has been shown that both the physical and chemical properties of soil decline with cultivation, with a corresponding decline in the yield. To study the removal of nutrients, bimonthly samples of cacao pods of both varieties from 4 different localities were analysed throughout the year. It was shown that there is little variation between the 2 varieties as well as in the NPK contents throughout the year and from one locality to another. It was calculated that the amounts of NPK removed from the soil in harvested Amelonado cacao are, respectively 47·3, 7·1 and 94·8 kg/ha, assuming an average yield of 1,255 kg dry beans/ha. The amounts of P and K are not expressed here as P_2O_5 and K_2O, but in bare P and K values.

Emechebe, A. M. (Department of Crop Science, Makerere Univ., Kampala, Uganda). **Some host factors affecting inoculation of cacao seedlings with Verticillium dahliae.** East African Agricultural and Forestry Journal (Kenya) v. 40(3) p. 217–277; January 1975.
Cacao seedling susceptibility to Verticillium dahliae increased with age. Root damage and complete root system inoculation increased incidence ofinfection. Incidence was reduced by (1) high atmospheric humidity, (2) defoliation 3 weeks before inoculation, (3) defoliation at inoculation time and continued defoliation afterwards; and (4) girdling 2 weeks before inoculation. Trinitario varieties were more susceptible than Amazonian or Amelonado varieties at low inoculum densities.

Williams, J. A.; Okoloko, G. E. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Periodicity of leaf flushing in Theobroma cacao, L.** Journal of the West African Science Association (Nigeria) v. 17(2) p. 135–143; October 1972.
Cacao tree flushing was studied at Gambari, Western Nigeria, Cacao trees show a periodicty of leaf flushing, with an average of 5 to 6 cycles per year, that is partially dependent on environment. The varieties behaved similarly but flushing pattern between years differed greatly. The degree of red poddedness of a variety and pink colour of young leaves were positively correlated. Mean temperatures were higher during flushing but no temperature threshold for onset of flushing was observed. The positive correlation between flushing and hours of sunshine, as observed in Costa Rica, was not considered in this study.

August 1976

Falade, J. A. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria. **Soil bulk density – moisture supply interaction in Amazon cocoa.** West African Journal of Biological and Applied Chemistry (Nigeria) v. 18(3) p. 15–22; October 1975.
In a laboratory experiment a strong interaction between soil bulk density and water supply on the growth of cacao was found. For the soil used (clay loamy) a bulk density of 1·35 g/m seemed to be critical for maximum growth.
Snoek, J. (Institut Français du Cafe et du Cacao (IFCC), Bingerville, Ivory Coast). **[Tests relating to the use of growth substances on cocoa trees in the Ivory Coast] Essais d'utilisation de substances de croissance sur cacaoyers en Côte d'Ivoire.** *Café, Cacao, Thé (France)* v. 20(1) p. 3–10; January 1976.
The growth retardants CCC (chlormequat chloride) and B9 (N-dimethylamino succinamic acid) were applied in various concentrations to cocoa seed gardens with several clones. When applied during flowering, they improved substantially the rate of fertilization of the ovules, resulting in a strong increase in the number of beans/pod (51% with 500 ppm of CCC). When applied before flowering, production was increased by 57% with 500 ppm of CCC, and by 60% with a mixture of 500 ppm of B9 and 600 ppm of Fruitone (AAA). It is thought that the growth retardants induce a temporary reduction of the development of small branches so reducing the competition for photosynthates between these branches and the ovules and young fruits.

Guénot, M.-C.; Perriot, J.-J.; Vincent, J.-C. (Institut Français du Cafe et du Cacao (IFCC), Montpellier, France). **[Development of the microflora and fatty acids of cocoa beans furing storage. Preliminary study] Evolution de la microflore et des acides gras des féves de cacao au cours du stockage: étude préliminaire.** Café, Cacao, Thé (France) v. 20(1) p. 53–58; January 1976.
Forastero cocoa beans from Cameroon were stored for 6 months at 28 ± 2°C and 80 ± 3% relative humidity. With an initial water content of 5.1%, the equilibrium moisture content was reached after 4 months of storage. The fungal population tended to stabilize itself after 1 month at a low level and consisted mainly of Mucor (M. pusillus); no yeast was shown to exist. Free fatty acids increased only slightly during storage with preferential liberation of palmitic and oleic acids.

Atanda, O. A. (Moor Plantation, Agricultural Research Council of Nigeria, Ibadan, Nigeria). **Assessment of WACRI Series I and II varieties of cocoa in Nigeria. 2. Pod value, butter-fat content and flavour assessment.** Ghana Journal of Agricultural Science (Ghana) v. 8(1) p. 3–10; April 1975.
Pod-value attributes, butter-fat content and flavour were investigated in open-pollinated Series I and II of cocoa in Nigeria. The results obtained are consistent with previous reports on cocoa which implicate environmental conditions and genotype in the final expression of pod value factors. The implications of these results are briefly discussed and it is re-affirmed that Series II varieties constitute a better general purpose variety than F_3 Amazon.

Okali, D. U. U.; Owusu, J. K. (Department of Botany, University of Ghana, Legon, Ghana). **Growth analysis and photosynthetic rates of cocoa (Theobroma cacao L.) seedlings in relation to varying shade and nutrient regimes.** Ghana Journal of Agricultural Science (Ghana) v. 8(1) p. 51–67; April 1975.
In Ghana, Amelonado and Amelonado × Scavina cocoa seedlings were grown in sand culture under different levels of shade and nutrient supply. Relative growth rate was maximal under medium shade and at highest nutrient level. Net assimilation rates were little affected by shade level. Net photosynthetic rate was highest for leaves developed in full daylight as a result of enhanced photosynthetic efficiency. On leaf area basis, net photosynthetic rate was highest in plants maintained at the highest nutrient level. On chlorophyll content basis there was no difference. Amelonado × Scavina grew more vigorously than Amelonado largely as a result of better leaf development in the former.

Leite, J. De O. (Seçao de Documentaçao Aerofotografica, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **[Disappearance of cacao plantations in the neighbourhood of Itabuna. A study of land use dynamics] Desaparecimento de cacauais em adjacências de Itabuna. Um estudo de dinâmica do uso-da-terra.** Boletim Técnico Centro de Pesquisas do Cacau (Brazil) no. 29, 31 p.; September 1975.
Using aerial photographs of 1945 and 1965, supplemented with field observations, it is possible to distinguish, in the cacao region of Bahia State, "stable areas" and "areas of decline". This decline corresponds in the first place with shallow soils, which prevent the development of the cacao tree and limit its resistance to drought. Other factors are a lack of cacao growing technology and a lack of credit facilities up to 1965. The tendency to decline may be reversed as a result of more research and extension work which at present is in progress.

Braudeau, J. (Institut Français du Cafe et du Cacao (IFCC), Paris, France). **[Cacao] El cacao.** Editorial Blume Barcelona (Spain) 297 p. 1970. [Es].
This is a first reprint of a Spanish translation of the book "Le cacaoyer", published in France in 1969. It deals with all aspects of cacao production: botany, physiology and ecology, diseases and pests, selections and breeding, vegetative multiplication, establishing a plantation, maintenance, harvesting and preparation of cocoa, rejevenation of plantings, costs of production, cocoa storage, quality aspects, the cocoa and chocolate industry, the world cocoa situation, and international cacao conferences. A bibliography of 252 entries concludes the book.

Mainstone, B. J. (Dunlop Estates Berhad, Malacca, Malaysia). **Cocoa on inland soils in peninsular Malaysia.** Planter (Malaysia) v. 52(598) p. 16–24; January 1976.
Up to 1961, cocoa had not been considered as a suitable crop for farmers anywhere in W. Malaysia because of stem "dieback". However, after introduction of some seedlings of another type than the Amelonado type in 1951 and later importations of similar material in 1961, the position began to change and there was more interest in cocoa planting. This Upper Amazon material was hardier, more precocious and suffered less from "dieback". It also could tolerate less shade and longer periods of water stress. Following the recommendations on cultural practices described in this article, cocoa appears to be an economical crop producing good yields of over 2,000 kg/ha of dry beans in a year, also on inland soils in W. Malaysia.

Murray, D. B. (ED.); Jones, E. (ED.); Quesnel, V. C. (ED.); Chalmers, W. S. (ED.); Fordham, R. (ED.); Iton, E. F. (ED.). (Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago). **IV International Cocoa Research Conference, St. Augustine, Trinidad, 8-18 January 1972.** 699 p. 1972.
These proceedings contain the texts of 81 papers read at the conference. The papers refer to the following research sections: Plant breeding (11); Soils, physiology, agronomy (22); Plant pathology (26); Entomology (10); Processing (7); and Miscellaneous (5). Brief summaries of the discussions are included as well.

Opeke, L. K. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Cacao breeding in Nigeria during the 1960–69 decade.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 25–31 1972.
Breeding programmes during the decade concerned have been aimed mainly at improving establishment ability and introduction of resistance/tolerance to the swollen shoot virus and black pod (Phytophthora palmivora) diseases. Other breeding work carried out refers to diallel crossing and inbreeding.

Vello, F.; Garcia, J. R.; Magalhaes, W. S. (Centro de Pesquisas do Cacao (CEPEC), Itabuna, Bahia, Brazil). **[Hybridization and selection of cacao in Bahia] Producão e selecão de cacaueiros híbridos na Bahia.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 38–56 1972 [Pt] tables, 10 refs; summaries.
Dry cocoa yields are listed of progenies derived from crosses between local cacao clones and clones of different genetic and geographical origin, as obtained in 12 field trials at different locations and using progenies from open pollinated Catongo cacao as control. Progenies from crosses between local clones and Upper Amazon or local clones yielded better and were more precocious than progenies from crosses between local clones and Trinitario cacao clones. Yields of 12 different 3-year-old clonal progenies ranged from 148 to 1,340 kg/ha as compared with 19 to 283 kg/ha for the Catongo seedlings.

Perez Zamora, A.; Reyes, E. H.; Reyes, L. C. De. (Estacion Experimental, Caucagua, Venezuela). **[The programme of genetic improvement of cacao in Venezuela] Programa de mejoramiento genético de cacao en Venezuela.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad. 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 57–68 1972.
Breeding work using locally selected cacao clones and introduced clones is described. Excellent results have been obtained from crosses between Criollo (Porcelana) cacao clones and Upper Amazon clones regarding vigour, precociousness in bearing, yield, and bean weight. Criollo clones of the Chuao and Ocumare types have shown good combining ability and homozygosity. Resistance to fungal diseases (Marasmius, Ceratocystis and Fusarium spp.) is evaluated.

Edwards, D. F. (Cocoa Research Inst., Tafo, Ghana). **The production of hybrid seed in Ghana.** In IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 69–72 1972.
The development of bi-clonal seed gardens to produce the CRIG series II hybrids is discussed. Hand pollination was found advantageous for improving pod production and controlling the cropping pattern.

Chee Yau Fah (Cocoa Research Station, Department of Agriculture, Quoin Hill, Sabah, Malaysia). **Review of cocoa breeding in Sabah.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 73–76 1972.
The characteristics of several introduced Trinitario, Amelonado and Upper Amazon clones are evaluated as a basis of a programme to breed for high-yielding varieties adaptable to local conditions. Results are given of a progeny trial initiated in 1964, in which 3 groups of hybrids derived from crosses between a number of the above clones are tested. Hybrids of Amelonado and Upper Amazon cacao proved to be much superior to Amelonado cacao not only in yield but also in early establishment and growth vigour.

Coral, F. J.; Soria, V. J. (Instituto Interamericano de Ciencias Agricolas (IICA), Turrialba, Costa Rica). **[Different degrees of self compatibility in Theobroma cacao L.] Differentes graus de autocompatibilidade em Theobroma cacao L.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972. Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 77–81. 1972.
The hypothesis of Knight and Rogers on sporophytic control by multiple alleles was checked in this study conducted in Costa Rica with some clones and their hybrids. The results have indicated some discrepancies from the expected data, and consequently, a new genetic model has been proposed to explain the mechanism of inheritance of the incompatibility system in cacao.

Atanda, O. A. (Cocoa Research Inst. of Nigeria (CRIN), Abidjan, Nigeria). **Heterotic pod production of double over single crosses in Theobroma cacao L.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 82–89 1972.
The heterotic pod production of 3 Nigerian × Trinidad (NT) double crosses over their respective inbred and single hybrid (NT) parent trees is reported. It is concluded that substantial additive and dominance effects operate in the inheritance of pod yield in cacao.

Molina Maggi, C. (Estacion Experimental, Caucagua, Venezuela). **[Preliminary results of regional trials in Venezuela] Resultados preliminares del proyecto de ensayos regionales de cacao en Venezuela.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 90–98 1972.
Preliminary results are given of regional trials started in 1963 with progenies derived from crosses between several Criollo, Trinitario, and Upper Amazon clones. The behaviour in respect to yield, quality and resistance of progenies of the 10 best combinations with 3 or 4 years of yield is described.

Chalmers, W. S. (Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad and Tobago). **The performance of Scavina hybrids in Trinidad and their future role.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 99–113 1972.
The breeding work carried out over the past years in Trinidad with the Upper Amazon Scavina selections, mainly the clones SCA 6 and 12, on account of their high-yielding ability combined with an apparent immunity to witches' broom disease is described. The search for the best genotypes to cross with the Scavinas continues, making use of inbreeding, sib and back crossing, 3-way crosses and incorporation of germplasm from other countries. Since yield potential is no longer a limiting factor in crop production, emphasis in the future will be placed on breeding for increased seed size and resistance to witches' broom disease, black pod and Ceratocystis. It is vitally important to collect new genetic sources of resistance to these major diseases of cacao.

Asomaning, E. J. A. (Cocoa Research Inst., Tafo, Ghana). **Recent cocoa nutrition studies: with particular reference to the Ghana experience.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 120–128 1972.
Studies conducted in Ghana on the nutrition of cacao, including the effect of the environment, field trials with shade and fertilizers, varietal differences, and the effect of nutrition on the incidence of diseases and pests, are reviewed.

Jadin, P. (Centre de Recherches, Institut Français du Cafe et du Cacao (IFCC), Bingerville, Ivory Coast). **[A study of the fertilizer requirements of cacao in the Ivory Coast using soil analysis] Etude de la fertilisation minérale des cacaoyers en Côte d'Ivoire à partir du diagnostic 'sol'.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 135–152 1972.
Pedological studies carried out on demonstration plots at different locations in the Ivory Coast have shown that for the choice of a fertilizer formula the balance between the elements is more important than the actual level of the elements. A linear relation was found between exchangeable bases and N for a given pH. A balance was also shown between K, Ca and Mg, which balance expressed as a percentage of total exchangeable bases had an optimum ratio of about 8% K, 68% Ca and 24% Mg. Furthermore, a balance between N and P, with an optimum ratio of 2, was found. In 4-year-old cacao, the adoption of this fertilizer formula has led to an increase of 300 and 600 kg/ha of dry cocoa in the 2nd year of application.

Egbe, N. E.; Omotoso, T. I. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Nutrient deficiencies of cacao in Nigeria.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 153–158 1972.
In Nigeria, N deficiency is the most widespread nutritional aspect of cacao. Positive responses to N fertilizing have been found with leaf N contents below 1·9% but visual deficiency symptoms occurred only at contents of less than 1·5%. No P deficiency symptoms have been observed as yet, but yields are increased by P fertilizing on many sites, particularly where leaf P contents of less than 0·2% and soil-available P (Bray and Kurtz) contents of less than 10 ppm have been recorded. Generally, soil contents of K, Ca, Mg and Zn are adequate. B contents of the soils vary from 0·02 to 0·40 ppm and B deficiency symptoms are becoming widespread in adult Amazon cacao plantations.

Cabala Rosand, F. P.; Miranda, E. R. De; Santena, C. J. L. De. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **[Interaction of shade and fertilizer in Bahian cocoa plantations] Interacción sombra fertilizantes en cacaotales de Bahia.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 181–189 1972.
In 30 to 40-year-old cacao plantations in Bahia, Brazil, 21 field trials have been carried out during a 7-year period on the effect of shade removal and fertilizing at a rate per ha of 105 kg N, 416 kg P_2O_5, 64 kg K_2O, 34 kg MgO and 45·7 kg CaO. Unshaded plots always gave higher yields than shaded plots. Fertilizing resulted in increased yields of dry cocoa, but in the shaded plots this increase was small and less than in the unshaded plots. The residual effect of fertilizing and the effects of shade removal and fertilizing on the incidence of black pod disease are discussed as well.

Capot, J. (Institut Français du Cafe et du Cacao (IFCC), Bingerville, Ivory Coast). **[Effect of fertilizers and spacing on the growth and yield of young cacao] Influence des apports fractionnés d'engrais et de la densité de plantation sur la croissance et la production des jeunes cacaoyers.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 190–198 1972.
In a field trial carried out in Upper Amazon cacao planted in 1964 on a sandy soil in the Ivory Coast, the effect was studied of annually NPK fertilizing in 2 or 6 equal split applications, combined with planting at a spacing of 2·5 × 30 cm, 2·5 × 2·5 m or 2·5 × 2·0 m. Over the first 4-year cropping period, fertilizing in 2 and 6 applications resulted in total yield increases of 10 and 26%, respectively, as compared with no fertilizing. Planting at a spacing of 2·5 × 3·0 m gave a total yield of 6,122 kg/ha of dry cocoa as compared with 5,365 and 5,194 kg/ha, respectively, for the 2 closer spacings. No interactions between fertilizing and spacing was observed.

Lainez, C. J. (Tropical Experiment Station, Instituto Nacional de Investigaciones Agropecuarias, Pilchilingue, Ecuador). **[Response of cacao to fertilizers on the alluvial soils of Rio Quevedo, Ecuador] Respuetas del cacao a la fertilización química, en las condiciones del suelo aluvial del Río Quevedo, Ecuador.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 204–209 1972.
In a 10-year field trial on the effect of NPK fertilizing in cacao, only N fertilizing resulted in a considerable yield increase. Leaf contents of P and K in unfertilized cacao were found adequate. The very high leaf content of Ca can be related to the occurrence of B deficiency in the soils of the region concerned.

Ashiru, G. A.; Jacob, V. J. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Potential pod production, pod loss, cherelle production and loss in cacao (Theobroma cacao L.).** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 247–256 1972.
A study has been made of the weekly rate of production of cherelles and the rate of wilt over a two year period. Conclusions are drawn on the relations between mature pods produced, cherelle wilt, leaf flushing and the climatic factors. Authors' summary.

Are, L. A.; Jacob, V. J. (Njala Univ. Coll., University of Sierra Leone, Fre-e town, Sierra Leone). **Vegetative propagation in Theobroma cacao L. seasonal influence on percentage bud take.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 257–260 1972.
In trials conducted in Nigeria over 4 years, time of patch budding on 8-month-old cacao rootstocks had a higher significant effect on final percentage budtake. More than 60% success was achieved in Aug.–Nov., coincident with a time of flushing of the parent trees providing the budwood. Budding is recommended for large-scale vegetative propagation instead of rooting stem cuttings, since it gives higher percentage success and is cheaper and easier to do.

Besse, J. (Institut Français du Cafe et du Cacao (IFCC), Bingerville, Ivory Coast): **[A comparison of two methods of establishment of cacao in Ivory Coast and the effect on yield, black pod loss and experimental precision] Comparaison de deux méthodes d'établissement de cacaoyers selectionnés en Côte d'Ivoire et leur influence sur la productivité, les pertes par pourriture brune et la précision des essais.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 261–274 1972.

Establishment of cacao plantations with the conventional system of planting under managed (thinned out) forest (I) was compared with establishment under about 1-year-old natural regrowth of felled forest (II). Drawbacks of system II are the high land preparation costs and the higher incidence of insect pests. However, the advantages of system II, which include much higher yields accruing from less shade and lower incidence of black pod disease, considerably outweigh the above-mentioned disadvantages. Further studies are being carried out regarding the economics of this promising new system.

Byrne, P. N. (Lowlands Agricultural Experiment Station, Keravat, New Britain, Papua New Guinea). **Cacao shade, spacing and fertilizing trials in Papua and New Guinea.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 275–286 1972.

From the results of trials conducted with Trinitario cacao, the optimum spacing for the local conditions would appear to be close to 3·90 m triangular. For practical reasons, shade is considered necessary for cacao establishment; however, trials have indicated that, provided other factors are not limiting, cacao having formed a complete canopy will respond positively to shade reduction. Under conditions of little or no shade, in general nitrogen fertilizing will be advantageous, and the same holds true for potassium fertilizing with respect to cacao grown on coralline soils.

Zevallos, A. C.; Alvim, P. De T. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **[Effects of drainage on cacao production] Efectos del drenaje sobre la producción del cacaotero.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 296–299 1972.

Yields of cacao areas with distinctly different groundwater tables were compared during a 5-year period. A moderately drained area, showing a water table of a little above 1 m for 13 months and a markedly lower one for the other months, had an average yield of 987 kg/ha of dry cocoa. The yield of a poorly drained area, having a water table near the surface for 41 months and below the 1 m mark for 19 months, averaged only 306 kg/ha.

Hutcheon, W. V. (Cocoa Research Inst., Tafo, Ghana). **The measurement of plant moisture status and the development of stress in cacao.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 312–319 1972.

Some methods to measure the internal moisture status of cacao are described and evaluated. The pressure chamber proved to be most useful in water relations studies; its construction and use are detailed. It was found that tensions of 15 atmosphere frequently developed on unshaded mature cacao during daytime irrespective of the soil moisture status. Daily minimum stress reflected soil water potential and maximum values were closely related to radiation intensity. Stress was highly dynamic. Dendrographs confirmed the existence of high daytime stress. The practical implications of the findings are discussed in relation to cacao agronomy, ecology and irrigation.

Fordham, R. (Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad and Tobago). **The water relations of cacao.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 320–325 1972.

The water relations of cacao are discussed in terms of the soil-plant-atmosphere system and previous work is reviewed. The need to record plant water status in all studies relating to the water requirements of the crop is emphasized, since, without such information results obtained can have only limited generalising value. Reference is made to the pressure chamber technique for determining plant water status, and preliminary data from cacao are presented to illustrate the versatility of the method. Suggestions for future research into factors influencing the water relations of the crop are briefly outlined. Author's summary.

Muller, R. A.; Njomou, S. E. (Institut Français du Cafe et du Cacao (IFCC), Nkoemvone, Cameroon). **[Chemical control of Phytophthora palmivora in the Cameroon] La lutte chémique contre Phytophthora palmivora au Cameroon.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 345–359 1972.

Annual crop losses in Cameroon due to black pod disease average some 50% of potential yield. Chemical control has to be practised, taking due account of local seasonal differences in the rainfall and pod infection pattern. In the East Cameroon region (I) with 2 rainy seasons, infection in the rainy season May–July is restricted to the pods attacked to the trunks up to a height of 2 m, whereas in the rainy season Sept.–Nov. all pods can become infected. In West Cameroun (II) with only 1 rainy season in May–Sept., all pods are equally susceptible. Chemical control in region I has proved to be effective and economic. Next to different copper fungicides, spraying of organotin formulations can be profitable. In region II, further studies are necessary to elaborate satisfactory chemical control methods.

Tarjot, M. (Institut Français du Cafe et du Cacao (IFCC), Bingerville, Ivory Coast). **[An ecological study of cacao with regard to the relation between susceptibility to Phytopthora palmivora and the water content of the pericarp of the pod] Étude écologique de la cacaoyère en relation avec la sensibilité envers le Phytophthora palmivora et la teneur en eau des tissus du péricarpe des cabosses.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 412–423 1972.
The effect of rainfall, temperature and relative air humidity on the susceptibility of cacao pods to infection by P. palmivora was studied. Rainfall had no direct effect on the pods but strongly promoted the liberation and spread of the zoospores of the fungus. Temperature also affected only the fungus in that a drop in temperature increased the liberation of the zoospores. A very high relative air humidity increases strongly the susceptibility of the pods to fungus infection and creates favourable ambient conditions for growth of the fungus.

Blaha, G. (Institut Français du Cafe et du Cacao (IFCC), Nkoemvone, Cameroon). **[Research on varieties resistant to Phytophthora palmivora: the reaction to experimental infection of pods] Recherche de cultivars résistants à Phytophthora palmivora. Étude comparative des réactions aux infections experimentales effectuées sur cabosses.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 435–455 1972.
In Cameroon, a number of locally selected and introduced clones of Trinitario 7acao as well as of Upper Amazon cacao have been tested under different ecological conditions regarding their susceptibility to artificial infection with P. palmivora.

Asare-Nyako, A. (Cocoa Research Inst., Tafo, Ghana). **A comparison of fungicides for the control of the black pod disease of cocoa caused by Phytophthora palmivora (Butl.) Butl. in Ghana.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 454–461 1972.
Kocide (cupric hydroxide) at 2·24 kg/ha and Perecol (copper oxychloride) at 3·36 kg/ha were the most effective of 6 chemicals tested in protecting cacao pods against secondary infection by P. palmivora. Compared with unsprayed plots, Kocide reduced infection from an average of 21·5% for the year to 6·3%.

Zentmyer, G. A. (University of California, Riverside, California, USA). **Resistance of cacao to Phytophthora palmivora.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 469–470 1972.
Stem inoculation tests have given significant data on resistance of various cacao clones to P. palmivora. Data will be presented on relative resistance of cacao clones, including Catongo and SCA 6 to several isolates of the fungus. Correlation has generally been good between glasshouse and field tests. Significant differences have been found with various isolates of the pathogen, for example, Catongo is more susceptible to a rubber isolate from Costa Rica than is YF 221. Author's summary.

Snyder, W. C.; Thomas, D. L.; Watson, A. G. (University of California, Berkeley, California, USA). **Fusarium – the unrecognized threat to world cacao production.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 487–489 1972.
Surveys have been made of the incidence of the Fusarium diseases of cacao which cause flower cushions to become unproductive by gall formation or flower proliferation. It is considered that they constitute a major threat to the crop. Authors' summary.

Legg, J. T.; Edwards, D. F.; Lockwood, G. (Cocoa Research Inst., Tafo, Ghana). **The swollen shoot problem in Ghana.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 490–492 1972.
In untreated areas of cocoa there is sequential development from small outbreaks of cocoa swollen shoot virus through larger outbreaks surrounded by scattered infection to extensive areas with a high incidence of disease. Each situation presents different problems for disease control. Outbreaks are treated by removal of visibly infected trees but control is complicated by latent infection. For the successful control of swollen shoot disease in Ghana, continuity of effort is required for many years in locating outbreaks and in frequent removal of visibly infected cocoa trees and their contacts. Replanting with resistant varieties in treated areas would slow down the rate of re-infection and so reduce the expenditure of control. Author's summary.

Espinoza, A.; Delgado, J.; Suárez, C. (Instituto Nacional de Investigaciones Agropecuarias, Pichilingue, Ecuador). **[Trials with systemic fungicides against "Mal de Machete" caused by Ceratocystis fimbriata in Ecuador] Pruebas con fungicidas sistémicos para combatir el "Mal de Machete" del cacao, causado por Ceratocystis fimbriata Ellis & Halsted, en el Ecuador.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 511–516 1972.
In laboratory studies, 8-month-old seedlings were infected artificially with C. fimbriata. The effect on the rate of survival of 10 seedlings was studied regarding treatment with 6 fungicides, i.e., Plantvax 75W (oxycarboxin), Vitavax 75W (carboxin), Benlate 50W (benomyl), Demosan 65W (chloroneb), Cercobin (thiophanate), and NF-35. Treatment with water solutions was carried out 2 times, either 40 and 20 days before infection or 4 and 24 days after infection, by spraying at 7·5 ml/plant or by watering into the soil at 15 ml/plant. Only watering into the soil of NF-35 (1,2 bis (3-ethoxycarbonyl-2-diureido) benzene 50%) proved to be very effective. This fungicide, applied at concentrations of 7·2, 5·4 and 3·6 g/l reduced the percentage of seedlings killed by the pathogen from 88·0 in the untreated control to 2·0, 2·7 and 13·2, respectively.

Lavabre, E. M. (Institut Français du Cafe et du Cacao (IFCC), Paris, France). **[Studies on the efficiency and reduction in cost of anti-mirid treatments on African plantations] Considérations sur l'efficacité et la réduction des couts des traitements antimirides dans les plantations africaines.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 521–531 1972.
Experiments conducted in the Cameroon and the Ivory Coast to reduce the high costs of spraying cacao against attack by mirids, mainly Sahlbergella singularis, are discussed. In the Ivory Coast, very promising results have been obtained with ultra-low volume (U.L.V.) spraying, using rates as low as 3 l/ha. The standard treatment is still with lindane, but endosulfan, Thiodan and Nuvacron (monocrotophos) have shown to be very effective insecticides as well (90–100% mortality in mirids exposed to the insecticide). In the Cameroon mist blowing has been practised already for many years with satisfactory results. Techniques are explained for minimizing the sanitary hazards involved in the adoption of U.L.V. spraying, and for improving its efficacy.

Owusu-Manu, E. (Cocoa Research Inst., Tafo, Ghana). **Biology and control of Bathycoelia thalassina (H.S.) (Pentatomidae Hemiptera), a pest of cocoa in Ghana.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 539–547 1972.
In Ghana, attack of cacao plantations by B. thalassina causes immature ripening of pods, and consequently, an estimated loss of cocoa production of at least 20%. Particulars regarding the biology of this pest are given. A number of insecticides are tested regarding their efficacy for chemical control. Prospects for biological control are discussed. At present, the incidence of parasitism and predation on this pest is low, possibly resulting from the intensive chemical control practised against the mirids attacking cacao.

Winder, J. A.; Silva, P. (Plano de Recuperaçao Economics-Rural da Lavoura Cacaueira (CEPLAC), Itabuna, Bahia, Brazil). **Current research on insect pollination of cocoa in Bahia.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 553–565 1972.
Various aspects of the bioecology of the cacao pollinating midges Forcipomyia spp. are investigated, including bredding sites, population dynamics, and the effect of insecticides, fungicides and climate on Ceratopogonid field populations. Empty, rotting cacao pod husks and leaf litter have been shown to provide breeding sites. BHC 1% did not appear to have any effect on Ceratopogonid leaf-litter populations; they seem to be influenced by the amount of soil water present, the population increasing when the soil is water-saturated. Cicadellidae, various Coccidae, and Toxoptera aurantii constitute the majority of insects permanently associated with cacao flowers in Bahia, but there is no evidence that they are active in pollination of cacao.

Mire, B. De; Mbondji Mbondji, P. (Institut Français du Cafe et du Cacao (IFCC), Nkoemvone, Cameroon). **[Insect pollinators of cacao in cross fertilization in the Cameroon] Insectes pollinisateurs du cacaoyer en fécondation croisée au Cameroon.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 566–569 1972.
A flower-loving insect species, Drosophila (Scaptodrosophila) triangulifer seems to have alone been responsible for more than 43% of identified fertilizations, followed by Crematogaster and Ceratopogonids, mainly of the Stilobezzia genus.

Leston, D. (Department of Zoology, University of Ghana, Legon, Ghana). **The ant mosaic: a fundamental property of cocoa farms.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 570–581 1972.
The nature of the pest population at any point in a cacao farm is largely determined by the identity of the dominant ant in the ant mosaic present in the plantation. Optimally, cacao in Ghana can be 65% protected from swollen shoot virus diseases and capsids by the beneficial ant mosaic components Oecophylla longinoda and Macromischoides aculeatus.

Quesnel, V. C. (Cocoa Research Unit, University of the West Indies, St. Augustine, Trinidad and Tobago). **Cacao curing in retrospect and prospect.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 602–606 1972.
Progress in cacao curing is reviewed from 1937 to the present day. The concept of internal fermentation as an oxidative process dependent on heat has given way to one that emphasizes the importance of hydrolytic reactions taking place under anaerobic conditions. The production of acetic acid is the key reaction in the pulp since acetic acid kills the seed, lowers the pH of the cotyledon to the range favourable for hydrolytic reactions, and maintains the pH of the pulp in a range too low for the proliferation of putrefactive bacteria. Furthermore its production and destruction liberate the heat necessary to bring the bean to the optimum temperature. Prospects for the future both at the research level and the technological level are outlined. Author's summary.

Maravalhas, N. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **Cacao processing in Bahia.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 607–611 1972.
Cocoa processing methods in Bahia are described. The results of experiments comparing different types of fermentors are summarized and preliminary results of studies related to the formation of chocolate flavour precursors during fermentation are given. The presence of acetaldehyde and ethyl acetate, and the role of amino acids and of the anaerobic phase in the fermentation process are emphasized.

Vivas, J. A.; Reyes, E. H. (Estacion Experimental, Caucagua, Venezuela). **[Studies in the use of Rohan trays in Venezuela] Estudios concernientes al uso del fermentador Rohan en Venezuela.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 612–619 1972.
Information is given regarding the appropriate use of the fermenting trays, fermentation time according to the type of cacao grown, and the necessity of regularly turning of the beans during fermentation.

Ghosh, B. N. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **Engineering aspects of cocoa drying in Brazil.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 620–629 1972.
Sun drying of cocoa is still traditional in Brazil, however, the availability of facilities for artificial drying is desirable due to the prevailing climate conditions. To further the establishment of artificial drying apparatus, a study has been initiated regarding the physical properties of the cocoa beans which have to be taken into account from the engineering standpoint. Other lines of investigation include, among other things, the use of (1) plastic covers for sun drying, (2) glass-covered drying platforms combined with artificial drying, (3) propane-butane gas heating, (4) freeze drying and (5) tunnel drying.

Adomako, D. (Cocoa Research Inst., Tafo, Ghana). **Studies on cocoa pod husk pectin.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 647–650 1972.
In Amazon ripe and immature cacao pods, dry pectin prepared by mild acid extraction forms 8–11 and 25–29%, respectively, of the dry husk. The carbohydrate composition of cacao pectin is similar to that of apple pectin. Further studies on the physico-chemical and jelly-forming characteristics are needed for the evaluation of cacao pod husks as a commerical source of pectin.

Vasconcelos, A.; Alencar, M. H.; Ferreira, H. I. S. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **[A new rehabilitation programme for cacao in Bahia] Novo programa de renovação de cacauais na Bahia.** In: IV International Cocoa Research Conference, St. Augustine, Trinidad, 8–18 January, 1972 Government of Trinidad and Tobago St. Augustine (Trinidad and Tobago) p. 677–686 1972.
Under a 10-year (1972–1982) programme, 150,000 ha of old cacao plantations, mainly owned by smallholders, will be replanted with high-yielding hybrids. Two-fifths of these new plantations will be established by total felling of the old cacao, and the balance by interplanting, using the old cacao trees as temporary shade which will be gradually removed. Along with the expansion of cacao growing in new areas and the application of improved cultivation techniques, the programme is expected to increase cocoa production from the pre-1970 annual level of about 160,000 tons to a volume of at least 320,000 tons by 1989/90.

Alvim, P. De T.; Machado, A. D.; Vello, F. (Divisao de Fitologia, Centro de Pesquisas do Cacau (CEPEC), Ilheus, Bahia, Brazil). **Physiological responses of cacao to environmental factors.** Revista Theobroma (Brazil) v. 4(4) p. 3–25; October 1974.
Effects of environmental factors on leaf water potential, growth rhythms, flowering, fruit setting, fruit development and seasonal changes in fruit load are discussed in the light of recent research in Brazil and elsewhere. Some plant factors, such as age and internal competition between fruits and flowers interact with environmental factors. Flushing and leaf abscission were found to be correlated with each other. Among environmental factors acting on flushing, moisture stress appeared to be the most critical one, both for bud break (flushing initiation) and leaf abscission. No support has been found for earlier theories according to which flushing would be controlled by changes in air temperature. Flowering seems to be controlled internally by competition with fruits (fruit load) and externally by a succession of dry-wet periods. Flowering is inhibited by extended dry periods as well as by excessive soil moisture.

Sharma, R. D.; Sher, S. A. (Divisao de Fitoparasitologia, Centro de Pesquisas do Cacau (CEPEC), Ilheus, Bahia, Brazil). **[Nematodes of the cocoa region of Espirito Santo, Brazil. Nematodes associated with cocoa (Theobroma cacao L.) Nematódios da região cacaueira do Espírito Santo, Brasil. I. Nematódios associados ao cacaueiro (Theobroma cacao L.).** Revista Theobroma (Brazil) v. 4(4) p. 26–31; October 1974.
Mixed populations of 20 genera and 26 species of plant parasitic nematodes were found; twelve species were associated with cocoa trees that had symptoms of die-back and sudden death.

(Institut Français du Cafe et du Cacao (IFCC), Paris, France). **[Annual Report 1975] Rapport d'Activité 1975.** Rapport d'Activité – Institut Français du Café et du Cacao (France) IFCC Paris (France) 114 p. 1976.
This report contains firstly information on chemical and technological research conducted in France regarding processing of cocoa and coffee. Furthermore, results are given of research carried out mainly with respect to selection and breeding in (1) the Ivory Coast, on Robusta and Arabusta coffee, cacao and kola, (2) Togo, on Robusta and Arabica coffee, cacao and tea, (3) the Cameroon Rep., on Robusta, Arabica and Arabusta coffee, cacao, and tea, (4) Madagascar, on Robusta and Arabusta coffee, and tea, and (5) New Caledonia, on Robusta and Arabusta coffee.

Soria, S. De J.; Wirth, W. W. (Divisao de Fitoparasitologia, Centro de Pesquisas do Cacau (CEPEC), Ilheus, Bahia, Brazil). **[Life cycles of the cacao pollinator midges, Forcipomyia spp. (Diptera: Ceratopogonidae) and some notes on larval behaviour in the laboratory] Ciclos da vida dos polinizadores do cacaueiro Forcipomyia spp. (Diptera: Ceratopogonidae) e algumas anotações sobre comportamento das larvas no laboratório.** Revista Theobroma (Brazil) v. 5(4) p. 3–22; October 1975.

(Cocoa Research Inst., Tafo, Ghana). **Annual report 1972/73.** Annual Report – Cocoa Research Institute (Ghana) Cocoa Research Inst. Tafo (Ghana) 184 p. 1975.
Reports on research conducted in 1972/73 refer mainly to the following subjects: (1) agronomy; (2) plant pathology – cacao swollen shoot disease (resistance and tolerance), black pod disease (epidemiology and chemical control), mealy pod disease (Trachysphaera fructigena); (3) entomology – capsids, mealy bugs, pollinating insects, miscellaneous insects; (4) plant breeding and selection – breeding trials, black pod resistance trials, pollination studies, cytogenetics; (5) physiology and biochemistry – cocoa products and by-products, virus studies, water relations of cacao; and (6) soil science – soil fertility, shade and cacao nutrition field experiments.

November 1976

Soria, S. De J.; Bystrak, P. G. (Divisao de Fitoparasitologia, Centro de Pesquisas do Cacau (CEPEC), Ilheus, Bahia, Brazil). **A new species of Forcipomyia (Diptera, Ceratopogonidae) described in all stages, with an account of its role as a cacao pollinator.** Revista Theobroma (Brazil) v. 5(2) p. 3–11; April 1975.
A new species of Forcipomyia named F. (Euforcipomyia) blantoni, is described. F. blantoni together with F. (Euforcipomyia) spatulifera are considered to be the main pollinators of cacao in Brazil.

Jacob, V. J.; Atanda, O. A. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Compatibility and fruit setting in Theobroma cacao L.** Revista Theobroma (Brazil) v. 5(2) p. 12–18; April 1975.
The fruit setting and compatibility status of 23 WACRI "C" cacao clones has been assessed, both with respect to use as male and female parent. The locally selected clone C 22 proved to be the best male parent with 55·7% fruit setting and 25·7% pod production, whereas the Amazon cacao selection C 57 was found to be the best female parent with 58·2% fruit setting and 18·2% pod production.

Blaha, G.; Lotodé, R. [A selection criterion of main importance for the cocoa tree in the Cameroon: the resistance to the black pod disease (Phytophthora palmivora)] Un critère primordial de sélection du cacaoyer au Cameroun: la résistance à la pourriture brune des cabosses (Phytophthora palmivora). Café, Cacao, Thé (France) v. 20(2) p. 97–116; April 1976.
The method adopted to screen for disease resistance simulated as much as possible natural conditions. The tests were carried out on living pods still on the tree, during the main rainy season, on trees receiving neither fertilizers nor pesticides. The infection was carried out at a point in the cortex using a suspension of zoospores of local aggressive strains. It was noted that the epidermal resistance to penetration of the fungus and resistance to its progression inside the cortex were sometimes inversely related (susceptibility tests must therefore take into account the 2 phenomena), and that certain clones definitely stimulated the formation of fructification organs of the fungus. The resistance to penetration of the fungus was lowered when the fruit was picked.

Babacauh, K. D.; Partiot, M. (Laboratoire de Phytopathologie, Ecole Nationale Superieure Agronomique, Abidjan, Ivory Coast). **[Phytophthora sp., a parasite of the cocoa tree in the Ivory Coast. First study of its morphological, physiological and pathogenic variability] Le Phytopthora sp., parasite du cacaoyer en Côte d'Ivoire. Première étude de sa variabilité morphologique, physiologique et pathogénique.** Café, Cacao, Thé (France) v. 20(2) p. 117–128; April 1976.
The results reported in this article show that the populations of Phytophthora sp. are heterogeneous. It is therefore concluded that a simultaneous study of host and parasite is indispensable in resistance-breeding.

Subramanian, T. R.; Abraham, E. V. (Department of Entomology, Tamil Nadu Agricultural Univ., Coimbatore, Tamil Nadu, India). **Pests damaging cocoa (Theobroma cacao L.).** Journal of Plantation Crops (India) v. 1(suppl.) p. 160 1973.
The important pests damaging cocoa are mealy bugs, scales, mirids (capsids) and stem borers. The mode of attack, damage caused, symptoms of attack, control and the distribution of these pests are described in detail. The distribution mode and nature of attack and damage caused by other pests like leaf thrips (Scelenothrips rubrocinctus Giard), aphids (Toxoptera aurantii) and the lace wing bug (Eocader vegandis) are also discussed. Brief description of the non-insect pests and a few storage pests are also given. Authors' summary.

December 1976

Atanda, O. A.; Jacob, V. J. (Cocoa Research Inst. of Nigeria (CRIN), Ibadan, Nigeria). **Yield characteristics of Theobroma cacao L. with special reference to studies in Nigeria.** Revista Theobroma (Brazil) v. 5(3) p. 21–36; July 1975.
A review is given of data obtained regarding various characteristics of cured cocoa production, including pattern of pod production, effects of genotype and environment on pod production, prediction of potential pod yield, selection for high pod yield, pod value, bean weight, number of beans per pod, shell content, wet to dry bean conversion rate, efficiency index, butter fat content, and flavour. Differences between the yield characteristics of West African Amelonado, Trinitario, Criollo and Amazon cacao types are emphasised.

Soria, S. De J. (Divisao de Fitoparasitologia, Centro de Pesquisas do Cacau (CEPEC), Ilheus, Bahia, Brazil). **[The role of stingless bees (Meliponinae) in the pollination of Theobroma cacao L. in tropical America] O papel das abelhas sem ferrão (Meliponinae) na polinizacão do cacaueiro na América tropical (Monografia).** Revista Theobroma (Brazil) v. 5(1) p. 12–20; January 1975.
A literature study on the role of bees in cacao flower pollination in Tropical America reveals that their role is accidental and inadequate. A general agreement exists among authors in considering Forcipomyia spp. midges as the main pollinators of T. cacao in Tropical America.

Morias, F. I.; Prado, E. P. Do; Cabala, R. F. P.; Santana, M. B. M. (Divisao de Solos, Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **[Effect of the ratio Ca/Mg of limestone on the growth of cocoa seedlings] Efeito da mistura de carbonatos de cálcio s magnésio no desenvol vimento de plantulas de cacau.** Revista Theobroma (Brazil) v. 5(1) p. 21–30; January 1975.
A fertilizer experiment under greenhouse conditions conducted in Brazil to determine the best calcium/magnesium ratio of limestone for the growth of young cacao trees showed there was a tendency for an increase in growth when the Ca/Mg ratio was increased from 0·1 to 2·0.

Bertrand, G. M. [Marketing of agricultural products in Togo; coffee and cacao] La commercialisation de produits agricoles au Togo; le café et le cacao. Options Méditerranéennes (France) v. 6(34) p. 88–93 1976.
A brief sketch of the importance of coffee and cacao for Togo's economy is followed by an analysis of the local marketing system and the share of producers and marketing agencies in the export price received. It is concluded that the main beneficiary of increased world prices has been the Office for Agricultural Products in Togo (OPAT), a government monopolistic marketing agency. The net profit of the afrmers has remained stable. Without more information on how OPAT has used its increased net income it is impossible to say whether this office has exploited the farmers or has been a valuable instrument in the economic development of the nation as a whole.

Byrne, P. N. Vascular-streak dieback of cocoa in Papua New Guinea and Peninsular Malaysia. Planter (Malaysia) v. 52(599) p. 49–53; February 1976.
The causative fungus (Oncobasidium theobromae) and the symptoms associated with vascular-streak dieback disease of cacao are described. In the early sixties this disease has become epidemic in several cacao growing areas of Papua New Guinea, causing estimated overall losses of 25–40%. Pruning out of infected branches is practicable for delaying build-up of the disease in newly infected areas. Selection of resistant (less susceptible) planting material is the most promising control measure to date. The importance of the disease in Peninsular Malaysia and the need to introduce control measures is stressed. Future cacao development should be based preferably on vegetative propagation of resistant planting material by means of budding.

Zak, D. L.; Keeney, P. G. (Department of Food Science, Pennsylvania State Univ., University Park, Pennsylvania, USA). **Changes in cocoa proteins during ripening of fruit, fermentation, and further processing of cocoa beans.** Journal of Agricultural and Food Chemistry (USA) v. 24(3) p. 483–486; May 1976.
During ripening of cocoa fruit the protein content of seeds decreased 25%, but consistent qualitative trends were not apparent. Most of the protein of unfermented beans could be solubilized and recovered. However, at the conclusion of fermentation only about one-third of the protein could be extracted from beans. The extractable protein fractions become progressively less pure during fermentation and at the end were only 40% protein. Fewer, more diffuse protein bands were evident on disc gels as fermentation advanced. Most of these changes are believed to involve protein interaction with polyphenols. Somewhat similar trends were noted during roasting and conching. Authors' summary.

Vernon, A. J. (Research Div., Department of Agriculture, Suva, Fiji). **Hybrid cocoa: progress report on trials, seed gardens and extension.** Fiji Agricultural Journal (Fiji) v. 37(1) p. 37–38; January 1975.
The 7 hybrids (A–G) discussed are crosses between Amelonado (Am) and 7 self-sterile, more or less canker-resistant clones, described in earlier publications. Hybrid A (Am × ICS 39) proved to be an early bearer, particularly under unfavourable conditions, and was capable of early recovery after hurricane damage. Hybrid C (Am × Sca 12) is now giving phenomenal yields (up to 3,180 kg dry cocoa/ha). The other hybrids (derived from ICS 60, ICS 89, Sca 6, GS 29 and ICS 40) are of little interest.

Sharma, R. D.; Maia, M. A. Z. (Centro de Pesquisas do Cacau (CEPEC), Itabuna, Bahia, Brazil). **Pathogenicity of the root-knot nematode, Meloidogyne incognita, to cocoa.** Nematropica (USA) v. 5(2) p. 28; October 1975.
Pathogencity studies showed that the root-knot nematode was pathogenic to cacao cv. "Catongo" and caused growth reduction, small internodes, thin stems, reduced number of leaves with reduced surface area, and reduced root systems with galls and fewer root hairs. Growth differences were evident 17 weeks after inoculation. Histological studies showed total disorganization of the stele, resulting in serious destruction of the xylem, phloem, pericycle and endodermis, making it difficult to identify these tissues.

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