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Productivity Evaluation of Maize - Soybean Intercropping System under Rainfed Condition at Bench-Maji Zone, Ethiopia

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Abstract

The study was carried out to evaluate the productivity of maize - soybean intercropping system and to identify the best combination that maximize productivity of the system. Maize hybrid (BH540) at 44,444 plants ha^{-1} 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%. Soybean seed yield of 1993.61 and 747.48 kg ha^{-1} was obtained from sole and intercropped soybean, respectively. 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. The GMV of the intercrops was increased with an increase in planting density of soybean. Furthermore, the GMV of intercrops (ETB 12176.00 per ha) was greater by means of 41.05% over sole cropped maize whilst lower than that of soybean sole cropped GMV by ETB 3772.90 per ha or 23.66%. However, MA had not significantly varied due to varieties and planting densities and cropping system. In additive intercropping system, maize intercropped with Awassa-95 at 50% planting density showed a yield advantage of 23.71% over sole cropped maize.

Keywords: Intercropping; Gross Monetary Value; Land Equivalent Ratio; Maize; Soybean.

Introduction

Soybean is one of a pre-eminent crop 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). It has been intercropped with maize successfully since soybean meal is often used to increase the typically low 6-9 % protein content of maize, it is reasonable to attempt to grow maize and soybean together (Martin *et al*., 1990). Maize (*Zea may* L.) has been recognized as a common and dominant main component crop in most intercropping systems because of its complementarity effects in many legumes crops. Therefore, in maize-legumes intercropping system maize with more than one crop recorded higher yields implying that maize-based cropping system is a good strategy of maximizing land use efficiency in the face of land scarcity.

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). The yield advantage obtained in intercropping over sole cropping of two crops which can be adopted to provide more the combined intercrops yield than combined sole crop yield. Hiebsch *et al.* (1995) stated that collective production from the component crops may be greater in intercropping than in sole cropping from a unit land area because of yield advantages occurred as a result of complementary use of resources by component crops as a result, growing two or more crops together is the increase in productivity per unit area (Sullivan, 2006).

Therefore, a cropping system consists of cropping pattern in terms of crop combination, spatial arrangement and sequences of cropping in addition to the resources, input management and technology attributed to involve in the production of the desired products through improving land productivity (Okigbo, 1981). A 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).

Bech (2005) supported that increasing stability of yields appears to be a major advantage of intercropping, therefore, a major reason for the pre dominance of intercropping in poorly developed agriculture is that it can give greater stability of yield over different seasons. In addition, maize based intercropping system with legume helps in improving soil health as well as yield crop (Beedy et al., 2010).

In Ethiopia, the total land of soybean production under peasant holdings covers about 6352.46 hectares (CSA, 2007). In the region, adequate and reliable rainfall with long length of growing period being the merits in diversifying crop production per unit area. In the region, soybean-maize intercropping is a common features of farmers with low productivity of the system; such system reduces the performance of different legume cultivars/intercrops in intercropping system. However, maize in association with legumes gives higher total yield and net return (Patra et al., 2000). Hence, the present investigation was carried out to evaluate intercropping advantages over the respective sole crop of maize with different soybean varieties and their proportions in the intercropping system.

Materials and methods

The field experiment was carried out in humid tropics of Bench-Maji zone during the main cropping season at experimental station of Semen Bench Woreda. The experimental site is situated at approximately 6° 52'N to 7° N latitude and 35.5° 21' E, altitude of above 1400 m. 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 with variation in the amount and distribution year to year. The area lies in hot to warm sub-humid lowlands with annual minimum and maximum average temperature of 22 °C and 29 °C, respectively. The soil type of the area is dominantly Nitisols with clay loams in texture and acidic in reaction which is agriculturally productive (Mesfin, 1998).

The 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 -2.60 m and tolerant to lodging blight (Mossisa et al., 2001).

In the cropping season, 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. 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.

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. Sole maize and soybean were planted at their optimum plant densities of 44,444 and 500,000 plants ha^{-1}, respectively. All recommended agronomic practices were employed for each crop as per the schedule. System productivity as whole were determined by using yield of component crop from net harvestable plot area.

Data Collected and Analysis

The total and partial land equivalent ratios (LER), gross monetary value (GMV) and monetary advantage (MA) were calculated by standard procedures. 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}). 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. Thus, LER can be calculated as:

$$LER = Yij / Yii + Yji / Yjj$$

Where:

Y- is the yield per unit area, Yij and Yji are intercrop yields of the component crops, i and j, and Yii and Yjj are sole crop yields. The partial LER value, Li and Lj, represent the ratios of the yields of crops i and j when grown as intercrops, relative to sole crops and can be expressed as:

$$Li = (Yij / Yii) \text{ and } Lj= (Yij / Yjj)$$

LER is the sum of the two partial land equivalent ratios so that;

$$LER = Li + Lj$$

Gross monetary value (GMV) and monetary advantage (MA) were calculated from the yield of maize and soybean in order to measure the productivity and profitability of intercropping as compared to sole cropping of the associated component crops (Mead and Willey, 1979). Monetary returns values were estimated on the basis of market price of produce (Maize and soybean) during the harvest period. Accordingly, GMV was calculated by multiplying yields of the component crops by their respective current market price for all varieties of soybean and maize yield. Thus, MA described by Willey (1979a) was calculated as:

$$MA = \text{Value of combined intercrops yield} \quad x \quad \frac{(LER - 1)}{LER}$$

Results and discussion

Yield Attributes of Component Crops

Neither the soybean varieties and planting densities nor the cropping system had a significant effect on number of grain per ear and Harvest Index (Table 1). There was a non-significant decreasing trend of maize grain per ear, harvest index and 1000-grain weight in intercropped maize as planting densities of soybean decreased from 75% to 25%. This is due to the development of complementarity as a result of which there was less competition for nitrogen at low planting density and there was a possibility of current transfer of fixed nitrogen to cereals crop like maize, however, a significant change in 1000-grain weight was noticed. Number of pods per plant was significantly reduced due to increase in planting density in intercropping system. Furthermore, it was significantly 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 2). 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. Number of seeds per pod was non-significantly ($P < 0.05$) different due to planting density and varieties and cropping system (Table 2).

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

Treatments	Grains per ear	Harvest Index (%)	1000- grain weight (g)	Grain Yield (kg/ha)
Soybean varieties				
Maize +AFGAT	309.16	38.04	283.26	2372.70
Maize +Awassa-95	337.27	47.64	386.90	3188.30
Maize +Crawford	323.29	40.09	303.65	2700.10
LSD (0 .05)	NS	NS	34.99	598.77
Soybean planting densities				
Maize + 25%	314.07	38.81	306.30	2520.40
Maize +50%	337.24	47.15	290.37	2971.40
Maize +75%	318.40	47.15	377.14	2769.20
LSD (0 .05)	NS	NS	34.99	NS
CV (%)	14.43	29.66	10.78	21.76
Cropping System[1]				
SC	311.27	40.05	305.85	3189.80
IC	323.27	41.92	324.60	2753.70
CV (%)	7.17	25.66	9.97	20.26
LSD (0 .05)	NS	NS	NS	NS

[1]:*SC= Sole cropping, IC= Intercropping, NS= Non-significant*

Maize Grain Yield

Grain yield of maize in intercropping differed markedly with respect to soybean varieties and interaction effect compared to other variety. However; the relative highest maize grain yield of 4181.20 kg ha^{-1} was obtained when maize was intercropped by Awassa-95 at 50% planting density (Table 2). However, the grain yield of intercropped maize slightly increased with an increase in planting density of component legumes. 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. This is due to a significant effect occurred among soybean varieties as some varieties grown vigorously might have depressed maize grain yield.

Table 2: 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 Seed Yield

An increasing trend was observed with respect to seed yield (kg ha-1) of soybean due to an increase in the proportion planting density from 25% to 75% under intercropped soybean conditions. Therefore, a seed yield ranged from 604.80 to 909.00 kg ha^{-1}, respectively was recorded (Table 3). This attributed to the inherent varietal characteristics in intercropping system and the differences in seed yield among varieties in the early season could be due to competition.

A significant varietal difference in seed yield was observed due to variety AFGAT and Crawford hence highest and lowest seed yield of 906.80 kg ha^{-1} and 643.20 kg ha-1, respectively were was observed from AFGAT and Crawford in intercropped with maize. The result attributed to varietal differences and the ability of individual variety to exploit the available resources like solar radiation, soil moisture and nutrients.

Table 3: Yield and yield attributes 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)**
Soybean Varieties				
Maize + AFGAT	34.98	2.21	13.08	906.80
Maize + Awassa-95	29.93	2.20	14.45	692.40
Maize + Crawford	25.78	2.24	16.81	643.20
LSD (0 .05)	6.31	NS	1.01	226.48
Soybean Planting Densities				
Maize + 25%	40.04	2.16	15.33	604.80
Maize + 50%	27.84	2.22	14.64	728.60
Maize + 75%	22.80	2.27	15.10	909.00
LSD (0 .05)	6.31	NS	NS	226.48
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
IC	30.23	2.22	15.02	747.48
LSD (0 .05)	NS	NS	0.67	162.26

[1]: *SC= Sole cropping, IC= Intercropping, NS= Non-significant*

Intercrop Yield

Yield of intercrops were reduced due to intercropping with maize. 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. This could be due to higher inter-specific competition for available resources such as nutrients, soil moisture and root spaces between intercrops. Furthermore, the seed yield of sole soybean was significantly 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} (62.51%) in intercropping as compared to the respective sole seed yields. This might be because of competition for light had an effect on bean yield in maize bean intercropping (Fisher et al., 1986).

Productivity of Intercropping

The productivity of intercropping was evaluated using the partial and total LERs as induces. The partial LER of maize varied significantly in terms of soybean varieties. A significant increase in partial LER (0.27 to 0.41) of soybean was calculated due to a proportional increase in planting densities (Table 4). 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.

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. 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.

The result revealed that GMV showed the same trend as the total LER due to planting densities (Table 4). The GMV increased with the increased in planting density of soybean in intercropped maize/soybean. This might be because of higher seed yield values and the higher price per kg of soybean which contributed more in gross monetary value than maize as depicted by monetary value of soybean varieties in intercrops. Thus, the highest GMV of ETB 13503.00 per ha (LER = 1.28) and lowest GMV of ETB 10510.00 per ha (LER= 1.06) were obtained when maize intercropped with soybean at planting densities of 75% and 25%, respectively. This depicted that The GMV of intercrops (ETB 12176.00 per ha) was higher than that of sole cropped maize (ETB 7177.00 per ha) or greater by means of 41.05%. However, the GMV (ETB 15948.90 per ha) of sole cropped soybean was by far superior to GMV of intercrops (ETB 12176.00 per ha) which showed that the GMV of sole cropped soybean was greater than that of intercrops by ETB 3772.90 per ha or 23.66% (Table 4). This might be because of a higher contribution of soybean seed yield from sole cropping (1993.61 kg/ha) compared to intercrop (747.48 kg/ha) as the higher price per kg of soybean.

Monetary advantage (MA) of intercropping was used to calculate the absolute value of the genuine yield advantage Willey (1979a) assuming that the appropriate economic assessment of intercropping should be in terms of increased value per unit of area of land. The result showed that an increase in MA with increase in planting density of soybean. Therefore, the highest MA was obtained due to variety Awassa-95 (ETB 3024.00 per ha) and at planting density of 75% (ETB 2962.00 per ha) in intercropping system.

Table 4: Partial and total Land Equivalent Ratio, Monetary value and monetary advantage as affected by soybean varieties and planting densities and intercropping system

Treatments	Partial LER		Total LER	Monetary value (Birr/ha)			Monetary Advantage MA[2]
	Maize	Soybean		Maize	Soybean	GMV[1]	
Soybean varieties							
Maize +AFGAT	0.74	0.41	1.16	5338.5	7254.50	12593.00	1572.00
Maize +Awassa-95	0.99	0.32	1.32	7173.6	5539.10	12712.70	3024.00
Maize +Crawford	0.84	0.29	1.14	6075.2	5145.90	11221.00	1428.00
LSD (0 .05)	0.18	0.10	NS	1347.20	1811.90	NS	-
Soybean planting densities							
Maize + 25%	0.79	0.27	1.06	5670.9	4838.60	10510.00	700.00
Maize + 50%	0.93	0.33	1.26	6685.6	5828.6	12514.00	2363.00
Maize + 75%	0.87	0.41	1.28	6230.8	7272.4	13503.00	2962.00
LSD (0 .05)	NS	0.10	NS	NS	1811.9	2453.80	-
CV (%)	21.76	30.32	19.17	21.76	30.32	20.17	-
Cropping system[3]							
SC	1.00	1.00	1.00	7177	15948.90	-	-
IC	0.97	0.34	1.20	6196	5979.90	12176.00	-
CV (%)	13.83	3.13	6.20	5670.9	4838.60	-	-
LSD (0 .05)	NS	0.05	0.15	6685.6	5828.6	-	-

[1,2,3:] SC= Sole cropping, IC= Intercropping, NS= Non-significant, PLER and LER=partial & total land equivalent ratio, GMV= Gross Monetary Value and MA= Monetary Advantage

Conclusions

The general productivity of the system become more effective and farmers in the area could be advantageous in additive mixture. A yield advantage in intercropping over sole cropping was obtained due to complementarity of component crops for better available resources utilization. GMV and LER were consistent with total seed yield of soybean obtained due to planting densities in additive intercropping. An economic assessment of intercropping should be in terms of increased value per unit of area of land. Hence, an increase in MA occurred with increase in planting density of soybean depicting yield become higher at high density of soybean. Maize - soybean intercropping found to be more valuable and productive compared to sole cropping. In general, the system appeared to be more helpful for small scale framers in the area.

Conflict of interests

The authors have not declared any conflict of interests.

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