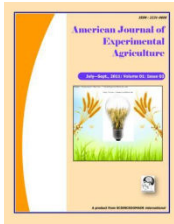

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Long Term Assessment of the Agronomic and Economic Benefits of Cocoa Food Crop Intercropping in the Absence of Fertilizer Application

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Research Article

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ABSTRACT

Aim: To investigate the long term benefit of intercropping cocoa with some food crops with no fertilizer input.
Study design: Randomized complete block design with four replicates.
Place and Duration of Study: Cocoa Research Institute of Ghana Substation at Bunso, between June 1998 and March 2011.
Methodology: Plantain, cassava and maize were planted alone or as mixtures to give the following intercrop combinations: sole crop cocoa, cocoa/plantain, cocoa/cassava, cocoa/maize, cocoa/cassava/plantain, cocoa/cassava/maize, cocoa/plantain/maize and cocoa/plantain/cassava/maize. The girth and height of cocoa seedling, the yield of the food crops and cocoa, some physic-chemical properties of the soil and the profitability of the various combinations were assessed using analysis of variance. Percentage canopy development of cocoa under the various treatments was analyzed after square root transformation of the data.
Results: Intercropping significantly ($P<0.05$) reduced the girth of cocoa seedlings in the cocoa/plantain combination only in the second year. The height of cocoa plant was not significantly influenced by the treatments. The cocoa/plantain/cassava/maize combination had the lowest but non-significant levels of N, P and K in the soil at the end of three years of food crop intercropping. Between 2001 and 2011, although the amount of harvested cocoa was not significantly affected by the treatments, cocoa beans from the intercrops was 28-60% more than the sole crop cocoa except in the case of the cocoa/cassava combination where there was a slight decrease in yield. Economic analysis of the treatments showed that intercropping was profitable. Higher net benefits were achieved

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where the combinations contained plantain and maize.
Conclusion: Intercropping cocoa with food crops is beneficial since it generally increased cocoa bean yield and income even in the absence of fertilizer application. It is suggested that intercropping should be carried out during establishment to ensure increased productivity of the land.

Keywords: Intercropping; cocoa; food crops; agronomic and economic benefits.

1. INTRODUCTION

Up to canopy closure, which usually starts 2-3 years after planting, cocoa is traditionally grown in association with food crops such as cocoyam, yam, maize, plantain, cassava, 'egusi' melon, cowpea and pineapple, okra, pepper etc (Hammond, 1962, Oladokun, 1990) for various reasons. The benefits of intercropping cocoa with food crops during establishment have been reported to include provision of food for the household, generation of income during the immature phase of cocoa to partially offset the cost of establishment, reduction in weed growth and, therefore, cost of weed control, reduction in insect pest damage and provision of temporary shade for the young cocoa to modify the microclimate (Egbe and Adenikinju, 1990; Adeyemi, 1985, 1988, 1999; Idowu, 1996; Anon, 2010).

In Ghana, food crop intercropping contributed greatly to the growth of the cocoa industry (Hammond, 1962). Within the West African environment, the agronomic and economic benefits of this system during establishment have been demonstrated in Ghana (Bonaparte and Toseafa 1979; Osei-Bonsu et al., 1998; Opoku-Ameyaw, et al., 2003a), Nigeria (Kolade et al., 1980; Adeyemi, 1985, 1999) and Cote D'Ivoire (Lachenaud, 1988). These earlier studies were short-lived and did not investigate the residual effect of food crop intercropping on the long term yield of cocoa and economics of the system. Again in their study, Osei-Bonsu et al. (1998) and Adeyemi (1999) applied fertilizer to the food crops since they anticipated competition for soil nutrients between the food crops and cocoa. However, small holder cocoa farmers in Ghana hardly use fertilizers during the establishment phase of cocoa cultivation and the merits of this farmer practice have not been fully investigated.

This paper, therefore, reports on the findings of a field trial undertaken to assess the long term agronomic performance and economic benefit of intercropping cocoa with some food crops without the use of fertilizers to minimize competition for nutrients as practiced by peasant cocoa farmers.

2. MATERIALS AND METHODS

2.1 Experimental Site

The experimental detail of this field trial has been reported elsewhere (Opoku-Ameyaw et al., 2003a). The trial was carried out at the Cocoa Research Institute of Ghana substation at Bunso (06°16´ N, 00° 27´ W, 242m ASL) from 1998 to 2011 using randomized complete block design with four replicates. The soil of the site is mainly Rhodic Ferrasol (FAO-UNESCO, 1977). The long term mean annual rainfall and temperature of the site are1631.7 mm and 25.5°C, respectively

2.2 Experimental Design and Management

Plot size was 324 m^2 and consisted of 36 cocoa trees planted at 3m x 3m in June, 1998. A permanent shade of *Gliricidia sepium* spaced at 6 m x 6 m was established in the plots in October, 1998. The cropping systems investigated were (a) sole cocoa, (b) cocoa intercropped with plantain, (c) cocoa intercropped with cassava, (d) cocoa intercropped with maize, (e) cocoa intercropped with cassava and plantain, (f) cocoa intercropped with cassava and maize, (g) cocoa intercropped with plantain and maize and (h) cocoa intercropped with plantain, cassava and maize. The maize, cassava and plantain were planted at 0.5 m x 1.0 m, 1.0m x 1.0m and 3.0m x 3.0m, respectively. The plantains were planted at the beginning of the trial in June 1998 and were not replanted after being destroyed by storms in 2000. Cassava was planted annually in June after harvesting the previous crop in May. Double cropping of maize was attempted in each year during the major (March to July) and minor (September to December) rainy seasons. Maize and cassava were intercropped during the first 3 years of establishment. Weeds in the plots were managed by slashing with a cutlass.

2.3 Data Collection

Soil samples from 0- 30cm depth were taken before the application of treatments and at the end of the food crop intercropping period in 2001 for soil analysis. This soil depth was chosen since the major proportion of the active roots of cocoa is concentrated within the top 15 cm layer while maximum root activity is within the top 3 cm zone (Ahenkorah1979), For the pre-treatment soil sampling, ten samples were collected taking into consideration the topography of the site. The samples were then bulked to form a composite sample. In the case of the sampling done at the end of the intercropping period, two samples per plot were collected and bulked for each treatment in a replicate. Total nitrogen was determined by the modified Kjeldahl method using Tecator Kjeltec Distiller (Bremner, 1965). Available phosphorus and organic carbon were determined by the methods of Truog (1930) and Tinsley (1950), respectively. The potassium content of the soil was also determined by atomic absorption spectrometry using ammonium acetate extraction.

Data were collected on the growth (girth and height of 16 core cocoa plants in the plot) and yield of cocoa, canopy closure of the cocoa at four and six years after transplanting, revenue from the food crops, some physico-chemical properties of the soil and cost of labour used for planting, weeding and harvesting. The girth of the cocoa seedlings was measured with a veneer caliper at 5 cm from the ground while the height was recorded with a metre rule. Measurement was started at transplanting and repeated at 3-monthly intervals until the seedlings attained the age of two years when it became impossible to use the veneer caliper. Percentage canopy closure of the cocoa plant was obtained by estimating the area shaded by the crown of three core trees within the rows and extracting the average per plot basis.

2.4 Statistical Analysis

Data on the soil properties, plant growth, yield of cocoa and canopy closure were analysed using ANOVA and treatment means separated by least significant difference. The data on percentage canopy closure were transformed into square root values before analysis. The net returns for each cropping system was computed from the total cost of production and the total revenue obtained from the different crops.

3. RESULTS AND DISCUSSION

3.1 Soil Properties

The physico-chemical properties of the soil recorded before the trial and after the food crop intercropping period (1998-2001) are presented in Table 1. With the exception of K, cultivation consistently reduced the levels of soil nutrients. The initial K level of the soil was lower than 0.20 cmol/kg K considered by Acquaye et al. (1965) to be unfavorable for the cultivation of Amazon cocoa in Ghana. This could be due to the fact that the land had recently carried a kola plantation and did not have enough time to fallow. Intercropping did not significantly affect the levels of the soil pH, % carbon, % nitrogen and available phosphorus although it consistently reduced the level of K in the soil. This finding is different from that of Lachenaud (1988) who rather observed a reduction in phosphorus content of the soil under cocoa plot that had been intercropped with food crops in La Cote D'Ivoire. The cocoa/plantain/cassava/maize package, which consisted of a combination of all the food crops, had the lowest levels of N, P and K at the end of the intercropping period. However, these were not lower than critical soil nutrient values of 0.09% N, 10 mg/kg P and 0.03cmol/kg K for cocoa cultivation reported in Nigeria by Egbe et al, (1989) and Aikpokpodion (2010).

Table 1. Effect of treatments on some physico-chemical properties of the soil during the food crop intercropping period (1998-2001)

Treatment	Soil properties				
	pH	% Carbon	% Nitrogen	P (µg/g)	K (cmol/kg)
Sole cocoa	5.62	1.84	0.195	22.50	0.215
Cocoa/plantain	5.80	1.91	1.196	22.19	0.172
Cocoa/cassava	6.12	2.14	0.206	22.18	0.191
Cocoa/maize	6.01	2.00	0.198	19.66	0.166
Cocoa/cassava/ plantain	6.19	1.82	0.207	22.20	0.165
Cocoa/cassava/ maize	5.61	1.87	0.197	23.60	0.152
Cocoa/plantain/ maize	5.88	1.57	0.223	21.14	0.155
Cocoa/plantain/ cassava/maize	5.86	1.61	0.177	16.79	0.104
F test	Ns	Ns	Ns	Ns	Ns
Pre-treatment level	5.89	2.26	0.254	25.15	0.165

Ns- Not significant at 5% probability

3.2 Cocoa Seedling Growth

Intercropping had no significant effect on stem girth in the first year. However, it significantly ($P<0.05$) reduced the girth of cocoa seedlings in the cocoa/plantain combination compared with the sole crop cocoa during the second year (Table 2). Wood (1985) suggested that plantains may be unsuitable temporary shade crop in some locations since they compete for moisture during the dry season and also for exchangeable K. The soil nutrient data in this study suggest that competition for K might not have accounted for the reduction in the girth of cocoa in the cocoa/plantain system since the level of this nutrient in this treatment was slightly higher than those of some of the combinations. The presence of cassava also tended to slightly suppress stem girth increment. This is consistent with the findings of Bonaparte and Toseafa (1979) but contrary to observations by Osei-Bonsu et al, (1998) who applied fertilizer in their study. Although cassava is generally known to take up large quantities of nutrients, particularly nitrogen and potash from the soil (Wrigley, 1985), the soil nutrient levels indicate that factors other than competition for soil nutrients might have caused the slight reduction in girth increments. The girth of seedlings in mixtures containing maize, generally, compared favourably with the sole crop cocoa confirming the findings of Bonaparte and Toseafa (1979). Moreover, cropping system did not significantly affect plant height. Cocoa plants in the intercropped plots were generally shorter than those in the sole crop in both years. Neither the proportion of trees that jorquetted at three years after transplanting nor the degree of canopy development at four and six years after transplanting was significantly influenced by intercropping (Table 2). It was, however, observed that the cocoa/cassava combination produced the lowest of these parameters measured in the study.

3.3 Cocoa Yield

The cocoa plants started bearing during the fourth year after planting. Intercropping did not significantly ($P > 0.05$) affect the yield of cocoa beans throughout the first ten years of bearing probably due to the high variability observed within the data (Tables 3 and 4). However, in relating cocoa yield of the different treatments to the sole crop cocoa, the yield from the cocoa/cassava system was marginally lower during the first six years of production. Thereafter, the negative effect of the cassava intercrop began to decline. Contrary to established fact that better stem development during establishment results in better yield (Glendining, 1960, 1966), the cocoa/plantain treatment and others that had previously contained plantain gave slightly higher cocoa yields than the sole cocoa treatment throughout the period despite the comparatively smaller girths of cocoa in the former treatments. Canopy closure was higher in plots that had previously supported plantains (Table 2). Thus, any initial suppression of growth might have been eroded by the fourth year after transplanting. In fact, a highly significantly ($P < 0.001$) positive relationship was observed between yield and canopy closure at 6 years after planting. The equation for the relationship was $Y = -904 + 17.0x$; $R2 = 97.4$ (where Y = yield and x = canopy closure). This indicates that in the early years of bearing, cocoa yield is influenced by size of the canopy and partially explains the slightly lower yields obtained in the cocoa/cassava plot than the sole cocoa. The generally better yield of intercropped cocoa than sole cocoa in the present study is similar to the findings of Adeyemi (1993) and may probably be due to a more favourable microclimate (Adeyemi, 1985) which might have resulted in better canopy development by the 4^{th} year (Table 2). The slight depression in yield of the cocoa/cassava combination is similar to the findings on coffee made by Opoku-Ameyaw et al. (2003b). It is interesting to note that although the cocoa/plantain/cassava/maize had the lowest levels of N, P and K in the soils at the end of the intercropping period (Table 1) this did not adversely affect cocoa yield when compared with the sole cropped cocoa. Examination of the 10 year cumulative yield shows that, with the exception of the cocoa/cassava combination, intercropping produced 28.8 % to 60.4% more yield of dried cocoa beans than sole crop cocoa. The presence of cassava seemed to have slightly depressed the cumulative yield of the mixtures probably as a result of its effect on canopy development.

Table 2. Effect of intercropping on the growth of cocoa seedlings and jorquette formation at three years and canopy closure at four years after transplanting

Treatment	Seedling growth Girth increment (mm)		Height increment (cm)		% Trees jorquetted	% Canopy closure	
	1st year	2nd year	1st year	2nd year		4th year	6th year
1. Sole cocoa	7.8	22.1	40.2	103.6	55.0 (45.0)	44.5 ***6.5 (1.19)***	82.4 ***9.1 (0.11)***
2. Cocoa/plantain	6.5	17.3	33.8	102.3	48.5 (44.2)	55.5 ***7.4 (0.40)***	87.2 ***9.3 (0.17)***
3. Cocoa/cassava	5.1	18.5	35.1	89.7	28.2 (32.0)	25.8 ***5.1 (0.16)***	63.8 ***7.9 (0.19)***
4. Cocoa/maize	7.3	23.5	29.3	96.3	37.5 (37.7)	58.2 ***7.6 (0.20)***	86.5 ***9.3 (0.31)***
5. Cocoa/cassava/plantain	5.0	18.7	32.7	93.7	46.9 (43.2)	51.5 ***7.0 (1.09)***	84.2 ***9.1 (0.58)***
6. Cocoa/cassava/maize	7.2	24.7	34.1	101.8	42.2 (40.9)	44.5 ***6.6 (0.84)***	80.0 ***8.9 (0.42)***
7. Cocoa/plantain/maize	6.8	19.2	29.4	78.6	36.0 (37.1)	53.5 ***7.2 (0.92)***	85.0 ***9.2 (0.33)***
8. Cocoa/plantain/cassava/maize	7.2	21.2	35.8	93.9	40.0 (36.5)	60.2 **7.6** ***(0.39)***	86.2 ***9.3 (0.09)***
F test	ns	*	ns	ns	ns	***ns***	***ns***
LSD (5%)		4.50					

ns- Not significant; values in parenthesis are arcsine transformed while those in bold and italics are square root transformations; bold values in italics and parenthesis are the standard errors of means of the square root transformations.

Table 3. Summarised ANOVA table indicating sources of variation in cocoa yield for the various years (2001-2011)

Source of variation	df	Mean squares for cocoa yields										
		2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Cumulative
Replicates	3	123.6	6713	38420	35358	172253	377909	5176	20519	862	17328	1244714
Treatment	7	122.9 ns	12430 ns	40893 ns	29613 ns	81312 ns	64412 ns	48032 ns	34896 ns	62309ns	7317 ns	1894564ns
Error	21	102.6	13831	45650	17418	57417	56483	32655	23068	40348	16928	1158296

ns- Not significant at 5% probability.

Table 4. Effect of intercropping on the yield of cocoa beans

Treatment	Yield (kg/ha)											
	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10	2010/11	Cumulative	% Increase/ Depression in yield relative to sole cocoa
Sole cocoa	7.5	91	300	265	412	566	215	278	386	458	2978.5 (±622)	
Cocoa/plantain	3.1	134	517	480	730	750	576	435	750	403	4778.1 (±557)	+60.4
Cocoa/cassava	1.3	82	284	203	280	412	282	409	378	465	2796.3 (±379)	-6.1
Cocoa/ maize	3.1	76	525	389	674	591	420	520	559	412	4169.1 (±314)	+40.0
Cocoa/cassava/plantain	0.6	208	480	370	575	585	360	375	462	485	3900.6 (±882)	+31.0
Cocoa/cassava/maize	13.0	113	433	396	585	581	326	593	507	537	4084.0 (±517)	+37.1
Cocoa/plantain/maize	1.9	153	505	398	575	765	436	441	634	477	4385.9 (±513)	+47.3
Cocoa/plantain/cassava/ Maize	14.9	221	535	370	530	435	344	433	510	442	3834.9 (±301)	+28.8
F test	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	**ns**	
CV (%)		**87.3**	**47.7**	**36.8**	**44.0**	**40.6**	**48.8**	**34.9**	**38.4**	**28.3**	**27.9**	

__n__s – Not significant at 5% probability; values in parenthesis are the standard error of mean

3.4 Food Crop Yields

The yields of cassava and maize decreased drastically after the first year (Table 5). This could be attributed to either reduction in soil fertility as a result of continuous cropping or increasing competition from the cocoa. This is contrary to the findings of Osei-Bonsu et al (1998) who in their study applied fertilizers to the food crops.

In the second and third years of intercropping, it was found that where more than one food crop was found in the combination, the yields of the food crops were lower compared to situations where only one crop was grown in association with cocoa. This appears to suggest that intense competition occurred between the foods crops for growth resources. The yield of the food crops in the cocoa/plantain/cassava/maize combination were the lowest during their first year of production indicating competition for growth resources even in this early stage of intercropping. The presence of cassava severely affected the yield of the second and third year plantings of maize but the reason for this is unknown.

Table 5. The effects of treatments on the yield of food crops during the intercropping period (1998-2001)

Treatment	Yield (kg/ha)						
	Maize (dry wt. of grain)			Plantain (fresh bunches)	Cassava (fresh tubers)		
	'98/99	'99/00	'01/11	'99/00	'98/99	'99/00	'00/01
Sole cocoa	-	-	-	-	-	-	-
Cocoa/plantain	-	-	-	2,591	-	-	-
Cocoa/cassava	-	-	-	-	13,375	1,407	1,111
Cocoa/maize	2,590	980	31	-	-	-	-
Cocoa/cassava/plantain	-	-	-	2,611	12,400	695	904
Cocoa/cassava/ Maize	2,490	131	0.9	-	13,050	1,823	1,302
Cocoa/plantain/ maize	2,410	189	35	3,637	-	-	-
Cocoa/plantain/ cassava/maize	1,750	30	4	1,639	10,350	1,424	573

3.5 Economic Benefit of the Treatments

Earlier studies in Ghana have concentrated on assessing the economic benefits of intercropping cocoa with food crops at the end of the establishment phase of cocoa when intercropping is no more possible and have found intercropping to be very profitable especially when the combinations contained plantains and cassava (Osei-Bonsu et al., 1998; Opoku-Ameyaw et al., 2003a). In the present study, the long term economic assessment indicated that although the cocoa/maize combination was not financially beneficial at the end of the food crop intercropping (1998-2001), the income from the cocoa compensated for the initial loss making intercropping generally profitable than sole cropping of cocoa (Table 6). Apart from the cocoa/cassava combination, the cumulative net benefit from the cocoa was higher in the intercropped plots than the sole crop cocoa and seemed to follow the trend of cocoa yield. When the total net benefit of the combinations are considered, it can be observed that intercropping is financially beneficial producing 6.9% (cocoa/cassava) to

69.2% (cocoa/plantain) more profit than sole cropping of cocoa. Higher net benefits were obtained when the combinations contained plantain and maize. Again, the benefit:cost ratios followed the same trend confirming that intercropping is more profitable than sole cropping of cocoa.

Table 6. Economics of the cocoa food crop intercropping during the first ten years (1992-2011)

Treatment	Cumulative net benefit (GHc)			% increase in net benefit due to intercropping	Benefit: Cost Ratio
	Food crops (1998-2001)	Cocoa (2002-2011)	Total		
Sole cocoa	--66.1	3261.9	3195.8		3.6
Cocoa/plantain	64.8	5343.4	5408.2	69.2	4.7
Cocoa/cassava	195.6	3221.5	3417.1	6.9	3.7
Cocoa/maize	12.2	4493.5	4481.3	40.2	4.0
Cocoa/cassava/plantain	299.2	4272.6	4571.8	43.1	4.3
Cocoa/cassava/maize	250.0	4698.1	4948.1	54.8	4.3
Cocoa/plantain/maize	15.0	4901.6	4916.6	53.8	4.3
Cocoa/plantain/ cassava/ Maize	219.2	4148.1	4367.3	36.7	3.9

4. CONCLUSION

Intercropping cocoa with food crops is beneficial since it has generally promoted the growth of cocoa and increased cocoa bean production and income even in the absence of fertilizer application. This vindicates peasant farmer practice and it is, therefore, suggested that intercropping cocoa with maize, plantain and, if possible cassava, should be carried out during establishment to ensure increased profitability of the system.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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