Productivity of soybean intercropping with cassava and maize

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Abstract

Two intercropping studies, soybean/cassava and soybean/cassava/maize, were undertaken at Fumesua and Pokuase in the Forest and Coastal Savanna zones, respectively, in 1992/93 and 1996/1997 to determine management practices for high productivity of soybean intercrops. In the soybean/cassava intercrop, planting soybeans 2 weeks before cassava was the most productive, with 52 per cent yield advantage. However, planting soybeans 4 weeks after cassava, with high intercropped cassava yields, had highest net benefit of ¢1.231 million ha^{-1}. Spatial arrangement was an important factor in the soybean/cassava/maize intercropping system. The most productive arrangements, measured by Land Equivalent Ratio (LER), were one row of maize and cassava, and one, two or three rows of soybean with yield advantage of 44-104%. Intercropping of soybean is productive and profitable. However, favourable pricing and marketing of soybean would improve on the economic benefits for increased soybean production in Ghana.

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Introduction

Soybean (*Glycine max* (L.) Merr.) is becoming an important crop in Ghana. Its high protein content, ranging from 40 to 42 per cent is approximately double the protein content of the indigenous legumes, cowpea (19-35%) and groundnut (25-30%) (Ennin-Kwabiah & Osei-Bonsu, 1993). Soybean, therefore, has the potential of providing an inexpensive source of protein both for human consumption and animal feed preparation.

To facilitate adoption by farmers, soybean needs to be adapted into the existing cropping systems. One of such approaches would be to intercrop soybean with cassava, a staple widely grown as an intercrop with maize in southern Ghana. In Thailand, Japan and Australia, a common soybean production practice by farmers is intercropping soybeans with cassava (Benjasil & Lampong, 1985; Tsay *et al.*, 1987). In addition to spatial and temporal complementarity of resource use by intercrops, a peculiar advantage of intercropping legumes and nonlegumes is the ability of legumes to fix atmospheric N_2, thereby, making N available for plant growth and development, and increased protein production. The other associated benefits of the N-fixing ability of legumes under intercropping are N-sparing and N-priming effects (Aggarawal *et al.*, 1992; Danso *et al.*, 1993), greater N-fixation efficiency of the intercropped legume compared to sole cropped legume (Rerkasem & Rerkasem, 1988), N-transfer to the intercropped nonlegume (Stern, 1993), and increased residual N for the benefit of succeeding crops compared to sole cropping of nonlegumes (Bandyopadhay & De, 1986; Ennin, 1997).

Crop production factors that have a major influence on competition, yield and productivity of intercropping systems include relative time of planting of component crops (Okeke, 1996), plant population density (Candal-Neto *et al.*, 1993; Asafu-Agyei *et al*,. 1998) and spatial arrangement (Tsay *et al.*, 1987; Arias *et al.*, 1990).

The objectives of the studies were to (1) investigate the agronomic and economic feasibility of introducing soybean into cassava based intercropping systems in Ghana, and (2) determine the influence/effects of spatial arrangement and relative time of planting on productivity of the soybean/cassava and

soybean/cassava/maize intercrops.

Materials and methods

Soils and rainfall

The soils and climate of Fumesua and Pokuase have been described by Asafu-Agyei *et al.* (1998).

Experiment 1

A soybean/cassava intercrop was established at Fumesua in the Forest Savanna and at Pokuase in the Coastal Savanna zones of Ghana during the rainy season of 1992. The experiment consisted of 16 treatments arranged in a 2 × 7 factorial with two sole crops for comparison and replicated three times in each location. The factors under study were two spatial arrangements (soybean in alternate rows with cassava, and double rows of soybeans with one row of cassava); seven times of planting soybeans (6, 4 and 2 weeks after cassava, simultaneous planting and 2, 4 and 6 weeks before cassava). Both sole and intercropped soybean were planted at 200,000 plants ha^{-1}. Cassava was planted in 1 m rows at a population of 10,000 plants ha^{-1}. The popular local cassava variety in each location was used: 'Ankra' (12-18 months, maturity and late branching) at Fumesua and 'Bosome Nsia' (6-9 months duration at Pokuase. The soybean used at both locations was 'Bengbie' (improved semi-erect 100-110 days variety). Weeds were controlled by hand-weeding.

Experiment 2

A three-crop spatial arrangement study of soybean/cassava/maize intercrop was undertaken in 1996 through 1997 at Fumesua and Pokuase. There were six intercrop spatial arrangements with sole crops of cassava, maize and soybean included for comparison. The experimental design was a randomized complete block (RCBD) with three replications per site. Between row spacing of 50 cm was maintained for all intercropping spatial arrangements. Within row spacing for intercropped maize was 50 cm, two plants/hill; soybean was 20 cm, two plants/hill and cassava was 1 m within row, unless otherwise stated. Sole cassava population was 10,000 plants ha^{-1}, sole maize 62,500 plants ha^{-1} and sole soybean 200,000 plants ha^{-1}. Improved crop varieties were used. The maize variety was 'Obatanpa' (105 days open pollinated, high quality protein maize); soybean was Anidaso (105-115 days semi-erect variety); and the cassava was 'Gblemoduade', a Crops Research Institute (CRI) improved 12 months high branching variety. Cassava and soybeans were planted simultaneously, 2 weeks before the maize. Starter compound fertilizer, NPK 20-20-0 and ammonium sulphate as side dressing were applied at the rate of 86:50 kg ha^{-1} $N:P_2O_5$. Weeds were controlled by hand-weeding.

Results and discussion

Experiment 1

Relative time of planting. Soybean planted before cassava gave the soybean competive advantage resulting in higher grain yields than soybean planted after cassava at both locations (Table 1). Yield reductions of intercropped soybeans planted before cassava ranged from -1 to 18 per cent of the sole crop yield. Planting soybeans simultaneously as cassava or after planting cassava resulted in higher soybean yield reductions ranging from 28 to 62 per cent of the sole cropped soybean yields (Table 1). Yield component analysis indicated that the high grain yields of intercropped soybeans planted before cassava could be attributed to high pod numbers per plant and high seed numbers per pod (Table 1).

While high soybean grain yields were obtained by planting soybeans 2-6 weeks before cassava, the growth of the long duration cassava, 'Ankra', was greatly reduced by delaying cassava planting 2-6 weeks as indicated by cassava plant height at the time of harvesting soybean at Fumesua (Table 2). After harvesting the soybean, cassava growth recovered such that by the time of harvesting cassava a year after planting, intercropping and relative time of planting had no significant effect on 'Ankra' cassava plant height (Table 2). Unlike 'Ankra', the growth of the 6-9 months local cassava

TABLE 1

Influence of Relative Time of Planning on Grain Yield and some Agronomic Characteristics of Soybean in a Soybean Cassava Intercropping System. Fumesua and Pokuase, 1992

	Plant height (cm)	*Plant/ m^2*	*Pod/ plant*	*Seed/ pod*	*Soybean grain yield (t/ha)*		*Yield reduction (%)*	
Relative time of planting	*Fumesua*				*Fumesua*	*Pokuase*	*Fumesua*	*Pokuase*
Soybean 6 weeks after cassava	59	10	37	2	0.881	0.651	44	56
Soybean 4 weeks after cassava	64	16	31	2	0.882	0.570	49	61
Soybean 2 weeks after cassava	59	16	24	2	0.978	0.564	38	62
Simultaneous	58	15	43	3	0.998	1.065	37	28
Soybean 2 weeks before cassava	59	14	64	4	1.591	1.319	-1	11
Soybean 4 weeks before cassava	58	16	55	3	1.293	1.360	18	8
Soybean 6 weeks before cassava	58	14	48	4	1.441	1.380	9	7
SED	ns	1.6	9.4	1.9	0.214	0.191		
Sole soyebean	63	14	55	4	1.574	1.480		

TABLE 2

Response of Cassava to Relative Time of Planting in a Soybean Cassava Intercropping System. Fumesua and Pokuase, 1993

	Cassava plant height (cm)				*Root weight (t/ha)*	
	At soybean harvest		*At final*	*Root diameter*	*Fresh*	*Dry*
Relative time of planting	*Pokuase*	*Fumesua*	*Fumesua*	*Fumesua*	*Fumesua*	*Fumesua*
Soybean 6 weeks after cassava	128	135	220	6.04	18.84	8.12
Soybean 4 weeks after cassava	137	116	229	6.18	20.39	9.11
Soybean 2 weeks after cassava	136	98	221	5.74	14.78	6.65
Simultaneous	128	81	213	6.18	15.02	6.91
Soybean 2 weeks before cassava	126	67	231	5.58	11.04	5.49
Soybean 4 weeks before cassava	131	41	218	5.33	6.69	2.97
Soybean 6 weeks before cassava	127	40	207	5.04	5.79	2.51
SED	ns	19.1	ns	0.29	2.57	1.15
Sole cassava	134	-	-	5.65	21.65	9.25

(Bosome Nsia) at the time of soybean harvest at Pokuase was not affected by relative time of planting soybean and cassava as intercrops (Table 1). Highest cassava yields at Fumesua were achieved when soybean planting was delayed 4-6 weeks after planting cassava. It is apparent that although the cassava growth recovered after harvesting of soybean, the competition offered

by the soybean during its growth period was important in establishing cassava root yields and, therefore, the cassava plant height, at the time of harvesting soybean (Table 2), could be a good index of the potential cassava yields at harvest.

As a system, the soybean/cassava intercrop was more productive and biologically more efficient than sole cropping of cassava or maize, as indicated by LERs greater than 1 in all intercrop treatments (Table 3). Productivity ranged from 19 per cent when soybeans were planted 6 weeks before cassava to a high of 52 per cent when soybean was planted 2 weeks before cassava. In this system, intercropped soybean yielded as much as much as the sole cropped soybean with the yield of intercropped cassava which was 51 per cent of the sole cropped cassava as bonus. The productivity of simultaneous planting was intermediate with 32 per cent yield advantage. A farmer who is more interested in cassava could intercrop soybeans 4-6 weeks after cassava and obtain productivity which is 43-46 per cent greater than sole cropping, with cassava yields of 87-94 per cent of sole cassava yields (Table 3). Unlike in cereal/legume intercrops where simultaneous and close to simultaneous planting have been found to result in highest productivity as a result of high relative yields of the legume (Ofori *et al.*, 1987), in this study, planting soybean 4-6 weeks after cassava also had high LER of 1.43-1.46 due to high relative yields of cassava. Apparently, competition from cassava for radiation and soil nutrients was less than from cereals even when cassava was planted 4-6 weeks before the soybean. The high productivity of the soybean/cassava intercrop at all relative planting times points to the high degree of complementarity of the legume/cassava intercrop in resource use. Mason *et al.* (1986) have also reported greater land use efficiency of 15-35 per cent for legume (cowpea and groundnut)/ cassava intercrops in their studies and 20-100 per cent in other studies.

Spatial arrangement. Spacial arangement did not appear to be an important factor in the soybean/cassava intercrop (Table 4) unlike reports from cereal/legume intercrops in which double rows of the legume between two rows of cereal was repeatedly more productive than alternating one row spatial arrangement (Ofori & Stern, 1987; Arias *et al.*, 1990). In the soybean/cassava intercrop both one row alternate soybeans and cassava, and double soybean rows between two

TABLE 3

Land Equivalent Ratios (LERs) of Soybean / Cassava Intercrop as Affected by Relative Time of Planting, Fumesua 1992-1993

Relative time of planting	*Soybean Grain yield t/ha*	*Relative yield*	*Cassava fresh Root weight t/ha*	*Relative yield*	*LER*
Soybean 6 weeks after cassava	0.889	0.56	18.84	0.87	1.43
Soybean 4 weeks after cassava	0.811	0.52	20.39	0.94	1.46
Soybean 2 weeks after cassava	0.978	0.62	14.78	0.68	1.30
Simultaneous	0.998	0.63	15.02	0.69	1.32
Soybean 2 weeks before cassava	1.591	1.01	11.04	0.51	1.52
Soybean 4 weeks before cassava	1.293	0.82	6.69	0.31	1.13
Soybean 6 weeks before cassava	1.441	0.92	5.79	0.27	1.19
SED	0.214		2.57		
Sole crop	1.574		21.650		

TABLE 4

Influence of Spacial Arrangements on Yield, Yield Components and Plant Height of Soybean in a Soybean/Cassava Intercropping System. Fumesua and Pokuase, 1992

Spatial arrangement	*Plant height(cm)*	*Plants harvested/m²*	*Pod number /plant*	*Seed number /pod*	*Grain yield t/ha*
Fumesua					
One row alternate	63	16	45	3	1.113
Double rows soybean/one row cassava	56	13	42	3	1.170
SED	2.6	0.9	ns	ns	ns
Sole soybean	63	14	55	4	1574
Pokuase					
One row alternate	46	28	30	2	0.810
Double rows soybean/one row cassava	49	49	28	2	1.164
SED	3.6	7.1	4.9	ns	0.27

rows of cassava had similar effect on soybean grain yields and cassava root yield, and root characteristics at both Fumesua and Pokuase (Table 5). It appears that due to the slow initial growth rate of cassava compared to maize, there was less competition between cassava and soybean for resources. Therefore, provision of a more equidistant spacing of the soybean in double rows spatial arrangement did not make more resources available to the soybean than to soybean in alternate row spatial arrangement. This apparently accounted for the similar effect of the spatial arrangement on the soybean/cassava intercrop. The lack of significant differences ($P \leq 0.05$) in both soybean and cassava yields under the different spatial arrangements resulted in similar crop productivity, measured by LER under both alternate rows and double soybean rows between two rows of cassava spatial arrangements (Table 6).

Net benefits. Partial budget analysis (Table 6) indicated that due to the current low selling price

TABLE 5

Agronomic Response of Cassava and Land Equivalent Ratios (LERs) of Soybean Cassava Intercrop as Affected by Spacial Arrangement, Fumesua 1992-1993

Spatial arrangement	*Plant height cm*	*Root diameter cm*	*Soybean grain yield t/ha*	*Relative yield*	*Cassava Fresh root weight t/ha*	*Relative yield*	*LER*
One alternate	223	5.71	1.113	0.71	13.59	0.63	1.34
Double rows soybean/ 1 row cassava	217	5.74	1.170	0.74	12.85	0.59	1.33
SED	ns	ns	ns		ns		
Sole crop	214	5.65	1.547		12.650		

TABLE 6

† Net Benefits of Soybean / Cassava Intercrop as Influenced by Relative Time of Planting, Fumesua 1992-1993

	Soybeans after cassava			*Simulta-neous*	*Soybean before cassava*			*Sole crops*	
Relative time of planting (week)	*6*	*4*	*2*	*0*	*2*	*4*	*6*	*Soybean*	*Cassava*
Mean soybean yield (t ha^{-1})	0.88	0.81	0.98	1.00	1.59	1.29	1.44	1.58	-
Mean cassava yield (t ha^{-1})	18.84	20.40	14.78	15.02	11.04	6.69	5.79	-	21.65
Adj. soybean yield (t ha^{-1})	0.71	0.66	0.78	0.80	1.27	1.03	1.15	1.23	-
Adj. cassava yield (t ha^{-1})	15.07	16.31	11.82	14.82	8.83	5.35	4.63	-	17.32
Gross field benefit									
Soybean (¢ × 1000 ha^{-1})	423	389	469	479	764	620	692	739	-
Cassava (¢ × 1000 ha^{-1})	507	1631	1182	1482	883	535	463	-	1732
Intercrop gross field benefit (¢ × 1000 ha^{-1})	1930	2021	1652	1961	1647	1156	1155	-	-
Variable cost (¢ × 1000 ha^{-1})	790	790	790	790	790	790	790	500	520
Net benefits (¢ × 1000 ha^{-1})	1141	1231	862	1171	857	366	365	239	1212

† Net benefits were calculated based on average variable costs in southern Ghana in 1998.

of soybean (average of ¢60,000/100 kg bag)) in southern Ghana, growing soybean as a sole crop was not very profitable. A more profitable enterprise of soybean production was intercropping it with cassava, with net benefits ranging from ¢365,000 ha^{-1} to ¢1.231 million ha^{-1} when soybean was planted 4 weeks after cassava. By spending an extra ¢390,000.00 ha^{-1}, the income from monocropped soybean increased five fold when soybean was planted 4 weeks after cassava. This intercrop produced the highest intercropped cassava yield which was 96 per cent of the monocropped cassava yield, and had a high LER of 1.46 although it was not the most productive soybean/cassava intercrop system. High intercropped cassava yield appeared to be an important factor for the attainment of high net benefits when soybeans were intercropped with cassava.

Experiment 2

At both Fumesua and Pokuase, highest productivity of soybean/cassava/maize-intercrop was achieved in spatial arrangements comprising not more than one row of maize and cassava, and one, two or three rows of soybean. (Table 7). These intercrops had yield advantage over sole cropping ranging from 44 to 104 per cent as measured by LER. The productivity of the one row cassava/ one row soybean/one row maize was due mainly to high intercrop yields of cassava in the high rainfall location of Fumesua, and maize in the drier location, Pokuase. On the other hand, the high

TABLE 7

Grain/Tuber Yield of Maize, Soybean and Cassava and Land Equivalent Ratios (LER) as Influenced by Spatial Arrangement of Soybean/Cassava/Maize Intercrop at Fumesua and Pokuase, 1996-1997

	Grain yield (t/ha)				*Cassava root yield t/ha*		*LER*	
	Maize		*Soybean*					
Spacial arrangement	*Fume-sua*	*Pokua-se*	*Fume-sua*	*Pokua-se*	*Fume-sua*	*Pokua-se*	*Fume-sua*	*Pokua-se*
†One row cassava/three rows soybean/one row maize	1.46	1.78	0.88	0.72	27.2	6.6	2.04	1.44
†Two rows cassava/three rows soybean/two row maize	1.56	2.19	0.44	0.36	23.6	8.8	1.47	1.28
†Three rows cassava/three rows soybean/three rows maize	1.11	1.89	0.25	0.28	16.1	7.8	0.95	1.08
†One row cassava/two rows soybean/one row maize	3.58	3.08	0.24	0.36	29.7	12.0	1.84	1.63
†One row cassava/three rows soybean/one row maize	1.95	2.52	0.52	0.31	34.9	14.4	1.96	1.48
†One row cassava/two rows soybean/one row maize	1.71	2.09	0.73	0.41	24.4	10.8	1.88	1.36
Sole crop	4.86	3.34	0.90	1.00	35.5	34.3	1.00	1.00
SED	0.94	0.31	0.39	0.12	6.52	2.38		

†Within row spacing of cassava = 50 cm.

productivity of the one row cassava/three rows soybean/one row maize is attributed to the high intercrop yield of soybean relative to sole soybean yields. In a high rainfall area as in the forest ecology of Fumesua, multiple rows of the understorey crop of soybean such as the one row cassava/three rows soybean/one row maize arrangement would offer a greater stability in the overall productivity than single row soybean. This is apparently due to a reduction in competition for resource from the upperstorey crops of maize and cassava.

Conclusion

Relative planting time of the components crops was found to be an important factor influencing the productivity and economic benefits of the soybean/cassava intercropp. Planting soybeans 2 weeks before cassava was the most productive, with 52 per cent yield advantage compared to sole cropping. However, biological efficiency did not imply economic efficiency and planting soybeans 4 weeks after cassava was the most profitable, with net benefits 500 per cent higher than sole cropped soybean. Spatial arrangement was an important management factor in the soybean/cassava/maize intercropping system. The one row maize/one row cassava/one, two or three rows soybean were the most productive three-crop systems with yield advantage of 44-104 per cent over sole cropping.

Intercropping of soybean has been found to be a productive, profitable and an attractive production system for soybeans in Ghana. This finding is expected to promote the production of soybean in the country. However, removal of the

bottlenecks in pricing and marketing of soybean would play a key role in the extent of adoption of soybean in Ghana.

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REFERENCES

Aggarwal, P. K., Garrity, D. P., Libon, S. P. & Morris, R. A. (1992) Resource use and plant interactions in a rice-mungbean intercrop. *Agron. J.* **84,** 71-78.

Arias, F. R., Dapaah, H., Ennin, S. & Gyampoh, M. (1990) Effect of chronological arrangement, spatial arrangement and varietal combination on yield and economic feasibility of maize-cowpea intercropped. In *Cereal legume intercropping: Proceedings of a workshop on research methods for cereal legume intercropping in Eastern and Southern African* (S. R. Waddington, A. F. E. Plamer and O. T. Edje, ed.). Mexico, D. F.: CIMMYT.

Asafu-Agyei, J. N., Osafo, D. M. & Ahenkora, K. (1998) Plant density and yield relationships of intercropped maize and cassava. *Acta agron. hung.* **46,** 59-70.

Bandyopadhay, S. K. & De, R. (1986) Nitrogen relationships and residual effects of intercropping sorghum with legumes. *J. agric Sci. Camb.* **107,** 629-632.

Benasi, L. V. & Na-Lampong, A. (1985) Soybean cropping systems in Thailand: Technical and socio-economic aspects. In *Soybean in tropical and subtropical cropping systems: Proceedings of a symposium, Tsukuba, Japan 26 September-October, 1983.* (S. Shanmu-gasundarum and E. W. Sulzberser, ed.). Analytical 112-120.

Candal-Neto, J. F., Dessaune-Filho, N. & Pacova, B. E. V. (1993) Planting density of two bean (*Phaseolus*) cultivars with different growth habits intercropped with maize in the mountain region of Espirito Santo, Brazil. *Revista-Ceres* **40,** 281-287.

Danso, S. K. A., Palmason, F. & Hardarson, G. (1993) Is nitrogen transferred between field crops? Examining the question through a sweet-blue lupin (*Lupinus angusti folius* L.) - oats (*Avena sativa*) intercrop. *Soil Biol. Biochem.* **25,** 1135-1137.

Ennin, S. A. (1997) *Nitrogen and solar radiation dynamics in soybean/maize systems.* (PhD Dissertation) University of Nebraska, Lincoln. USA.

Herberts, S. J., Putnam, D. H., Poos-Flyd, M. I., Vargas, A. & Creighton, J. F. (1984) Forage yield of intercropped corn and soybean in various planting patterns. *Agron. J.* **76,** 507-510.

Mason, S. C., Leihner, D. E. & Vorst, J. J. (1986) Cassava-cowpea and cassava-peanut intercropping. I. Yield and land use efficiency. *Agron. J.* **78,** 43-46.

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

Okeke, J. E. (1996) Effects of spatial arrangement and relative time of planting on intercropped maize and cassava. *Trop. Sci.* **36,** 6-10.

Rerkasem, K. & Rerkasem, B. (1988) Yields and nitrogen nutrition of intercropped maize and riccbean (*Vigna umbellata* [Thumb] Ohwi and Oshashi). *Pl. Soil.* **108,** 151-162.

Stern, W. R. (1993) Nitrogen fixation and transfer in intercropping systems. *Fld Crops Res.* **34,** 335-356.

Tsay, J. S., Fukai, S. & Wilson, G. L. (1987) The response of cassava (*Manihot esculenta*) to spatial arrangement and to soybean intercrop. *Fld Crops Res.* **16,** 19-31.

Willey, R. W. (1979) Intercropping - its importance and research needs. Part I. Competition and yields advantages. *Fld Crop Abstr.* **32,** 2-10.