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YIELD AND PRODUCTIVITY OF COMPONENT CROPS IN A MAIZE-SOYBEAN INTERCROPPING SYSTEM AS AFFECTED BY TIME OF PLANTING AND SPATIAL ARRANGEMENT

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ABSTRACT

Two field experiments were carried out in 2007 and 2008 to determine the appropriate sequence of planting and spatial arrangement of component crops in the maize-soybean intercropping system for optimum grain yield and production efficiency. The experimental design was a randomized complete block design with three replications. Treatments consisted of combinations of five relative times of planting either maize or soybean and two spatial arrangements of soybean (alternate or double rows). One sole crop each of maize and soybean was added for comparison. The results indicated that the relative time of planting and spatial arrangement are important factors determining the productivity of the maize - soybean intercropping system. The crops must be planted simultaneously to obtain adequate yields of both crops. However, the spatial arrangement to adopt in order to obtain high yields for the component crops differed. For maize spatial arrangement of single rows of maize alternating with single rows of soybean gave the best yields. In contrast, a spatial arrangement of single rows of maize alternating with double rows of soybean recorded the best yields with respect to soybean. LER values recorded were in general greater than unity, implying that it will be more productive to intercrop maize and soybean than grow them in monoculture.

Keywords: maize, soybean, intercropping, grain yield, land equivalent ratio, spatial arrangement.

INTRODUCTION

The growth of two crops together in the same field during a growing season may result in inter specific competition or facilitation between the plants (Zhang and Li, 2003). Thus, the overall mixture densities and the relative proportions of component crops are important in determining yields and production efficiency of cereal - legume intercrop systems (Willey and Osiru, 1972; Lakhani, 1976).

The growth and yield of legume component is reduced markedly when intercropped with high densities of the cereal component in a maize/bean intercrop system. Increasing maize density three-fold, from 18,000 to 55,000 plants/ha caused reduction of 24% in leaf area index and 70% in seed yield of the associated bean (Gardiner and Craker, 1981). Fisher (1977) studied maize/bean intercrop systems at varying densities which at harvest were 13,700, 27,000 and 47,700 plants/ha of maize combined with 23,300, 56,300 and 121,000 plants ha^{-1} of beans, respectively, designated as low, medium, and high densities. At each density, the yield of intercrop maize did not differ from those of the sole maize. However, intercrop bean yield significantly increased with a rise in bean density. The seed yields of beans were 320 kg ha^{-1}, 650 kg ha^{-1} and 940 kg ha^{-1} from the lowest to the highest density. Although maize contributed more than 80% of the mixture yield at each density, the land equivalent ratio (LER) values followed the trends in intercrop bean yields: 0.57, 0.92 and 1.39 from the lowest to the highest density. Using replacement series designs in a maize-cowpea intercrop system, Chang and Shibles (1985) also showed that the level of the maize population generally imposed a limit on the yield of the intercrop cowpea and that there was no effect of increasing cowpea density.

The relative time of sowing a component crop is an important management variable manipulated in cereal - legume intercropping systems. Andrews (1972) pointed out that differential sowing improves productivity and minimizes competition of growth-limiting factors in intercropping. Willey (1979) also pointed out that sowing component crops at different times ensures full utilization of growth factors because crops occupy the land throughout the growing season. Francis *et al.* (1976) found that sowing maize and beans 5 - 15 days apart reduced yield of the intercrop compared to sole crops. In contrast to simultaneous sowing, maize sown 5 - 15 days earlier than beans increased maize yields by 13 - 43%, but the associated bean yields were reduced by 20 - 27%. On average, intercropping efficiency measured as LER was 39% higher when beans were sown 5 - 15 days before maize. Another study by Francis *et al.*, (1982) on maize intercropped with four contrasting beans cultivars sown 5 - 10 days apart, suggests that near-simultaneous sowing of component crops is optimal to attain the highest combined yields and intercropping efficiency. Osiru and Willey (1976) confirmed that manipulating the time intervals between growth durations of component crops influences efficiency of cereal -legume intercrop systems. In an 85-day bean and 120-day maize combination, a yield advantage of 20% was removed by sowing beans 28 days after maize. May (1982) also reported that a yield advantage of 32% completely disappeared when green gram was sown one week after bulrush millet.

Row arrangement, in contrast to arrangement of component crops within rows, may also influence the productivity of an intercropping system (Mohta and De, 1980; Oseni and Aliyu, 2010). In a maize/groundnut intercrop system, Evans (1960) obtained LERs of 1.09 in the same row arrangement compared to 1.30 in alternate rows and 1.38 in a hill arrangement. However, Agboola and Fayeni (1971) did not observe any difference whether maize and cowpea were planted in the same or alternate rows. In maize/soybean and sorghum/soybean intercropping studies conducted by Mohta and De (1980), the yields of the cereals were not affected by intercropping with soybean when arranged in either single or double alternate rows. In the maize/soybean combination, there was a 31% yield increase in the intercropped soybean when components were arranged in double alternate row and 1.25 in the single alternate row arrangement.

In Ghana, information on the effects of relative time of planting and spatial arrangement of component crops on productivity of maize-soybean intercrops is scanty. The objective of this paper was therefore to examine the effects of these factors on the yield and productivity of the component crops in maize/soybean intercropping trials conducted in the coastal savanna ecology.

MATERIALS AND METHODS

Location of the experiments

The experiments were carried out at the Teaching and Research Farm of the University of Cape Coast, Cape Coast, Ghana from October 2007 to January, 2008 (Experiment 1) and from June to October, 2008 (Experiment 2). Rainfall in this area ranges between 800mm and 1000mm annually. It has a bimodal rainfall pattern. The major season occurs from March to July, with maximum in June and minor season from September to November, with maximum in October. Between 60-70% of the total annual rain falls in the major season and 30-40% in the minor season (Asamoa, 1973). The mean monthly temperature is about 26.5^{0}C. The soils of the area are sandy clay loam, belonging to Benya series, which is a member of the Edina-Benya-Udu compound association, developed under Sekondian material. They are classified as Typic Haplustult (USDA Soil Taxonomy) and Haplic Acrisol (FAO/UNESCO).

Planting material

One variety each of maize and soybean was used. The maize variety was Obatanpa and the soybean variety was Anidaso. Obatanpa is a white dent, medium-maturing (105-110 days) variety. It has a plant height of 175cm and an average grain yield of 4.5 ton ha^{-1} (CRI, 1990). The soybean variety (Anidaso) is resistant to shattering, nodulates freely with the indigenous cowpea/groundnut rhizobia in Ghanaian soils. It matures in 105-115 days, with a plant height of 35-40cm and yields 1.2-1.8 ton ha^{-1} (CRI, 1994).

Experimental procedure

Treatments and experimental design

The design was a randomized complete block design (RCBD) with three replications. Treatments consisted of combinations of five relative times of planting either maize or soybean and two spatial arrangements. Each plot measured 6.4 m x7.2 m. There were 36 plots in all with 12 plots in each block. One sole crop each of maize and soybean was added for comparison. The additive series, in which mixtures have been achieved by adding together the plant populations used in the pure stand treatments, was used. Treatment details are provided in Tables 1 and 2.

Table-1. Treatment combinations and days of planting.

Treatment code	Description
T_1S_1	Maize planted same day with soybean, soybean in alternate rows
T_1S_2	Maize planted same day with soybean, soybean in double rows
T_2S_1	Maize planted 14 days before soybean, soybean in alternate rows
T_2S_2	Maize planted 14 days before soybean, soybean in double rows
T_3S_1	Maize planted 28 days before soybean, soybean in alternate rows
T_3S_2	Maize planted 28 days before soybean, soybean in a double rows
T_4S_1	Maize planted 14 days after soybean, soybean in alternate rows
T_4S_2	Maize planted 14days after soybean, soybean in double rows
T_5S_1	Maize planted 28 days after soybean, soybean in alternate rows
T_5S_2	Maize planted 28 days after soybean, soybean in double rows
Sole maize	Sole maize
Sole soybean	Sole soybean

Table-2. Expected plant spacing and population density for maize and soybean.

Crop	Spacing	Plant/Hill	Expected No. of Plants	
			m^2	Ha
Maize	90cm x 40cm	2	5.55	55, 555
Soybean	90cm x 20cm	2	11.11	111,111
	45cm x 20cm	2	22,22	222,222

Planting and cultural practices

The site during the minor season (Experiment1) was previously planted with cowpea. The site for the major season (Experiment 2) was previously planted to maize. The land was disc ploughed and disc harrowed just before planting. Planting was done between 8/10/2007 and 5/11/2007 for Experiment 1 and between 25/6/2008 and 23/7/2008 for Experiment 2. Maize was planted 3 seeds per hill and thinned to 2 seeds per hill; soybean was planted 4 seeds per hill and thinned to 2 seeds per hill.

During Experiment 2, rainfall was very low. The field was therefore irrigated once every week during the period of the trial. Fertilizers were applied only to maize. NPK 15-15-15 fertilizer at the rate of 250 kg ha^{-1} by side placement two weeks after planting, urea at 125 kg ha^{-1} was applied top dressed six weeks after planting. Total fertilizer nutrients applied therefore worked up to 95.0.N; 37.5 P_20_5; 37.5 K_2O kg ha^{-1}. The plots were weeded during the 2^{nd}, 4^{th} and 7^{th} week after planting.

Data collection

Yield data were taken on both crops at harvest**.** The harvested maize cobs and soybean pods from each plot were shelled and the grains weighed. Moisture contents of grain samples were immediately taken using a moisture meter. The final grain yields of the crops were standardized to 15% and 12% moisture content for maize and soybean, respectively. The production efficiency was based on Land Equivalent Ratio (LER) expressed as:

Land equivalent ratio (LER) = (Yij/Yii) + (Yji/Yjj)

where y is the yield per unit area, yii and yjj are sole crop yields of the component crops i and j and yij and yji are the intercrop yield (Mead and Willey, 1980). LER is the sum of the two partial land equivalent ratios.

RESULTS AND DISCUSSIONS

Maize grain yield

In Experiment 1, time of introduction of soybean significantly affected maize grain yield (Table-3). Maize planted simultaneously with soybean (T_1) or before the introduction of soybean (T_2, T_3) out yielded maize planted after soybean (T_4, T_5). Analysis of variance showed that maize planted in alternate rows with soybean (S_1) gave significantly higher grain yield than those planted in double rows of soybean (S_2) (Table-3). The effect of the interaction between time of introduction of soybean and spatial arrangement was not significant. Sole maize recorded higher grain yield than the intercropped mean. Results in Experiment 2 followed similar pattern as those recorded for Experiment 1 (Table-3).

Table-3. Effect of time of planting and spatial arrangement on maize grain yield (kg ha^{-1}).

Experiment 1				Experiment 2			
Time of introduction	Spatial arrangement		Mean	Time of introduction	Spatial arrangement		Mean
	S_1	S_2			S_1	S_2	
T_1	2214.0	2044.0	2129.0ab	T_1	3686.3	4000.1	3843.7a
T_2	2348.0	2362.3	2305.2ab	T_2	3273.7	3356.3	3315.0a
T_3	2471.0	2402.0	2436.5a	T_3	4034.3	3754.3	3894.3a
T_4	2155.0	1749.7	1952.3b	T_4	2632.0	2258.0	2445.0b
T_5	1021.0	916.7	968.8c	T_5	707.0	55.3	381.2c
Mean	2041.8a	1894.9b	1968.4	Mean	2866.7a	2685.0b	2775.8
Sole maize = 2405.7 LSD = 305.6 CV = 9.3%				Sole maize = 3360.3 LSD (0.01): T = 863.0 CV = 18.9%			

The reduction in grain yield of maize introduced late into a maize-legume intercrop has also been demonstrated by other workers (Nnoko and Doto, 1980; Francis *et al.*, 1982). For example, Nnoko and Doto (1980) intercropped maize and soybean at four planting schedules viz, soybean planted 2 weeks before maize, simultaneously planting and maize planted 1 week before soybean. The results indicated that in all cases, grain yield of the cereal component declined, with the greatest reduction being recorded when the soybean was planted

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before maize. The reduction in the yield of the cereal component in the present study and those of other workers has been attributed to inter specific competition for resources (Nnoko and Doto, 1980; Francis *et al*., 1982, Caballero *et al*., 1995; Assefa and Ledin, 2001) and shading of the maize seedlings by the already established soybean plants (Misbalhumanir *et al*., 1989), leading to reduction in leaf area (Enyi, 1973; Addo-Quaye, Darkwa and Ocloo, 2011), crop growth rate and net assimilation rate (Addo-Quaye, Darkwa and Ocloo, 2011).

Maize alternating with single rows of soybean (S_1) outyielded maize alternating with double rows of soybean (S_2). This observation may be due to the use of additive series in this study which ended up having double the population of soybean. This led to intense competition with the maize plants, resulting in lower yields. Similarly, Pal *et al.*, (1993) reported of reduced intercrop yields when they investigated the effects of component density on the yield of sorghum or maize intercropped with soybean. In sorghum-cowpea intercrop study, Oseni and Aliyu (2010) confirmed that yields of component crops varied with the row arrangements of the crops. Sole crops of sorghum and cowpea also recorded higher values for both grain and stover/haulm yields. Higher values of CGR and NAR recorded in most cases for maize alternating with single rows of soybean (Addo-Quaye, Darkwa and Ocloo, 2011), might have also contributed to their better grain yield compared to the observed values for maize plants alternating with double rows of soybean.

Soybean grain yield

The time of introduction of soybean and spatial arrangement significantly influenced soybean grain yield (Table-4). The earlier soybean was introduced into maize, the higher its grain yield. Soybean planted 28 days before maize (T_5) recorded the highest grain yield while soybean planted 28 days after maize (T_3) did not produce any grain. The effect of the interaction between time of introduction of soybean and spatial arrangement on grain yield was also significant. Maize planted 28 days after soybean with soybean in double rows recorded the highest grain yield while treatments in which maize was planted 28 days before soybean recorded no yield at all. Sole soybean recorded higher grain yield than the intercropped mean. The results recorded in Experiment 2 were similar to those recorded for Experiment 1 (Table-4) although grain yield for Experiment 2 was significantly higher than that for Experiment 1.

Table-4. Effect of time of planting and spatial arrangement on soybean grain yield (tha^{-1}).

Experiment 1				Experiment 2			
Time of introduction	Spatial arrangement		Mean	Time of introduction	Spatial arrangement		Mean
	S_1	S_2			S_1	S_2	
T_1	0.27de	0.58bc	0.42b	T_1	0.47cd	0.59c	0.53ab
T_2	0.14e	0.24de	0.19c	T_2	0.36cde	0.53c	0.45c
T_3	0.00f	0.00f	0.00d	T_3	0.21e	0.27de	0.24d
T_4	0.34d	0.68b	0.51b	T_4	0.52c	0.90b	0.71b
T_5	0.52c	0.98b	0.75a	T_5	1.00b	1.50a	1.25a
Mean	0.25b	0.50a	0.38	Mean	0.51b	0.76a	0.64
Sole soybean = 1.02 LSD (0.01): T = 0.09, T*S = 0.13 CV = 13.7%				Sole soybean = 1.55 LSD (0.01) : T = 0.17, T*S = 0.24 CV = 15.6%			

Soybean planted before the introduction of maize (T_4, T_5) recorded higher grain yield than soybean introduced after maize. Similarly Nnoko and Doto (1980) observed that planting soybean before cereal gave significantly higher yields than planting soybean at the same time or after the cereal, with the earlier planting schedule resulting in the highest yield. In the present study, number of pods per plant was found to be positively correlated with grain yield. Also the average plant height of the soybean plants was slightly increased as time of introduction of soybean was delayed. This led to thinner plants and fewer nodes on the main stem. There were thus fewer sites available for flower production and consequently lower number of pods. The introduction of soybean very late into maize (T_3) yielded no grain in all combinations in Experiment 1. This may be due to the fact that maize by virtue of its fast growth habit and early planting developed rapidly and formed closed canopy.

The maize plants therefore maintained a competitive advantage over the slower growing and shorter soybean plants, completely suppressing their growth and ultimately yielding no grains. The significantly high growth functions observed for soybean plants introduced earlier than maize could have contributed to their superior grain yield. For instance, LAI, CGR, and NAR were all observed to be significantly higher in soybean planted before maize (T_4 and T_5) than in soybean introduced late into the maize crop (Addo-Quaye, Darkwa and Ocloo, 2011).

Although, the yields for both row arrangements were lower than that of the sole crop, double rows of soybean alternating with single maize rows (S_2) recorded 50 per cent significantly higher grain yield than soybean planted in alternate row arrangement with maize (S_1). Similarly, Tsay (1985) recorded 31% yield increase in grain yield of the intercropped soybeans when it was planted in double row arrangement with the maize compared to single rows. Sharma *et al.*, (1994) noted that light interception by soybeans grown in paired rows with maize was greater than when arranged in single alternating rows. Plants in wider row width generally accumulate their LAI at a slower rate than plants in narrow row width (Weber *et al.*, 1966). Thus light interception and early development of leaf area resulted in higher photosynthesis and consequently a higher grain yield in the double row plots. In an earlier study, growth analysis of the component crops indicated a significantly higher crop growth rate in soybean planted in double arrangement with maize than those planted in alternate row arrangement with maize (Addo-Quaye, Darkwa and Ocloo, 2011).

Land equivalent ratio

In Experiment 1 LER was significantly influenced by time of introduction of soybean (Table-5). Soybean planted simultaneously with maize (T_1) gave the highest LER while maize planted 28 days before soybean ($T_{3)}$ gave the lowest. The effect of spatial arrangement was also significant. Soybean planted in double rows with maize (S_2) recorded higher LER than maize alternating with single rows of soybean (S_1). Interaction between time of introduction of component crops and spatial arrangement also influenced LER significantly. The highest LER was recorded by treatments in which maize was planted simultaneously with soybean (T_1S_2) while maize planted 28 days before soybean (T_3S_2) gave the lowest. In Experiment 2, soybean planted before maize (T_4 and T_5) or planted simultaneously with maize (T_1) generally recorded higher LER than soybean planted after maize, T_2 and T_3 (Table-5). Spatial arrangement did not significantly affect LER. Interaction between time of introduction of component crops and spatial arrangement also recorded the highest LER for T_1S_2 while treatment T_5S_1 recorded the least.

Table-5. Effect of time of planting and spatial arrangement on land equivalent ratio (LER) of maize/soybean intercropping system.

Experiment 1				Experiment 2			
Time of introduction	Spatial arrangement		Mean	Time of introduction	Spatial arrangement		Mean
	S_1	S_2			S_1	S_2	
T_1	1.96bc	1.42a	1.31a	T_1	1.40ab	1.56a	1.48a
T_2	1.13cb	1.23abc	1.18ab	T_2	1.21bc	1.33abc	1.12ab
T_3	1.04cd	1.01cd	1.02b	T_3	1.32abc	1.31abc	1.32ab
T_4	1.21abc	1.40ab	1.30a	T_4	1.11cd	1.26bc	1.19b
T_5	0.96d	1.37ab	1.30a	T_5	0.85e	0.96de	0.91c
Mean	1.11b	1.29a	1.16	Mean	1.18	1.28	1.23
LSD (0.01): T =0.15, T*S = 0.21 CV = 7.6%				LSD (0.01): T = 0.23, T*S = 0.24 CV = 11.3%			

According to Edje (1987), if the LER is equal to 1, then there is no difference in yield between growing the crop in pure or mixed stand. If the LER is greater than 1, there is a yield advantage when both crops were grown as mixed compared to pure stands? If however the LER is less than 1, it will be better in terms of yield to grow both crops separately, as it indicates yield disadvantage. In the present study the LER was greater than 1 in almost all the treatments, indicating that it is advantageous to grow maize and soybean in association than in pure stands. It is evidenced from the results, therefore, that simultaneous planting which recorded the highest LER (1.31and 1.48 for Experiments 1 and 2, respectively) is the best arrangement for maize-soybean intercropping.

Several workers have also obtained LER greater than 1 in maize-soybean intercropping. Allen and Obura (1983) observed LER of 1.22 and 1.10 for maize-soybean intercrop in two consecutive years. Raji (2007) and Muoneke *et al.*, (2007) had also reported of higher production efficiency in maize/soybean intercropping systems. The higher productivity of the intercrop system compared to the sole crop may have resulted from complementary and efficient use of growth resource by the component crops (Li *et al.*, 2003; Li *et al.*, 2006). For example, Sivakumar and Virmani (1980) observed that in maize - pigeon pea intercrop; dry matter production per unit of photosynthetic active radiation (PAR) absorbed was higher in the mixture than in the sole crops. The higher PAR conversion efficiencies of these systems relative to the sole crops may be due to spread of light over greater leaf area, and more efficient distribution of light in the intercrop canopies during early stages of growth.

The maize component contributed more to the total LERs of the mixture as shown by the partial LER of maize in the results. This observation is similar to the findings of Muoneke *et al*., (2007) who evaluated the effects of maize planting density on the growth, yield and productivity of maize/soybean intercropping system. It has been reported by West and Griffith (1992), and Ghaffarzaeh *et al*., (1994) that soybean yield tends to be lower whilst maize yield tends to be higher under soybean/maize intercropping systems. In cereal-legume intercropping, the cereal components usually tend to have greater competitive ability because of their relatively higher growth rate, height advantage, and more excessive root system (Ofori and Stern, 1987). Lima Filho (2000) also showed that the leaf water potential, stomatal conductance, transpiration and photosynthesis were all higher in intercropped maize than the sole crop.

Maize planted with double rows of soybean recorded higher values of LER than maize alternating with single rows of soybean though this was not significant for Experiment 2. This may be attributed to the fact that soybean population was twice that of the single row arrangement. This finding is in agreement with those of Chowdhury and Rosario (1993) who observed the highest LER when both intercrop components were at their optimum sole crop populations in maize-mung bean trial. The higher values of grain yield and LER observed in Experiment 2 over Experiment 1 was probably due to better amount of water received by plants during the second experiment when the plots were irrigated.

CONCLUSIONS

The results of the present study have demonstrated that relative times of planting and spatial arrangement are important factors determining the yield and productivity of the maize - soybean intercropping system. If the farmer wants the highest possible maize yield plus some addition of soybean then the obvious choice is planting the maize 2 weeks before the soybean. Planting soybean 28 days after maize should be avoided because the soybean may not produce any yield at all. If the objective is to obtain the highest possible soybean yield plus some maize then the choice should be planting soybean 2 weeks or 4 weeks before maize. The crops must however be planted simultaneously to obtain adequate yields of both crops.

The effect of spatial arrangement on grain yield of both crops was significant. However, the spatial arrangement to adopt in order to obtain high yields for the component crops differed. In the case of maize, the results indicated that a spatial arrangement of single rows of maize alternating with single rows of soybean gave the best yields. In contrast, a spatial arrangement of single rows of the maize alternating with double rows of soybean recorded the best yields with respect to soybean. LER values recorded were in general greater than unity, implying that it will be more productive to intercrop maize and soybean than grow them in monoculture. In this case simultaneous planting of the two component crops should be adopted since that treatment recorded the highest LER in both experiments.

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