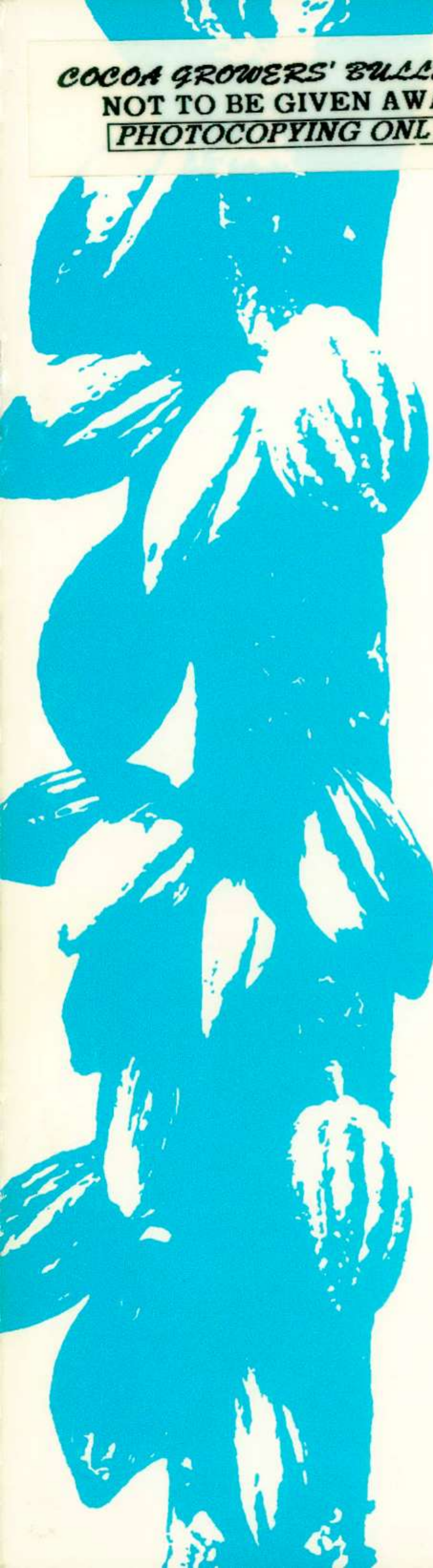

COCOA GROWERS' BULLETIN

Number 51 **June 1998**

Contents

Cadbury Limited
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EDITORIAL

It is clear that there are many aspects of our global life style which must become more "sustainable", though definitions of sustainability are many and varied. In terms of agricultural production, we favour a now widely used definition, as follows : *"Development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (Bruntland 1985, Mandate for Change : Key Issues, Strategies and Workplan)*. Regardless of the definition, sustainability is a critical concept for our survival as a dominant species on earth.

Perhaps as much as 85% of global cocoa production is cultivated by smallholders with modest plots of the crop planted as part of a mixed farming system. Although the yield per hectare is generally low (and sometimes very low - approaching a hunter-gathering economy), there are some environmental benefits to the system, namely:

- Cocoa is most often grown under shade - resembling the full canopy of a rain forest;
- Cocoa produces considerable leaf litter;
- Cocoa gives good soil cover;
- Species diversity is maintained in such a cocoa farm;
- Food crops can often be also grown as a nurse crop as well as within and around cocoa plots;
- Dried cocoa beans are easily transportable, thus minimising losses of produce in transit to market and giving freedom to locate cocoa farms in areas with poorer infrastructure.

However, low yields under traditional systems of cocoa cultivation should not be allowed to continue indefinitely because very real inefficiencies exist - for example, an excessive area of land is utilised. As pressures on soils of good structure and fertility become daily more severe in all cocoa growing areas, higher yields per unit area are required. Improved methods of sustainable cocoa cultivation must therefore be devised with improved productivity per unit area of land. Research and investigations will be required to achieve this. For any agricultural system to be sustained, it requires renewable and non-renewable resources to be in balance with the ability to supply these resources and the outputs to be expected. In the longer-term, this means the minimal practicable use of non-renewable resources. A start has been made at an International Workshop held recently in Panama. The text of conclusions of this gathering of industry, researchers and growers representatives is available on the Smithsonian Institute Website (WWW.SI.EDU).

In this issue, there is one article of relevance to methods of more sustainable cocoa cultivation (Ayanlaja, 1998) and it is hoped to publish many more in the future on similar themes. Further research is needed to establish the role of cocoa in systems of sustainable agriculture under various cocoa growing environments.

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

Cocoa Growers' Bulletin is published by Cadbury Schweppes plc as an information service to cocoa growers, plantation staff, extension officers and research workers. It is distributed free with one copy being sent to each name on the current mailing list. Any correspondence including requests for names to be added to the mailing list should be sent to R.A.Lass, Editor, Cocoa Growers' Bulletin, Technical Development Department (VS2), Cadbury Limited, P.O.Box 12, Bournville Lane, Bournville, Birmingham, B30 2LU, England.

REVIEW OF PRODUCTION, CONSUMPTION, STOCKS AND PRICES

Steve A. Wakeling

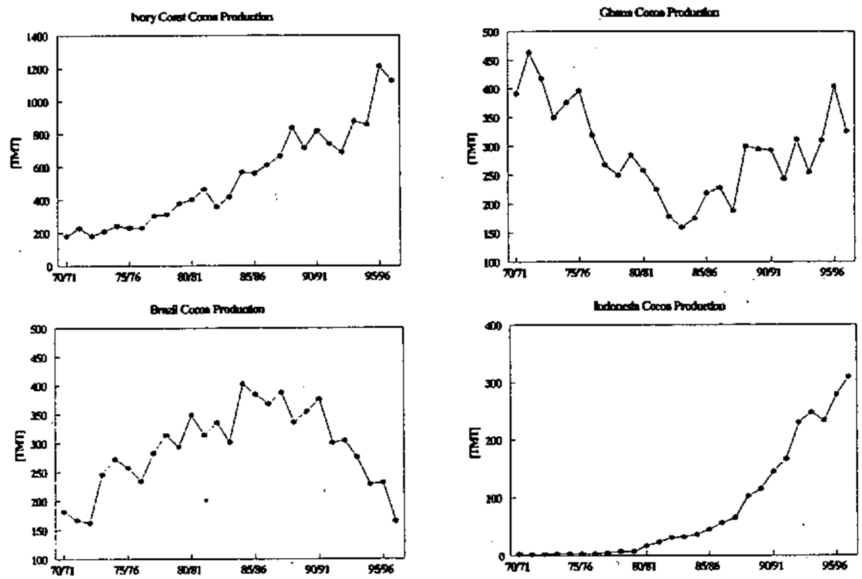
(October 1996 - January 1998)

PRODUCTION

E D & F Man Limited Cocoa Market Report No.360 reported that World production in 1996/97 would be 2,676 TMT ('000 tonnes), which would be 7.5% down on the record high of 2,892 TMT in 1995/96. The main losses were from the Ivory Coast, Ghana and Brazil which fell by 88 TMT, 78 TMT and 67 TMT respectively. The only country to show a substantial increase over 1995/96 was Indonesia which increased by 31 TMT.

E D & F Man Limited Cocoa Market Report No.360 has forecast that 1997/98 cocoa production will rise by 2.7% over 1996/97 to 2,749 TMT. The countries showing substantial increases over 1996/97 were the Ivory Coast, Ghana and Indonesia who were forecast to increase by 49 TMT, 74 TMT and 20 TMT respectively. The country forecast to show the biggest fall was Ecuador where heavy rains, induced by El Nino, had adversely affected the crop. It was forecast to fall from 101 TMT to 50 TMT.

WORLD COCOA SUPPLY AND DEMAND



Source: **E D & F Man Limited, Cocoa Market Report No.360.**

WORLD COCOA PRODUCTION DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.360
(January 1998)

	1993/ 1994 **	1994/ 1995 **	1995/ 1996 **	1996/ 1997	1997/ 1998 (i)
Cameroon	97 [2]	109 [2]	117 [-3]	120	120
Ivory Coast	879 [34]	859 [-17]	1,214 [89]	1,126	1,175
Ghana	255	310 [1]	404 [14]	326	400
Nigeria	140	140	155 [5]	162	155
Others	30	26	30 [4]	37	32
Total Africa	**1,401** [36]	**1,444** [-14]	**1,920** [109]	**1,771**	**1,882**
Brazil	276	229	232 [13]	165	168
Colombia	49 [-2]	48 [-4]	45 [-6]	45	45
Ecuador	79 [1]	83 [2]	103 [10]	101	50
Mexico	39	43	36 [1]	43	43
Peru	11	13 [1]	15 [3]	13	13
Venezuela	18	16	16	14	15
Others	12	12	13 [-1]	14	13
Total C. & S. America	**484** [-1]	**444** [-1]	**460** [20]	**395**	**347**
Dominican Rep.	58	55	55	47	52
Others	10	12	10	11	11
Total West Indies	**68**	**67**	**65**	**58**	**63**
Indonesia	248	234	279 [-11]	310	330
Malaysia	204	120	116 [11]	98	85
Papua New Guinea	31	29	35 [1]	26	25
Others	19	15	17	18	17
Total Asia & Oceania	**502**	**398**	**447** [1]	**452**	**457**
WORLD TOTAL	**2,455** [35]	**2,353** [-15]	**2,892** [132]	**2,676**	**2,749**
% change in production from previous season	4.5 [5.3]	-4.2 [-2.0]	22.9 [6.3]	-7.5	2.7

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

WORLD COCOA CONSUMPTION DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.360 (January 1998)

	1993/ 1994 **	1994/ 1995 **	1995/ 1996 **	1996/ 1997	1997/ 1998 (i)
France	95	108	111 *-1*	106	110
Germany (Fed. Rep)	319	290 *-17*	277 *-23*	266	270
Italy	65	69 *-1*	73 *3*	71	72
Netherlands	331	350	385 *8*	402	410
United Kingdom	170	154	191 *8*	173	175
Others	154	149 *2*	158 *8*	168	171
Total Western Europe	**1,134**	**1,120** *-16*	**1,195** *3*	**1,186**	**1,208**
FSU/USSR	90	80	80 *-5*	85	85
Other Eastern Europe	68 *-7*	67 *-9*	72 *-8*	74	75
Total Eastern Europe	**158** *-7*	**147** *-9*	**152** *-13*	**159**	**160**
Ivory Coast	110	108	135 *15*	150	180
Others	76 *5*	98 *-6*	117 *1*	131	145
Total Africa	**186** *5*	**206** *-6*	**252** *16*	**281**	**325**
Brazil	220 *-4*	189 *-5*	192 *-13*	180	180
United States	317	331 *-1*	345 *-8*	394	408
Others	178 *4*	189 *-10*	198 *-3*	202	196
Total America	**715**	**709** *-16*	**735** *-24*	**776**	**784**
Malaysia	103	101 *1*	96 *-4*	98	94
Others	192 *1*	221 *-2*	247 *-3*	267	270
Total Asia & Oceania	**295** *1*	**322** *-1*	**343** *-7*	**365**	**364**
WORLD TOTAL	**2,487** *-2*	**2,503** *-41*	**2,677** *-20*	**2,766**	**2,842**
% change in grindings from previous season	1.9	0.6 *-1.6*	7.0 *1.0*	3.3	2.7

(i) Forecast.

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

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

CONSUMPTION

E D & F Man Limited Cocoa Market Report No.360 anticipated that World cocoa consumption (as measured by World grind) would rise to 2,766 TMT, an increase of 3.3% on 1995/96. The major increases were from Africa, USA and Indonesia.

E D & F Man Limited Cocoa Market Report No.360 forecast that the 1997/98 World grind will grow by 2.7%. The main area of increase is forecast to be Africa, particularly the Ivory Coast.

STOCKS

E D & F Man Limited Cocoa Market Report No.360 indicated that for the 1996/97 season there would be a deficit of 117 TMT, the 5th deficit in 6 years, though end season stocks were expected to remain above one million tonnes. It also forecast that there will be a deficit in 1997/98 of 120 TMT. Yet again they believe that end season stocks will remain above one million tonnes.

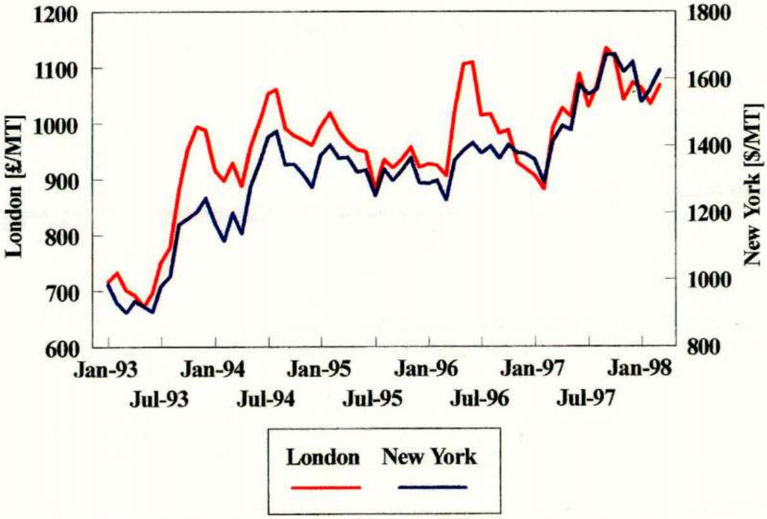
WORLD COCOA STOCK DATA

Reproduced from E D & F Man Limited Cocoa Market Report No.360 (January 1998)

	1993/ 1994 **	1994/ 1995 **	1995/ 1996 **	1996/ 1997	1997/ 1998 (i)
Stock change	-56 *37*	-174 *26*	186 *151*	-117	-120
Closing stocks **(including buffer stock)**	1,252 *-8*	1,078 *17*	1,264 *168*	1,147	1,027
Stock/consumption ratio **(including buffer stock)**	0.50 *-0.01*	0.43 *0.01*	0.47 *0.06*	0.41	0.36

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

NEW YORK AND LONDON TERMINAL MARKETS - 2nd POSITION



Source: Cadbury Limited, Bournville, Birmingham, UK.

COCOA IN PERU

Harry C. Evans *, Ulrike Krauss **, Rolando Rios Rutz *, Tomislav Zecevich Acosta **** and Enrique Arevalo-Gardini *****

HISTORICAL

The literature on the pre-Colombian cultivation of cocoa in Peru is sparse and, what little there is, remains contradictory. Johnson (1912) in his book on cocoa, its cultivation and preparation grandly declared that: "It was cultivated and highly appreciated as a beverage in Mexico and Peru long before Colombus discovered the New World ...". Knapp (1920) similarly stated that: "Another people that share with the Aztecs the honour of being the first great cultivators of cacao are the Incas of Peru ...". However, Towle (1961) refuted any suggestion that the Incas cultivated cocoa, since he could find no reference to the crop in the early accounts of the useful plants of Peru, and, perhaps even more damning, no remains of cocoa (*Theobroma cacao*) have been recovered from Peruvian archaeological sites. This was endorsed by Willey (1971), who considered that cocoa was not included in the agro-ecosystem that existed in pre-Colombian Peru. Much earlier, Wiener (1880) suggested that cocoa fruits had been depicted on prehistoric pottery but this has not been validated. A search of past and current literature relating to the archaeology and history of Peru failed to find any evidence that cocoa was cultivated pre-conquest, despite references to the Pizarro expedition of 1526 in which, "Broad patches of cultivated land intervened disclosing hillsides covered with the yellow maize and the potato, or checkered in the lower levels with blooming plantations of cacao", and, "burning regions of the palm and the cocoa-tree that fringe the borders of the ocean", are described (Prescott, 1847). However, Vega (1609) in a comprehensive review of agricultural crops in Peru (pre- and post-Inca) makes no mention of cocoa, whilst going into considerable detail on the cultivation of coca (*Erythroxylum coca*). In his discussion of the plants of "Antis" (literally the jungle beyond the Andes), he describes a small, melon-sized fruit called manjar blanco (= blancmange) which had inedible, almond-like seeds and a hard inner rind like a dry calabash, with much esteemed pulp, "... sweet with a slight bitter tang which makes it delicious". Could this be cocoa or another *Theobroma* species, such as *T.bicolor* (known locally as "majambo" in eastern Peru and as "cacau do Peru" in Brazil) which best fits this description, and that the translators of the chronicles of the Conquistadores confused coca, cacao and cocoa? The almond-like form of the cocoa beans, which are still referred to as almendras in Latin America, was the description used by the early Spanish chroniclers for the product in Mexico (Schultes, 1984). The latter author went on to conclude that the Amazonian Indians knew nothing about its economic potential, presumably as a tradable commodity, but only valued it for the sweet pulp. This 'hunter-gatherer' rather than agricultural approach can still be seen today in western Amazonia where *Theobroma* and *Herrania* species are invariably left when primary forest is felled. Thus, there is a clear distinction between the botanical birthplace of cocoa (the Amazonian region or "Oriente" of Peru, Ecuador and Colombia), and its region of domestication in

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Mesoamerica (Cuatrecasas, 1964). Schultes (1984), therefore, posed the question, "But if the Amazonian Indians were unaware of the great value of the seeds for chocolate, how did the plant begin to spread from the western Amazon to such distant areas ..., what sparked such an odyssey, ... or did some tribe discover and utilise the caffeine-rich seed - a use of which, for lack of written records in this forested area, we are still unaware?" He then maps out the possible cultivation and trade routes, one of which was via the western slopes of the Ecuadorian Andes, possibly substantiating the coastal cocoa sightings of Pizarro's expedition. Stone (1984) also categorically stated that cocoa was never cultivated in its native habitat before the arrival of the Spaniards, although it was concluded that the acid-sweet pulp was either used to refresh or to make a fermented product, and that the beans were always discarded. It was further speculated that merchants trading along the Pacific coast carried the pods for refreshment, since they are convenient to transport and pulp quality is maintained for considerable periods because of the thick pod husk. Between 600-200 BC, Mayan traders travelled regularly to South America (Willey, 1971).

There is no doubt that north-eastern Peru is a centre of origin or diversity of the genus *Theobroma*, and this region is considered to be one of the main gene centres (Krug and Quartey-Papafio, 1964). Cuatrecasas (1964) listed seven species from the region, with *T.cacao* subsp. *leiocarpum* said to occur spontaneously in the rainforests of Amazonian Peru. Earlier, Pittier (1925) described two forms of cultivated cocoa in Peru, both with small fruits, the commonest type ("cacao chuncho") having spherical, rugose pods although MacBride (1956) concluded that all the specimens found in the wild in Peru probably belong to subsp. *leiocarpum*, "characterised by ovoid, obtuse, smooth pods".

TABLE 1 : COCOA PRODUCTION IN PERU BY DEPARTMENT - 1995

Department	No. of Farms	Area (ha)
Tumbes	47	31 (0.1)
Amazonas	2,282	3,121 (6.5)
Cajamarca	1,257	1,409 (2.9)
Huanuco	3,331	5,588 (11.6)
Pasco	515	923 (1.9)
Junin	4,246	9,745 (20.2)
Loreto	135	236 (0.5)
San Martin	3,225	3,390 (7.0)
Ayacucho	6,010	11,125 (23.0)
Cusco	6,761	11,900 (24.6)
Ucayali	499	611 (1.3)
Madre de Dios	133	216 (0.4)
Total	**28,441**	**48,295**

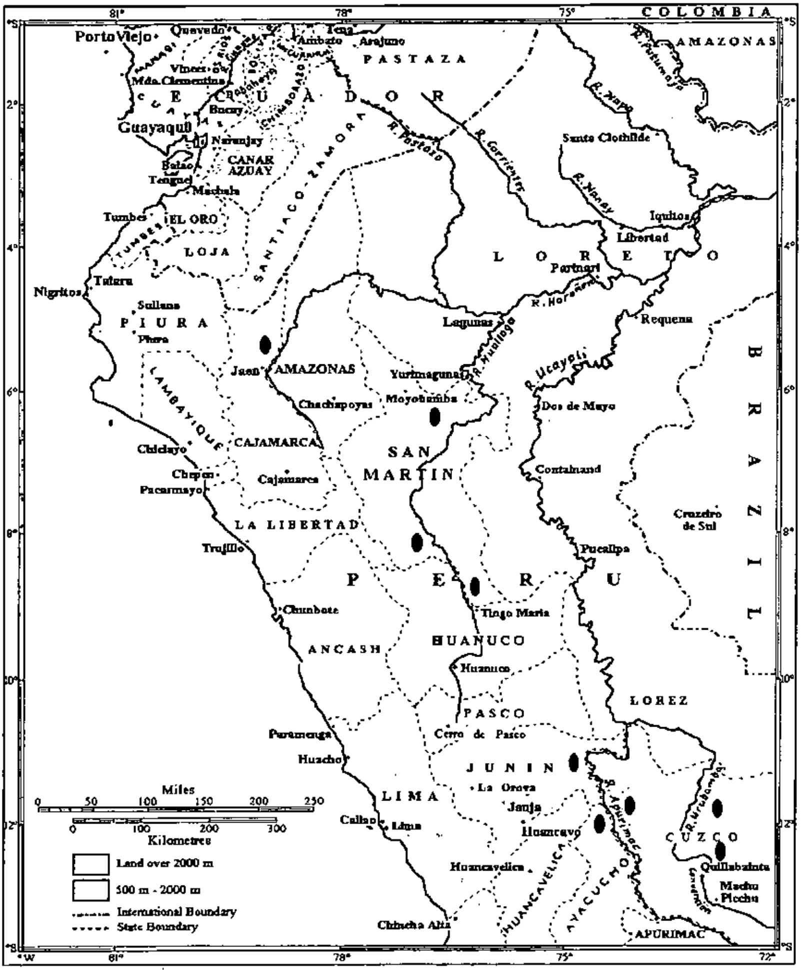
(% in parentheses)

Source : Third National Agricultural Census, 1995.

DISTRIBUTION, CLIMATE AND SOILS

Cocoa is commonly grown in the tropical valleys of eastern Peru along the rivers Amazonas, Apurímac, Marañon, Huallaga, Pachitea, Ucayali and Urubamba at altitudes below 800 m above sea level (Figure 1), unevenly distributed between Departments (Table 1). The optimum average annual temperature is around 25°C and the minimum mean temperature 15°C and the absolute minimum 10°C. Temperature determines the geographic distribution (altitude and latitude) of cocoa in Peru more than any other factor (Anon, 1991).

FIGURE 1 : PERU, SHOWING THE MAIN RIVER SYSTEMS AND COCOA PRODUCING AREAS (⬮)



Precipitation is the most variable factor in the cocoa-producing areas and ranges from 1200 to 3500 mm per annum. Although most areas have one pronounced rainy season between November and March, rain is well distributed throughout the year. In the drier cocoa-producing areas, a water deficit (evaporation greater than precipitation) can occur for three to five months whereas wetter areas such as Tingo Maria possess no defined dry season (Anon, 1991). Rain induces flowering; thus, the harvesting period about 180 days later, coincides with the drier months April to September. Although cocoa is very sensitive to wind, this is rarely a problem in Peru unless cocoa is produced with little or no shade in the few areas where wind speeds of more than 4 m per second occur.

Cocoa soils in Peru range from clays to sandy loams. A depth of 1-1.5 m and good water retention characteristics are optimal. At the same time, drainage should be good enough to keep the soil aerated at most times. Inundations occur regularly along the alluvial banks of the Huallaga river and do not seem to impede root growth severely if they last for only short periods (Anon, 1991). In comparison to other perennial tree crops, cocoa is well adapted to poorer, acidic, Amazonian soils. However, a good soil should have more than 3.5% organic matter, a pH-value between 6.0 and 7.5, an exchangeable base content of 12 meq/100 g in the topsoil and 5 meq/100 g in the subsoil. A pH of 5.0 is regarded as minimum because of the possibility of aluminium toxicity (Anon, 1991).

PRODUCTION SYSTEM

Cocoa is produced on smallholdings. For example, Katip (1994) gives average farm sizes in the Marañon basin as between 2-5 ha (see also Table 1), usually under shade. Although some farmers plant under thinned, natural forest, many clear the area completely by slash and burn methods before planting temporary (banana/plantain, pigeon pea, papaya, cassava) and permanent shade, often legume trees (*Erythrina* spp, *Gliricidia* spp., *Inga* spp., *Leucaena* spp., *Pithecellobium edwallii*) or fruit trees (coconut, zapote). This is particularly common when so-called monte, a shrub vegetation which succeeds previous crops, often coca, is cleared. The recommendation is a 3.5 m x 3.5 m spacing of cocoa under 50-60% pre-established shade. In reality, however, farmers prefer whole numbers and 4 m x 4 m is the most favoured spacing system (Galarza, 1983). In traditional production systems in the Upper Huallaga Valley, Rios (1992a) recorded low cocoa planting densities (500 plants/ha) due to the dense shade which resulted in low productivity. Other more modern systems, intercropping with banana/plantain (2 m x 3 m), cocoa (4 m x 5 m) and shade trees (8 m x 8 m), can give respectable annual yields of both cocoa (700 kg/ha) and banana/plantain (8-15 t/ha).

Young plants are usually raised in nurseries and transplanted but recommendations for vegetative propagation also exist, and, indeed, a simple and cheap method of propagation suitable for the smaller farmer was pioneered in the 1970s at the experimental station in Tingo Maria (Nosti, 1963). Bud and scion grafts, both laterally- and terminally- inserted, are common and many farmers are competent grafters with a success rate of over 90%. For propagation by seed, hybrids produced by controlled pollination are available at certain centres. A mixture of about five hybrids is recommended and sometimes even compulsory to ensure good cross-pollination.

GERMPLASM

Germplasm selection in Peru began in the 1940s at least on a small scale. Forastero clones, originating in the northern lowland rainforest, were collected in Iquitos and disseminated to cocoa-producing areas. F.J.Pound collected and selected Peruvian germplasm extensively (Pound, 1943). Many commercial and now 'international' clones have their origin in these collections, for example Pound 7 and Pound 12 were frequently used parents for crosses with the UF (United Fruit) clones from Costa Rica and ICS clones from Trinidad. The famous Scavina clones are believed to be named after an hacienda (possibly Sabina) in the "*Selva*" of Peru (Anon, 1991). Other Peruvian lineages are the collections from Iquitos-Marañon (IMC), Morona (MO), Nanay (NA), Parinari (PA) (Bartra, 1993; Gonzales, 1996).

The National Germplasm Improvement Project began with the introduction of foreign germplasm to Peru in 1953: UF-2, UF613 from Costa Rica, ICS-1, ICS-6, ICS-29, ICS-48, SCA-6, SCA-12 from Trinidad and EET-59, EET-61 and EET-82 from Ecuador. These clones started to produce only a year and a half after planting and especially ICS-1 produced up to 1000 kg/ha. In 1955, the germplasm collection was expanded with clones introduced from Jaen, La Convencion (Cusco) and the forests along the Huallaga, and from 1957-1958 by further introductions from Colombia and Costa Rica. Selection at this stage was for high yields (Anon, 1991).

In 1962, the emphasis of germplasm improvement changed: witches' broom was now the main priority together with high yields. In the Experimental Station of Tulumayo near Tingo Maria, the hybrids SCA-6 x IMC-67, SCA-6 x ICS-1 and SCA-6 x ICS-6 were selected and remained unsurpassed for a long time under "*Selva*" conditions. In the following years, 21 clones were crossed and compared, with the emphasis on Upper Amazon crosses of Forastero, both with each other and with Trinitarios. Gradually, more local collections were incorporated (Anon, 1991).

Unfortunately, terrorism in the 1980s destroyed much of the investigation effort made in Tulumayo. Although old plantations could theoretically be recuperated, the identification of clones as well as information and research results were lost during the attacks. Today, the Tulumayo Station, which comprises a total of 400 ha with some 200 ha of agricultural potential, belongs UNAS (Anon, undated). Much of this is still abandoned but germplasm evaluation of cocoa has resumed.

In the last ten years, new collections from the Huallaga and Ucayali valleys have attracted particular attention as a potential source of resistance against all three major cocoa diseases present in Peru: witches' broom, black pod and frosty pod rot (*Moniliasis*). The latter is now the paramount problem and the main focus of the germplasm improvement programme. The Huallaga collection originated largely from managed or abandoned farms, whereas the Ucayali collection includes a significant proportion of germplasm from the rainforest. The germplasm bank of UNAS contains 25 international clones as well as 62 Huallaga and 51 Ucayali clones. The latter, in fact, comprises collections from both the Ucayali and Urubamba river systems (Lama, 1991). Lopez (1993) characterised 20 of these clones and found them to be trees of low to intermediate vigour, self-compatible with small ovoid pods and small seeds. Additional collections of international clones are present at Tocache, Chazuta, San Alejandro, Pucallpa, and Shebonya in the Huallaga Valley (Anon, 1996) and recently at Pichari (Apurimac) and Quillabamba (Cusco).

Tests for disease resistance and high yield are on-going at UNAS in Tingo Maria. Promising varieties are presented in Table 2 (compiled from Rios, 1994 and Anon, undated). Although good yields combined with a reasonable levels of resistance against each disease could be identified, multiple disease resistance has yet to be been found. More research is needed to consolidate preliminary findings and future efforts should address the production of hybrids with multiple disease resistance. The Huallaga and Ucayali collections would appear to be promising starting material, since many are highly productive, particularly H-9, H-12, H-34, H-35, H-45, H-47, H-54, H-60, U-8, U-12, U-26, U-38, U-39, U-65 and U-68. Unfortunately the disease resistance levels of these collections have not yet been adequately assessed.

TABLE 2 : COCOA VARIETIES WHICH APPEAR PROMISING BASED ON YIELD AND DISEASE TOLERANCE

International Clones	Huallaga Collection	Ucayali Collection
Crinipellis perniciosa SCA-12	None	U-10 U-54
Phytophthora capsici UF-913	None	None
Phytophthora palmivora UF-613	H-24	None
Moniliophthora roreri ICS-95	None	None

DISEASES

Undoubtedly, diseases are the major constraint to cocoa production in Peru with up to 100% pod losses being observed in extreme cases. The main diseases are discussed in order of current importance.

Frosty Pod Rot (*Moniliasis*)

Frosty pod rot, caused by *Moniliophthora roreri* (Cif. & Par.) Evans et. al., was first scientifically studied in the Los Rios Province of Ecuador in 1917 (Rorer, 1918). However, its detection in Peru was governed by almost 40 years of uncertainty. McLaughlin (1950) was the first to "report" it in Jaen (Cajamarca), Tingo Maria, (Huanuco) and Convencion (Cusco). However, Burgos (1954) rejected this claim after visiting the same sites. Reynoso (1965) apparently confirmed McLaughlin's earlier identification but failed to describe the symptomatology, whilst Ampuero (1967) probably used this information to report its spread into Peru. These observations remained controversial (Aranzazu, 1988; Evans, 1981; Suarez, 1987) until Hernandez et. al. (1989) initially confirmed the presence of *M.roreri* in Bagua Grande and Utcubamba (Amazonas) and later traced its spread throughout the northern "*Selva*"; Jaen and Cutervo in Cajamarca Dept., and Condorcanqui in Amazonas Dept. (Anon, 1991). These surveys are now regarded as validated. By 1992, the disease had reached San Martin Department in the Upper Huallaga Valley (Rios et. al., 1993), the remote Apurimac Valley by 1995, and the Ene Valley in 1996 (Arevalo and Ram, 1997). In affected areas, losses range from 10% to 100% which has resulted in the abandonment of many fields (Katip, 1994). Overall losses are around 40-50%. Currently, it is estimated that 88% of Peruvian cocoa farms are affected by the disease. Only the cocoa-producing areas of San Alejandro in the Ucayali Valley, Quillabamba to Cusco in the Urubamba Valley and Madre de

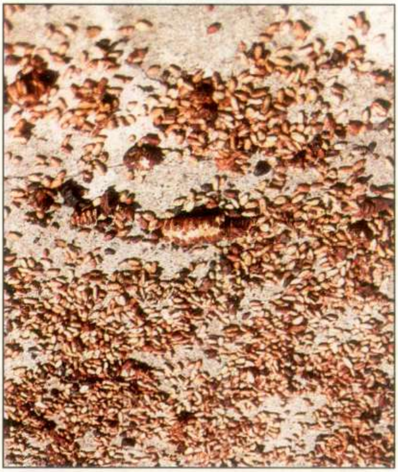
PLATE 1 : ABANDONED COCOA FARM IN THE APURIMAC VALLEY, HEAVILY INFESTED WITH FROSTY POD ROT (*M.RORERI*). WITCHES' BROOM AND CAPSID DAMAGE ARE ALSO EVIDENT

Dios are still free of disease, but it is only a question of time before the pathogen arrives. From this region, it is only 600-700 km to the Brazilian plantations in the State of Rondonia, not a great distance for an efficient, aerially dispersed pathogen.

M.roreri may have been brought into Peru via San Ignacio Province (Cajamarca Department), from Ecuador. Prior to the border conflict, Ecuadorians and Peruvians exchanged products in agricultural fairs in this region. Alternatively, *M.roreri* may have entered naturally along the Rio Santiago because the disease was first reported near the border at Chapiza after several negative surveys in the area. It is most probable that the fungus dispersed southwards from infested areas in Amazonian Ecuador, notably in the Napo region. Evans (1981) presented evidence to show that the Andes had proven to be a potent barrier to natural spread of *M.roreri* from its centre of origin in western Ecuador/Colombia, since the disease was never encountered on wild cocoa in eastern Ecuador before the 1980s. Evans (1981) speculated, however, that its arrival in the Aguarico-Napo region was imminent, following colonisation along the oil roads, and that man would be the vector by transporting latently-infected pods. If this were the case, then it took between 5-7 years to reach north-east Peru, a distance of some 500-600 km. Rios et. al. (1993) report on attempts to eradicate the disease in San Martin Dept., advocating placing bags around infected pods before removal from the tree, subsequently burying them and applying lime to the pod. These recommendations remain. The failure to contain the disease, its rapid spread and the subsequent abandonment of cocoa farms (Plate 1) is a salutory warning to neighbouring, disease-free countries.

PLATE 2 : "*MONILIASIS*" AWARENESS POSTER, SET UP BY CAIN ALONG COLONIST ROADS IN HUANUCO DEPARTMENT, PERU

PLATE 3 : DRYING FLOOR FOR COCOA BEANS IN THE APURIMAC VALLEY; NOTE THE "CLUMPED" BEAN MASSES GLUED TOGETHER WITH THE BROWNISH- WHITE MYCELIUM OF *M.RORERI*



The long-term strategy is to develop an integrated pest management package and to promote this through effective extension to the farmers; in the short-term, CAIN is highlighting the problem in rural areas through a poster campaign (Plate 2), in order to encourage the farmers to take effective action.

Much remains to be done, however, particularly in the more remote areas, such as the Apurimac Valley where the extension service has been non-existent due to terrorist activities and, as a consequence, awareness of the disease is at a low level to the extent that diseased beans may comprise the greater part of the "harvest"; a situation graphically illustrated in Plate 3.

Witches' Broom Disease

Up until the arrival of *M.roreri* in the late 1980s, this disease, caused by the agaric *Crinipellis perniciosa* (Stahel) Singer, was the major constraint to production in Peru. Efforts to control the disease concentrated initially on chemical methods (Rios, 1986) and then on germplasm improvement (Rios, 1994). *C.perniciosa* is indigenous to eastern Peru and can be found attacking wild *Theobroma* spp. in remnant forest around Tingo Maria (Authors, pers. obs.), typically causing only leaf swellings and branch cankers. Although pod infection does not appear to be high, probably due to limited dispersal of inoculum in the traditionally-grown (sheltered, shaded) cocoa farms, sporulation on old pods can be impressive (Plate 4). The initial symptoms of pod infection cannot be distinguished from those caused by *M.roreri*, and there can now be little doubt that the erroneous records of frosty pod rot in northern Peru in the 1950s and 1960s (McLaughlin, 1950; Reynoso, 1965) were, in fact, *C.perniciosa* pod infection. Evans (1981) reported on a similar scenario in Bolivia in the 1970s.

PLATE 4 : BASIDIOCARPS OF WITCHES' BROOM INABUNDANCE ON DECAYING POD IN ABANDONED COCOA FARM UNDERGOING REHABILITATION, HUANUCO DEPARTMENT

Black Pod Disease

Two species of *Phytophthora* spp., (*P.capsici* Leon. and *P.palmivora* (Butl.) Butl.,) have so far been reported from Peru (Anon, 1991; Rios, 1994), but their impact on production is limited compared with the above two diseases.

PESTS

There are no insect pests of major consequence in Peru, although *Monalonion dissimulatum* (Capsidae) can build-up to high populations in semi-abandoned farms and cause some pod damage (Plate 5). In particularly wet areas, such as the Tulumayo region, epiphytes can present a serious problem to the tree growth and control of these mosses, lichens and algae has been recommended using a 15 % detergent spray (Benito, 1992).

PLATE 5 : *MONALONION* DAMAGE IN SEMI-ABANDONED FARM,APURIMAC VALLEY; NOTE ADULT INSECT AND NYMPH

PRODUCTION

In 1996, national cocoa production was estimated at 22,867 metric tons on 32,200 ha (Table 3); although the latter figure is at odds with that from the 1995 census (Table 1). Most cocoa was produced in the Departments of Cusco (40.4%), Ayacucho (23.8%) and the Region of Andres A. Carceres (23.8%) whereas the other seven Regions together account for the remaining 12%. This is largely due to the distribution of production zones: Cusco (31.8%), Ayacucho (24.1%) and Andres A. Carceres (30.0%), but also to variations in yield between the geographically separated cocoa-growing zones, ranging from 341 kg/ha in Tumbes to 902 kg/ha in Cusco. Tumbes and La Libertad are in the dry northwest and are marginal for cocoa whereas the Inca Region (Cusco) is perfectly suited for cocoa and is still free from Moniliasis. The low levels of yield in the Northeast, Loreto and Andres A. Carceres can be attributed to the effect of the disease combined with the neglect of cocoa plantations as a result of intensive cultivation of alternative crops (especially coca) in these areas.

Farmgate prices show an almost reverse trend to yields. The Northeast had low yields but the highest farm-gate prices, followed by Ayacucho and the Huallaga Valley which stretches through Andres A. Carceres and San Martin. The latter two Regions still suffer from terrorist activity (Shining Path as well as Tupac Amaru rebels) and are the world's greatest coca-producing area. This resulted in neglect of cocoa and other crops and high rates of permanently abandoned land, of 28% and 43% respectively (Webb and Fernandez, 1997). Lowest farmgate prices were obtained in the Ucayali and Urubamba (Inca) Valleys, where yields are above average (Fujimori et. al., 1997), but where cocoa producers and towns are isolated and transport costs are correspondingly high. Thus, the farmgate price tends to be related to the efficiency of road communications within the Regions.

TABLE 3: COCOA PRODUCTION, AREA HARVESTED, YIELD AND FARMGATE PRICE IN DIFFERENT REGIONS AND DEPARTMENTS OF PERU IN 1996

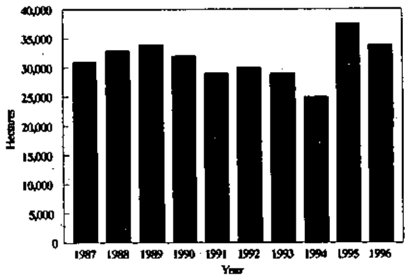
Region Departments	Production (t)	Area (ha)	Yield (kg/ha)	Farmgate Price (US$/kg)
Grau	**96**	**161**	**596**	**0.86**
Tumbes	14	41	341	0.78
Amazonas	82	120	683	0.86
North East	**1,567**	**2,951**	**531**	**1.1**
Lambayeque	11	20	550	1.2
Amazonas	221	388	570	0.36
Chota	75	155	484	1.08
Jaen	1,260	2,388	528	1.22
Jaen, Pucara, San Ignacio	473	871	543	1.17
Bagua, Utcubamba	787	1,517	519	1.26
La Libertad	**11**	**21**	**524**	**0.84**
Libertadores Wari	**5,440**	**7,746**	**702**	**0.93**
Ayacucho	5,440	7,746	702	0.93
José Carros Mariategui	**24**	**38**	**632**	**0.84**
Puno	24	38	632	0.84
Inca	9,289	10,328	899	0.68
Cusco	9,247	10,254	902	0.68
Madre de Dios	42	74	568	0.81
Ucayali	**247**	**308**	**802**	**0.59**
Andres A. Carceres	**5,434**	**9,676**	**562**	**0.97**
Huanuco	2,026	4,290	472	1.00
Pasco	68	98	694	0.95
Junín	3,340	5,288	632	0.94
San Martin	**741**	**936**	**792**	**0.88**
Loreto	**18**	**35**	**514**	**0.85**
Total	**22,867**	**32,200**	-	-
Average	-	-	**710**	**0.84**

Source : Fujimori et. al., 1997.

Temporal changes both in areas planted with cocoa and in cocoa production from 1987-1996 are shown In Figures 2-3. Both trends have the same pattern: there was a slight decline in the early 1990s due to

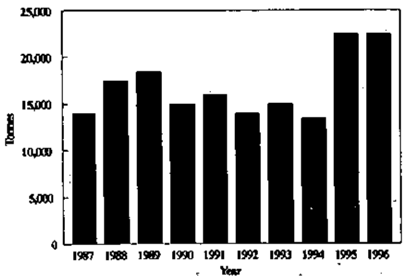
Moniliasis but a significant improvement in 1995 and 1996. In contrast, in the Huallaga Valley, where political instability and illicit cultivation of coca impinge directly on cocoa production, more extreme changes are evident (Figure 4). Throughout the 1980s until the early 1990s, the Shining Path (Sendero Luminoso) terrorised most of the Huallaga Valley making travel and transport of commodities dangerous, technology transfer almost impossible and industrial investment out of the question. Only CAIN bought cocoa and coffee in Tingo Maria during this period. From the mid 1980s onwards, the security situation improved steadily for the next decade and this can be seen in gradually increasing production in the Huallaga Valley up to 1991. From 1992 onwards, diseases, almost exclusively Moniliasis, became the limiting factor for production. Recently, efforts have been directed at improved disease control and this has encouraged farmers to rehabilitate their cocoa plantations and to replant. Hence, the steady increase in production from 1994 onwards (Figure 3), particularly in the Huallaga Valley (Figure 4), which undoubtedly has been helped by the slump in prices of coca leaf.

FIGURE 2 : AREAS UNDER COCOA PRODUCTION IN PERU (1987-1996)



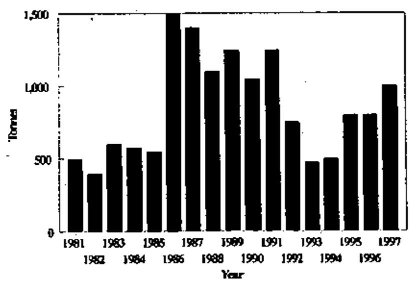
Source : Webb and Fernandez 1997

FIGURE 3 : COCOA PRODUCTION IN PERU (1987-1996)



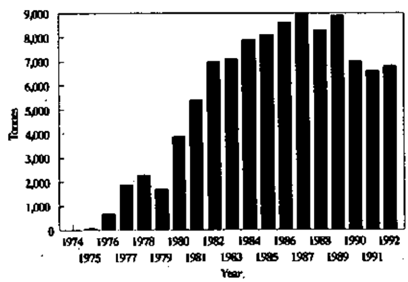
Source : Webb and Fernandez 1997

FIGURE 4 : COCOA PRODUCTION IN THE UPPER HUALLAGA VALLEY (1981-1997)



Source : CAIN Internal Report.

FIGURE 5 : EXPORTS OF COCOA (METRIC TONNES) FROM 1974-1992



Source : Fujimori et. al., 1996.

COCOA EXPORTS

Data on cocoa exports dating back to 1950 are available, although trade was erratic up to the mid 1970s when it began to rise substantially (Figure 5), and has increased 700% since 1978 (Benito, 1992). However, the spread of Moniliasis from 1990 onwards led to a nation-wide reduction of exports following the decline in production

A detailed breakdown of export and import volumes of cocoa products is shown in Table 4. Peru is a net importer of cocoa beans but a net exporter of all other cocoa products. The trade balance is thus consistently positive (Tables 4-5). Peru has signed duty free agreements with Colombia. Ecuador and Venezuela but only the ones with Ecuador and Venezuela cover cocoa and its products. Since December 1995, mutual duty free import/export arrangements with Ecuador include all cocoa products except sweetened or flavoured cocoa powder and baby food containing cocoa. Sweetened and flavoured cocoa powder is the only product Peru can export duty-free to Venezuela; this agreement is unilateral and much older (Fujimori et. al., 1996).

TABLE 4: EXPORT AND IMPORT OF COCOA PRODUCTS IN METRIC TONS (1993-JUNE 1996)

Product	1993		1994		1995		1996	
	Export	Import	Export	Import	Export	Import	Export	Import
Cocoa beans	41	100	0	3,591	0	884	66	0
Liquor (paste)	645	0	72	0	1,017	0	1,322	0
Cocoa powder	1,650	0	397	0	212	0	189	0
Cocoa butter	3,655	0	4,461	0	5,538	0	2,249	0
Cocoa shell	0	0	0	0	69	0	0	0

Source : Comercio exterior.

TABLE 5 : EXPORTS (US$/T) OF COCOA PRODUCTS (1993-JUNE 1996)

Product	1993	1994	1995	1996
Cocoa beans	9,780	nd	nd	727.3
Liquor (paste)	2,891	527	2,305	2,322
Cocoa powder	764	476	514	433
Cocoa butter	2,378	3,098	3,719	3,687
Cocoa shell	nd	nd	72.5	nd
Total (in bean equivalent)	**17,460**	**5,343**	**8,436**	**9,048**

(nd = no data)

Source : Fujimori et. al., 1996.

Cocoa products are popular among Peruvians but statistics exist only for Metropolitan Lima which is not necessarily representative of the country as a whole. On the other hand, almost half of the country's population live in greater Lima, including Callao. Whereas in 1995, 12% of sweetened cocoa-drinks were imported from Chile and Ecuador, only 4% were imported in 1996. Imported, unsweetened cocoa powder only comprised 0.2% (Webb and Fernandez, 1997).

Cocoa beans are imported from Ecuador more or less all year round to facilitate economic processing of cocoa in Peru. Liquor (paste) and cocoa butter are exported. Main buyers of liquor (paste) are Argentina, Australia, Chile, the Netherlands, Russia, Spain and USA. Cocoa powder is sold to Argentina, Bolivia, Chile, Finland, Germany, Poland, Russia and United Arab Emirates and cocoa butter to Argentina, Belgium, Bolivia, France, Germany, Italy, the Netherlands, Poland, Russia, Spain, UK and USA, but the distribution between these countries varies greatly over the years. Cocoa shell is exported to Argentina only. Exports of cocoa and its products were lucrative in 1993 (Table 4). The production of cocoa butter responded to favourable prices. In addition to the trade in cocoa beans and products, pectin is extracted from the pod husk for use in jellies and jams (Ríos, 1992a) and can also be used in animal feed as partial substitute for maize, which has to be brought from the Andean region. UNAS has carried out detailed studies on pod husk in feed for calves (Choque and Pérez, 1996), poultry (Vicuña, 1974) and pigs (Rios, 1992b).

FUTURE

Approximately 16,000 ha of abandoned plantations have potential for rehabilitation, predominantly in the Urubamba, Huallaga and Apurimac Valleys (Anon, 1991). As noted by Cuatrecasas (1964): "The rehabilitation or replacement of old plantations, better disease control, and the improvement of pruning methods are the most important problems awaiting solution." This still holds true, particularly after the arrival of *M.roreri*. Efforts are being made not only to rehabilitate the crop but also the farmers, previously dedicated to illicit coca production, through so-called alternative development. Although there are many critics of this system (Painter, 1994), such programmes offer a life-line and a future to the small farmers. With over 200,000 ha of land suitable for cocoa production in the Amazonas Department alone (Cuatrecasas, 1964), Peru has the potential to be a significant producer in the long-term, if disease problems can be addressed and the security situation stabilizes sufficiently.

ACKNOWLEDGEMENTS

The U.S. Department of Agriculture (USDA) and the Organisation of American States (OAS), provided the funding for the collaborative programme with UNAS (Tingo Maria) which made this article possible.

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THE EFFECT OF FERMENTATION TIME AND WASHING OF COCOA PRIOR TO DRYING ON COCOA QUALITY IN PAPUA NEW GUINEA

Neil Hollywood *

INTRODUCTION

Cocoa Board regulations in Papua New Guinea state that cocoa should be fermented in at least 600-700 kg quantities, with a minimum bean depth of 50 cm, for seven to eight days and preferably with a turn applied each day of a fermentation. These regulations appear to be based on results of cut tests and the length of time that elevated temperatures are maintained with this mass of cocoa. With cut test results, the proportion of brown, fully fermented dried beans increases with the length of time of a fermentation. The literature on cocoa fermenting practices is generally vague on the effects of length of fermentation times with statements such as Criollo material is generally fermented for two to three days whereas Forastero is fermented for longer periods of five to seven days (Wood and Lass, 1985; Lehrian and Patterson, 1983). It would appear that the length of time of fermentations conducted in various countries is dependant on a number of factors including, quantity to be fermented, genetic material, cut test results, economic factors and end user requirements. Compared to fermentation times conducted in some countries, the length of fermentations applied in PNG appear unnecessarily long. This trial was therefore conducted to establish effects of fermentation time on cocoa quality attributes under conditions in Papua New Guinea.

In some countries eg Indonesia, washing of cocoa is applied prior to drying to reduce shell content (Ardhana, 1990). With the particular genetic material they have, this can lead to shell contents of around 12% which compares favourably with the high (15-18%) shell content of PNG cocoa. High shell content constitutes a major criticism of PNG cocoa and the effect of a simple washing procedure was therefore monitored in tandem with a study of the effect of length of fermentation time.

METHODS

In this trial, samples of cocoa were taken from a 1200 kg commercial box fermentation, of mixed hybrid Amazonian x Trinitario cross genetic material, at CCRI's Tavilo Research Station. Sampling was conducted on days 3, 4, 5, 6 and 7 of the fermentation. Samples were divided into washed and unwashed subsamples and then further divided into sun dried and artificially dried subsamples. In this way, four dried bean samples of artificially dried (AD), unwashed (A); artificially dried, washed (B); sun dried (SD) unwashed (A) and sun dried washed (B), were generated on each day. Washing consisted of placing the cocoa sample (approximately 6 kg) in 1.5 times it's volume of water in a plastic bucket and soaking for two hours. No mechanical agitation was employed. After the two hour soak period, beans were separated by pouring the mixture through a sieve. In this manner, the effects of washing on shell

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content and length of fermentation time were conducted simultaneously. Artificial drying was conducted by an electrical drying cabinet which achieved 7% moisture in three days. Sun drying consisted of placing samples on a drying rack in the sun for six days. After six days, samples were generally around 10% moisture and were then finished in the artificial drier. In this manner, drying times were standardised. Four replications of the entire experiment were conducted. Samples were analysed for chemical and physical attributes by standard procedures of the CCRI's cocoa quality laboratory. These results are presented as averages of the four replications. Two replications of each treatment were forwarded to Nestle UK, for flavour analysis and results are presented as the averages of them.

RESULTS AND DISCUSSION

Results presented in Figure 1 demonstrate the increase in shell content which occurs with increasing fermentation time. In commercial situations, the increase in shell content from 14.9 to 16.6% from day five to day seven for artificially dried unwashed beans would be particularly relevant.

The results also demonstrate reductions in shell content due to washing on each day of the fermentation. For artificially dried cocoa from day seven, the usual length of a PNG commercial fermentation, a reduction from an average of 16.6% to an average of 13.3%, ie. 3.4% decrease, was obtained by washing. It is also interesting to note that sun dried samples for unwashed beans generally had a lower shell content than the corresponding artificially dried samples but this effect was negated by washing.

FIGURE 1 : THE EFFECT OF LENGTH OFFERMENTATION TIME AND WASHING ON THE SHELL CONTENT OF DRIED COCOA

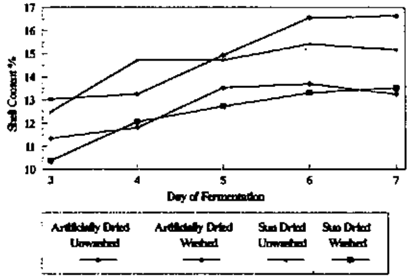
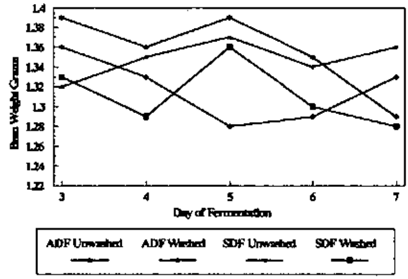


FIGURE 2 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON THE WEIGHT OF DRIED COCOA BEANS



It would appear logical that cotyledon weight would decrease with length of fermentation time due to breakdown of bean components, especially polysaccharides. Figure 2 does not show a clear picture of the effect of fermentation time on bean weight. There appears to be a general trend downwards with increasing length of fermentation time. Both washing and length of fermentation time have an effect on shell content and this in turn will have an effect on bean weights. Moisture contents of dried beans vary, and therefore the best way to present the bean weight data is to present it as cotyledon dry weight. In this way, the effect of different treatments on shell content should be minimised and effects of different moisture contents eliminated. These results are presented in Figure 3. These demonstrate a downward trend in cotyledon dry weight with length of fermentation time at least for some of the washing / drying treatments. The fact that a consistent trend is not evident for each treatment is possibly due to fact that bean sizes are quite variable with hybrid material and an inadequate replication of tests may have occurred. At present, bean count data is based on one calculation of the weight of at least 50 beans from a subsample.

FIGURE 3 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON DRY WEIGHT OF COTYLEDON

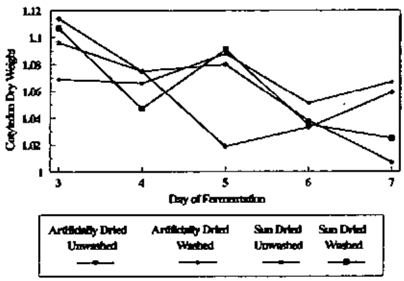
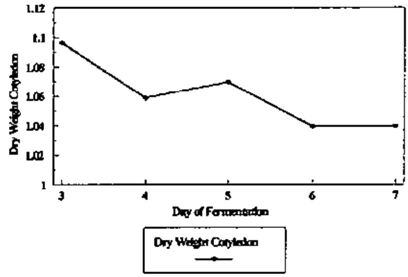


FIGURE 4 : THE EFFECT OF FERMENTATION TIME ON COTYLEDON DRY WEIGHT (BULK DATA ALL WASH/DRYING TREATMENTS)



The results in this Table indicate a 7.2% higher cotyledon dry weight for day five artificially dried unwashed cocoa compared to day seven artificially dried unwashed cocoa. This figure, if typical, is extremely important for the industry. In an attempt to further establish the effect of length of fermentation time on cotyledon dry weight, all data for drying and washing treatments was averaged as shown in Figure 4.

These figures again indicate strongly a decreasing amount of cotyledon with increasing length of fermentation time. The difference between day five and day seven is 2.9%. This result may be misleading as sun drying and artificial drying are very different processes ie. the difference for artificially dried samples may be much higher. Again, if this type of result is typical it is of extreme importance to the industry.

Figures 5 and 6 indicate a reduction in acidity for almost all washing treatments. This is reflected in higher pH values and lower titrable acidity in virtually all washed samples compared to the corresponding unwashed sample. The procedure could therefore have some application where a reduction in acidity is considered desirable. The highest pH values were obtained for day three beans indicating the low level of acidity at this stage of the fermentation and insufficient time for an equilibration of pulp and cotyledon acidity levels. On day four, considerable decreases in pH were noted in artificially dried samples but this did not occur in the sun dried samples. This fact probably indicates that by day four acetic acid is the main organic acid involved and it evaporates during sun drying. The rapid change in pH values between days three and four indicates that some profound changes in chemistry are occurring at this stage. From days five to seven only slight changes in acidity occurred. In virtually all cases, sun dried samples had lower levels of acidity than corresponding artificially dried samples, indicating the evaporation of acetic acid during sun drying. The similar pH and TA levels for sun and artificially dried beans on day three is probably indicative of low levels of volatile acetic acid at this stage of fermentation.

FIGURE 5 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON THE pH OF DRIED COCOA

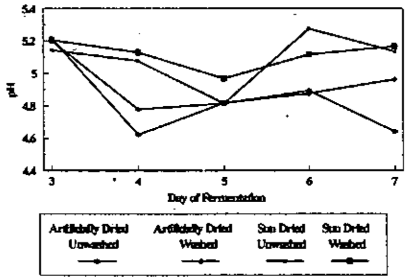
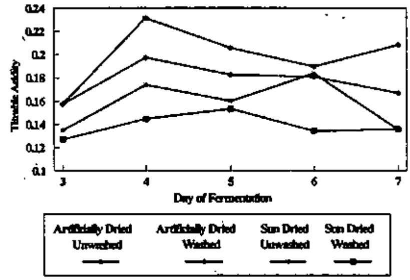


FIGURE 6 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON TITRABLE ACIDITY (meq citric acid / 100g) OF DRIED COCOA



A completely unexpected result of this trial was the effect of the wash procedure, prior to drying, on cut test results. Figures 7, 8 and 9 demonstrate a consistent increase in numbers of brown beans and corresponding decrease in purple and partly purple bean counts due to washing, for almost all fermentation times, whether sun or artificially dried. The reason that the wash procedure would contribute to an increase in brown beans is not immediately apparent as it is generally regarded as being effected by the degree of fermentation of the cocoa as well as oxidative reactions by enzymes such as polyphenol oxidise during both fermentation and drying. Soaking cocoa for two hours should not effect the extent of fermentation or increase oxygen penetration of beans at that stage. Possibly, the removal of some of the pulp during washing could effect oxygen penetration later during drying. Whatever the cause of this effect on cut test results is, it is an interesting observation which does not appear in the literature.

FIGURE 7 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON PERCENTAGE BROWN BEANS IN CUT TEST

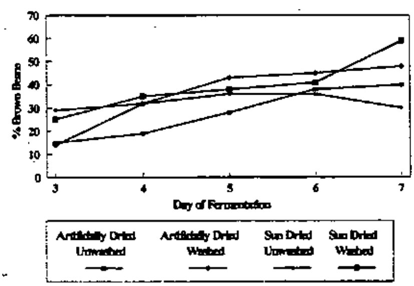
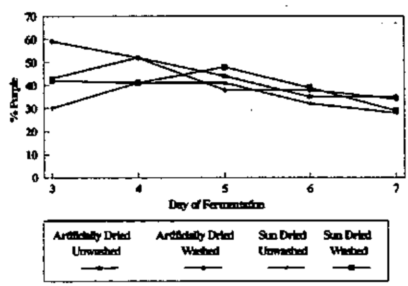


FIGURE 8 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON PERCENTAGE PURPLE BEANS IN CUT TEST



During sun drying, the length of time of fermentation as well as oxidative processes are extended due to slow moisture loss and this is reflected in the figures, with sun dried samples always having higher percentages of brown beans than the corresponding artificially dried sample. The effects of washing and sun drying compounded each other, with brown bean percentages being consistently higher in washed, sun dried samples than unwashed, sun dried samples.

FIGURE 9 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON PERCENTAGE PARTLY PURPLE BEANS IN CUT TEST

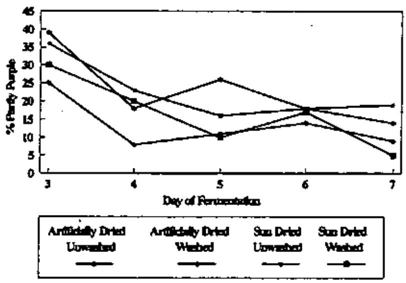
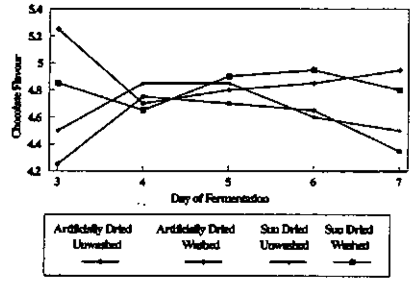


FIGURE 10 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON CHOCOLATE FLAVOUR SCORES



Diesel fired artificial drying is the main form of drying in the plantation sector and hot air kiln drying in the smallholder sector of PNG. The results indicate an increase in the percentage of brown, fully fermented beans and corresponding decrease in purple and partly purple beans with increasing fermentation time. This type of result is probably the basis of recommendations regarding length of fermentation for PNG.

The Nestle flavour evaluations indicate strongly that there needs to be a reconsideration of the supposed connection between cut test results and flavour. It is generally considered that the higher the percentage of brown beans present, the higher chocolate flavour will be. This is demonstrably not the case (Figure 10). It is difficult to explain why washed, artificially dried beans from three days of fermentation have the highest chocolate flavour score. It could be related to the fact that these samples also had the highest pH values. For unwashed, artificially dried beans, the highest chocolate flavour scores occurred on day four and then declined every day beyond that. This indicates that commercial fermentations in PNG could be too long.

For washed artificially dried samples, chocolate flavour increased every day after four days of fermentation and on every day, washed artificially dried samples had higher chocolate flavour scores than the corresponding unwashed sample. This result does not correspond to pH values and it is difficult to understand why it is happening.

Generally, sun dried cocoa tends to have higher chocolate flavour scores than artificially dried cocoa and this is presumably due to the slower drying allowing greater acid loss and flavour precursor development. In this instance, on most days, sun dried samples had slightly higher chocolate flavours than the corresponding artificially dried samples. However, these increases were minor when compared to the effect of washing, which substantially increased chocolate flavour scores. The washing was conducted purely to reduce shell content and to find a substantial effect on chocolate flavour as well as cut test results is unexpected. It is also difficult to explain how washing could increase the levels of any compounds associated with chocolate flavour. As suggested for cut test results, removal of pulp by washing may effect oxygen penetration and hence oxidative reactions during drying. Washing may also leach compounds which tend to mask chocolate flavour.

With unwashed, artificially dried samples, acidity flavour scores tended to increase with length of fermentation time. In general, this corresponded to pH value changes with fermentation time. The results do not correspond much to titrable acidity possibly because of the changing composition of organic acids as a fermentation proceeds. Surprisingly, washed artificially dried samples registered higher acidity levels every day except day seven. This is in complete contrast to the chemical analyses for pH and titrable acidity and the reason is not readily apparent.

FIGURE 11 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON ACIDITY FLAVOUR SCORE

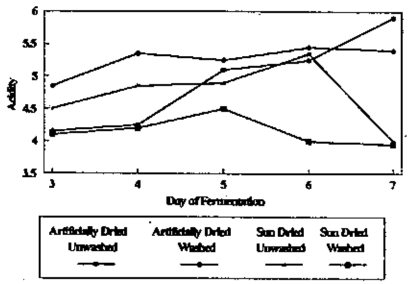
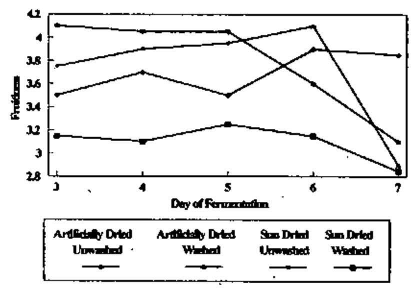


FIGURE 12 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON FRUITINESS FLAVOUR SOCRES



With unwashed, sun dried samples, a significant decrease in acidity flavour score only occurred on day seven. Again this does not correspond with the chemical analyses. For washed, sun dried samples, acidity scores were the lowest of any category and this does correspond with chemical analysis (Figure 11).

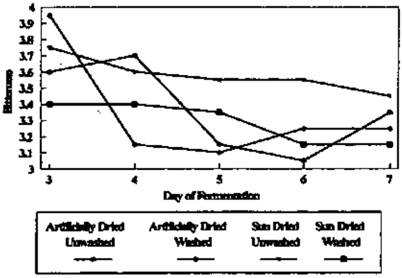
Fruitiness is usually associated with acidity because fruitiness comes from acetate ester compounds. All of the samples had fruitiness levels below the PNG standard and this is difficult to understand given the very acidic nature of Tavilo cocoa. It is also difficult to explain the decreases in fruitiness for unwashed, artificially dried samples each day after day five. Washing artificially dried cocoa had the effect of reducing fruitiness prior to day four and then increasing it on days five and six. This may have something to do with the nature of compounds producing this flavour attribute.

With unwashed, sun dried samples, fruitiness and acidity scores tended to correspond closely. Similarly, washed sun dried samples had corresponding acidity and fruitiness scores (Figure 12).

All samples had bitterness scores above the PNG standard. As could be expected, samples from day three had the highest bitterness levels. In all cases, bitterness did not change greatly after day five. Again this gives an indication that fermentation times beyond five days are not beneficial. Washing did not appreciably affect bitterness in the artificially dried samples, but did substantially decrease it in sun dried samples. Sun dried, unwashed samples had higher bitterness levels than artificially dried ones indicating a reaction occurring during slow drying to increase this flavour attribute (Figure 13).

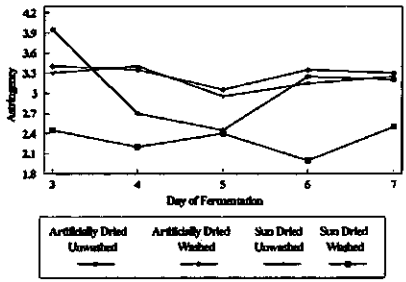
As for bitterness, astringency levels were highest for day three samples, but surprisingly were not affected to a great extent by the length of fermentation time. Only in sun dried samples, did astringency decrease due to washing (Figure 14).

FIGURE 13 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON BITTERNESS (*) FLAVOUR SCORE



(*) *High bitterness scores are undesirable.*

FIGURE 14 : THE EFFECT OF LENGTH OF FERMENTATION TIME AND WASHING ON ASTRIGENCY (*) FLAVOUR SCORE



(*) *High astringency scores are undesirable.*

For all categories, off-flavours increased between day six and seven, probably indicating over fermentation during this period. Descriptions of off-flavours were as follows: (the term nil refers to no description being given by taste panellists rather than the absence of off-flavours)

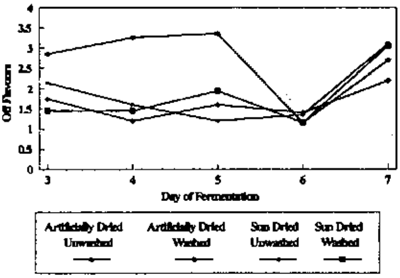
AD A3 rep 1	woody, earthy, mouldy
AD B3 rep 1	nil
SD A3 rep 1	chemical
SD B3 rep 1	chemical
AD A4 rep 1	raw, green
AD B4 rep 1	nil
SD A4 rep 1	nil
SD B4 rep 1	nil
AD A5 rep 1	woody, earthy, mouldy
AD B5 rep 1	earthy
SD A5 rep 1	nil
SD B5 rep 1	nil
AD A6 rep 1	nil
AD B6 rep 1	nil
AD A6 rep 1	nil
SD B6 rep 1	nil

AD A7 rep 1	woody, earthy, mouldy
AD B7 rep 1	nil
SD A7 rep 1	chemical, earthy
SD B7 rep 1	woody, earthy

In the second replication, no taste panellists noted off-flavours. It is difficult to link any of these off-flavours with fermentation time as the same descriptors appear for ADF A days 3, 5 and 7, although the chemical nature of them probably does change with time.

In sun dried samples, washing did not affect off-flavour levels. However for artificial drying, washing did substantially reduce it for every day except day six when a substantial reduction in off-flavour scores in unwashed samples occurred. For nearly every treatment, a minimum level of off-flavours occurred on day six and then increased dramatically on day seven. The fact that higher levels of off favours occurred on day five than day six for artificially dried samples is probably not cause to recommend six rather than five days. These flavours are not due to overfermentation or putrefaction and would probably be removed during processing (Figure 15).

FIGURE 15 : THE EFFECT OF LENGTH OF FERMENTATIONTIM AND WASHING ON OFF-FLAVOUR SCORES



CONCLUSION

The washing procedure employed in this experiment was soaking of cocoa in a plastic bucket and so as no mechanical agitation is employed, it should not prove difficult to scale this procedure up to the commercial situation. Some of the costs involved could be offset by decreased labour costs for five day fermentations.

There are several possible recommendations which can be made from the results presented. They indicate that there does not seem to be any benefit in continuing fermentations for seven days and that five would be adequate in the PNG situation. Washing of cocoa prior to drying appears to be beneficial for a number of reasons. A comparison of attributes of artificially dried cocoa from a seven day fermentation, no wash and five day fermentation with and without washing is given in Table 1.

With a five day fermentation, a decrease in shell content of 1.7% as compared to a typical seven day fermentation could be expected. With washing, the decrease is 3.11%. These reasons alone are sufficient to consider both a reduction in fermentation time and washing to remove shell content. Fermenting for five days appears to beneficially decrease bean count ie. the average weight of beans is higher as is weight of cotyledon. This is probably due to a breaking down of bean components during fermentation. The decrease in bean count is negated by washing, due to shell loss. The figures for average bean weight and therefore yield, from fermenting a given quantity, are particularly interesting. For day five unwashed samples, they indicate both a decreased shell content and an 8.2% increase in dried bean yield after fermentation. Washing negates this by removing shell. This increase in yield is significant and suggests that washing should not be conducted for reasons of decreased yield. It would require assessment of expected prices to determine whether going for a combination of 8.2% yield increase and 1.7% shell decrease is preferable to a combination of no yield increase and 3.11% shell decrease.

TABLE 1 : QUALITY ATTRIBUTES OF SEVEN DAY FERMENTED, UNWASHED, ARTIFICIALLY DRIED COCOA WITH FIVE DAY FERMENTED WASHED AND UNWASHED, ARTIFICIALLY DRIED COCOA SAMPLES

Attribute	Artificially Dried day 7 no wash	Artificially Dried day 5 no wash	Artificially Dried day 5 + wash
Shell content %	16.64	14.94	3.53
bean count	77.75	71.83	78.04
Average bean weight	1.286g	1.392g	1.281g
% increase in bean weight over day 7	0	8.2%	- 0.38%
weight cotyledon	1.0720g	1.1840g	1.1077g
% increase weight cotyl. over day 7	0	10.44%	3.33%
pH	4.64	4.81	4.82
TA	0.21	0.21	0.18
Flavour			
Choc. flavour	4.35	4.7	4.8
Acidity	5.9	5.1	5.25
Fruitiness	3.1	4.05	3.5
Bitterness	3.35	3.15	3.1
Astringency	3.2	2.45	3.05
Off-flavours	2.7	3.35	1.6
Cut test			
% brown	40	28	43
% purple	35	44	38
% part/purple	14	26	11

All of the flavour attributes tend to provide additional reasons for trialing reduced fermentation times and washing on a commercial level, with comments requested from end users. Chocolate flavour scores increase, acidity decreases and fruitiness increases both with decreased fermentation time and washing. Bitterness and astringency are relatively unaffected and washing appears to reduce off-flavours. In addition, there is also the possibility that applying a longer soaking period or even several, two hour soakings in fresh water, could reduce shell content and improve flavour attributes to a greater extent. In this case, it would be necessary again to consider expected prices in relation to the decreases in total product yield due to washing.

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SURVIVAL OF *PHYTOPHTHORA PALMIVORA* AND *PHYTOPHTHORA MEGAKARYA* ON AND IN ROOTS OF COCOA SEEDLINGS

Isaac Y. Opoku * and Bryan E.J. Wheeler **

INTRODUCTION

Black pod caused by *Phytophthora palmivora* has been associated with cocoa in Ghana almost since the crop was introduced. Losses attributed to the disease have remained relatively low, estimated nationally as between 4.9 - 13.5% (Dakwa, 1987). In contrast, during the 1985/86 season, severe black pod resulting in losses ranging from 60 - 100% was reported in the Akomadan district. The pathogen responsible for this outbreak was identified as *Phytophthora megakarya*, the first incidence of this species in Ghana. On the basis of new records of severe black pod, it was then estimated to be spreading at the rate of 3 km per year (Dakwa, 1987). It is now the major species in Bechem district in the Brong/Ahafo region, in parts of Volta, and it continues to spread to other areas.

In Ghana, there is a marked dry season, usually between mid-November and mid-March when there are few cocoa pods on the trees and black pod infection is virtually absent. How then do *P.palmivora* and *P.megakarya* survive from one production season to the next? Over the years, evidence has accumulated which indicates that in different regions there are associations with cocoa roots of particular *Phytophthora* species including *P.palmivora* (Turner and Asomaning, 1962; Onesirosan, 1971), *P.megakarya* (Ward and Griffin, 1981), and *P.capsici* and *P.citrophthora* (Pereira, 1988). From extensive epidemiological studies, Gregory et. al. (1984) concluded that living cocoa roots play a key rôle in the multiplication and conservation of *P.megakarya* in Nigeria and they suggested that this situation could obtain for other *Phytophthora* species.

Spread of *P.megakarya* in Ghana may well have occurred through moving infected plant material but its subsequent development on cocoa roots presupposes movement of its infective propagules (zoospores) into soil from pod infections either resulting in fungus-root associations or a resevoir of "dormant" (encysted) zoospores which might then be stimulated to germinate subsequently when contacted by new root growth.

The experiments described here were concerned with the recovery of *P.palmivora* and *P.megakarya* from roots of cocoa seedlings following their inoculation either directly by dipping them in zoospore suspensions or indirectly by applying zoospores to soils in which seedlings were growing. They sought to answer questions such as "Can the fungus survive in association with cocoa roots without causing severe damage? and "Can it survive for a period appropriate for re-establishing infections in a new crop?"

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MATERIALS AND METHODS

Seedlings were raised in soil-based compost (John Innes No.3, washed and graded silver sand and Irish moss peat in a 2:1:1 ratio respectively) in plastic pots in a glasshouse at Imperial College at Silwood Park, Ascot, UK, from pods (T79/501 x Amel) sent by air from Tafo, Ghana. Seedlings between one month and 3 months old were used.

One isolate of *P.palmivora* (designated GHP1) from Tafo and one isolate of *P.megakarya* (GH13) from Akomadan were used, both obtained from infected, green cocoa pods.

Cultures of the isolates were prepared on 20% V8 juice agar in 9cm plastic plates and incubated under continuous light at 25°C for 9 days. Each plate was flooded with 20 ml sterile distilled water (SDW) previously chilled to 4°C and kept at 4°C for 20 min followed by another 20 min at 25°C in a darkened incubator. Zoospore concentrations were checked with a haemocytometer. Root samples were obtained by removing the whole seedling from its pot and shaking off the soil from the roots. Living root pieces, each approx. 1 cm long, were cut from both main (tap) and side (secondary) roots. Roots were considered living if they were white inside.

The root pieces were either surface sterilized by soaking them in 10% sodium hypochlorite soultion for 10 min and then rinsed in three changes of SDW or they were rinsed in SDW only. The pieces were plated on PPMA (*P.palmivora - P.megakarya* agar) developed especially for the isolation of these two fungi (Opoku 1994). All cultures were incubated in the dark at 25°C and observed for *Phytophthora* colonies between day 2 and day 6.

Quantitative results were analysed using chi-square or the Fisher exact probability test.

EXPERIMENTS

Experiment 1 : Dip Inoculation of Roots in High Concentrations of Zoospores

Suspensions containing 10^3, 10^4 and 10^5 zoospores/ml of *P.megakarya* were prepared. Two month-old cocoa seedlings were inoculated by dipping the roots in the appropriate zoospore suspension for 1 min or in SDW (control). The seedlings were re-potted immediately and watered once daily. Ten seedlings were used per treatment. The seedlings were scored as dead or alive 6 wk after inoculation. From 9 weeks plants which had survived inoculation with zoospores were sampled at weekly intervals for 4 wk and the roots tested for the presence of *Phytophthora*. On each occasion, one plant from each inoculum level was removed and two samples of root pieces each consisting of 20 pieces of side roots and 4 main root pieces were prepared. One sample was surface sterilized, the other sample rinsed in SDW only. Both samples were plated on PPMA.

Some seedlings died in all treaments with *P.megakarya* (Table 1). Young leaves of most inoculated plants collapsed one week or 2 wk after inoculation, turned brown and then dropped. The number of seedlings which died was not always clearly related to the inoculum dose. Only the treatment with 10^5 zoospores/ml had a significant effect (P = 0.0054) in relation to the SDW control.

TABLE 1 : SURVIVAL OF COCOA SEEDLINGS AND RECOVERY OF FUNGUS FROM ROOTS FOLLOWING INOCULATION WITH *PHYTOPHTHORA MEGAKARYA*

Inoculum (Zoospores/ml)	Seedlings Alive at 6 wk (out of 10)	% Recovery * of *P.megakarya* from	
		Main Roots	Side Roots
0	10	-	-
103	7	38	14
104	9	69	19
105	4	81	43

* Based on a sample for each inoculum level of 32 main root and 160 side root pieces.

P.megakarya was isolated from the roots of all surviving plants at each inoculum dose. Examination of the data for main roots and side roots showed that, at each level of inoculum, treatment with hypochlorite had no signifivant effect ($P > 0.05$) on the recovery of *P.megakarya*. Further tests on the combined data at each inoculum level showed that there were no significant differences between sampling dates, suggesting that there was little, if any, further fungal development between 9 wk and 12 wk. For both main roots and side roots, the frequency of recovery increased with inoculum dose and was corresponding higher for main roots than side roots despite the larger sample size of side roots (Table 1).

Experiment 2 : Dip Inoculation of Roots in Low Concentrations of Zoospores

Experiment 1 showed that high levels of inoculum could kill seedlings and therefore did not seem a good model for studying survival of the fungus on roots in relation to the field situation. This experiment therefore used low inoculum levels with observations over a longer (6 month) period.

TABLE 2 : RECOVERY OF *PHYTOPHTHORA PALMIVORA* AND *P.MEGAKARYA* FROM COCOA ROOTS TO 6 MONTHS AFTER INOCULATION

Species	Root Type	No. Root Pieces * from which Fungus was Isolated on Month					
		1	2	3	4	5	6
P.palmivora	main root	9	5	**3**	2	2	1
	side root	14	9	10	6	**4**	3
P.megakarya	main root	10	**5**	4	3	2	2
	side root	15	13	8	7	**5**	4

* Out of 10 main root and 100 side root pieces.
Values in bold and underlined (eg. **2**) differ significantly ($P < 0.05$) from the corresponding value for month 1.

Suspensions of 200 zoospores/ml were prepared from cultures of *P.palmivora* and *P.megakarya*. Eight seedlings were inoculated with *P.palmivora* and eight seedlings with *P.megakarya* by dipping their roots in the appropriate zoospore suspension for 3 min before re-potting. One plant from each set was designated at random for sampling every month. On each occasion, 50 side root and 5 main root pieces were either surface sterilized in sodium hypochlorite or rinsed in SDW before plating on PPMA.

The two fungi were isolated from roots over the 6-month period. There were no significant differences between root pieces treated with hypochlorite and those rinsed in SDW on any occasion. Totals for each root type are therefore given in Table 2. Generally there was a gradual decline in the frequency with which the fungi were isolated. With main root pieces there was a significant ($P < 0.05$) drop in recovery of *P.palmivora* between month 1 and month 3 and with *P.megakarya* between month 1 and month 2. With side root pieces there was not a significant decline in recovery (over month 1) until month 5 for both fungi. The inference is that side roots provide a better niche for the two fungi to survive.

Experiment 3 : Zoospores Applied to the Soil Surface

The previous experiment indicated that both *P.palmivora* and *P.megakarya* could be recovered from roots 6 months after they were inoculated directly with low concentrations of zoospores . However, in the cocoa plantation these fungi are likely to be washed from infected pods onto the soil. So this experiment addressed the question, "Could these fungi become established on roots if their zoospores were applied to the soil surface?".

Six week-old seedlings were re-potted and watered daily. Treatments (zoospore application regimes) were started one month later. In the initial treatment, 20 ml of a suspension containing 10^3 zoospores/ml were sprayed on to the soil surface of each pot. Subsequent applications of a similar dose were made at 3-day intervals to give five treatments: one application and two, three, four and five applications of zoospores. Within each treatment three plants were inoculated with *P.palmivora* and three plants with *P.megakarya* and one plant inoculated with each fungus was designated at random for sampling at 7, 14 and 21 days after its last inoculation. On each day, two samples of root pieces from each plant, each sample consisting of 20 pieces from side roots and 5 pieces from the main root, were washed in SDW for one hour. One sample was then plated on PPMA; the other sample was surface strerilized with hypochlorite before plating on PPMA.

Recovery of both *Phytophthora* species from roots generally increased with the number of applications of zoospores applied to the soil surface. For each species, corresponding values for root pieces treated with hypochlorite and those washed only in SDW did not differ significantly nor did the combined values for these two treatments for each sampling date within each isolate/zoospore application. Isolate totals (Table 3) were therefore analysed using chi-square. The recovery of both fungi from root pieces in treatment 5 (five applications of zoospores) was first compared with that of treatment 1 (one application of zoospores). With pieces of main root, there was no significant difference ($P > 0.05$) in recovery either of *P.palmivora* or of *P.megakarya*. With pieces of side roots, highly significant ($P < 0.001$) chi-square values were obtained for similar comparisons with both *P.palmivora* ($X^2 = 11.31$) and *P.megakarya* ($X^2 = 11.71$). Other comparisons with treatment 1 did not give significant chi-square values. Five applications of zoospores thus increased the incidence of recovery from side roots but not from main roots.

TABLE 3 : RECOVERY OF *PHYTOPHTHORA PALMIVORA* AND *P.MEGAKARYA* FROM COCOA ROOTS FOLLOWING INOCULATIONS OF THE SOIL SURFACE

Species	Root Type	No. Root Pieces * from which Fungus was Isolated with these Soil Applications of Zoospores				
		1	2	3	4	5
P.palmivora	main root	3	2	3	6	7
	side root	1	2	3	6	**<u>15</u>**
P.megakarya	main root	2	3	3	4	6
	side root	0	1	2	4	**<u>13</u>**

* Out of 30 main root and 120 side root pieces.
Values for side roots in bold and underlined (eg. **<u>15</u>**) differ significantly ($P < 0.05$) from the corresponding value for one application of zoospores.

Experiment 4 : Recovery of *P.palmivora* and *P.megakarya* after Application of Zoospores to the Soil Surface

This experiment examined survival of the two *Phytophthora* species over a period of 6 months after five applications of zoospores. Fourteen pots with seedlings were treated with five applications of *P.palmivora* zoospores as described for treatment 5 of Experiment 3. Fourteen pots were similarly established using *P.megakarya* and a further fourteen pots using equal amounts of mixed zoospores of both species to give the same overall total of zoospores per pot. Three pots of seedlings were treated only with SDW to provide "controls", if required.

The plants in each zoospore treatment were randomized in pairs (plants A and B) for sampling. The first sample was taken 7 days after the last zoospore application and subsequent samples were taken at monthly intervals for 6 months. On each occasion plant A in each treatment was chosen. Plant B was retained for another test if no fungus was recovered from plant A. Two root samples from each plant were prepared each with 50 pieces of side root and 5 pieces of main root. One sample was rinsed only in SDW, the other was surface streilized before plating on PPMA.

Colonies obtained one month to 6 months after treatments with mixed zoospores were characterized as *P.palmivora* or *P.megakarya* on the basis of their colony morphologies (Brasier & Griffin, 1979). Colonies from root pieces were tranferred to fresh plates of 20% V8 agar and incubated at 25° C. After 4 days, colony morphologies were assessed and isolates with a stellate-striate pattern assigned to *P.palmivora* or to *P.megakarya* when this pattern was not apparent.

Recovery of the two fungi was not significantly different in any comparison of the hypochlorite and SDW treatment, so these values are combined in Table 4. Recovery of both fungi, either singly or combined, was low from pieces of main roots though the results did indicate that at least *P.palmivora* could survive for 5 months. The large samples of pieces from side roots permitted comparisons of the recovery at different times using chi-square. There was no significant decline in recovery (over that at Day 7) until month 5 for *P.palmivora*, month 3 for *P.megakarya* and month 6 for the mixture of the two species. The results showed that in this system *P.palmivora* could be recovered from roots up to 5 months and *P.megakarya* for at least 6 months.

TABLE 4 : RECOVERY OF *PHYTOPHTHORA PALMIVORA* AND *P.MEGAKARYA* FROM COCOA ROOTS BETWEEN DAY 7 AND 6 MONTHS AFTER APPLICATIONS OF ZOOSPORES TO THE SOIL SURFACE

Species Applied	Root Type	No. Root Pieces * from which Fungus was Isolated						
		Day	Month					
		1	1	2	3	4	5	6
P.palmivora	main root	2	1	1	1	1	1	0
	side root	14	9	5	6	7	**1**	0
P.megakarya	main root	2	1	1	0	0	0	0
	side root	12	10	43	**2**	**3**	**3**	**1**
P.palmivora and	main root	2	2	1	0	0	0	1
P.megakarya	side root	11	9	9	7	8	**4**	**1**

* Out of 10 main root and 100 side root pieces.
Values for side roots bold and underlined (eg. **2**) differ significantly ($P < 0.05$) from the corresponding value for Day 7.

There was no indication that one species predominated or that its survival was substantially altered when mixed inocula were applied to the soil (Table 5).

TABLE 5 : CHARACTERIZATION OF ISOLATES FROM SIDE ROOTS FOLLOWING APPLICATIONS OF BOTH *PHYTOPHTHORA PALMIVORA* AND *P.MEGAKARYA* TO THE SOIL SURFACE

Species Isolated	No. Isolations * on Month					
	1	2	3	4	5	6
P.palmivora	4	6	6	5	1	0
P.megakarya	5	3	1	3	3	1

* Based on a sample of 100 side root pieces.

Experiment 5 : Infectivity of *P.palmivora* and *P.megakarya* Recovered in Soil Water

This experiment sought to establish whether the association between the two fungi and roots, demonstrated in Experiment 4, could give rise to potentially infective inoculum. It used three pots from that experiment which were not required for sampling, one each for soil treated with *P.palmivora*, *P.megakarya*, and SDW, 4 months after these pots had been so treated. First, suspensions of small amounts of the surface soil (0-3 cm) were plated on PPMA but no *Phytophthora* was recovered. Next, the drainage holes on the three pots were sealed with a double layer of parafilm and several layers of tape to prevent water loss. The soils in each pot was then saturated by applying SDW gradually until a thin film of water remained permantly on top of the soil. Each pot, except the aerial part of the seedling was covered with a polythene bag to prevent direct evaporation of water from the soil. After 24h, soil suspensions were withdrawn from the top soil using sterile Pasteur pipettes and 0.5 ml portions were spread on PPMA. There were ten replicate plates for each pot.

One colony each of *P.palmivora* and *P.megakarya* were recovered using soil suspensions from pots inoculated with singly with each species. Two colonies were also obtained from soil inoculated with a mixture of the two species and both colonies were identified as *P.megakarya*. Tests on cocoa pods showed that all these isolates were highly pathogenic.

DISCUSSION

The main purpose of this set of experiments was to examine the hypothesis of Gregory et. al. (1984) that *P.megakarya*, and possibly other cocoa *Phytophthoras*, have a primary life cycle on the ephemeral feeding roots of cocoa. These associations with roots, it was suggested, enable the fungi to survive dry seasons and then, when rain occurs and soils become saturated, to produce zoospores which concentrate at the soil surface from which they are transported to pods near the base of the trunk by fine droplets produced by impacting rain.

The experiments focused mainly on the establishment of *P.palmivora* and *P.megakarya* on roots and their ability to survive. The amount of inoculum to use and its placement were major problems. Dipping roots in zoospore suspensions ensured contact with much of the root system but scarcely represented the field situation. Nevertheless, these particular experiments showed that the fungus could become intimately associated with roots because they could be recovered from washed root pieces over a period of several months. However, if high zoospore concentration were used, the seedlings died.

Repeated application of low doses of zoospores to the soil proved to be a better technique, and has the merit of simulating the movement of fungal propagules by rain washing over infected pods, but these low doses themselves presented problems of sampling. Comparatively large numbers of root pieces had to be used to recover the low amounts of *Phytophthora* and to determine survival. But the recovery of such low levels over 4-6 month periods indicated more realistically how the fungus might survive on roots from one season of pod production to the next, especially since continued root growth would offset any harmful effect on a mature tree as well as providing new sites for this limited amount of colonization.

The extent of root colonization by the two *Phytophthora* species depended on the number of zoospore applications to soil (Table 3). Recovery of *Phytophthora* from field soils is thus more likely when black pod is abundant and the fungus is washed onto soil. This is apparent in the data of Ward and Griffin (1981). In Nigeria they recovered *P.palmivora* and *P.megakarya* frequently from roots sampled between June and November, when there was plenty of inoculum, but not in samples collected before July when inoculum from trees was relatively sparse.

Although, in the experiments described here, both *P.palmivora* and *P.megakarya* persisted in association with roots for at least 6 months, recovery of both fungi generally declined with time. The evidence is that the roots enable a low population of the fungus to survive but not that cocoa roots are important sites for fungal multiplication (Gregory, 1981). The experiments indicated that side roots provide a better niche for both *P.palmivora* and *P.megakarya* but the results must be interpreted with some caution because the extent of sampling main roots was limited. Nonetheless, this finding does agree with the sampling done in Nigeria; Ward and Griffin (1981) isolated both *P.palmivora* and *P.megakarya* frequently from current and the previous year's roots but only rarely from older lateral roots.

Precisely where these fungi are in roots is less clear. Recovery from root pieces treated with hypochlorite and those washed only in SDW was similar. It might be argued that the fungi invade the roots but are generally within in the surface layers. Other reports suggested that the *Phytophthora* species were inside roots. For example, Ward and Griffin (1981) recovered *P.palmivora* and *P.megakarya* from roots surface sterilized in 2% calcium hypochlorite for 15 min and Pereira (1988) isolated *P.palmivora, P.capsici* and *P.citrophthora* from cocoa roots surface sterilized in 3% sodium hypochlorite for 3 min and then rinsed in ethyl alcohol.

The recovery of *P.palmivora* and *P.megakarya* propagules from water collected from the soil surface (Experiment 5) has an important epidemiological significance. Although it was not clear what propagules were recovered, it demonstrated the potential of the two species to reach the soil surface. Cameron and Carlile (1977) found that zoospores of *Phytophthora* species, including *P.palmivora*, tended to swim against gravity resulting in a high concentration of zoospores just below the surface film. From there zoospores could be splashed by rain onto cocoa pods or other susceptible sites. The mode of survival of the *Phytophthora* species in cocoa roots remains a topic worth further investigation.

ACKNOWLEDGMENTS

The authors thank Dr G.K.Owusu and Dr L.A.A.Ollennu for their suggestions in the preparation of this paper. The first author also thanks the British Council for providing financial support during his stay at Imperial College, Silwood Park, UK, where this study was undertaken.

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A FARMING SYSTEMS ANALYSIS OF THE MISTLETOE PROBLEM IN GHANAIAN COCOA

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INTRODUCTION

Mistletoes, (family *Loranthaceae*), are common parasites of trees in the humid forest zone of West Africa. Williams (1963) and Phillips (1977) list 39 forest species, seven ornamental plants and seven fruit species, including cocoa, which are hosts of *Tapinanthus bangwensis,* the most widespread mistletoe in Ghana. About 70% of mistletoe infestations on cocoa in the country have been attributed to *T.bangwensis* (Room, 1972). Infection of cocoa by mistletoe results in the death of the branch distal to the host-parasite union, damage which leads to loss of vigour, reduction in pod yield and eventual death of the tree. Regular removal by pruning has therefore been considered an essential management practice since the 1920s (Bunting, 1926). Pruning has remained the recommended control method and is described in cocoa management manuals prepared by Cocoa Research Institute of Ghana and currently used by Cocoa Services Division (CSD) extension officers (Manu & Tetteh, 1987). These assume that farmers have access to a long handled "standard pruner" which allows the removal of individual mistletoe plants from high in the cocoa canopy. As the rate of growth of mistletoe is relatively slow in the early stages of infection, Room (1972) considered that control every other year would be effective. When a pruner is unavailable farmers are said to climb the tree and cut out the mistletoe with a cutlass (Phillips, 1977). However since the 1970s studies have highlighted the widespread infestation of cocoa farms by mistletoes which in many instances, particularly where cocoa trees are old and consequently tall, have been reported to grow more or less uncontrolled. For example a study in Offinso District, Ashanti Region concluded that there was "very widespread abundance of mistletoes in the study area; generally control was not reported to be practised" (Henderson and Jones, 1990). A recent survey indicated that mistletoe is a problem in all of the six cocoa producing regions which were studied and concluded that the parasites are among the causes of the decline in cocoa production in Ghana (Anon, 1995a).

Ghana's cocoa production declined from the mid 1960s when it accounted for 33% of global cocoa supplies (570,000 tonnes in 1964/5), reaching an all time low of 158,000 tonnes in 1983/4 (Anon, 1995a; Anon, 1996). This has been attributed to consistently low internal producer prices, and the management neglect that these generate. Following the Ghana Government's Economic Reform Programme and associated pricing reforms in the early 1980s cocoa output began to rise reaching a level of 300,000 tonnes in 1990. Despite some fallback during the early 1990s production has been increasing as producer prices have improved significantly. The value of cocoa to rural communities has remained considerable with the industry providing employment and income for over 24 per cent of the population and for many households in the cocoa belt it provides the main source of employment and cash for non-food expenditures such as school and medical fees (Anon, 1995a). Dramatic increases in producer prices over the past three years, and the likelihood that international cocoa prices will remain on a rising trend beyond the year 2000 (Bateman et. al., 1987) provide an opportunity to address the decline in

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Ghanaian cocoa. This is particularly the case with control of mistletoes and other crop protection measures which require regular seasonal investment. A study was therefore undertaken which aimed at understanding farmers' perceptions of mistletoes and their control, and sought to investigate the potential for the adoption of control measures.

UNDERSTANDING THE IMPORTANCE OF MISTLETOE

The Field Study

This field study was designed to develop an understanding of the farming and livelihood system (including farmer resource levels) and the principal constraints facing cocoa production in Ghana as they are perceived by farmers. The work focused on crop protection issues, and specifically the control of mistletoes, using semi-structured group interviews (a rapid appraisal technique).

Due to the relatively short period of time available to conduct the fieldwork it was concentrated in two areas - Eastern and Ashanti Regions. Group interviews were conducted in 19 villages (see Overfield and Riches, 1997 for village summaries) focusing on three different aspects:

i. The general farming and livelihood system (including credit and labour/enterprise arrangements and knowledge systems);
ii. General problems with cocoa production including crop protection issues;
iii. Detailed discussions on mistletoe control and other crop protection measures.

The interviews, conducted with groups of farmers in each village, covered land tenure, access to credit, farm inputs and agricultural knowledge, labour arrangements, age and cultivar profile of cocoa farms, farmer perceptions of cocoa production constraints, crop protection practices including mistletoe control, cocoa marketing and perceptions of the future role of cocoa in the livelihood of the village. Group size varied from 3 to 46 informants (with most in the 15-20 range); a total of 444 growers participated in the fieldwork. Each group session lasted from 60 to 90 minutes and where time allowed was followed with inspection of a nearby cocoa farm which generated further discussion. The interviews were conducted by NRI and CRIG staff with additional logistical support provided by extension officers of the Cocoa Services Division (CSD).

Structure of the Farming and Livelihood System

Tables 1 and 2 rank the importance of the various crops grown by the farmers interviewed. Farmers were asked to list and rank all the crops grown in the village; the results presented in the table represent the top three ranking crops only as mentioned (upon consensus) during the meetings.

It is clear that plantain, cassava and maize dominate the food crops in the cocoa growing areas in which the fieldwork took place. These crops are also important sources of cash income as Table 2 reveals; though all are much less significant than cocoa. Cocoa was the dominant source of cash in all the communities visited as part of the field study. Not only is it a source of cash but also of status and credit;

pledging one's cocoa trees to money lenders is one of the few sources of credit available to farmers at the current time.

TABLE 1 : RANKING OF FOOD CROPS

Crop	Number of Times Mentioned *	% of Villages **
Plantain	19	100
Cassava	17	89
Maize	13	68
Cocoyam	5	26
Rice	3	16
Vegetables	1	5

* Top three ranking crops only (meeting consensus).

** Percentage of villages placing crop in the top three ranking positions.

TABLE 2 : RANKING OF CASH CROPS

Crop	Number of Times Mentioned *	% of Villages **
Cocoa	19	100
Maize	9	47
Cassava	8	42
Plantain	6	32
Rice	3	16
Vegetables	3	16
Cocoyam	2	11
Sugar Cane	1	5
Ginger	1	5
Kola Nuts	1	5
Citrus	1	5
Banana	1	5

* Top three ranking crops only.

** Percentage of villages placing crops in the top three ranking positions.

Table 3 is concerned with all other sources of cash income and it is clear that a number of sources are available to rural communities in cocoa growing areas. However apart from petty trading, these activities are not widespread throughout the community and only affect a few individuals. Additionally the village meetings revealed (in terms of the overall community) that all these activities generally pale into virtual insignificance compared to agricultural activities and especially in relation to cocoa. This confirms the findings of previous studies (Anon, 1995a; Anon, 1995b; Henderson and Jones, 1990) that cocoa despite recent declines is still a fundamental component of the rural livelihood system in Ghana and is therefore worthy of further concern and investment; farmers are still very committed to the crop and do not really want to shift into any major alternatives.

TABLE 3 : OTHER ECONOMIC ACTIVITIES (CASH SOURCES)

Economic Activity	Number of Times Mentioned	% of Villages *
Petty Trading	15	79
Artisans	15	79
Distilling	11	58
Livestock	8	42
Employment	8	42
Oil Palm Processing	4	21
Gari Processing	3	16
Soap Making	2	11
Logging	2	11
Kenkey Making/Selling	2	11
Firewood Selling	2	11
Charcoal Making	2	11
Baking	1	5
Broom Making	1	5

* Percentage of villages mentioning the income source (all sources, not just highest ranking).

Ghanaian Cocoa Costs of Production and Economic Returns

Details on costs of production are impossible to collect when utilising group-based rapid appraisal techniques. This information has also been the subject of previous studies and the results of one in particular (Asante, 1992) are worth summarising here.

Using a classification system based on level of technologies and landowning status (landowners and abusa [1] caretakers) Asante calculated the marginal net economic benefits (MNEB) associated with cocoa production (based on survey work in 1988 and using 1992 prices for labour and cocoa). At technology levels (for full definition see Asante, 1992) which account for the largest single group of farmers [2] (about 60%) the net benefits are positive for landowners, abusa farmers (owners) but negative for abusa tenants (caretakers). For the next level of technology (T2), accounting for 25% of cocoa growers (which involves the use of hybrid seed) all returns are positive and higher than technology level one (T1).

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[1] In which the landowner takes two-thirds of the proceeds and gives one-third to the caretaker. The landowner is supposed to provide all the inputs (but usually does not in current circumstances) and therefore takes the major share. However, for younger caretakers, when plantings are often old (and therefore lower yielding), there is general dissatisfaction with this share making cocoa caretaking an unattractive proposition; landowners said it was virtually impossible to attract caretakers under this system in some areas.

[2] This includes seed taken from own farm, planting at stake, at random spacing, high density with 2500 or more plants/hectare, infrequent brushing, no pruning and infrequent removal of mistletoe. Little or no spraying against capsids or blackpod, shade control not normally practised. This group accounts for approximately 60% of all cocoa growers (World Bank/FAO, 1986).

However these returns/hectare (total before dividing shares between owners and caretakers) remain small at T1 - 32430 Cedis (£9.53 at current exchange rates [3]) and for T2 - 53493 Cedis (£15.73). Cocoa is a marginal economic activity at low levels of technology and it is against this economic background that any recommendations for improvements in mistletoe control have to be set.

Age of Plantings, Age of Farmers, Caretaker Systems and Economic Incentives

The most recent national survey revealed that 67 % of cocoa farms were in the age range 8-30 years (i.e. economically productive), 20% too old and unproductive (31-60 years) and 9% not yet at full bearing (less than 7 years old); approximately two-thirds of farmers were found to be over 50 years old (limiting physical exertion - important for mistletoe control) with less than 4% younger than 30 years (Anon, 1995a). Footnote 1 describes how the economic incentives to abusa caretakers (a very significant proportion of cultivators) were negative for the largest proportion of growers (using the lowest level of technology); this is a serious disincentive for the uptake of any new or adapted technologies including those related to mistletoe control.

Farmer's Perceptions of Constraints

The ranking of the farmer identified cocoa production constraints is presented in Table 4.

TABLE 4 : RANKING OF COCOA PRODUCTION CONSTRAINTS *

Problem	Number of Times Mentioned	% of Villages
Mistletoes	9	100
Capsids	15	79
Blackpod	10	53
Termites	6	32
Stemborers	4	21
Weeding	3	16

* Other constraints were also mentioned by one or two villages but have not been included in the table. See Overfield and Riches, 1997 for further detail.

Mistletoes come out at the top of this table with all villages expressing a concern over their control (very closely related to the lack of long-handled pruners and old, and therefore tall, trees); this is higher than in many previous studies and it is possible that the focus of this work may have biased the results. However all previous studies (Anon, 1995a; Henderson and Jones, 1990) have all placed mistletoes high in the rankings (usually at number 2 or 3) and it is clear that farmers perceive mistletoes to be a major constraint on their cocoa farms. The rest of the rankings in this study are similar to the previous studies with the exception of weeding which usually appeared near the top of the rankings; this problem relates to seasonal labour shortages due to competition from food crops during their main season.

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[3] At the time of this study (July, 1997) this was in the region of £1 = Cedis 3400. However, at the time of Asante's work, the Cedi was much stronger at around 1$ = Cedis 459, which would have produced a return/hectare of $70.65 (£46.63).

There is considerable interest and enthusiasm for controlling mistletoes by farmers but they are constrained by the lack of physical supply of long-handled pruners, and thus the danger and unpleasantness of removal by machete after climbing up the tree. The lack of economic incentive for abusa caretakers (who are younger and therefore physically more able to conduct this activity) also influences the level of neglect on this cocoa management area.

Access to Credit

Underlying many of the constraints identified in Table 4 is lack of capital to deal with them, which is in turn related to liquidity and lack of credit in rural areas. In the rural areas visited during the field study only one significant and widespread form of credit appears to exist which is the pledging of cocoa farms (and occasionally other higher value personal items) to money lenders. Money lenders charge interest of more than 100% per annum and require security to cover the whole value of the loan. The high charges associated with this form of credit virtually preclude its use in cocoa or other agricultural production and its use appears to be generally limited to emergencies (funeral expenses etc.). This effectively means that there is no affordable credit in rural areas for agricultural investment at the current time; this is clearly a major constraint and one which affects any future work on mistletoe control - an institutional system needs to be devised to address this problem.

Current Control Measures

Mistletoes which infest cocoa are also a feature of the canopy of forest trees which shade cocoa farms. These provide a constant supply of mistletoe seed, brought into the cocoa canopy by birds, and regular action is necessary to keep the crop healthy. Two methods of mistletoe control, pruning of infected branches or coppicing of cocoa trees, were undertaken with varying degrees of intensity throughout the surveyed villages. Some pruning had been undertaken in all bar one village during the previous two years. Participation ranged from 5 to 60% of all farmers interviewed; in 10 villages (out of 19) 30 to 60% of farmers prune out mistletoe regularly. Coppicing is undertaken as a last resort in an attempt to rehabilitate trees on which a large proportion of the canopy has been killed by infections. Coppicing was mentioned by farmers in only 4 villages and does not appear to be a common practice.

Although those who do prune indicated that this would be done every year, inspection of cocoa farms revealed that many of the mistletoe plants which had been cut are large and would appear to have been growing for some years. One problem is that mistletoes are not easy to see, particularly in the canopy of tall trees. Secondly there may be many infestations in one tree, so farmers will remove those which are most obvious and that are causing the most dieback of the host. The majority of pruning is carried out with a cutlass; farmers either use home made ladders or climb tall cocoa trees to reach infested branches. This is not without danger; a number of farmers reported falls and injuries. Mistletoe removal is also made unpleasant by biting red ants which are associated with them. Some farmers, have given up pruning because of the danger involved. As an alternative to the cutlass, a cocoa pod harvesting hook (a small sickle) attached to the end of a long pole is sometimes used. While this can be effective for cutting off small mistletoe plants, it is little use on larger infestations high in the tree canopy.

Farmers remember the days - 10 to 20 years ago - when long handled (imported) "standard pruners" were readily available and widely used for mistletoe control. Only 16 working pruners were reported in the 19 villages in which our study was conducted. In 12 villages all of the pruners which had once been available are now broken and have been discarded. We understand that pruners were last sold in 1991.

The price paid by growers for mistletoe removal is approximately 20-40% higher than labourers demand for other cocoa management operations such as weeding, reflecting that climbing trees and using a cutlass is generally accepted to be an unpleasant, difficult and potentially dangerous task. Even so a number of farmers reported that it can be difficult to find labourers willing to take on the task. There is considerable variation in the willingness of the few farmers who still own a pruner in working order to allow others to us it. While a few may lend pruners, there can be a charge of ¢2000 to ¢3000 per day (£0.58 to £0.88)); others refuse to lend or hire, indicating that this would lead to damage.

Can Mistletoe Control be Improved in the Future?

During village meetings cocoa farmers demonstrated a clear understanding of the mistletoe problem, that seeds are spread in the crop canopy by birds, and that infestation leads to a reduction in host vigour and, when no pruning is carried out, the eventual death of the tree. That growers are clear about the need to manage the problem is to some extent associated to the pivotal role of cocoa in the farming system. Cocoa plots are an important form of security, probably the only vehicle which many households can use to gain credit. Farmers see the maintenance of the farms, albeit at a very low level of productivity, as an essential duty so that the trees can be passed on to future generations. Mistletoe control should therefore be viewed in a different light to other important crop protection constraints. It allows the maintenance of the health and longevity of the farm and therefore the potential that with increasing producer prices the "good days" may one day return. Capsid or black pod control is more responsive to immediate producer price changes due to the short term nature of the control brought about by chemical application and the high cost of inputs. Furthermore a number of factors must be in place to enable farmers to apply chemicals - including the timely supply of inputs and sprayers, let alone liquidity. With access to suitable equipment mistletoe control, on the other hand, can be sustainable without seasonal purchases.

There is therefore considerable interest and enthusiasm in the farming community for controlling mistletoes although the constraints described earlier in this article have clearly reduced farmers ability to deal with the problem. The regularly stated view of farmers is that the problem is far worse than it was 20 years ago when pruners were generally available and when cocoa trees were shorter. During the intervening period the average age of cocoa farmers has increased and older farmers are unable to climb trees to remove mistletoes. Cocoa production is a marginal economic activity at the low levels of technology and inputs used by the majority of producers. It is generally agreed that in the past cocoa owners expected tenants to remove mistletoe regularly to maintain the health of the farm. With owners now making little investment in their crop following a number of years of poor producer prices many tenants are no longer prepared, particularly with no access to pruners, to even attempt to control mistletoe.

The likely high cost of pruners in relation to net returns per hectare suggest that it will be very difficult for individual farmers to purchase pruners, especially when credit is not readily available. Even returns from hybrid cocoa with regular pest control, accounting for 25% of growers, are small at little more than

¢50,000 per hectare (£14.70) (Asante, 1992). It is unlikely that a pruner could be fabricated and supplied to the market at less than ¢50,000 (£14.70). This throws up institutional questions about how to supply pruners effectively (groups/subsidies etc.). Despite these constraints there still appears to be an overwhelming demand for pruners from farmers. While it is clearly difficult to focus on the value of an item which is not currently available, farmers suggested that they would be prepared to pay ¢10-15,000 (£2.94-£4.41) for a pruner. A number suggested that groups of 5-6 farmers could get together and buy one.

Mistletoes are not a new problem and have been covered in other reports; recommendations have also been made about the supply of long-handled pruners. There is a clearly a need for an intervention to deal with the problem and any future work should have as its focus kick-starting the pruner supply (design, local manufacture, field testing including cost benefit analysis and farmer perceptions) and development of appropriate mechanisms of ownership (to deal with the capital cost). It is important to act now on the back of rising international (and therefore domestic) cocoa prices which will probably only last for a few seasons whilst farmers have the incentive and potential cash flow to deal with it. Investments carried out now or very soon would continue to yield returns for farmers when prices inevitably take a downturn. Our analysis emphasises the use of a pruner for mistletoe management. This was a technology which found widespread acceptance in the past. There appears to be no reason to doubt that in the right enabling environment there would once again be widespread adoption.

ACKNOWLEDGEMENTS

This article is published with the permission of the Executive Director, CRIG. The study was funded by the Department for International Development (DFID) of the United Kingdom.

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

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