Relative time of planting and spatial arrangement for soybean/maize intercropping

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Abstract

Soybean/maize intercropping was studied at Fumesua and Pokuase in 1992. The objectives of the study were to determine: (i) the growth and physiology of soybean intercropped with maize, and (ii) the effects of relative planting time and spatial arrangement on productivity of soybean/maize intercrop. Intercropping reduced soybean yields by an average of 66 per cent at Fumesua and 35 per cent at Pokuase, due to reduction in leaf area per plant, dry matter per plant and number of pods per plant. The highest yield advantage of 51 per cent was achieved by simultaneous planting at Pokuase because of high relative yields of both soybean (0.81) and maize (0.70). In fumesua, soybean/maize intercropping was more productive than sole cropping only when soybean was planted 10 days after maize with 22 per cent yield advantage. This intercrop also had the highest leaf area ratio (LAR) of 21 cm^2g^{-1}. Spatial arrangement of soybean between the 90 cm rows of maize was not as important as relative planting time in influencing productivity of the soybean/maize intercrop.

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Introduction

Intercropping is the predominant cropping system for food crop production in Ghana. Intercropping of soybean with cereals is a common farmers' pracrice in various parts of the world. Soybean/ maize intercropping is a common farmers' practice in India (Sharma & Mehta, 1991). Soybeans intercropped with maize have been reported by several workers in Australia, Zimbabwe and United States of America (Herbert *et al.*, 1984; Weil & McFadden, 1991). Soybean intercropped with other crops such as sorghum and wheat in Puerto Rico and the United States of America (Ofori & Stern, 1987) and cassava in Thailand (Benjasil & Lampong, 1985) have also been reported.

In Ghana, soybean is a relatively new crop. However, it can play an important role in the cropping systems because of its ability to fix atmospheric nitrogen. Farmers also plant various intercrop component crops randomly, lacking knowledge in spatial and temporal arrangements of component crops. Yield advantages realized in intercropping have been attributed to the principle of temporal and spatial complementarity of the component crops (Willey, 1979).

In recent years, the role of biological nitrogen fixation of legumes in improving the nitrogen economy, productivity of legume intercrops and the intercrop soil environment has been emphasized (Sterm, 1993; Sangakkara, 1994). Relative time of planting and spatial arrangement are agronomic practices which have been reported to influence yield advantage of cereal/legume intercrops by affecting interspecific competition and the degree of complementarity of the component crops (Willey, 1979; Ofori & Stern, 1987; Ennin & Arias, 1988; Arias *et al.*, 1990).

The objectives of the study were to determine: (i) the growth and physiology of soybean intercropped with maize, and (ii) the effects of relative time of planting and spatial arrangements on the productivity of soybean/maize intercrop.

Material and methods

A soybean/maize intercrop was established at Fumesua (66° 43' N, 1° 36' W) in the Forest Savanna zone, and Pokuase (5° 36 N, 00° 1' W) in the Coastal Savanna zone of Ghana during the major rainy season of 1992. The soils at Fumesua belong to the Asuansi series (classified as Ferric Acrisol (FAO/UNESCO) or Paleustult (USDA)) (Asamoah, 1968). The topsoil usually has two to three layers. The top layer, about 5 cm thick, is dark grey gritty loam to gritty clay loam. The subsoil contains mainly quartz gravel in a clay matrix. The soils at Pokuase belong to the Akroso series (classified as Dystric Cambisol (FAO/UNESCO) or Dystrochrepts (USDA)). The parent material of this soil is a colluvium derived from granite and occurs on a gradient of 2-6 per cent. The subsoil texture varies from loam though clay loam to clays. The monthly total rainfall for the locations is indicated in Table 1.

and sprayed with roundup (a.i. glyphosate 360 g l^{-1}) at the rate of 4 l ha^{-1}. The first planting date for the simultneous and other relative planting times at both locations was may 1992. Maize in both sole crop and intercrop systems was planted at 55,000 plants ha^{-1} in 90 cm rows and soybean was planted at 222,000 plants ha^{-1} in both sole crop intercropping systems. Maize was fertilized with a split application of 90 kg N ha^{-1} and with 54 kg P_2O_5 ha^{-1}. Weeds were controlled by hand weeding.

TABLE 1

Monthly Total Rainfall (mm) for Fumesua and Pokuase in 1992

	Month												
Locations	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Total*
Fumesua	0	6.6	76.7	114.8	138.7	114.6	68.8	19.1	246.1	63.2	79.8	37.3	965.7
Pokuase	0	0	32.6	30.5	123.4	31.3	28.9	6.6	183.2	67.4	129.5	16.5	649.9

Experimental design

The experimental design was a randomized complete blok, consisting of 16 treatments arranged in a 2 × 7 factorial with two sole crops. The factors under study were (i) two spatial arrangements: soybean in alternate rows with maize, and double rows of soybeans between two rows of maize; and (ii) seven relative times of planting the component crops: planting soybeans 30, 20 and 10 days after maize, simultaneous, and planting soybeans 30, 20 and 10 days before maize.

Planting materials used were developed at Crops Research Institute. The maize cultivar was Dobidi, an open-pollinated 120 days cultivar. The soybean cultivar used was Bengbie, a highly promiscuous nodulating cultivar with semi-erect growing habit and 100-110 days duration.

Cultural practices

Land preparation at both locations involved no-till, where the fields were slashed with a mower

Plant sampling and calculations

At final seed filling stage of soybeans (R6) (Fehr *et al.*, 1971), five soybean plants per plot were randomly selected and harvested at soil level at Fumesua only. Leaf laminae were separated from petioles and leaf area measured using a leaf area meter model GA-5 (Ogawa Seiki Company Ltd, Japan). Plant parts were put together and oven-dried at 80 °C till constant weight. Leaf area ratio (LAR) was derived from leaf area and dry matter according to Gardner *et al.* (1985) as follows:

$$LAR = L_A/W$$

where L_A = leaf area, and W = Total plant biomass.

The biological efficiency and productivity of the intercrop was measured by land equivalent ration (LER), which is the summation of the ratio of intercrop to sole cropped yields of the component crops in the intercrop system (Balaasubramanian & Sekayange, 1991).

Results and discussion

Soybean physiology

Leaf area. Leaf area development was greater in intercrops than sole cropped soybean when soybean was planted before maize (Table 2). Total leaf area per plant was highest with the longest delay (30 days) in maize planting after soybean. Delay in soybean planting after maize resulted in significant ($P < 0.05$) reductions in leaf area development with least leaf area per plant when soybeans were planted 30 days after maize. Two factors, namely competition from the well-established maize and a lower amount of rainfall received in July-August (Table 2) with delayed soybean planting, could account for the decreasing leaf area development with delayed planting of intercropped soybean.

Dry matter. Dry matter production of soybeans followed a similar trend to leaf area development (Table 2). Highest dry matter per plant was achieved when soybeans were planted 30 days before maize and decreased significantly with delay in soybean planting, with least dry matter production when soybean was planted 30 days after maize. The faster leaf area development of soybean in intercrops where soybean was planted before maize coupled with less competition from the delayed maize and higher rainfall resulted in the high photosynthate production and, hence, high dry matter. Other workers have established similar relationships (Herbert *et al.*, 1984). However, greater competition from the maize, shading and moisture stress as soybean planting delayed in the intercrop systems where soybean was planted after maize, resulted in a reduction in leaf area development and, hence, plant growth and development.

TABLE 2

Physiological Basis for Yield Differences in Intercropped Soybeans at Fumesua, 1992

Relative time of planting	*Leaf area/ plant (cm^2)*	*Dry matter/ plant (g)*	*LAR† (cm^{-2}g^{-1})*	*Pods/ plant*	*Seeds/ pod*	*Grain yield (Mg ha^{-1})*
Soybean 30 days after maize	527	31	17	0.0	0.00	0.00
Soybean 20 days after maize	1027	56	18	19.5	1.49	0.22
Soybean 10 days after maize	970	47	21	19.3	1.36	0.47
Simultaneous	1186	87	14	22.9	1.25	0.44
Soybean 10 days before maize	1582	129	12	30.7	1.65	0.74
Soybean 20 days before maize	1395	136	10	29.7	1.52	0.60
Soybean 30 days before maize	1979	174	11	39.8	1.85	1.36
SE	357	25.24	-	5.84	0.16	0.08
Sole soybean	1374	121	11	29.5	1.89	1.61

†LAR = Leaf area ratio

Leaf area ratio (LAR). Compared with sole cropping LAR increased in simultaneous planting and increased further with delays in intercropped soybean planting relative to the maize (Table 2). This trend was opposite of the trend in leaf area and dry matter development. The highest LAR was achieved when soybean was planted 10 days after maize. The LAR development for sole cropping and all the intercrop systems where soybean was planted before maize were similar and lower than all intercrops systems where maize was planted at the same time or before soybean. This indicates that the soybean crop adjusted its physiology under greater competition and stressful conditions so as to be able to compete and survive. It, therfore, increased the proportion of assimilates partitioned to photosynthesizing tissue rather than respiring tissue (Gardner *et al.*, 1985), under limited assimilate production caused by increasing competition from intercropped maize.

Grain yields

Relative time of planting. Relative time of planting soybean and maize significantly ($P \leq 0.5$) influenced grain yeilds at both Fumesua and Pokuase (Tables 4 and 5). As soybean yields increased with earlier plantings of soybean in the intercrop, maize yeilds decreased and *vice-versa.* The highest yield of a crop was achieved when it was planted 30 days before the component crop in the intercrop. It was only at Pokuase that soybean planted 30 days after maize produced 0.12 Mg ha^{-1} grain (Tables 3 and 5). Maize planted 30 days after soybean at both locations and soybean planted 30 days after maize only at Fumesua produced no grain (Tables 2 and 4). The reduction in yield when planting of a component crop was delayed could be due to a combination of limited rainfall availability and increased competitive ability of the established component crop.

Mean reduction in intercrop soybean grain yields were higher (66%) at Fumesua than at Pokuase (35%) (Tables 4 and 5). Physiological factors contributing to the high reduction in intercropped soybean yields were reduction in leaf area per plant, dry matter per plant and number of pods per plant (Tables 2 and 3). Planting soybeans 30 days before maize had the highest intercrop yield and the highest leaf area, dry matter and number of pods per plant. These findings support earlier studies (Chui & Shibles, 1984; Mason *et al.*, 1986), which showed that reduction in the number of pods per plant accounted for yield reductions associated with intercropped legumes. In addition to pod set, this study shows the importance of greater leaf area development and dry matter production in determining high intercropped soybean yields.

Spatial arrangement. At both Fumesua and Pokuase, grain yield of intercropped soybean was significantly ($P < 0.5$) influenced by spatial arrangements with no influence of spatial arrangement on maize yields (Tables 6 and 7). Although intercropped soybean yields by all spatial arrangements were lower than sole cropped soybean yiedls, the double row of soybean between two rows of maize arrangement had significantly higher yields than the alternating one

TABLE 3

Physiological Basis for Yield Differences in Intercropped Soybeans at Pokuase, 1992

Relative time of planting	*Plant height (cm)*	*Pods/plant*	*Seeds/pod*	*Grain yield (Mg ha^{-1})*
Soybean 30 days after maize	30	10	1.83	0.12
Soybean 20 days after maize	37	11	2.01	0.14
Soybean 10 days after maize	42	15	1.96	0.35
Simultaneous	43	34	1.88	0.39
Soybean 10 days before maize	49	31	1.99	0.25
Soybean 20 days before maize	43	33	1.64	0.33
Soybean 30 days before maize	48	41	2.08	0.61
SE	3.04	4.78	NS	0.07
Sole soybean	45	43	2.03	0.48

TABLE 4

Effect of Relative Time of Planting on Grain Yields and Productivity of Maize/Soybean Intercrop at Fumesua, 1992

Relative time of planting	Grain yield (Mg ha^{-1})		Yield reduction (%)		LER
	Soybean	Maize	Soybean	Maize	
Soybean 30 days after maize	0.00	3.72	100	13	0.86
Soybean 20 days after maize	0.22	3.52	86	17	0.96
Soybean 10 days after maize	0.47	3.94	71	7	1.22
Simultaneous	0.44	2.75	73	35	0.92
Soybean 10 days before maize	0.74	1.94	54	54	0.91
Soybean 20 days before maize	0.60	1.82	63	57	0.80
Soybean 30 days before maize	1.36	0.00	16	100	0.85
SE	0.08	0.31			
Sole crop	1.61	4.25			

TABLE 5

Effect of Relative Time of Planting on Grain Yields and Productivity of Maize/Soybean Intercrop at Pokuase, 1992

Relative time of planting	Grain yield (Mg ha^{-1})		Yield reduction (%)		LER
	Soybean	Maize	Soybean	Maize	
Soybean 30 days after maize	0.12	1.78	75	-2	1.26
Soybean 20 days after maize	0.14	1.59	71	9	1.20
Soybean 10 days after maize	0.35	1.12	26	42	1.32
Simultaneous	0.39	1.23	19	30	1.51
Soybean 10 days before maize	0.25	1.05	47	40	1.13
Soybean 20 days before maize	0.33	0.00	31	100	0.69
Soybean 30 days before maize	0.61	0.00	-28	100	1.28
SE	0.07	0.23			
Sole crop	0.48	1.75			

row maize and soybean. Apparently, at the same soybean population density, the interplant competition for radiation interception, nutrients and moisture among the soybean plants was reduced in the double rows soybean arrangement. Reddy *et al.* (1989) and Chui & Shibles (1984) have also reported that spatial arrangements that reduced competition between maize and lodging, and increased pod set resulted in greater soybean grain yield.

Biological efficiency or productivity of intercrops

Relative time of planting. LER is a measure of the biological efficiency of the intercrop. The highest LER of 1.22 was obtained at Fumesua when soybeans were planted 10 days after maize

TABLE 6

Spatial Arrangement Effect on Grain Yields and Productivity of Maize/Soybean Intercrop at Fumesua, 1992

Spatial arrangement	Grain yield (Mg ha^{-1})		Yield reduction (%)		LER
	Soybean	Maize	Soybean	Maize	
One alternate row of soybean and maize	0.49	2.53	70	41	0.9
Double rows of soybean between two rows of maize	0.60	2.53	63	41	1.0
SE	0.04	0.17			
Sole crop	1.61	4.25			

TABLE 7

Production of Maize/Soybean Intercrop as Influenced by Spatial Arrangement at Fumesua, 1992

Spatial arrangement	Grain yield (Mg ha^{-1})		Yield reduction (%)		LER
	Soybean	Maize	Soybean	Maize	
One alternate row of soybean and maize	0.26	1.02	46	42	1.13
Double rows of soybean between two rows of maize	0.37	0.88	24	50	1.27
SE	0.04	NS			
Sole crop	0.48	1.75			

and the highest LER of 1.51 was obtained at Pokuase with simultaneous planting (Tables 4 and 5). Planting soybeans 10 days after maize also had a high LER of 1.32 at Pokuase. These results support the review on cereal/legume intercrops by Ofori & Stern (1987) who concluded that simultaneous and close to simultaneous planting resulted in highest biological efficiency and productivity of cereal/legume intercrops. It should be noted that treatments with high productivity had the least total reduction in yields compared with sole crops (Tables 4 and 5). This implies that planting soybeans 10 days after maize in Fumesua and Pokuase and also simultaneously at Pokuase offered the least interpecific and intraspecific competion, a requirement for high productivity of intercrop systems (Willey, 1979). It was also found that at Fumesua where soybean growth was studied, planting soybean 10 days after maize, which was the only treatment with yield advantage over sole cropping in this location, also had the highest leaf area ratio of soybean (Table 2). Preferenitial partitioning of assimilates to photosynthesizing tissue rather than respiring tissue, therefore, appears to be an important factor that leads to greater biological efficiency and productivity of an intercrop system than sole cropping.

Apart from planting soybeans 10 days after maize at Fumesua, other intercrop treatments had

LERs less than one, indicating that those treatments did not have any yield advantage over the sole crops. These findings at Fumesua indicate that in high rainfall areas, proper choice of relative time of planting was a critical factor for yield advantage to be realized when intercropping maize and soybeans. Unlike Fumesua, most of the LERs obtained at Pokuase were greater than one, indicating that intercropping maize and soybeans at this location was more productive than planting sole crops. This finding confirms reports (Reddy & Willey, 1981; Natarajan & Willey, 1986; Ennin, 1997) that although yields are less under drier conditions, intercropping results in higher productivity compared to sole crops under limited moisture conditions, as a result of increased water use efficiency.

Spatial arrangement. Double rows of soybean had slightly higher intercrop productivity than alternate rows (Tables 6 and 7) similar to reports of cereal/legume intercrops (Ofori & Stern, 1987; Ennin & Arias, 1988). These differences were due to higher soybean yield produced, as spatial arrangement significantly influenced soybean grain yield without affecting maize grain yield at both locations.

Conclusion

Relative time of planting was a critical management factor determining growth, grain yields, biological efficiency and productivity of the soybean/maize intercrop. Mean reduction in intercropped soybean yield was greater at Fumesua (66%) than at Pokuase (35%). Physiological factors which contributed to the high reduction in intercropped soybean yields at Fumesua were reduction in leaf area per plant, dry matter per plant and number of pods per plant. Highest LER of 1.22 and 1.51 were achieved when soybeans were planted 10 days after maize or simultaneously with maize at Fumesua and Pokuase, respectively. Preferential partitioning of assimilates to photosynthesizing tissue rather than respiring tissue appeared to be an important factor that led to greater biological efficiency and productivity of the soybean/maize intercrop system. While double rows of soybean between two rows of maize resulted in greater soybean yields than alternate rows, spatial arrangement did not appear to be as important as relative planting time in influencing productivity of the soybean/maize intercrop system. Soybean/maize intercropping could become a stable alternative to growing maize or soybean as monocrops in dry locations in the country.

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