

Influence of Varieties and Population of Intercropped Soybean with Maize on Land Equivalent Ratio (LER) and Growth Monetary Value (GMV) of the Component Crops

Teshome Gutu[1*] Tamado Tana[2] Negash Geleta[3]
1. Oromia Agriculture Research Institute, Haro Sabu Agricultural Research Center
2. Haramaya University, College of Agriculture and Environmental Sciences, School of Graduate Studies, Ethiopia P.O.Box:138, Dire Dawa, Ethiopia

Abstract
The study was conducted to determining the effect of varieties and population densities of soybean intercropped with maize on LER and GMV of components of associated crops. The experiment was laid out in RCBD with three replication in factorial combination of three soybean varieties (Boshe, Ethio-Yugoslavia and Didesa) and three soybean plant populations (25%, 50% and 75%) along with respective sole crop of soybean varieties and maize BHQPY-545. The partial land equivalent ratio (PLER) and total land equivalent ratio (TLER) of maize and soybean intercrops were significantly ($P<0.01$) affected by plant population and soybean variety. The highest LER (1.54) was obtained from the combination of 100% maize x 50% soybean followed by 100% maize x 75% soybean (1.51) and the lowest was from 100% maize x 25% soybean (1.38). The GMV of intercrops was highly significantly ($P<0.01$) affected by main effect of soybean variety and plant population and cropping system. The highest GMV (36490 ETB ha^{-1}) and the lowest (32390 ETB ha^{-1}) were obtained from varieties Didesa and Ethio Yugoslavia intercropped with maize, respectively. Considering the experimental findings intercropping of maize with 50% soybean population and Didesa Variety was recommended for the study area.
Keywords: Glycine max, GMV, LER, intercropping, plant populations, sole cropping, Zea mays 1.

INTRODUCTION

Intercropping, the agricultural practice of cultivating two or more crops in the same space at the same time is an old and commonly used cropping practice which aims to match efficiently crop demands to the available growth resources and labor. The most common advantage of intercropping is the production of greater yield on a given piece of land by making more efficient use of the available growth resources using a mixture of crops of different rooting ability, canopy structure, height, and nutrient requirements based on the complementary utilization of growth resources by the component crops (Lithourgidis *et al.,* 2011)

Competition among mixtures and population densities of the component crops in cereal legume intercropping is the major aspect affecting yield as compared with sole cropping of cereals. A number of indices such as land equivalent ratio (LER), competitive ratio (CR), relative crowding coefficient (K), aggressive (A), growth monetary value (GMV), net return (NR) and area-time equivalent ratio (ATER), and intercropping advantage have been proposed to describe competition within and economic advantages of intercropping systems. Among indices being used for assessing competition between intercrops, land equivalent ratio (LER) is the most commonly used for intercrop versus sole crop comparisons (Agegnehu *et al.,* 2006).

In research trials, the researcher's mixture and pure stand in separate plots. Yields from the pure stands, and from each separate crop from within the mixture, are measured. From these yields, an assessment of the land requirements per unit of yield can be determined. This information tells the yield advantage the intercrop has over the pure stand, if any. They then know how much additional yield is required in the pure stand to equal the amount of yield achieved in the intercrop. The calculated figure is called the Land Equivalent Ratio (LER).

LER ratio concept was proposed by Willey and Osiru (1972) to be used as an index of combined yield for evaluating the effectiveness of all forms of intercropping. As an index of combined yield, LER provides a quantitative evaluation of the yield advantage due to intercropping (Willey, 1979). LER could be used either as an index of biological efficiency to evaluate the effects of various agronomic variables (e.g. fertility levels, density and spacing, comparison of cultivars performance, relative time of sowing, and combinations) on an intercrop system in a locality or as an index of productivity across geographical locations to compare a variety of intercrop systems (Chetty and Reddy, 1980).

LER can be expressed as: $\frac{Y_{ij}}{Y_{ii}} + \frac{Y_{ji}}{Y_{jj}}$ where, Y_{ij} and Y_{ji} are intercrop yields of the component crops i and j, and Y_{ii} and Y_{jj} are sole crop yields, respectively.

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.

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). Differences in competitive ability affect the relative performance of component crops and thus the LER value of different cereal- legume intercrop systems.

2. MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Haro Sabu Agricultural Research Center (HSARC) during the main cropping season from June to October 2013. HSARC was located in western Ethiopia in Oromiya region at 550 km away from Addis Ababa. It lies at latitude of 8^o 52'51" N and longitude 35^{o}13'18'' E and altitude of 1515 m above sea level. It has a warm humid climate with average minimum and maximum temperature is 14^{o}C and 30^{o}C, respectively. The area receives average annual rain fall of 1000 mm and its distribution pattern is uni-modal. The rain periods covers from April to October. The soil type of the experimental site was reddish brown and its pH is 5.82. The area were characterized by coffee dominant based farming system and crop-livestock mixed farming system in which cultivation of maize, sorghum, finger millet, haricot bean, soybean, sesame, banana, mango, sweet potato and coffee are the major crops grown in the area. Improved maize variety (BHQPY-545) was used as main crops and three soybeans varieties namely Boshe, Ethio Yugoslavia and Didesa were used.

Treatments and Experimental Design

The experiment consisted of two factors, namely three soybean varieties and three soybean plant populations. Three different proportions of a plant population of 333,333ha^{-1}, were considered as optimum for sole cropped soybeans, were taken as the intercrop soybean plant populations: 25% (83,333 plants ha^{-1}), 50% (166,666 plants ha^{-1}) and 75% (249,999 plants ha^{-1}) were intercropped as additive series between the two maize rows at the same time. Uniform populations of 44,444 plants ha^{-1} were maintained for maize in both intercropping and sole cropping. The experiment was arranged in Randomized complete Block design with three replication in factorial arrangement of three soybean varieties and three soybean plant populations totaling nine intercropping treatments and there were four additional treatments (sole maize, sole Boshe, sole Ethio Yugoslavia and sole Didesa) totaling thirteen treatments. The spacing for sole and intercropping maize was 75cm x 30cm and the gross plot size was 15.75m^2 (3.75m x4.2m) and the net plot area was 6.75m^2 (2.25m x3m). Each intercrop maize plot consisted of five rows of maize and four row of soybean. The spacing of sole soybean was 60cm x 5cm and the gross plot size 15.12 (3.6m x4.2m) and the net plot area was 7.2m^2(2.4m x3m). Soybean was intercropped between two maize rows at 37.5cm away from maize row with inter row 5.3cm, 8cm and 16cm representing 75%, 50% and 25% of the recommended population, respectively. The central three rows of soybean were harvested and one row was used for destructive sampling. i.e for counting number of nodule per plant and for measuring Leaf area and Leaf area index.

Experimental Procedures

The experimental field was ploughed and harrowed by a tractor to get a fine seedbed and leveled manually before the field layout was made. Both maize and soybean varieties were planted simultaneously on June 13, 2013. Two seeds per hill of both maize and soybean were planted and thinned to one plant per hill one week after emergence. At planting full dose of DAP (18% N, 46% P_2O_5) at the rate of 100 kg ha^{-1} was applied uniformly into all plots. Half of N in the form of urea (46% N) at the rate of 200 kg ha^{-1} was applied into sole maize and maize/soybean intercropped plots at the time of planting and the remaining half N was applied at knee height growth stage of maize. Urea (N) was not applied in to sole soybean assuming the soybean could benefit from self-fixed nitrogen. Hand hoeing and weeding were done as required. Both maize and soybean were harvested from the net plot after they attained their normal physiological maturity, i.e. when 75% of plants in a plot formed black layer at the point of attachment of the kernel with the cob for maize and when 95% of pod color changed to yellow and their leaves started shading for soybean and the both maize and soybean were threshed manually.

Soil Sampling and Analysis

Soil sample was taken at a depth of 0-30 cm in a zigzag pattern randomly from the experimental field. Composite samples were prepared for analysis to determine the physico-chemical properties of the soil of the experimental site. The composited soil sample was air-dried, ground and sieved to pass through a 2 mm sieve. Total nitrogen was determined following kjeldahl procedure as described by (Cottenie, 1980); the soil pH was determined by using a digital pH meter (Page, 1982). Organic carbon was determined following wet digestion method as described by (Walkley and Black, 1934); and the available phosphorous was measured using Olson II methods (Olsen et al., 1954); cation exchange capacity (CEC) was determined by ammonium acetate method (Cottenie, 1980)and soil texture was determined by Bouyoucons Hydrometer method (Bouyoucos,1962).

Statistical Data Analysis

Analysis of variance was carried out using General Linear Model of ANOVA using SAS version 9.0 software (SAS Institute Inc. 2002). Mean separation was carried out using Least Significance Difference (LSD) test at 5% probability level.

3. RESULTS AND DISCUSSION

Physicochemical Properties of the Soil

Result of the laboratory analysis for the soil samples taken before planting of the experimental site. The analysis indicate that the soil had total nitrogen content of 0.436% which was high according to Tekaligne *et al*. (1991) where 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. Where organic matter content of the soil (4.715%) is medium according to the classification of Berhanu (1980) where soils with organic matter content of >5.20, 2.6-5.2, 0.8-2.6 and <0.8% were classified as high, medium, low and very low, respectively, in their organic matter status.

With regards to the available phosphorus, Tekalign *et al.* (1991) described soils with available P <10, 11-31, 32-56, >56ppm as low, medium, high and very high, respectively. Thus, the soil available P (6.283ppm) content of experimental sites was low. The soil cation exchange capacity describes the potential fertility of soils and is an indicator of the soil texture, organic matter content and the dominant types of clay minerals present. In general, soils high in CEC contents are considered as agriculturally fertile. According to Landon (1991), top soils having CEC greater than 40 Cmol (+)/kg are rated as very high and 25-40 Cmol (+)/kg as high, 15-25, 5-15 and < 5 Cmol (+)/kg of soil are classified as medium, low and very low, respectively in CEC. Thus, the CEC of the 23 Cmol(+)/kg is rated as medium.

The analytical results indicated that the textural class of the experimental site was mainly of sandy loam soil with a proportion of 73% sand, 6 % clay and 21% silt. Thus, the textural class of the experimental soil is ideal for maize production (Onwueme and Sinha, 1991). The soil reaction (pH) of the experimental site was 5.82 showing moderate acidity, but it is within the optimum range for maize production, i.e. 5.5 -7.0.

Soil characteristic	***Value***
Particle size (%)	
Sand	*73*
Silt	*21*
Clay	*6*
Textural class	*Sandy loam*
pH (1:2.5 H_2O)	*5.82*
Organic matter (%)	*4.715(%)*
Total nitrogen (%)	*0.436*
Available phosphorous (ppm)	*6.283*
Cation exchange capacity (Cmol (+)/kg)	*23 Cmol(+)/kg*

Table 1: *Physico-chemical propertie*

Total Land Productivity and Gross Monetary Evaluation

The productivity of this experiment was evaluated by calculated total land equivalent ratio (LER) and Gross Monetary Value (GMV). The total land equivalent ratio (LER) was calculated by adding up partial land equivalent ratio of maize and soybean.

The partial land equivalent ratio (PLER) and total land equivalent ratio (TLER) of maize and soybean intercrops were significantly (P<0.01) affected by plant population and soybean variety. Whereas the interaction of the variety and population had significant effect on maize partial land equivalent ratio. In all the intercrops, the LER was more than unity, which showed that intercropping of maize and soybean was advantageous than sole cropping. The highest LER (1.54) was obtained from the combination of 100% maize x 50% soybean followed by 100% maize x 75% soybean (1.51) and the lowest was from 100% maize x 25% soybean (1.38) .The highest LER (1.54) indicates that the combination of 100% maize and 50% soybean gave a 54%

yield advantage than planting maize or soybean independently as sole crops. This result was in agreement with the report of Kidane *et al.* (1990) where the LER of maize/soybean intercrops ranged from 1.2 to 1.8 in Ethiopia. Similarly, Muoneke *et.al.* (2007) reported LER of 1.02-1.63 from maize/soybean intercropping. Similarly, Allen and Obura (1983) observed LER of 1.22 and 1.10 for maize/soybean intercrop in two consecutive years.

Similar to plant population, soybean varieties also showed significant differences in LER. The highest LER (1.56) was obtained from variety Didesa followed by variety Boshe (1.46) and the lowest was recorded from variety Ethio Yugoslavia (1.40). This indicated that variety Didesa was more advantageous for intercropping with maize over the two varieties. This result implies that productivity of the intercrop can be enhanced through selection of suitable varieties for intercropping as they have different growth habits and growth durations, which may result in different interactions with maize in the intercrop. The lowest LER recorded for soybean variety Ethio Yugoslavia could indicate that the variety might be not suitable for intercropping system when compared to the two varieties. Similarly, Santalla *et al.* (2001) demonstrated that different common bean varieties responded differently in terms of yield reduction under intercropping. Muoneke *et al.* (2007) noted that soybean grain yield was depressed by intercropping with maize. Cropping system showed highly significant ($P<0.01$) effect on LER where the LER of intercropping was 1.48 which showed 48% yield advantage and efficient land utilization by intercropping as compared to the sole cropping. This higher value of LER in intercropping treatments compared to sole cropping of soybean might be due to better utilization of land, light, nutrients and water.

In addition to LER, Gross Monetary Value (GMV) was used to evaluate economic advantages. The GMV of intercrops was highly significantly ($P<0.01$) affected by main effect of soybean variety and plant population and cropping system. The highest GMV of 35750 ETB ha^{-1} was obtained from plant population of 50% soybean and the lowest GMV of 31730 ETB ha^{-1} was obtained from plant population of 25% soybean. In line with this, Biruk (2007) reported the highest GMV (4530 ETB ha^{-1}) from planting density of 75% of common bean inter cropped with maize and the lowest GMV (3674ETB ha^{-1}) was obtained from planting density of 25% common bean intercropped with maize.

The highest GMV (36490 ETB ha^{-1}) and the lowest (32390 ETB ha^{-1}) were obtained from varieties Didesa and Ethio Yugoslavia intercropped with maize, respectively.

In this experiment intercropping gave higher GMV (34269 ETB ha^{-1}) than sole cropping of maize (21990 ETB ha^{-1}) and soybean (25200 ETB/ha). This finding was in agreement with Yesuf (2003) reported that sole sorghum and haricot bean gave the least GMV 2784.30ETB ha^{-1} and 2047.50ETB ha^{-1} respectively in sorghum/haricot intercropping.

Table 2: Effect of soybean varieties and plant population on Land Equivalent Ratio (LER) and Gross Monetary Value of sole and intercropped maize and soybean

Treatment	Grain yield (t/ha)		LER			MV		
Soybean population per ha	Maize	soybean	Maize	Soybean	Total	Maize (Birr/ha)	Soybean (Birr/ha)	GMV (Birr /ha)
75% (249,999)	6.90b	2.09a	0.94b	0.57a	1.51a	20700b	14630a	35330a
50% (166,666)	7.11a	2.06a	0.97a	0.57a	1.54a	21330a	14420a	35750a
25% (83,333)	7.03a	1.52b	0.96a	0.42b	1.38b	21090a	10640b	31730b
LSD (0.05)	0.11	0.22	0.02	0.06	0.06	340.12	1602.8	1747.8
Soybean varieties								
Boshe	7.11a	1.80b	0.97a	0.49b	1.46b	21330a	12600b	33930b
Didesa	7.03a	2.20a	0.96a	0.60a	1.56a	21090b	15400a	36490a
Ethio Yugoslavia	6.90b	1.67b	0.94b	0.46b	1.40b	20700b	11690b	32390b
LSD (0.05)	0.11	0.22	0.02	0.06	0.06	340.12	1602.8	1747.8
CV (%)	1.61	12.13	1.63	11.11	4.36	1.61	12.13	5.10
Cropping system								
Intercropping	7.013b	1.89b	0.95b	0.52b	1.48a	21039b	13230b	34269
Sole	7.33a	3.60a	1.00a	1.00a	1.00b	21990a	25200a	-
LSD (0.05)	0.18	0.78	0.02	0.009	0.03	560.83	5717	-
CV (%)	1.13	12.60	1.07	1.29	0.43	1.11	4.16	-

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 significantly Difference ($P< 0.05$); CV= Coefficient of variation; LER= Land Equivalent Ratio; GMV= Gross Monetary Value; MV= Monetary Value

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