The establishment and early yield of cocoa intercropped with food crops in Ghana

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SUMMARY

A cocoa-food crop intercropping trial was set up in 1988 at the Cocoa Research Institute of Ghana, Tafo. The effects of plantain, cassava, and maize as intercrops with cocoa only and in their various combinations on the establishment, growth of the cocoa, and the profitability of the food crops were studied in a randomized block experiment with five replicates. Mixed hybrid cocoa seedlings were planted at 3 m × 3 m and *Glyricidia maculata* provided permanent shade in all plots. Three years after planting, the sole cocoa with *Glyricidia maculata* was inferior in growth to the cocoa interplanted with food crops. Cocoa in treatments which included maize showed superior growth and better precocity. Yield of each food intercrop with cocoa only was higher than when combined with other food crops. Sole cocoa gave less revenue equivalent to the operational costs during the establishment phase. The other food crop combinations with cocoa gave net revenue gain in the first 2 years after planting. The economic evaluation of the food crop combinations indicated that treatments which included cassava were the most profitable.

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RÉSUMÉ

OSEI-BONSU, K., AMOAH, F. M. & OPPONG, F. K.: *L' encracinement et le rendement tôt de cacao semé entre les lignes des cultures vivières au Ghana.* Un essai de cacao-culture vivière semés en lignes alternantes étaient établis en 1988 à l' Institut Ghanéen de Recherches en Cacao à Tafo. Les effets de plantain, de manoic et maïs en tant que des cultures semées entre les lignes de cacao unique et de leurs combinaisons diverses sur l'encracinement, la croissance du cacao et la rentabilité des cultures vivières étaient étudiées dans une expérience en bloc choisie au hasard vaec cinq replicatifs. Des semis de cacao de hybride mixte étaient plantés a 3m × 3m et *Glyricidia maculata* pourvaient l'ombrage permanent dans tous les lots. Trois ans aprés la plantation, le cacao unique avec *Glyricidia maculata* était inférieur en croissance au cacao semé entre les lignes des cultures viviéres. Le cacao dans les soins qui comprenaient le maïs montrait une croissance superieure et une précocité meilleure. Le rendement de chaque culture vivière semée entre lignes de cacao unique étaiet plus élevé que lorsqu'elle combinait avec d'autres cultures vivirière. Le cacao seul donnait moin de revenu équivalent aux coûts opérationnels pendant la phase de l'encracinement. Les autres combinaisons de culture vivrière avec le cacao donnaient un gain revenu net dans les deux premières années aprés la plantation. L'évaluation économique des combinaisons de culture vivrière indiquait que les traitements qui comprenaient le manoic étaient les plus rentables.

Introduction

Traditionally, cocoa farmers in Ghana establish their farms with food crops into which cocoa seed is either sown directly at stake or seedlings planted (Benneh, 1987; La Anyane, 1963). The temporary shade provided by the food crops provides direct shade to the cocoa seedlings. The farmer in turn depends on the food crops as a staple for the household and for economic sustenance during the growth period of the cocoa.

Food crop farms usually combine common staples such as plantain, cocoyam, maize, yams, cassava, and vegetables in various proportions and with different spatial arrangements (Owusu-Bempah, 1988; Wills, 1962). Scientifically, very little interest has been shown in this complex

farming system (Fordham, 1983) for failing to satisfy the conventional requirements of treatment standardization (Willey, 1985). However, the merits of such intercropping systems have recently been shown in cocoa-tree crop systems (Egbe & Adenikinju, 1990; Oladokun, 1988; Kolade, 1986; Alvim & Nair, 1986; Adegeye, 1985) and in cereals combined with legumes (Francis, 1986; Ofori & Stern, 1987). The adoption of any system of agricultural production is usually influenced by socio-economic factors including the risk factor associated with a particular farming system. Thus, in spite of the emphasis of research and development on monocrop systems, intercropping remains wide- spread (Fordham, 1983). The economics of such intercropping practices and the biological advantages to the soil must, therefore, be evaluated as a whole (Willey, 1985). Such information is lacking on the cocoa-food crop cropping system in Ghana.

This study aimed to evaluate the effect and profitability of some cropping systems on cocoa establishment in Ghana.

Materials and methods

The experiment was set up at the Cocoa Research Institute of Ghana, Tafo, between 1988 and 1990 on land which had previously been under cocoa for more than 20 years. The old stand of cocoa was completely grubbed and the land cleared of debris by localized (heap) burning, a practice referred to as "controlled burning" (Webster & Wilson, 1969), in preparation for the planting of the food crops.

A randomized block design with five replicates was used. Plots measured 18 m × 18 m. The treatments evaluated were as follows:

Sole cocoa (control)
Cocoa/plantain intercrop
Cocoa/cassava intercrop
Cocoa/maize intercrop
Cocoa/plantain/cassava intercrop
Cocoa/cassava/maize intercrop
Cocoa/plantain/maize intercrop
Cocoa/plantain/cassava/maize intercrop

Maize was planted at 1 m × 0.5 m, cassava at 1 m^2, and plantain at 3 m × 3 m, with plant populations of 20,000, 10,000, and 1,111 ha^{-1}, respectively. The maize, cassava, and plantain in each plot were at 0.5, 1, and 3 m from cocoa stands, respectively. Six -month-old cocoa seedlings of uniform growth were transplanted in June 1988 at 3 m × 3 m (1,111 plants ha^{-1}). *Glyricidia maculata* was planted in all plots at a spacing of 6 m × 6 m and later thinned to 12 m × 12 m to provide permanent shade for the cocoa. Maize was planted in April and September each year and harvested in July and December, respectively. The first cassava crop planted in April, 1988 was harvested in February 1989, and subsequently recropped between March and February of each year. Vacancies in the plantain were filled every year. The last planting of food crops was carried out in 1990 after which the closed cocoa canopy did not permit further intercropping.

A basal dressing of 68 kg ha^{-1} sulphate of ammonia and 45 kg ha^{-1} triple superphosphate was applied annually to all treatments until the 3rd year (1990) to augment the soil nutrients after the long period that the area was under cocoa. In addition, treatments which were planted with cassava received 45 kg ha^{-1} muriate of potash each year as recommended (Nye & Stephens, 1962). Soil samples from 0 to 30 cm depth were taken from the experimental area and also from an adjacent fallow plot infested mainly by *Chromolaena odorata* before and after the experiment was planted.

Weed control, on treatment basis, was carried out manually or chemically with glyphosate at 2.5 l ha^{-1} as and when necessary. Data were collected by man-day requirements for weeding, shade adjustment, chupon removal, and harvesting on treatment basis. Girth and height were measured on 16 core cocoa seedlings at 3-monthly intervals beginning at 6 months after transplanting. Insect pest was control led as and when necessary using Unden. Food crop yields were estimated from a core area of 12 m^2 per plot during harvesting. Yield of plantain was estimated on bunch fresh weight, cassava on fresh tuber weight, and maize on shelled

grain weight of about 13 per cent moisture content. The Ministry of Food and Agriculture prices published monthly were used to compute the prices of the food items on per hectare basis. The discounted net benefit of each cropping system was computed from the total production cost and the gross revenue (CIMMYT, 1988). Early flowering and the number of healthy pods produced were also used to evaluate the effects of different treatments on the cocoa.

Results

Table 1 shows the soil characteristics of the study area. The data do not, however, represent the inherent nutrient status of the soil as the experimental plots were fertilized. The carbon contents of the soils under the fallow (more than 10 years) and mature cocoa were higher compared with those from soil in the experimental areas. Except for moderate to strongly acidic reaction in soils from the cocoa/plantain treatment, the *p*H values of the other soils were similar. The base exchange capacities of the soils under the different treatments were similar in value but much lower than those under the fallow.

Table 2 shows data on cocoa seedling growth. There were no significant differences in the girth of cocoa seedlings in treatments which included maize; such seedlings being significantly bigger ($P \leq 0.05$) than the other treatments in 1988/89. In 1989/90, cocoa from the maize intercrop produced significantly bigger ($P \leq 0.05$) stems than those from the cassava/maize and plantain/maize systems. These were in turn bigger than those from the other systems ($P \leq 0.05$). Cocoa inter-planted with cassava, maize, cassava/maize, and plantain/maize were significantly taller ($P \leq 0.05$) than those from the other treatments in 1988/89 and 1989/90.

Table 3 shows the yields of food crops intercropped with cocoa. Generally, food crop yields tended to be higher when intercropped with cocoa only than when combined with other food crops and cocoa. However, whether planted solely or in mixture, food crop yields were higher during the 2nd year of cropping. Yields dropped drastically in the 3rd year despite the application of fertilizers. Similarly, maize planted in September gave poorer yields than those of April each year.

Cocoa intercropped with maize showed a significantly higher ($P \leq 0.05$) proportion of flowered plants after 2 years than in all other treatments whilst the sole cocoa treatment gave the least number of flowered plants (Table 4). Three years after planting, there were no differences in pod production from cocoa intercropped with cassava, maize, cassava/maize, and plantain/maize, but these treatments gave higher ($P \leq 0.05$) pod yields than sole cocoa, cocoa intercropped with plantain, cassava /plantain, and plantain/cassava/maize. Sole cocoa and cocoa intercropped with plantain gave similar yields which were significantly higher ($P \leq 0.05$) than cocoa intercropped with plantain/cassava or plantain/cassava/maize (Table 4).

Table 5 shows the expected revenue computed by annual sale of the food crops. Among the three food crops, cassava gave the highest gross revenue, followed by plantain and maize. The cassava/plantain/maize intercrop gave the highest gross revenue over the 3-year period, followed by cassava/plantain and cassava/maize. Intercropping cocoa with maize alone gave the lowest gross revenue. A discounted net benefit analysis on the gross revenue receipts and the total operational cost (Table 6) showed that sole cocoa gave net revenue deficit equivalent to the operational costs on yearly basis. All food crop combinations with cocoa yielded net revenue gain in 1988 and 1989. However, in 1990, net revenue loss was recorded in the cocoa/cassava and cocoa/maize treatments although the cumulative incomes from the other two previous years seem to indicate that the system is profitable. For profitability of the systems, cocoa/plantain/cassava, cocoa/cassava/maize, and cocoa/plantain /cassava/maize were superior to the other treatments.

Discussion

Much of the success of intercrops in cocoa establishment depends on understanding the role each component plays in the system. From indigenous

TABLE 1

Some Characteristics of the Soil under the Different Cropping Systems

Treatment	Exchangeable bases							Exchangeable bases						
	pH	*N*	*C*	*P*	*K*	*Mg*	*Ca*	*pH*	*N*	*C*	*P*	*K*	*Mg*	*Ca*
		Percentage		*Total*	*Mg/100 g soil*				*Percentage*		*Total*	*Mg/100 g soil*		
	0 - 15 cm depth							*0 - 30 cm depth*						
Sole cocoa	5.9	0.23	0.93	208.8	4.73	13.66	65.0	5.8	0.13	0.44	140.8	2.76	9.05	37.0
Cocoa/Plantain	4.8	0.22	0.83	219.3	4.37	11.03	69.4	5.7	0.13	0.46	142.0	2.66	8.39	46.8
Cocoa/Cassava	5.7	0.16	0.80	195.5	5.22	9.79	50.0	5.6	0.10	0.38	140.5	3.66	8.32	32.7
Cocoa/Maize	5.0	0.13	0.81	211.8	4.35	9.13	41.9	5.6	0.07	0.43	138.8	3.04	7.08	32.8
Cocoa/Plantain/Cassava	7.0	0.11	1.03	234.5	3.99	14.48	77.5	6.8	0.07	0.43	144.7	2.84	9.99	77.2
Cocoa/Cassava/Maize	5.9	0.16	0.84	230.3	2.94	11.27	57.1	5.7	0.07	0.42	163.3	1.79	9.38	36.9
Cocoa/Maize/Plantain	5.8	0.19	0.73	212.5	2.87	9.13	66.9	6.0	0.11	0.36	136.5	1.74	6.91	38.9
Cocoa/Maize/Plantain/Cassava	6.2	0.11	0.71	211.8	2.89	10.12	56.4	6.0	0.07	0.37	131.5	2.50	8.31	34.4
Control (Fallow Area, Pre-treatment)	7.4	0.13	1.35	256.4	6.11	28.38	139.4	7.5	0.06	0.65	241.3	2.69	14.91	119.0
Control (Mature Cocoa Soil, Pre-treatment)	5.8	0.09	1.63	307.2	5.49	30.14	139.9	5.4	0.05	1.12	241.3	1.73	20.57	88.6
SED (28 df)	0.6	0.06	0.18	32.67	1.36	2.15	20.83	0.5	0.03	0.07	21.76	0.95	1.23	20.86

TABLE 2

Effect of Intercropping Food Crops on the Growth of Cocoa Seedlings

Treatment	Mean girth increment (mm)		Mean height increment (cm)	
	1 year after planting	*2 years after planting*	*1 year after planting*	*2 years after planting*
Sole cocoa	8.31b	14.52e	37.2b	65.7d
Cocoa/Plantain	8.39b	16.62d	36.2b	69.5d
Cocoa/Cassava	9.07b	18.28c	47.1a	95.0a
Cocoa/Maize	10.40a	22.69a	51.9a	90.1a
Cocoa/Plantain/Cassava	8.05b	13.77e	37.3b	75.6c
Cocoa/Cassava/Maize	10.14a	19.62b	46.2a	96.9a
Cocoa/Plantain/Maize	10.11a	19.94b	49.1a	95.2a
Cocoa/Plantain/Cassava/Maize	9.30ab	15.38c	52.4a	87.7b

Means in columns carrying same letter are not significantly different at $P \leq 0.05$

TABLE 3

Yield (kg/ha) of Food Crops in Mixtures with Cocoa

Treatment	Plantain			Cassava			Maize		
	1988	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*
Cocoa	-	-	-	-	-	-	-	-	-
Cocoa/Plantain	6125	7089	3728	-	-	-	-	-	-
Cocoa/Cassava	-	-	-	14373	12426	2402	-	-	-
Cocoa/Maize	-	-	-	-	-	-	2970	3482	445
							3204*	3018*	-
Cocoa/Plantain/Cassava	3211	5934	2584	12829	11497	2722	-	-	-
Cocoa/Cassava/Maize	-	-	-	16061	13804	4319	1943	4012	436
Cocoa/Plantain/Maize	4728	4834	3306	-	-	-	2247	1534	210
							815*	766*	-
Cocoa/Plantain/Cassava/Maize	1453	5467	2056	13762	11183	3136	2072	+	398

*Minor season crop

+Crop failure

TABLE 4

Effect of Food Crops Intercropping on Flowering and Pod Production of Cocoa

Treatment	*Number of flowered plants ha^{-1} 2 years after planting*	*Usable cocoa pods ha^{-1} 3 years after planting*
Sole cocoa	125e	712b
Cocoa/Plantain	236d	798b
Cocoa/Cassava	416c	1094a
Cocoa/Maize	666a	1150a
Cocoa/Plantain/Cassava	194ed	356c
Cocoa/Cassava/Maize	500b	1235a
Cocoa/Plantain/Maize	555b	1249a
Cocoa/Plantain/Cassava/Maize	197ed	458c

Means in column carrying same letter are not significantly different at $P \leq 0.05$

TABLE 5

Revenue Expectations (Cedis) ha^{-1} from Food Crops Intercropped with Cocoa

	Plantain			*Cassava*			*Maize*			*Gross revenue on yearly basis*			
Treatment	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*Total*
Cocoa	-	-	-	-	-	-	-	-	-	-	-	-	-
Cocoa/Plantain	306250	425370	186405	-	-	-	-	-	-	306250	425370	186405	918025
Cocoa/Cassava	-	-	-	431183	497040	72072	-	-	-	431183	497040	72072	1000295
Cocoa/Maize	-	-	-	-	-	-	185190	259980	13338	185190	259980	13338	458508
Cocoa/Plantain/Cassava	160556	356028	129175	384877	459869	81657	-	-	-	545433	815897	210832	1572162
Cocoa/Cassava/Maize	-	-	-	481833	552176	129558	58298	260496	13080	540131	712672	142638	1395441
Cocoa/Plantain/Maize	236375	290022	165290	-	-	-	91854	91984	6285	328229	382006	171575	881810
Cocoa/Plantain/Cassava/Maize	72637	328026	102786	412853	447324	94092	62150	97912	11931	7640	873262	208809	1629711

TABLE 6

Cost Benefit Analyses (Cedis ha^{-1}) for Intercropping Trial

	Labour cost			*Fertilizer and insecticide cost*			*Herbicide cost*			*Total operational cost*			*Discounted net benefit*		
Treatment	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*	*1988*	*1989*	*1990*
Sole Cocoa	28,605(144)	31,929(132)	34,645(112)	30,250	33,852	33,852	10,160	15,819	7,260	69,015	81,600	75,757	-55,212	-52,224	-38,788
Cocoa/Plantain	32,379(163)	42,089(174)	42,378(137)	30,250	33,852	33,852	7,160	10,546	4,280	69,789	86,487	80,510	+189,169	+216,885	+54,218
Cocoa/Cassava	43,504(219)	60,472(250)	60,010(194)	41,180	44,788	44,788	33,680	5,250	-	118,364	110,510	104,798	+250,254	+247,379	-16,756
Cocoa/Maize	32,181(162)	45,233(187)	29,077(94)	30,250	33,852	33,852	7,160	10,546	4,280	69,591	89,631	67,209	+92,479	+109,023	-27,582
Cocoa/Plantain/Cassava	44,696(225)	59,989(248)	62,794(203)	41,180	44,788	44,788	7,160	10,546	4,280	93,036	115,323	111,862	+357,676	+455,196	+50,673
Cocoa/Cassava/Maize	60,786(306)	83,210(344)	63,722(206)	41,180	44,788	44,788	3,680	5.270	-	105,646	133,268	108,510	+347,588	+70,819	+17,474
Cocoa/Plantain/Maize	35,955(181)	48,378(200)	48,255(156)	30,250	33,852	33,852	7,160	10,546	4,280	73,365	92,776	86,387	+203,891	+185,107	+43,616
Cocoa/Plantain/ Cassava/Maize	64,560(325)	87,322(361)	65,578(212)	41,180	44,788	44,788	3,680	5,270	-	109,420	137,380	110,366	+350,576	+470,964	+50,403
Rate of pay per diem	198.65	341.89	309.32												

Figures in parentheses represent mandays used for all farm operations

knowledge acquired over the years, peasant cocoa farmers have identified the shade requirement of cocoa. Apart from the selective forest tree shade left for the mature cocoa, fast-growing annual food crops are planted to provide shade for the cocoa seedlings and also as subsistence to the farmer. In this way, farmers obtain the protection and growth of a tree crop underplanted in the food crops by direct regular brushing and indirect shade provided by the food crops. Benneh (1987) and Owusu-Bempah (1988) have elaborated on the roles played by both culture and gender to help achieve success in this land-use system where men would rather be concerned with the tree crop while women take care of the food crops. The food derived from this system provides for the immediate energy needs of the farming household while the excess is usually sold to generate income for other needs of the family (Benneh, 1987).

The financial returns from the food crops appear to determine the choice of the crop types cultivated by the farmer (Owusu-Bempah, 1988). This confirms the assessment of Bonaparte & Toseafa (1977) that cash flow constraints during the growth period of cocoa is a very important hindrance to rehabilitating cocoa farms. Moreover, the results of Bonaparte & Toseafa (1977) that cocoa growth was not adversely affected when intercropped with maize, vindicates the peasant farmer practices. This finding has been confirmed in this study, and also with cassava and plantain which are always intercropped with cocoa by farmers.

However, contrary to the findings of Bonaparte & Toseafa (1979), cassava did not affect the growth of cocoa when planted alone or in combination with other food crops, probably because all the cassava plots in the study were fertilized. The cocoa/plantain system now recommended (Manu & Tetteh, 1988) was not superior to the other treatments for cocoa growth, and the plantain/maize and plantain/cassava/maize intercrops enhanced better cocoa girth development than plantain alone. This may point to the need for a fast-growing shade plant such as cassava or maize to provide early good shade for cocoa rather than plantain which takes about 6 months to form a canopy.

Furthermore, the long dry season and the windstorms in March/April usually devastate the plantains so that effective shade is not actually provided to the cocoa in the latter part of the dry season when the shade is needed most. The poor performance of the sole cocoa treatment may have been due to poor shade provided by the *Glyricidia maculata*, initially owing to its slow establishment and later by its propensity to flower in the dry season when shade is most needed. This factor encouraged severe weed competition in the treatment which would also have slowed down the cocoa seedling growth (Bonaparte & Toseafa, 1977).

When compared with sole cocoa treatment, the shade provided by the food crops reduced weed growth considerably. Similar observations on weed competition in exposed plots have been made by Adenikinju, Esam & Adeyemi (1989) and Oladokun (1988). In shade efficiency studies of some temporary species, Hall (1962) noted that less weed infestation occurred in banana plots than in those with plantain, tree cassava or tree cassava/plantain mixtures, owing to the better shade provided by the banana. Cocoa seedling height was not depressed by intercropping with cassava, maize or plantain probably because seedling girth may be the more sensitive measure of growth than height (Glending, 1960).

On *pro rata* basis, treatments producing bulky starch crops such as cassava and plantain gave the highest net revenue. Such treatments might have improved the efficiency of light interception and conversion in this system (Fordham, 1983). This is advantageous to farmers in the interim period as they wait for the proceeds from the cocoa crop. The net revenue loss in 1990 from cocoa/cassava and cocoa/maize intercrops may be explained by the poor growth and subsequent lower yield of the food crops owing to the well-developed cocoa and *Glyricidia* canopies. However, the revenue from the first 2 years of intercropping

with these food crops makes the system economically profitable over the sole cocoa system.

Indigenous knowledge also vindicates the farmer for intercropping several food crop species to guard against failure of the enterprise. This was noted in the negative net revenue returns of cocoa/cassava and cocoa/maize systems in the 3rd year of cropping. Cassava must, however, be used with caution as it is reputed to impoverish the soil in intensive cultivation. Cassava may also be associated with white thread disease, *Fomes lignosus* (Doku, 1969). No such effects were, however, recorded in this study.

It must be pointed out that fertilizers which were applied in the study are not routinely used by farmers. However, the spatial arrangements of the food crops were similar to what is recommended for monoculture regimens compared to what is practised by farmers. There was, therefore, the need to augment soil fertility with chemical fertilizers to obtain the true potential of the system. Additionally, as the land had been cropped with cocoa for several years, the application of the fertilizer probably enhanced the establishment of the cocoa component.

In the traditional system which uses no fertilizers, and food crops are planted at low densities, the system appears to be self-sustaining within the first 3 years of intercropping (La Anyane, 1963). Such a system will not be harmful to the cocoa. There were no clear differences in the fertility level of the soils from the different treatments due to the application of the fertilizer. This implies that while the land is under perennial crops such as cocoa, soil nutrients may be depleted whether or not food crops are incorporated in the system. However, if high densities of the food crops are to be planted with the cocoa, then chemical fertilizer supplement may be required so that the development of the cocoa seedlings is not adversely affected.

Conclusion

Intercropping food crops with cocoa enhances growth and precosity of the cocoa. It also provides food for the household and cash to defray part of the initial capital outlay required for establishing cocoa farms. A basal dressing of chemical fertilizer may be necessary when intercropping cocoa at high food crop densities on soils which had previously been cropped with cocoa.

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REFERENCES

Adegeye, J. A. (1985) An evaluation of food crop farming inside old cacao groves. *Niger. agric. J. (Ibadan)* **19/20**, 12-122.

Adenikinju, S. A., Esam, E. B. & Adeyemi, A. A. (1989) Nursery techniques, propagation and management of cacao, kola, coffee, cashew and tea. In *Progress in tree crops research in Nigeria*, 2nd ed., pp. 1-27. Ibadan, Cocoa Research Institute of Nigeria.

Alvim, R. & Nair, P. K. R. (1986) Combination of cacao with other plantation crops: An agroforestry system in southeast Bahia, Brazil. *Agrofor. Syst.* **4**, 3-15.

Benneh, G. (1987) Land tenure and agroforestry land use in Ghana. In *Proceedings of an International Workshop on Tenure Issues in Agroforestry, May 27-31* (ed. J.B. Raintree). *Nairobi, Kenya.*

Bonaparte, E. E. N. A. & Toseafa, D. W. K. (1977) Weed control. In *Rep. Cocoa Res. Inst. Ghana. An. Rep.* **1974-75**, 30-38.

Bonaparte, E. E. N. A. & Toseafa, D. W. K. (1979) Cocoa/Food crop experiment. In *Rep. Cocoa Res. Inst. Ghana An. Rep.* **1979/80-1980/82**, 15-16.

CIMMYT (1988) *From agronomic data to farmer recommendations: An economics training manual.* Completely revised edition. Mexico, D.F.

Doku, E. V. (1969) *Cassava in Ghana.* Accra: Ghana Universities Press.

Egbe, N. E. & Adenikinju, S. A. (1990) Effects of intercropping on potential yield of cacao in south

western Nigeria. *Café Cacao Thé* **34** (3), 142-146.

Fordham, R. (1983) Intercropping : What are the advantages? *Outlook on Agriculture* **12** (3), 142-146.

Francis, C. A. (1986) *Multiple cropping systems.* New York: Macmillan.

Glendining, D. R. (1960) The relationship between growth and yield in cocoa varieties. *Euphytica,* **9**, 351-355.

Hall, T. H. R. (1962) Establishment and maintenance experiments: Shade efficiency experiment. *Rep. West Afr. Cocoa Res. Inst.* **1960/61**, 50-54.

Kolade, J. A. (1986) Influence of different densities of cocoa and oil palm on yield performance of cocoa. *Turrialba* **36** (3), 345-353.

La Anyane, S. (1963) *Ghana agriculture: Economic development from early times to the middle of the 20th Century.* London, Oxford University Press.

Manu, M. & Tetteh, E. K. (1987) *A guide to cocoa cultivation. (Tech. Bull. Cocoa Res. Inst. Ghana),* Ghana Cocoa Board.

Nye, P. H. & Stephens, D. (1962) Soil fertility. In *Agriculture and land use in Ghana* (ed. J. B. Wills), pp. 127-142. London, Accra, New York: Oxford University Press.

Ofori, F. & Stern, W. R. (1987) Cereal-legume intercropping systems. *Adv. Agron.* **41**, 41-90.

Oladokun, M. A. O. (1988) Tree crop based agroforestry in Nigeria: A check list of crops intercropped with cacao. *Agrofor. Syst.* (paper under review).

Owusu -Bempah, K. (1988) The role of women in species selection for agroforestry farming systems in rural areas of Ghana. In *Gender issues in farming systems research and extension* (ed. S.V. Poats, M. Schmink and A. Spring). Colorado, USA: Westview Press.

Webster, C. C. & Wilson, P. N. (1969) *Agriculture in the tropics.* London: Longman.

Willey, R. W. (1985) Evaluation and presentation of intercropping advantages. *Expl. Agric.* **21**, 119-133.

Wills, J. B. (1962) The general pattern of land use. In *Agriculture and land use in Ghana* (ed. J. B. Wills), pp. 201-225. London, Accra, New York: Oxford University Press.