Intercropping robusta coffee with some edible crops in Ghana: Agronomic performance and economic returns

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ABSTRACT

A field trial aimed to investigate the agronomic performance and profitability of intercropping robusta coffee (*Coffea robusta*) with some pulses and food crops at the Cocoa Research Institute of Ghana, Tafo, from 1996 to 2001. The pulses studied were jack bean (*Canavalia ensiformis*) and cowpea (*Vigna unguiculata*), with maize (*Zea mays*), cassava (*Manihot utilisima*) and plantain (*Musa paradisiaca*) as food crops. Two sole coffee treatments with weeds either manually or chemically controlled were used as controls. Coffee stem girth was not significantly affected by intercropping. Plant height in coffee was, however, significantly increased when intercropped with cassava during the 1st year. Intercropping with cassava also significantly reduced coffee yield by 47.3 per cent, while plantain caused a non-significant reduction of 16 per cent. On the other hand, jack bean, cowpea and maize increased coffee yields by 19.1, 2.0 and 21.6 per cent, respectively. Coffee intercropped with cassava had the highest discounted net economic benefit, followed by coffee intercropped with plantain, jack bean, maize and cowpea. Sole coffee with chemical weed control and sole coffee with manual weed control had the lowest discounted net economic benefits. While the cassava and plantain combinations are recommended to satisfy the need for food and income for the peasant farmer, the maize and jack bean combinations are assessed as the best packages for the commercial farmer whose ultimate aim is high coffee production for export.

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RÉSUMÉ

OPOKU-AMEYAW, K., OPPONG, F. K., OFORI-FRIMPONG, K., AMOAH, F. M. & OSEI-BONSU, K.: *Semailles de café robusta en lignes alternantes de quelques cultures comestibles au Ghana: Rendement agronomique et les rentabilités économiques.* Un essai sur le terrain pour étudier le rendement agronomique et la rentabilité de semailles de café robusta (*Coffea robusta*) en lignes alternantes de quelques gousses et cultures vivrières s'est déroulé à L'Institut de Recherche en cacao du Ghana à Tafo de 1996 à 2001. Les gousses étudiées étaient haricot du jaquier *(Canavalia ensiformis)* et dolique *(Vigna unguiculata)* avec maïs *(Zea mays)*, manioc (*Manihot utilisima*) et plantain *(Musa paradisiaca)* comme les cultures vivrières. Deux traitements de café seul oú les mauvaises herbes étaient désherbées manuellement ou chimiquement étaient utilisés comme les contrôles. La circonférence de tronc de café n'était pas considérablement affecté par les semailles en lignes alternantes. La taille de plante en café était, toutefois, considérablement augmentée lorsqu'il est semé entre les lignes de manioc pendant la première année. Semailles entre les lignes de manioc également reduisait considérablement le rendement de café par 47.3 %, alors que le plantain provoquait une réduction non-considérable de 16 %. Par contre, la présence de haricot du jaquier, dolique et maïs augmentaient les rendements de café respectivement par 19.1, 2.0 et 21.6 %. Le café semé en lignes alternantes de manioc donnait le plus élevé de l'avantage économique net escompté suivi par le café semé en lignes alternantes de plantain, haricot du jaquier maïs et dolique. Le café seul avec le contrôle chimique de mauvaise herbe et le café seul avec le contrôle manuel de mauvaise herbe rendait le plus bas avantage économique net escompté. Pendant que les combinaisons de manioc et de plantain sont recommandées pour satisfaire le besoin de nourriture et de revenu de petits agriculteurs, les combinaisons de maïs et de haricot du jaquier sont analysées comme les meilleurs systèmes pour l'agriculteur commercial, dont le but final est la production élevée de café pour l'exportation.

Introduction

Coffee, like other perennial crops, has a long gestation period during which returns to investment are lacking. During this establishment phase, weed control is a major management problem, particularly where shade is lacking. The adverse effect of weeds on the growth of coffee has been established by Periera & Jones (1954) and Robinson (1964). However, their complete removal, sometimes by chemical weed control, can expose the soil to the risk of erosion and other environmental hazards. It is also evident that many weed species are evolving herbicide resistance, thus making their control less effective and costly (Lebaron & Gressel, 1982). Mitchell (1988) reported that continuous slashing could eliminate broad-leaved weeds and the emergence of grass species and sedges which are more difficult to control. This situation, therefore, requires the development of a strategy that simultaneously provides income and reduces weed growth, and hence the cost of establishment.

Peasant farmers in the tropics have traditionally used intercropping with food crops to solve the problems of food sustainability, income generation, and weed control during establishment of tree crops (Egbe & Adenikinju, 1990). The beneficial effects of food crop intercropping in cocoa cultivation in Ghana have been reported by Osei-Bonsu, Amoah & Oppong (1998). Similar cultural practices may be in use in cultivating coffee. However, the effects of the food crops on the growth and productivity of coffee under Ghanaian conditions have not been scientifically assessed.

Intercropping robusta and arabica coffee with food crops such as beans, groundnuts, soyabeans, rice, yams and maize have been reported elsewhere (Okelana, 1982; Snoeck, 1988; Wrigley, 1988; Njoroge, Waithaka & Chweya, 1993). However, the conflicting reports of Okelana (1982) and Snoeck (1988) on the suitability of maize as an intercrop for coffee indicate that the success of any intercropping system could be influenced by the type of crops used and location specific factors.

This study, therefore, assessed the agronomic performance and economic benefit of intercropping coffee with some edible crops in Ghana.

Materials and methods

The Tafo station of the Cocoa Research Institute of Ghana (CRIG) (latitude 6°11' N, longitude 0° 22'; altitude 220 m) was used for the experiment. The soils at the site of the trial are Ferric Lixisols (FAO/UNESCO, 1990).

A randomized complete block design with four replicates was used. Each plot measured 225 cm^2 and consisted of 25 coffee (*Coffea robusta*) trees planted at 3 m × 3 m in June 1996. The coffee trees were maintained as double stems and topped to maintain a height of about 2.2 m. A permanent shade of *Gliricidia sepium* spaced at 6 m × 6 m was established in the plots in October 1996. The following cropping systems were investigated:

(a) sole crop coffee with manual weed control
(b) sole crop coffee with chemical weed control
(c) coffee intercropped with jack bean
(d) coffee intercropped with cowpea
(e) coffee intercropped with maize
(f) coffee intercropped with cassava
(g) coffee intercropped with plantain

Weeds in the intercropped plots were controlled manually while those in the sole coffee with chemical weed control treatment were managed with Glyphosate at 360 g ai/ha until the end of intercropping (1999). Thereafter, all plots were manually weeded. The edible crops were grown in between the coffee rows and were spaced at 0.25, 0.5, 1.0 and 1.5 m away from the coffee plants for the cowpea, jack bean, maize and cassava, respectively. The planting distances used were 0.25 m × 0.25 m for cowpea, 0.5 m × 0.5 m for jack bean and maize, and 1.5 m × 1.5 m for cassava. The plantains were spaced at 3.0 m × 3.0 m in the centre of four coffee plants and planted at the beginning of the trial in June 1996. Cassava was planted annually in June after harvesting the previous crop in May. Double cropping of the jack bean, cowpea, and maize was attempted in

each year during the major (March to July) and minor (September to December) rainy seasons.

Intercropping was practised for the first 3 years of establishment (up to the major season plantings of 1999) for all crops. However, plantains survived for only the first 2 years but were not replanted. Soil samples from 0 to 30 cm depth were collected before the treatments were applied and at the end of the intercropping period in 1999 to determine soil *p*H, organic carbon, total nitrogen, available phosphorus, and exchangeable potassium.

The effects of the treatments on the growth (girth and height) and yield of the coffee, yield of edible crops, weed composition, soil properties, and cost of production were measured. The net returns for each cropping system was computed from the monetary value of the yields of the edible crops and coffee, using the prevailing market prices for the crops and the cost of labour and chemicals during the experimental period. The increase or depression in coffee revenues due to the edible crop was calculated by working out the differences in gross revenues from coffee in the intercropped treatments and the sole coffee with manual weed control.

Results

Soil properties

Table 1 shows the values of some selected soil properties at the beginning of the trial and at the end of intercropping. The differences in the properties measured among the cropping systems were not significant, although organic carbon and total nitrogen contents tended to be higher in the sole coffee with manual weed control and coffee intercropped with jack bean. Compared with the pre-treatment soil properties, cultivation of crops generally influenced the soil characteristics. However, organic carbon, total nitrogen, and available phosphorus contents of the soil declined at the end of the intercropping period.

Coffee plant growth

Although treatment differences were not significant, intercropping coffee with cassava and plantain slightly reduced the girth of the coffee plants 2 years after establishment, with cassava intercropping producing the smallest girth of coffee plants even in the 1st year (Fig. 1). However, the height of the coffee plants was significantly ($P<0.05$) increased by intercropping with cassava within the 1st year of establishment, but the difference was not significant at the end of the 2nd year.

Coffee yields

The coffee plants started bearing 18 months after transplanting. Typically, the yield of the first

TABLE 1

Effect of Cropping System on Some Selected Soil Properties at 0-30 cm Depth

Cropping system	*Soil properties*				
	p*H*	*C (%)*	*N (%)*	*Available P (µg/g)*	*K (meq/100 g)*
Sole coffee with manual weed control	6.60	1.27	0.137	5.61	0.169
Sole coffee with chemical weed control	5.75	0.79	0.086	7.35	0.111
Coffee intercropped with jack bean	6.42	1.16	0.123	7.17	0.169
Coffee intercropped with cowpea	6.07	0.84	0.099	6.17	0.192
Coffee intercropped with maize	5.91	0.78	0.092	7.18	0.173
Coffee intercropped with cassava	6.29	0.75	0.089	6.99	0.145
Coffee intercropped with plantain	5.85	0.74	0.094	6.22	0.121
Sig. level	Ns	Ns	Ns	Ns	Ns
Pre-treatment values	6.56	1.54	0.135	10.02	0.171

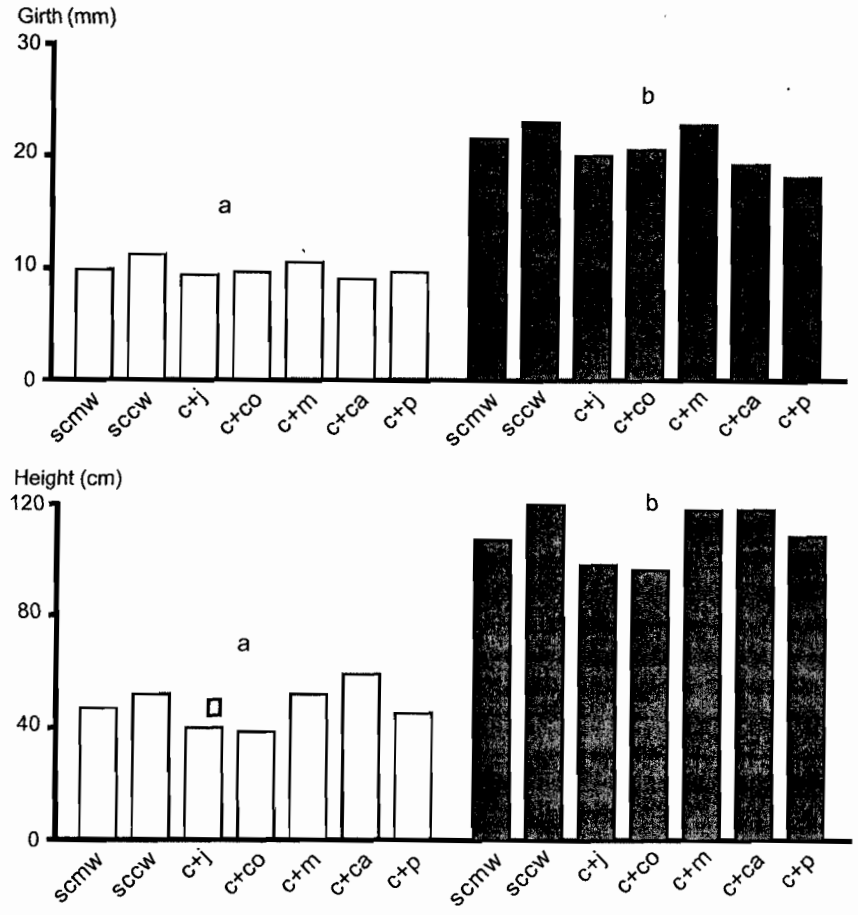

Fig. 1. The effect of cropping system on coffee plant girth and height at (a) 1 and (b) 2 years after transplanting, respectively (scmw = sole coffee with manual weed control, sccw = sole coffee with chemical weed control, c+j = coffee + jackbean, c+co = coffee + cowpea, c+m = coffee + maize, c+ca = coffee + cassava, and c+p = coffee + plantain.

crop was highly variable. The effect of intercropping on the yield of coffee became evident from the 2nd-year crop (Table 2). When compared to the sole coffee with weeds manually controlled, intercropping with cassava severely affected coffee yields throughout the trial, causing a significant reduction of 47.3 per cent in the cumulative yield. Although plantain also generally decreased coffee yields, the reductions were less drastic (16.7 %) compared to those from cassava. In 3 out of the 5 years of cropping, coffee intercropped with cowpea produced lower but non-significant coffee yields than the sole coffee. The cumulative yield of this cropping system was marginally better (2 %) than that from the sole coffee with manual weed control.

On the other hand, jack bean and maize generally increased coffee yields over sole coffee with manual weed control. The yield of coffee intercropped with jack bean was significant ($P<0.01$) in 1999. The jack bean and maize cropping systems produced cumulative yield increases of 19.1 and 21.6 per cent, respectively. Of the two sole crops, the herbicide-treated plot

produced higher but non-significant coffee yield than the manually weeded plots. Coffee yields from the herbicide-treated plots compared favourably with those from coffee intercropped with jack bean and maize.

Generally, the effect of treatments on coffee yield compared to the sole coffee with manual weed control abated remarkably during the post-intercropping period, except the plots intercropped with plantain which maintained similar reductions in total coffee yield during and after intercropping (1997-1999 and 2000-2001 periods, respectively). The percentage increase or reduction in coffee yield compared to the sole coffee with manual weed control during (first value) and after intercropping (second value) were as follows:

sole coffee with chemical weed control, +40, +2 %
coffee intercropped with jack bean, +43, +4 %
coffee intercropped with cowpea, +33, -17 %
coffee intercropped with maize, +42, +9 %
coffee intercropped with cassava, -56, -42 %
coffee intercropped with plantain, -16, -17 %

Yields of edible crops

Table 2 shows the yields of the edible crops. The establishment of maize, cowpea, and jack bean encountered some problems as the trial progressed which impacted adversely on their yields. These crops were sometimes damaged by birds, rodents, fungal disease (only cowpea), and erratic rainfall in the early part of the season, resulting in poor establishment and yield.

Weed succession

The initial vegetation was made up mainly of *Chromolaena odorata*. Table 3 shows the composition of the weed types after 2, 4 and 5 years of applying treatments. With the exception of the sole crop with chemical weed control and

TABLE 2

Yields of Coffee Berries and Edible Crops

	Yield of fresh coffee berries (kg/ha)						*Food crop yield (kg/ha)*				
Cropping system	*1997*	*1998*	*1999*	*2000*	*2001*	*Cumulative*	*1996*	*1997*	*1998*	*1999*	*Total*
Sole coffee with manual weed control	20	1813	5088	6516	4495	17932					
Sole coffee with chemical weed control	46	2007	7625	6538	4698	20914					
Coffee intercropped with jack bean	6	2000	7920	6219	5208	21353	683+	750	140	193	1766
Coffee intercropped with cowpea	121	1521	7552	5174	3966	18334	146+	297	30++	156	497
Coffee intercropped with maize	28	2126	7708	6677	5274	21813	1426+	3551	537+	778	6292
Coffee intercropped with cassava	29	650	2345	3226	3202	9452	-	16437	9233	12233	37903
Coffee intercropped with plantain	55	1181	4604	4764	4337	14941	-	3288	5236	-	8524
Sig. level	*	Ns	**	Ns	Ns	**					
Sed (18 df)	33.3	-	1329	-	-	2762					
CV (%)	107.3	58.0	30.7	34.5	46.0	22.1					

*$P<0.05$, ** $P<0.01$, + Only minor season crop, ++ Only major season crop

cassava plots, *Synedrella nodiflora* was the most dominant weed species in the treatments during the period of intercropping. The cassava plots were colonized mainly by the grass species, *Paspalum conjugatum*. The proportion of *P. conjugatum* was reduced with the cessation of the intercropping, while *S. nodiflora* became the most dominant weed species in the cassava treatment.

Economic benefit of the packages

All treatments were profitable, producing benefit:cost ratios in excess of 2. The intercrop systems produced better cumulative discounted net economic benefits than the sole coffee with manual weed control (Table 4). Although cassava and plantain severely depressed the revenue from coffee in these cropping systems, the revenue from these crops compensated for the loss. These cropping systems produced the highest net economic benefits. The relatively lower net economic benefit of the cowpea system compared to the other intercrops could be attributed partly to the establishment problems encountered, which severely affected its yield.

Discussion

The choice of any edible crop for intercropping would depend on its biological effect on the main crop and its economic value over the few years during which intercropping is possible. Peasant farmers in Ghana cultivate cassava, plantain and maize, which form the bulk of the staples used in the household. In this study, while jack bean, cowpea and maize did not affect the growth and yield of coffee, cassava and plantain reduced coffee yields. The adverse effect of cassava and plantain on coffee yield is consistent with the findings of Mitchell (1965) and N'Goran & Snoeck (1987). The increased coffee plant height, coupled with the slight reduction in its stem girth observed in the coffee/cassava intercrop system during the 1st year, is symptomatic of competition for light during this period. The coffee plants were shaded by the cassava , and this might have partly contributed to the reduced coffee yield in the cassava plots.

Grasses have been reported to exert severe competition on coffee (Wrigley, 1988). The cassava plots were dominated by the grass species *P. conjugatum* during the period of intercropping. Probably, *P. conjugatum* might have augmented the competition of cassava on the coffee. Although the plantains had been destroyed by windstorms by the end of 1998, the adverse effect of this crop on coffee yield persisted up to the year 2000, probably due to its high water and potash uptake (Wrigley, 1988). The slightly lower value of potash in the coffee/ plantain system relative to the other systems, except sole coffee with chemical weed control (Table 1), seems to support this assertion.

In a cocoa/food crop intercropping study, Osei-Bonsu *et al.* (1998) reported that no adverse effect was observed when cassava and plantain were planted with cocoa. The adverse effect of these crops on coffee indicates that the shade they provide may be inappropriate for coffee. This contradicts the recommendation of Ampofo & Osei-Bonsu (1988) that a temporary shade of plantain should be provided in the cultivation of coffee. Snoeck (1988) asserts that maize grows too high and competes with coffee plants. The results of the study reported here do not support such a view, probably because the shade provided by the maize crop was not dense enough to offer any competition for light to affect the coffee. This seems to support the findings of Okelana (1982) which considered maize as a suitable intercrop for coffee.

The absence of any adverse effects of jack bean and cowpea could be partly because they are low growing and are, therefore, incapable of posing any competition for light. Another factor that might have worked in favour of jack bean, cowpea, and maize is their shorter maturity period compared to cassava and plantain (N'Goran & Snoeck, 1987). It is, however, not easy to discern the extent to which the problems encountered in the establishment of jack bean, cowpea, and maize

TABLE 3

Effect of Cropping Systems on Weed Composition

Cropping system	*Weed composition (%)#*					
	Paspalum conjugatum	Pennisetum purpureum	Synedrella nodiflora	Ageratum conyzoides	Chromolaena odorata	Rottboelia cochinchinensis
Sole coffee with manual weed control	31.3 **32.8** [12.0]	0.3 **5.6** [0.0]	60.3 **53.8** [68.1]	0.0 **0.2** [4.4]	3.0 **1.0** [1.3]	0.0 **2.1** [1.1]
Sole coffee with chemical weed control	3.8 **2.9** [20.3]	3.5 **2.1** [0.0]	3.3 **4.8** [35.4]	5.8 **44.6** [25.0]	1.8 **1.1** [3.1]	0.0 **28.9** [0.6]
Coffee intercropped with jack bean	12.5 **21.5** [5.3]	0.0 **0.0** [0.9]	65.0 **60.0** [80.0]	1.3 **1.3** [10.6]	0.0 **0.4** [0.3]	0.0 **4.3** [0.0]
Coffee intercropped with cowpea	1.0 **22.4** [13.1]	0.4 **0.0** [0.0]	67.5 **62.3** [61.4]	0.5 **2.6** [10.3]	0.0 **0.4** [2.9]	0.0 **7.9** [6.5]
Coffee intercropped with maize	1.0 **22.4** [13.1]	2.3 **3.8** [0.0]	87.3 **46.2** [60.0]	0.5 **17.1** [17.1]	0.0 **0.8** [0.1]	0.0 **6.5** [0.0]
Coffee intercropped with cassava	63.8 **29.3** [8.5]	0.3 **0.0** [0.4]	22.0 **64.9** [82.6]	0.3 **0.8** [4.3]	9.5 **1.3** [0.6]	0.0 **0.4** [1.6]
Coffee intercropped with plantain	10.0 **20.0** [21.3]	0.3 **3.4** [0.0]	73.8 **61.4** [67.0]	1.5 **0.0** [5.0]	6.0 **0.8** [1.5]	0.0 **6.3** [0.0]

Data collected during the period of intercropping in April 1999 (plain figures) and after intercropping in June 2000 (bold figures) and June 2001 (figures in parentheses).

TABLE 4

Economics of Cropping Systems

Cropping system	*Discounted cost of production/ha (¢ × 1000)*							*Discounted revenue per ha (¢ × 1000)*						
	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Total*	*1996*	*1997*	*1998*	*1999*	*2000*	*2001*	*Total*
Sole coffee with manual weed control	23.4	73.3	85.2	109.1	130.7	145.1	566.8	-	6.8	423.7	706.7	599.8	346.7	2083.7
Sole coffee with chemical weed control	18.5	70.6	50.8	100.5	130.8	147.0	518.3	-	14.6	467.8	1056.2	601.8	362.3	2505.7
Coffee intercropped with jack bean	38.4	129.4	132.8	333.5	128.8	151.6	914.4	498.1	538.7	537.5	1182.6	575.6	401.8	3734.3
Coffee intercropped with cowpea	39.3	123.3	130.2	406.3	121.1	139.0	959.1	106.2	228.0	368.1	1115.6	476.2	306.0	2600.1
Coffee intercropped with maize	48.1	205.4	186.7	422.3	131.8	152.0	1146.3	344.3	637.9	599.6	1209.7	614.7	406.7	3812.9
Coffee intercropped with cassava	35.8	158.4	156.9	225.2	107.2	133.6	817.0	-	2301.2	1067.6	1141.7	297.0	246.3	5062.8
Coffee intercropped with plantain	63.5	128.5	109.4	82.7	117.1	145.2	646.4	-	1412.6	1631.1	639.4	438.6	334.6	4456.4

TABLE 4 (continued)

Cropping system	*Discounted net benefit/ha (¢ × 1000)*							*Benefit: cost ratio*	*Increase/ depression in gross revenue from coffee/ha (¢ × 1000)*
	1996	*1997*	*1998*	*1999*	*2000*	*2001*	*Cumu-lative*		
Sole coffee with manual weed control	-23.4	-66.5	+338.5	+597.6	+469.1	+201.6	+1516.9	3.7	-
Sole coffee with chemical weed control	-18.5	-56.0	+417.0	+958.7	+471.0	+215.3	+1987.5	4.8	+421.7
Coffee intercropped with jack bean	+459.7	+409.3	+404.7	+849.1	+446.8	+250.2	+2819.8	4.1	+460.1
Coffee intercropped with cowpea	+66.9	+104.7	+237.9	+709.3	+355.1	+167.0	+1640.9	2.7	+140.2
Coffee intercropped with maize	+296.2	+432.5	+412.9	+787.4	+482.9	+254.7	+2666.6	3.3	+514.4
Coffee intercropped with cassava	-35.8	+2142.8	+910.7	+916.5	189.8	+112.7	+4236.7	6.2	-1043.6
Coffee intercropped with plantain	-63.5	+1284.1	+1521.7	+556.7	+321.5	+189.4	+3809.9	6.9	-377.9

in the trial might have contributed to the non-adverse effect of these crops on the performance of the coffee.

The superiority of sole coffee with chemical weed control over that of manual weeding confirms the findings of Oppong *et al.* (2001). The yield of the sole coffee with chemical weed control was similar to that of jack bean, cowpea, and maize. The better performance of coffee in association with the jack bean, cowpea, and maize could partly be attributed to the better weed control observed earlier in the trial (1996-1999) when intercropping was practised. This may be confirmed by the significant yield differences recorded only during this period (Table 2). Opoku-Ameyaw *et al.* (1999) indicated a slight increase in the frequency of weed control in the jack bean, cowpea and maize resulting from the need to prepare the land for replanting of the crops and their respective weed control requirements during cultivation. Wrigley (1988) stated that, ideally, young coffee should not be intercropped, since the competition from the food crops could cause prolonged reduction in coffee yield. The positive effect of intercropping with jack bean, cowpea, and maize in this trial indicates that in some cases coffee can benefit from better husbandry practices resulting from the care given to the intercrops (Snoeck, 1988).

Njoroge *et al.* (1993) reported high economic benefits from intercropping arabica coffee with some food crops. A similar observation was made in this study. For the peasant farmer, the combination giving the highest economic benefits may be the most attractive package. As this work indicates, this would favour incorporating cassava and plantain into the system, which at the farmers' level, may seem prudent as it will supply their needs for income and household staple. However, for the commercial farmer whose interest is the production of coffee for export, the package that promotes high coffee yield would be the most appropriate option. The results of this study suggest that the most attractive option would be to select either the maize or jack bean combinations which did not severely affect coffee

yield. The extra income derived from the sale of maize or jack bean could be regarded as 'bonus', and could be used to purchase the plantain and cassava needs of the household.

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