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Full Length Research Paper

Intercropping Soybean (*Glycine max* L. Merr.) at Different Population Densities with Maize (*Zea mays* L.) on Yield Component, Yield and System Productivity at Mizan Teferi, Ethiopia

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The present study was carried out to evaluate maize - soybean intercropping effect on yield components and yield of the intercrops and to identify the optimum population density and variety of soybean maximizing productivity of the system. Treatments were maize hybrid (BH540) at recommended population density and three soybean varieties (AFGAT, Awassa-95 and Crawford) in a factorial combination of three planting densities (25%, 50% and 75%) of the recommended population density of soybean with the respective sole of each variety of component crops were arranged in a randomized complete block design with three replications. Sole cropped maize grain yield (3189.80 kg ha^{-1}) was non-significantly greater than intercropped (2753.70 kg ha^{-1}) by means of 13.67%. However, maize intercropped with Awassa-95 at 50% planting density showed a yield advantage of 23.71% over sole cropped maize. A 100-seed weight (g) of soybean showed a significant difference due to varieties and cropping system. Soybean seed yield of 1993.61 and 747.48 kg ha^{-1} was obtained from sole and intercropped soybean, respectively. The intercropping system increased 100 - seed weight by 12.84% and reduced seed yield on average 62.51% compared to sole cropped. In all combinations, LER was greater than one justified that a yield advantage of (14-32%) and (6-28%) as depicted by LER 1.14-1.32 and 1.06 -1.28 due to varieties and planting densities, respectively. Generally, as LER was superior in all intercrops evaluating that the productivity of maize-soybean intercropping showed a higher relative yield advantage of 32% over sole cropping. Therefore, a variety Awassa-95 at 50% planting density was better in resources utilization attributed to yield under this additive intercropping system.

Keywords: Intercropping, land equivalent ratio, maize and soybean

INTRODUCTION

Cropping system is common practice among small-scale farmers in tropics. There are several advantages to intercropping relative to sole cropping for small scale farmers in terms of socio-economic, biological and ecological aspects of the system (Willey, 1979 and Raji, 2007). Intercropping is a principal means of intensifying crop production both spatially and temporally, to optimize production per unit area from limited land holdings and improves the returns (Storck et al., 1991). Small-scale farmers have been bearing mixed cropping for various reasons which include increased monetary returns, insurance against crop failure and reduction of pests due to biological diversity within the system (Singh and Balyan, 2000 and Ghosh et al., 2006). Cereal-legume intercropping is widely practiced in southwestern parts of Ethiopia; Bench Maji zone. Hence, the use of such cropping system in the Southern region is attributed to high density of population to assure yield stability and maintaining a sustainable yield over year (Tenaw et al., 2006). In Ethiopia, the total land of soybean production under peasant holdings covers about 6352.46 hectares (CSA, 2007). It is one of a pre-eminent crops in providing cheap and inexpensive protein (40%) and oil (20%) which determines the economic worth of the crop on the globe (Thomas and Erostus, 2008). In spite of its importance, the productivity and marketable surplus have remained very low in the region. The country has an early, medium and late maturing varieties of soybean have a great potential in short, intermediate and longer rainfall areas, respectively. These maturity groups are also considered to be more suitable for multiple cropping systems particularly in longer rainfall areas (ICARDA, 2006). Therefore, the economic and nutritional value, a great yield potential, a wide range of adaptability and high productivity per unit area of soybean and maize intercropping preferred by resource poor farmers against sole cropping system (Muoneke et al., 2007). In the region, adequate and reliable rainfall with long length of growing period being the merits in diversifying crop production per unit area. Legumes are the major food legumes supplementing the stable diet maize (*Zea mays* L.) and taro (*Colcolus esculanta L.*) and grown mainly as an intercrop with maize in conventional intercropping system.

Therefore, maize-soybean intercropping have been reported to increase the efficiency of land use through improved soil productivity, maintaining a sustainable yield over the year and increasing the total crop yield per unit area over sole crop through better use of resources by the components (Lal, 2003). There is a potential for higher productivity of maize-soybean intercropping when inter specific competition is less than intra competition that improves crop grain yield per unit area compared to sole cropping when appropriate agronomic practices are applied to reduce competition between the companion crops (Tenaw et al., 2006). In the region, soybean-maize intercropping is a common features of the farmers but it is practicing in a traditional mixed cropping system using unimproved cultivars of soybean in intercropping this decrease the productivity of the system. In addition, the effect of management such as planting density of the intercrops used in the system has an influence on yield and yield components, and the performance of soybean cultivars under various densities in the intercropping system.

MATERIALS AND METHODS

Description of study area

The experiment was conducted during the main cropping season of 2012/13 at Mizan-Teferi College of Agricultural experimental field, Semen Bench Woreda of the Bench Maji zone. the experimental site is situated at approximately 6^0 52'N to 7^0 N latitude and 35.5^0 21' E, altitude of 1400m. The soils is typically Nitisols with clay - loam soil in texture. The study area is one of among the highest annual rain fall receiving area in Ethiopia which is characterized by its bimodal rainfall pattern with long rainy season, mean annual rainfall 1800 mm. The mean maximum and minimum temperatures were 29 ^{0}C and 22 ^{0}C, respectively.

Associated crops

Three soybean varieties (AFGAT, Awassa-95 and Crawford) and maize hybrid (BH540) were used. On the basis of (ICARDA, 2006) classification, AFGAT and Awassa-95 varieties are indeterminate growth habit with a maturity period of four and three months, respectively. And the growth habit of Crawford is determinate and matures at three months. The maize hybrid (BH540) developed by Bako Agricultural Research center was the other components of the intercrop. The crop matures in a period of five months, the plant height ranging from 2.30 -2.60m and tolerant to lodging blight (Mossisa et al., 2001). The intercrop components crops are widely grown a countrywide at different agro-ecologies of Ethiopia both in sole and intercropping system. In the cropping season of 2012/13, the system was evaluated on randomized complete block design in factorial arrangement with three replications. The system comprised row intercropping with the soybeans sown between maize rows and sole cropping of the components crops. Both soybean and maize were sown in rows of plot size 6 m X 3 m. Maize seeds were sown in rows with 75cm inter-row spacing and 30cm intra-row spacing in cropping system. In the system, row intercropping of soybean was done between consecutive eight (8) rows of maize at 75%, 50% and 25% of recommended plant densities of sole soybeans varieties (500,000 plants ha^{-1}) at 40cm of inter-row spacing. Finally, the intra-row spacing for soybean varieties was adjusted according to planting density in the system. Hence, the mean soybean population ha^{-1} used in the intercrop for 75%, 50% and 25% was 375,000, 250,000 and 125,000 plants, respectively. For sole cropping, both the soybean and maize were planted at their optimum plant densities of 500,000 and 44,444 plants ha^{-1}, respectively. All recommended agronomic practices were employed for each crop as per the schedule. The net harvestable plot area was used for intercropping and sole cropping of components crops for determination of final yield.

Data collected and analysis

Number of pods per plant, number of seeds per pod and a 100- seeds weight of each soybean varieties were recorded. The entire soybean and maize crop in net plot area were harvested for determination of seed yield and maize grain yield and converted to hectare basis (kg ha^{-1}). Soybeans and maize yield were used to calculate Land Equivalent Ratios (LER), the relative land area required for sole crop to produce the yield achieved in intercropping (Mead and Willey, 1979). Accordingly, the partial LER (individual crop's LER) and total LER (sum of individual crop's LER) were used as indices to evaluate the productivity of intercropping systems. Comparison between partial LER of the component crops indicates the competitiveness of the individual species and the total LER is a measure of the relative yield advantage. Thus,

$$LER = \frac{Yab}{Yaa} + \frac{Yba}{Ybb}$$

Where:
Yab = yield per unit area of maize in intercropping
Yaa = yield per unit area of maize in sole
Yba = yield per unit area of soybean in intercropping
Ybb = yield per unit area of soybean in sole

RESULTS AND DISCUSSION

Soybean yield and yield components

Findings indicated that soybean seed yield (kg ha^{-1}) was significantly (P < 0.05) varied with respect to the planting density and varieties and the cropping system. The result revealed that progressive increment in seed yield of soybean was recorded as planting density of varieties increased from 25% to 75% which ranged from 604.80 to 909.00 kg ha^{-1}, respectively (Table 1). Besides, the seed yield of sole soybean was significantly higher than the intercropped soybean. Hence, the seed yield of 1993.61 and 747.48 kg ha^{-1} was obtained for sole and intercropped soybean, respectively. The soybean varieties used differed under the intercropping system, for instance; highest seed yield of 906.80 kg ha^{-1} was resulted from AFGAT intercropped with maize while the lowest yield of 643.20 kg ha^{-1} was obtained from Crawford. These two varieties were significantly differed from each other but both did not vary significantly from Awassa-95. This might be because of the varietal differences and the ability of individual variety to exploit the available resources like solar radiation, soil moisture and nutrients. Muoneke et al. (2007) also confirmed on maize/soybean intercropping that the differences in seed yield between the two varieties in the early season could be attributed to the inherent varietal characteristics in intercropping system. Generally, with increasing in soybean planting density an increasing trend of seed yield per ha was observed. The seed yield of sole soybean was greater than that of intercropped by 1246.13 kg ha^{-1}. However, the intercropping was additive, due to intercrops competition, soybean suffered a yield reduction of 1246.13 kg ha^{-1}

Table 1: Yield and yield components of the associated soybean grown in sole and intercropped with maize as affected by soybean varieties and planting densities

Treatment	Pods/plant	Seeds/pod	100- seed weight (g)	Seed yield (kg/ha)	Maize yield (kg/ ha)
Soybean Varieties					
Maize + AFGAT	34.98	2.21	13.08	906.80	2372.70
Maize + Awassa-95	29.93	2.20	14.45	692.40	3188.30
Maize + Crawford	25.78	2.24	16.81	643.20	2700.10
LSD (0 .05)	6.31	NS	1.01	226.48	598.77
Soybean Planting Densities					
Maize + 25%	40.04	2.16	15.33	604.80	2520.40
Maize + 50%	27.84	2.22	14.64	728.60	2971.40
Maize + 75%	22.80	2.27	15.10	909.00	2769.20
LSD (0 .05)	6.31	NS	NS	226.48	NS
Sole Soybean Varieties					
AFGAT (100%)	28.00	2.2	11.80	1859.70	-
Awassa-95 (100%)	28.00	2.2	11.9	2029.50	-
Crawford (100%)	20.00	2.2	15.70	2091.70	-
Cropping System[1]					
SC	25.30	2.23	13.09	1993.61	3189.80
IC	30.23	2.22	15.02	747.48	2753.70
LSD (0 .05)	NS	NS	0.67	162.26	NS

[1:] *SC= Sole cropping, IC= Intercropping, PLER=partial land equivalent ratio and LER=total land equivalent ratio*

(62.51%) in intercropping as compared to the respective sole seed yields. Tamado and Eshetu (2000) also obtained similar result that sole common bean produced significantly higher seed yield as compared to the intercropping system. This might be because of competition for light had an effect on bean yield in maize bean intercropping (Fisher et al., 1986). Significant differences in 100 seed weight of soybean was recorded due to soybean varieties and cropping system. The highest 100 seed weight of 16.81g for Crawford while the lowest 100 seed weight of 13.80 g for AFGAT was obtained (Table 1). Number of pods per plant varied among soybean varieties and non-significantly varied due to cropping system. The highest number of pods per plant (34.98) for AFGAT and the lowest number of pods per plant (25.78) was obtained for variety Crawford (Table 1). Number of seeds per pod was non-significantly ($P < 0.05$) different due to the main effects and cropping system (Table 1).

Yield and yield attributes of maize

Result revealed that with the exception of cropping system the plant density and varieties the interaction effect were significantly ($P < 0.05$) affected 1000 grain weight. The highest 1000 kernel weight of 501.83 g was obtained when maize intercropped with a variety Awassa-95 at 75% planting density whereas the lowest maize 1000 grain weight of 251.16 g was obtained from the intercropping of maize with AFGAT at 50% planting density (Table 2). Therefore, relatively 1000 grain weight of maize was consistently increased as planting density of Crawford increased from 25% to 75%.

Maize grain yield differed markedly in terms of

Table 2: The interaction effect of soybean varieties and planting densities on 1000 grain weight (g) of maize grown in sole and intercropped with soybean

	Soybean Varieties			
Planting Densities	AFGAT	Awassa - 95	Crawford	Mean
25%	305.85	344.13	268.91	306.29
50%	251.16	314.73	305.21	290.36
75%	292.78	501.83	336.81	377.14
Mean	283.26	386.89	303.64	
LSD (0.05)	60.60			

Table 3: Grain yield (kg ha^{-1}) of maize grown in sole and intercropped with soybean as influenced by interaction effect of soybean varieties and planting densities

	Soybean Varieties			
Planting Densities	**AFGAT**	**Awassa - 95**	**Crawford**	**Mean**
25%	2374.80	2600.90	2585.50	2520.40
50%	2376.50	4181.20	2356.50	2971.40
75%	2366.70	2782.70	3158.30	2769.23
Mean	2372.67	3188.27	2700.10	
LSD (0.05)	1037.10			

soybean varieties and interaction effect. However, neither the cropping system nor soybean planting densities significantly influenced maize grain yield (Table 3). The highest maize grain yield of 3188.30 kg ha-1 was obtained when maize intercropped with variety Awassa-95. In contrast, the lowest grain yield of 2372.70 kg ha-1 was from maize intercropped with AFGAT. The relative highest maize grain yield of 4181.20 kg ha-1was obtained when maize was intercropped by Awassa-95 at 50% planting density (Table 3). In mixture of Awassa-95 at 50% planting density was greater by 1824.70 (43.64%) than that of yield obtained in Crawford at 50% planting density at which the lowest maize yield was achieved. The result agreed with that of Muoneke et al. (2007) who reported that in maize/soybean intercrops, maize grain yield was significantly affected among soybean varieties as some varieties grown vigorously might have depressed maize grain yield. Regarding cropping system, sole cropped maize grain yield (3189.80 kg ha^{-1}) was non-significantly superior compared to intercropped (2753.70 kg ha^{-1}) by means of 436.10 kg ha^{-1} (13.67%) implied that maize grain yield was non-significantly reduced by 13.67% due to intercropping. Similarly, Chemeda (1997) also found a yield reduction of maize grain by 24% in intercropping could be due to higher inter-specific competition for available resources such as nutrients, soil moisture and root spaces between component crops.

Productivity of Intercropping

Productivity of intercropping was evaluated using the partial and total LERs as induces. The partial LER of maize varied significantly ($P < 0.05$) in terms of soybean varieties and the interaction effect.

In contrast, partial LER of soybean was significantly ($P < 0.05$) influenced due to planting densities and cropping system (Table 4). The highest partial LER of 1.31 was recorded when maize intercropped with Awassa-95 at 50% planting density and followed by a variety Crawford at 75% (Table 4). Yield of maize due to variety Awassa-95 at 50% planting density was higher than an average yield of sole cropped

Table 4: The interaction effect of soybean varieties and planting densities on partial land equivalent ratio of maize grown in sole and intercropped with soybean

	Soybean Varieties			
Planting Densities	**AFGAT**	**Awassa-95**	**Crawford**	**Mean**
25%	0.73	0.81	0.81	0.79
50%	0.75	1.31	0.74	0.93
75%	0.74	0.87	0.99	0.87
Mean	0.74	0.99	0.85	
LSD (0.05)	0.33			

Table 5: Partial Land Equivalent Ratio (PLER), Total Land Equivalent Ratio (Total LER), as affected by soybean varieties and planting densities in sole and intercropped maize and soybean

Treatments	Partial LER		Total LER
	Maize	Soybean	
Soybean Varieties			
Maize + AFGAT	0.74	0.41	1.16
Maize + Awassa-95	0.99	0.32	1.32
Maize + Crawford	0.84	0.29	1.14
LSD (0 .05)	0.18	0.10	NS
Soybean Planting Densities			
Maize + 25%	0.79	0.27	1.06
Maize + 50%	0.93	0.33	1.26
Maize + 75%	0.87	0.41	1.28
LSD (0 .05)	NS	0.10	NS
Cropping System[1]			
SC	1.00	1.00	1.00
IC	0.97	0.34	1.20
LSD (0 .05)	NS	0.05	0.15

[1:] *SC= Sole cropping, IC= Intercropping, PLER=partial land equivalent ratio and LER=total land equivalent ratio*

maize. The productivity of maize-soybean intercropping as determined by partial and total LER was effective. In all intercrops LER was superior in resources use efficient as compared to sole cropping this justified that the intercropping was better than their respective sole cropping. The intercropped maize yielded the equivalent of 74% to 99% and 79% to 93% of its sole crop yield in terms of soybean varieties and planting densities, respectively. This showed that it was an advantageous as compared to sole cropping of either of the component crops as depicted by total LER values above one indicated complementarity in resource utilization by the component crops. Muoneke et al. (2007) confirmed that the values above unity in most systems indicated complementarity in resource utilization by the component crops. In addition, soybean varieties yielded the equivalent of 29% to 41% of their sole crop yield, while 27% to 41% of their sole crop yield was obtained due to soybean planting densities. Therefore, a yield advantage of 20% over sole cropping was obtained due to complementarity of component crops that enables to exploit available resources efficiently compared to sole cropping of each component crops. In general, the relative yield advantage of soybean intercropped with maize was up to 32% due to a variety Awassa-95 that was higher than could be achieved by growing the associated crops separately.

A higher total LER of 1.20 was obtained in intercropping compared to sole cropping. However, the total LER showed a non-significant increase trend with increase in soybean planting densities thus the maximum and minimum LER of 1.28 and 1.06 were recorded when maize was intercropped with soybean planting densities at 75% and 25%, respectively (Table 5).

CONCLUSIONS

Intercropping of maize with soybean found to be more valuable and productive compared to sole cropping system. The general productivity of the system become more effective and farmers in the area could be advantageous in additive mixture. Maize-soybean intercropping particularly with variety Awassa -95 at 50% planting density appeared to be more remunerative.

Conflict of Interests

The author(s) have not declared any conflict of interests.

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