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Influence of intercropping maize (*Zea mays* L.) and soybean (G*lycine max* (L.) Merril and blended NPS rate on land equivalent ratio and monetary value at Bako

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Abstract
Total LER was significantly affected by soybean population. The highest (13.02) was recorded for 25% soybean population. Gross Monetary Value was significantly affected by main effect of fertilizer and soybean population and highly significantly affected by cropping system. In this regard 25% soybean population was the best in intercropping system to maximize the productivity and 50kg NPSha^{-1} was the best compatible rate in intercropping for this experiment.

Keywords: Gross monetary value, intercropping system, Soybean population

Introduction

Land equivalent ratio (LER) is the relative area of land under mono crop which is needed to obtain the yield produced in intercropping (Willey, 1979) [9]. The partial LER (individual crop's LER, it is referred as PLER) and total LER (sum of individual crop's LER) are 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, i and j the component crops, Yij and Yji are intercrop yields of the component crops, Yii and Yjj are sole crop yields and 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) and Lj= (Yji / Yjj). LER is the sum of the two partial land equivalent ratios so that; LER = Li + Lj. When LER measures 1.0, it indicates that the amount of land required for plant ‘i’ and plant ‘j’ grown together is the same as that for the plant ‘i’ and ‘j’ in pure stand (i.e., there is no advantage to intercropping over pure stand). When LER>1, a large area of land is needed to produce the same yield of sole crop of each component than with an intercropping. For example, an LER of 1.25 implies that the yield produced in the total intercrop would have required 25% more land if planted in pure stands. LER below 1.0 shows a disadvantage to intercropping. For example, if the LER was 0.75, then we know the intercrop yield was only 75% of that of the same amount of land that grow pure stands. LER gives an accurate assessment of the biological efficiency of intercropping and this is a useful tool in research (Ofori and Stern, 1987).

The LER of maize-soybean intercrops ranged from 1.2 to 1.8 in Ethiopia (Kidane, 2010) [3]. If LER value is equal to one, it means that there is no yield advantage but when LER is more than one, then there is yield advantage. Rahimy *et al.* (2003) [7] reported that LER in intercropping is higher than monoculture intercropped maize and soybean. It is, however, important to present actual yields along with LER in reporting the results of intercropping studies. Generally, the value of LER is determined by several factors including density and competitive ability of the component crop in mixture, crop morphology and duration, and management variables that affect individual crop species. It has been suggested that in density studies of cereal-legume intercrop systems, the sole crop yield used as standardization factor for estimating LER should be at the optimum density of the crop. This avoids the confounding of beneficial interactions between components with a response to change in densities. The values of LER follow the density of the legume component rather than that of the cereal (Ofori and Stern, 1987).

Gross monetary value (GMV) and monetary advantage (MA) are calculated from the yield of the two crops in order to measure the productivity and profitability of intercropping as compared to sole cropping of the associated component crops (Mead and Willey, 1979) [9]. Monetary returns values will be estimated on the basis of market price of produce of the crops used in intercrop during the harvest period. Accordingly, GMV was calculated by multiplying yields of the component crops by their respective market price for all the produce to evaluate economic advantages. Thus, MA described by Willey (1979) [9] was calculated as:

$$MA = \text{Value of combined intercrops yield} \times \frac{LER-1}{LER}$$

Materials and Methods

Site Description

The experiment was conducted at BARC during 2017 cropping season. The experimental site is located at Bako in the Western part of the country in the Oromia National Regional State. Bako is located at 250 km far from Addis Ababa city. The soils at the experimental site are nitosols. The Center is located between 37°1'00''E to 37°3'40"E and 9°4'20''N to 9°7'20''N (Fig. 1). Annual minimum and maximum temperature is 13.5^0C and 29.7^0C respectively and receives average annual rainfall of 1237mm with maximum precipitation being received in the months of May to August (Bako Agricultural office profile).

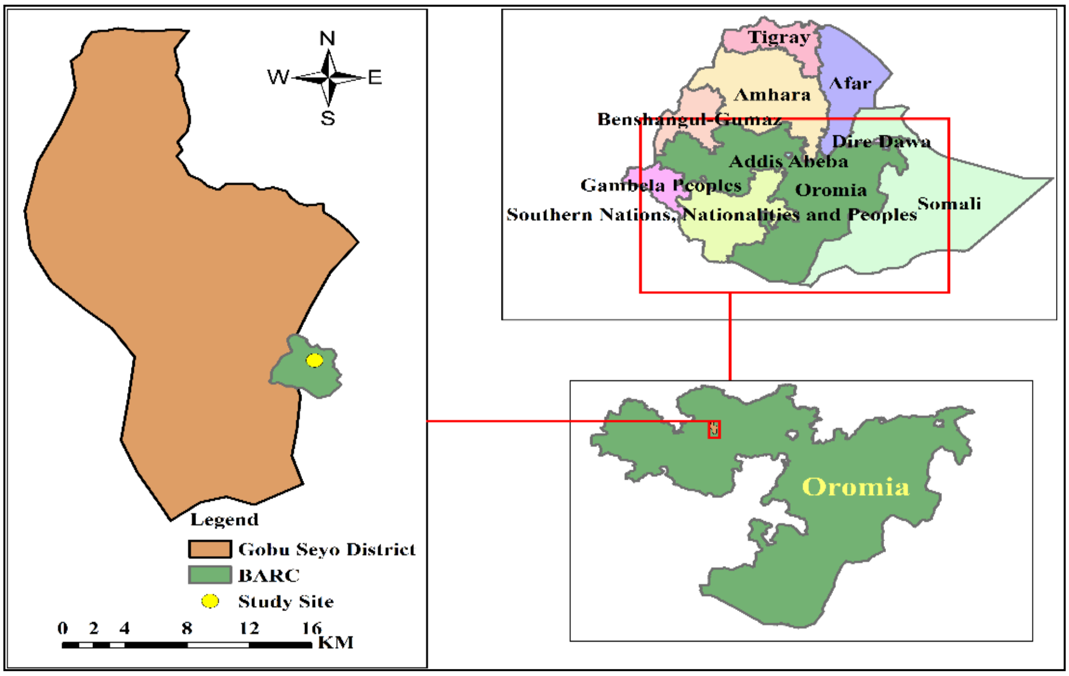

Fig 1: Description of the study area

Soil Sampling and Analysis

Composite soil samples were randomly collected from the field at a depth of 0-30 cm before from randomly selected places which represent the whole field and from14 sampling spots after the onset of experiment to represent the experiments effect. However, during post soil sampling soil samples were taken at the bases of five plants taken randomly from each plot and between the maize and soybean rows in the intercrops. Soil was analyzed at Horticoop Soil and Water Analysis Laboratory in Bishoftu for total nitrogen, available sulphur and available phosphorus, exchangeable calcium, magnesium, potassium and sodium, pH and soil texture as described by Allison (1960) [1] and Ibitoye (2006) [2].

Soil condition of experimental area

The analysis indicated that the soil had total nitrogen content of 0.13% (Table 1) which was medium according Tekalign *et al.* (1991) [8]. They classified soil total N availability of <0.05% as very low, 0.05-0.12% as poor, 0.12-0.25% as moderate and >0.25% as high. With regards to the available phosphorus of 2.97 ppm, Tekalign *et al*. (1991) [8] described soils with available P<10, 11-31, 32-56, >56ppm as low, medium, high and very high, respectively. Thus, the soil available P (2.97ppm) content of experimental sites was low.

The sulphur (29.12) was medium as per the criteria developed by Mehlich-3 method. The analytical indicated that the textural class of the experimental site was silt soil with a proportion of 10% sand, 16 % clay and 74% silt. Thus, the textural class of the experimental soil is ideal for maize production (Onwueme and Sinha, 1991) [6]. The soil reaction (pH) of the experimental site was 5.21 showing moderate acidity according (Tekalign, 1991) [8], but it is within the optimum range for maize production, *i.e.* 5.5 -7.0 (Table 1).

Table 1: Selected physico-chemical properties of experimental soil

Soil characteristic	**Value**
Total nitrogen (%)	0.13
Available phosphorus (ppm)	2.97
Sulphur (ppm)	29.12
pH-H_20	5.21
Particle Size distribution (%)	
Sand	10
Silt	74
Clay	16
Textural class	Silty

Experimental Materials and Treatments

The soybean variety Didesa, maize variety BH 546 and the newly introduced blended NPS fertilizer with 19% nitrogen, 38% P_2O_5 and 7% sulfur were used. The soybean variety, Didesa was released by BARC (Bako Agricultural Research Center), yellow in color, adapted to an altitude of 1200-1900m above sea level and late maturing variety (137-145 days to maturity). It has a yield potential of 3.3t ha^{-1} at research center. The maize variety, BH 546 was released by CIMMYT, white in color, good husk cover and better reaction to known diseases of the area. Grow at mid altitude (1000-2000m.a.s.l) having a high yield advantage with a mean yield potential of 8.7 tons/ha across several locations under optimum management conditions. Intermediate maturing, takes 100-130 days to maturity three-way cross hybrid released for high-potential maize growing areas. Its narrow semi-erect leaves make it desirable for high-density planting and inter-cropping with legumes, a common practice in most maize growing areas of the country. The treatments consisted of three planting densities of soybean (25%, 50% and 75%) and four NPS fertilizer rate (0, 50, 100 and 150 kg ha^{-1}) (Table 2**)**. The NPS treatments are based on national recommendation of 100 kg ha^{-1} for maize by Ministry of Agriculture (MoA). The experiment consisted of two factors, namely four fertilizer rates and three soybean plant populations with twelve treatments. The treatment combinations were sole maize, maize + soybean and sole soybean. The experiment was laid out in randomized complete block design (RCBD) with three replications.

Table 2: Details of treatment combination of the experiment

R. No	Treatment Description
1	Maize + 25% soybean + 0 kg NPS ha^{-1}
2	Maize + 25% soybean + 50 kg NPS ha^{-1}
3	Maize + 25% soybean + 100 kg NPS ha^{-1}
4	Maize + 25% soybean + 150 kg NPS ha^{-1}
5	Maize + 50% soybean +0 kg NPS ha^{-1}
6	Maize + 50% soybean +50 kg NPS ha^{-1}
7	Maize + 50% soybean +100 kg NPS ha^{-1}
8	Maize + 50% soybean +150 kg NPS ha^{-1}
9	Maize + 75% soybean + 0 kg NPS ha^{-1}
10	Maize + 75% soybean+50 kg NPS ha^{-1}
11	Maize + 75% soybean +100 kg NPS ha^{-1}
12	Maize + 75% soybean +150 kg NPS ha^{-1}
13	Sole Maize +100 kg NPS ha^{-1}
14	Sole soybean +100 kg NPS ha^{-1}

Results and Discussion

Total Land Productivity and Gross Monetary Evaluation

Land Equivalent Ratio

The productivity of intercropping was evaluated using the partial and total LERs as indices. Soybean population showed highly significant (P<0.05) effect on partial LER of maize, however NPS rate and interaction effect did not show significant effect. The partial LER for soybean was highly significant (P<0.05) due to soybean population and interaction, however it is not significant due to NPS rate and cropping system. The highest (0.46) partial LER of soybean was found from 150 kg NPS ha^{-1} with 50% soybean population and the lowest (0.13) from 150 kg NPS ha^{-1} with 25% soybean population (Table 3).

Table 3: Interaction effect of the intercropped NPS rates and Soybean populations on Partial Land Equivalent of soybean in maize/soybean intercropping

Soybean population per ha	NPS rates (kg ha^{-1})			
	0	50	100	150
(25%) 125, 000	0.23e	0.26e	0.25e	0.13f
(50%) 250, 000	0.34c	0.30d	0.44ab	0.46a
(75%) 375, 000	0.45a	0.45a	0.41b	0.42ab
Intercropping mean			0.96	
Sole mean			1.00	
	NPS rates x soybean population		Cropping system	
LSD (P< 0.05)	0.037		0.063	
CV (%)	6.37		1.81	

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of variation

The total land equivalent ratio showed significant (P<0.05) effect due to the main effects of soybean population, however no significant effect on NPS rates, interaction and cropping system. The highest total LER (1.32) and (1.11) was obtained from 25% and 50% soybean population, respectively (Table **4**).

Table 4: Effect of soybean population, NPS rates and cropping system on Land Equivalent Ratio (LER) of sole and intercropped maize and soybean

Treatment	Grain yield (t ha^{-1})		LER	
Soybean population per ha	**Maize**	**Soybean**	**Maize**	**Total**
25%	11.16a	0.66b	1.81a	1.32a

50%	9.22b	1.17a	1.70b	1.11b
75%	8.83b	1.30a	1.18b	1.16b
LSD (0.05)	0.87	0.14	1.00	1.02
NPS rates (kgha^{-1})				
0	9.71	1.03	1.13	1.29
50	9.36	1.02	1.1	1.2
100	10.06	1.11	1.2	1.2
150	9.82	1.02	1.1	1.23
LSD (0.05)	NS	NS	NS	NS
CV (%)	10.68	16.32	10.63	10.56
Cropping system				
Intercropping	1.23a	0.34b	1.49	13.6
Sole	0.91b	3.07a	1.00	1.00
LSD (P< 0.05)	7.53	0.03	NS	NS
CV (%)	15.32	0.51	6.49	6.02

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference(P< 0.05); CV = Coefficient of Variation

Monetary Value

The monetary value of maize was not significantly affected by NPS rate but highly significantly (P<0.05) affected by soybean population and significantly (P<0.05) affected by interaction effect but non-significantly affected by fertilizer rates. The highest monetary value (970.70) was due to 50 kg NPS ha^{-1} and 25% soybean population while lowest (663.95) due to 50 kg NPS ha^{-1} and 75% soybean population affected non-significantly by cropping system (Table 5). Indicating that, the 25% soybean population with 50 kg NPS ha^{-1} is profitable.

Table 5: Interaction effect of the intercropped NPS rates and Soybean populations on monetary value of maize in maize/soybean intercropping

Soybean population per ha	NPS rates (kg ha^{-1})			
	0	**50**	**100**	**150**
(25%) 125, 000	920.04a	970.70a	946.36a	793.28bc
(50%) 250, 000	710.07cd	701.03cd	734.26bcd	856.12ab
(75%) 375, 000	688.53cd	663.95d	774.43bcd	747.20bcd
Intercropping mean			739.2	
Sole mean			616.8	
	NPS rates x soybean population		Cropping system	
LSD (P<0.05)	124.82		872.9	
CV (%)	9.35		36.65	

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = least significant difference (P< 0.05); CV = coefficient of variation

Monetary Value of soybean was highly significantly (P<0.05) affected by main effect of soybean population and interaction effect however it was not affected by NPS rate and cropping system. The highest (131.33) monetary value was found from 150kg NPS ha^{-1} with 50% soybean population and lowest (37.94) was recorded from 150kg NPS ha^{-1} with 25% soybean population (Table 6).

Table 6: Interaction effect of the intercropped NPS rates and Soybean populations on Monetary Value of soybean in maize/soybean intercropping

Soybean population per ha	NPS rates (kg ha^{-1})			
	0	**50**	**100**	**150**
(25%) 125, 000	66.09e	75.13e	71.96e	37.94e
(50%) 250, 000	99.28c	87.8d	126.30ab	131.33a
(75%) 375, 000	128.38a	128.87a	11.42b	121.96ab
Intercropping mean			275.80	
Sole mean			288.25	
	NPS rates x soybean population		Cropping system	
LSD (P< 0.05)	10.51		18.1	
CV (%)	6.28		1.83	

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation

Gross monetary value (GMV) was significantly (P<0.05) affected by soybean population and interaction effect, however it was not affected by NPS rate and cropping system. The highest (1018.31) GMV was due to 100 kg NPS ha^{-1} with 25% soybean population and the lowest (788.71) due to 50 kg NPS ha^{-1} with 50% soybean population (Table 7).

Table 7: Interaction effect of the intercropped NPS rates and Soybean populations on Gross Monetary Value in maize/soybean intercropping

Soybean population per ha	**NPS rates (kg ha^{-1})**			
	0	**50**	**100**	**150**
(25%) 125, 000	1006.80a	955.18abc	1018.31ab	831.22e
(50%) 250, 000	809.35e	788.71e	860.56de	987.45abcd
(75%) 375, 000	816.92e	792.82e	891.86bcde	869.15cde
Intercropping mean			892.6	
Sole mean			1027.4	
	NPS rates x soybean population		Cropping system	
LSD (P< 0.05)	127.37		875.31	
CV (%)	8.48		25.95	

Means within the same column followed by the same letter or by no letters of each factor do not differ significantly at 5% probability level; LSD = Least Significant Difference (P< 0.05); CV = Coefficient of Variation

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 partial LER of soybean varied highly significantly in terms of soybean population, interaction effect and cropping system whereas non-significantly affected by the NPS rate. The highest (0.46) partial land equivalent of soybean was found from 150 kg NPS ha^{-1} with 50% soybean population and the lowest (0.13) recorded from 150 kg NPS ha^{-1} with 25% soybean population. The total land equivalent ratio showed significant differences due to the main effects of NPS-rates, soybean population and cropping system. The highest partial LER of soybean was recorded for (0.45) 150 kg NPS ha^{-1} with 50% soybean population and lowest (0.19) was recorded for 150 kg NPS ha^{-1} with 25% soybean population. The highest LER (11.89) and the lowest (13.02) was obtained from soybean population of 25% and 100 kg NPS ha^{-1}, respectively. Cropping system showed non-significant differences on LER.

The monetary Value of maize was highly significantly (P<0.05) affected by soybean population and significantly (P<0.05) affected by interaction effect but non-significantly affected by NPS rates. The highest monetary value (970.70) was recorded for 0 kg NPS ha^{-1} and 25% soybean population while lowest (663.95) recorded for 50 kg NPS ha^{-1} and 75% soybean population. On the other hand, this affected non-significantly by cropping system. Monetary value of soybean was highly significantly (P<0.05) affected by main effect of plant population, interaction effect and cropping system. The highest(131.33)monetary value was found from 150 kg NPS ha^{-1} with 50% soybean population and lowest (37.94) was recorded from 150 kg NPS ha^{-1} with 25% soybean population. This is non-significantly affected by cropping system. Gross Monetary Value was significantly (P<0.05) affected by main effect of NPS and soybean population highly significantly affected by cropping system. The highest (1018.31) gross monetary Value was found for 100 kg NPS ha^{-1} with 25% soybean population and the lowest (788.71) for 50 kg NPS ha^{-1} with 50% soybean population. It is non-significantly affected by cropping system. Thus, the result remarks that proper decision should be given while practicing intercropping of maize/soybean. In this regard 25% soybean population was the best in intercropping system to maximize the productivity and 50 kg NPS ha^{-1} was the best compatible rate in intercropping. To reach better conclusive recommendation, it needs further investigation on the selection of additional best compatible NPS-rates, plant proportion and repetition of this study on more locations and seasons.

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