Vol. 11(1), pp. 30-36, January-June 2020
DOI: 10.5897/JCO2018.0182
Article Number: 209A4A064169
ISSN 2141-6591

http://www.academicjournals.org/JCO

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Journal of Cereals and Oilseeds

Full Length Research Paper

Competition indices and monetary advantage index of intercropping maize (*Zea mays* L.) with legumes under supplementary irrigation in Tselemti District, Northern Ethiopia

Tesfahun Mekuanint

Shire-Maytsebri Agricultural Research Center, Shire-Endasilase, Tigray, Ethiopia.

Received 18 April, 2017; Accepted 27 September, 2017

An understanding of competitive and monetary indices such as land equivalent ratio (LER), land equivalent coefficient (LEC), relative crowding coefficient (K) and monetary advantage index (MAI) is critical in recommending cropping systems in a given area. To appreciate this, an experiment was conducted in Tselemti, Tigray region, Northern Ethiopia. Maize (*Zea mays* L.) was intercropped with Soybean and Mung bean in a 50:50 ratio under rainfed conditions and supplemented with irrigation in the 2016/17 season to determine the effect of leguminous competition on maize and the economic viability of the intercropping system over sole cropping. The experiment was laid in a split-plot design in three replications with intercropping taking the main plots and supplementary irrigation to sub-plots. The LER values were generally greater than one which indicated the yield advantages of intercropping over sole cropping. LEC was well above 25% and this means that intercropping was more productive. The highest value of LEC was recorded in wheat-lentil mixtures. The relative crowding coefficient (K) showed that the legumes were more dominant over maize. Although both maize-soybean and maize-mungbean mixtures showed economic advantage, as recorded by positive MAI, maize-soybean intercropping system proved more profitable under rainfed conditions whereas under supplementary irrigation, maize-Mungbean recorded a higher value of MAI. Conclusively, it was demonstrated that maize-soybean combinations were more advantageous in terms of yield and monetary advantage for smallholder farmers in Tselemti area who depend on rainfed farming.

Key words: Competition, mungbean, intercropping, supplementary irrigation, soybean, maize.

INTRODUCTION

Moisture stress negatively affects the physiological and agronomic growth of maize, resulting in significant yield reduction (Balla et al., 2008). However, the use of self-sustaining low input technologies has been suggested as

*Corresponding author. E-mail: tmekuanint@gmail.com.

Table 1. Chemical and physical characteristics of the soil of experiment.

Sand (%)	Clay (%)	Silt (%)	K ppm	Av.P ppm	Tot. N (%)	C (%)	EC (dSm^{-1})	PH
25	42	33	130.3	1.2	0.1022	1.06	0.32	6.08

EC: Electrical conductivity; CEC: Cation exchange capacity; Tot.N: Total nitrogen; Av.P: Available phosphorus.

a sustainable approach to build soil productivity of such areas, with minimum use of external inputs. Supplementary irrigation has also been reported to increase yields in drylands by more than 50% (Bello, 2008). Cereal-legume intercropping is among such practices recommended for soil restoration in Ethiopia (Coxhead and Oygard, 2008).

Intercropping is a multiple cropping system that combines the planting of two or more crops species simultaneously in the same field during a growing season (Mousavi and Eskandari, 2011). It has the capacity to fulfill several agro ecological goals such as enhancing the natural nutrient regulation (Chapagain, 2014), efficient use of resources, and weed supprFession (Chapagain, 2014; Ghanbari et al., 2010) among others. In Ethiopia, intercropping forms part of the smallholder farming systems where maize (*Zea mays* L.) and sorghum (*s. bicolor* L.) dominate as main crops (Tarekegn and Zelalem, 2014).

Despite its numerous benefits, the practice is being abandoned for sole cropping since the current extension services and technologies in the country are promoting sole cropping. Hence in many parts of Ethiopia, farmers mostly harvest only once in a year on sole crop basis even in areas that receive sufficient rainfall (Yayeh et al., 2014b). Nevertheless, this does not provide sufficient food supply for the households and does not make efficient use of the limited resources such as rainfall and land.

However, management practices that emphasize the integration of maize with leguminous species could optimize the use of environmental resources, increase production where land area expansion is not possible and also enhances rich and diversified diet options. Yet, these benefits and interaction were not properly studied in the study area. Studies in other areas have shown that indices such as land equivalent ratio (LER) are useful to substantiate the resource utilization efficiency of intercropping system (Willey and Osiru, 1972), land equivalent coefficient (LEC) to measure the strength of the relationship (Adetiloye et al., 1983), relative crowding coefficient (K) to measure the relative species dominance of multiple cropping (De Wit, 1960), and monetary advantage index (MAI) to evaluate the economic benefits of intercropping over sole cropping (Willey, 1979).

Therefore, such indices should be taken into account in recommending cropping systems for a given area. Thus, the objectives of this paper were;

(1) To determine the effect of competition among the two different leguminous species (soybean *Glycine max* (L.) Me rril) and Mungbean (*Vigna radiata*) in maize intercropping;
(2) To study the economic viability of intercropping maize with soybean and mungbean compared to its sole cropping under supplementary irrigation (SI).

MATERIALS AND METHODS

Description of the study area

The field study was conducted at Tselemti wereda, which is found in North Western Tigray administration zone during the 2016/2017main cropping season (about 13^0 59'N, 38^0 14'E at 1323 meters above sea level). It is located in the arid agro-ecology with a unimodal type of rainfall received around June. Agriculture is the main livelihood of the community in the study area. Known for their mixed farming system, the rural people depend on crop and livestock production in addition to agro forestry practices for their living. People are also engaged in traditional gold mining as a main off- farm income. Soil in the area is classified as clay (Table 1 and Figure 1).

Experimental design and treatments

Maize variety, obtained from Melkassa Agricultural research center was intercropped with two legume species; Soybean and Mung bean in the ratio of 1:1 under rainfed and supplementary irrigation in a split-plot design with three replications. The main plot constituted the two intercropping combinations while supplementary irrigation was applied to the sub-plots. Pure stands of maize, soybean and mungbean as well as the solitary ratios of Maize-legume intercropping were planted. Sole maize was planted at a seeding rate of 125 kg ha^{-1}, sole soybean and mungbean at seeding rates of 65 and 30 kg ha^{-1} respectively. Whereas for the intercropped treatment of maize, half of the recommended seeding rate was applied. Maize was drilled 75 cm between rows, while Soybean was drilled at a spacing of 60 cm and Mung bean was planted at a spacing of 10 x 40 cm. The space between the rows of maize and any legume rows was 20 cm. A basal fertilizer application of Di ammonium phosphate (DAP) (18% N, 46%P) at a rate of 100 $kgha^{-1}$ and 50 $kgha^{-1}$ urea (46% N) at planting, while the second half of urea was top-dressed at tillering stage. A 135 mm supplementary irrigation was applied to the irrigated sub-plots at booting stage to replenish soil moisture during the dry spells.

Competition indices and monetary advantage index

Land equivalent ratio (LER)

LER was used as the first criteria to demonstrate the advantages mixed cropping over the other among the different species (Willey,

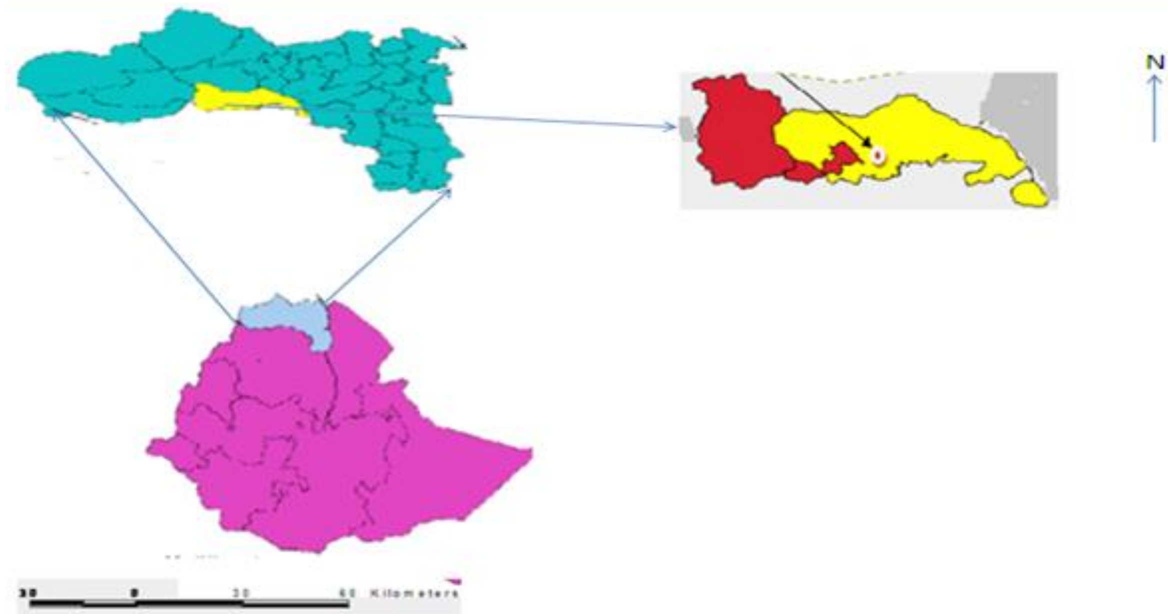

Figure 1. Location of the study area.

1979). It shows the effectiveness of intercropping in resource utilization in the environment in comparison with monocropping (Mead and Willey, 1980). In other words, LER can be used to indicate complementarities among species in the intercrop (Yayeh et al., 2014b). A unitary value of LER is the reference value. LER value greater than one indicates that intercropping is advantageous over sole cropping in terms of growth and yield of both species. A value of LER less than one, indicates the negative effect of the interaction on the species in the mixture (Ofori and Stern, 1987; Yayeh et al., 2014b). Therefore, LER was calculated according to Willey and Osiru (1972), as;

LER = LER Wheat (A) + LER Legume (B);

where, LER wheat $=(\frac{Y_A I}{Y_A S})$ and LER Legume $= (\frac{Y_B I}{Y_B S})$

Where:

$Y_A I$ and $Y_B I$ are yields of wheat and legume in the intercrop respectively while $Y_A S$ and $Y_B S$ are the sole crop yields of wheat and the legumes respectively.

Land equivalent coefficient (LEC)

The strength of the intercropping interaction was determined using land equivalent coefficient (LEC), also referred to as the productivity index (PC). LEC was used because it is a more superior index in evaluating crop mixture performance in terms of mixture productivity (Adetiloye et al., 1983). Thus, was calculated as;

LEC = L*a* x L*b*

Where:

L*a* = LER of main crop and L*b*= LER of intercrop

coefficient (PC) is 25%, that is, a yield advantage is obtained if LEC value exceeds 0.25.

Crowding coefficient (K)

Crowding effect is also one of the indices used in computing the competition effect of intercropping. It gives a measure of the relative dominance of one species over the other in multiple cropping (Banik et al., 2006). Each of the species within an intercropping has its own relative crowding coefficient and the one with higher values are said to be more dominant (De Wit, 1960). It was calculated according to the formula below;

$$Kab = \frac{\text{Yab}}{\text{Yaa} - \text{Yab}} \quad \text{and} \quad Kba = \frac{\text{Yba}}{\text{Ybb} - \text{Yba}}$$

Where:

Kab and Kba are the relative crowding coefficient of wheat in legume and legume in maize respectively; Yaa and Ybb are yields of maize and legumes in monoculture; Yab is the yield of maize in poly culture with a legume and Yba to denote the yield of the legume in the intercrop. When the value of K is greater than 1, there is a yield advantage, when K is equal to 1, it indicates no yield advantage and K values less than one show a yield disadvantage of intercropping.

Monetary advantage index (MAI)

The economic feasibility of intercropping over sole cropping was calculated using the monetary advantage index (MAI). MAI is an important index in determining economic viability of intercropping. It was calculated according to Willey (1979) as;

For a dual-crop mixture, the minimum expected productivity

$$\text{MAI} = \frac{(\text{value of combined intercrops})\text{x}\ (\text{LER} - 1)}{LER}$$

Table 2. Land equivalent ratio (LER) and Land equivalent coefficient (LEC) of maize-legume intercropping at Tselemti, Ethiopia in 2016/2017.

Rainfed	Supplementary irrigation							
	LER				LER			
Treatment	**Maize**	**Legume**	**Total**	**LEC**	**Maize**	**Legume**	**Total**	**LEC**
Maize + Soybean	1.06	0.77	1.83	0.82	1.47	0.91	2.38	1.34
Maize +Mungbean	0.78	0.46	1.24	0.36	1.38	0.52	1.9	0.72

The higher MAI value will indicate more profitable cropping system over the other (Muhammad et al., 2008). The value of the component crops were computed basing on the average market price in Tselemti area in Ethiopian Birr (ETB) after harvest time.

Data analysis

Data were statistically explored using the descriptive analysis of variance (ANOVA). Gen Stat version 14 was used for each of the indices (Payne, 2014) according to standard analysis of variance procedures (Gomez and Gomez, 1984), and least significant difference (LSD) test at 5% probability level using Duncan's multiple range test was used to compare the treatment means.

RESULTS AND DISCUSSION

Competitive indices

Land equivalent ratio (LER) and land equivalent coefficient (LEC)

LER is an effective and widely used index for comparing intercropping systems due to different species growing on the same piece of land (Beets, 1982; Yayeh et al., 2014b). Intercropping maize with Soybean and Mung bean under rainfed and supplementary irrigation significantly ($p < 0.05$) affected LER.

In general, the partial LER for maize was lower in maize-legume mixtures than in sole wheat both in rainfed and with supplementary irrigation. Higher partial LERs (0.77 and 0.91) were registered under maize-soybean mixtures under rainfed and supplementary irrigation respectively (Table 2). Intercropping Maize with Soybean gave higher values of total LER (1.83 and 2.38) respectively compared to maize-mungbean mixtures under rainfed and supplementary irrigation (Table 2). This indicates that 83% (0.83 ha) and 138% (1.38 ha) more land area in sole cropping system would produce the same yield as in the intercropping system of maize and soybean under rainfed and supplementary irrigation respectively.

Nevertheless, maize-mungbean also gave LER values greater than one under both water regimes, also indicating a yield advantage over sole cropping (Table 2). This also demonstrates that intercropping systems were more effective in utilization of environmental resources for growth and yield formation over sole cropping. Similar results were also reported by Yayeh et al. (2014a) who reported values of LER well above one in wheat-lupine and barley-lupine intercropping.

Likewise, Caballero et al. (1995) reported intercropping vetch with oat to be advantageous in terms of yield over sole cropping. According to Willey (1979), intercropping systems with constantly higher LERs well-above one are considered more resource-use efficient than mono crops. Muhammad et al. (2008) and Yadav and Yadav (2001) also reported yield advantage in crop mixtures than equivalent sole crops on the same land area. However, this varies with the species combination and seeding ratio.

High population of cereals have been reported to negatively affect the overall yield, hence resulting in LER values less than one. For instance, B. Yayeh et al. (2014a) reported LER values less than one in lupine-barley and lupine wheat intercropping in the ratios of 75:100 and 50:100 respectively. This was probably due to higher competitive ability of the cereals at higher populations. Matching duration of maturity between the component crops was also reported to reduce the value of LER to less than one in lupine-finger millet intercropping since they were assumed to have critical resource demands at the same time period (Yayeh et al., 2014a) (Table 2).

The study showed that the LEC of maize was significantly affected ($p < 0.005$) by intercropping with soybean and Mung bean, and LEC was generally greater than 25% in all the treatments (Table 2). Maize-Soybean intercropping demonstrated more productivity as was demonstrated by higher LEC values of 0.82 and 1.34 in rainfed and irrigated conditions respectively as compared to Maize-mungbean mixture (Table 2). Expectedly, supplementary irrigation recorded higher LEC than rainfed conditions as shown in the Table 2. The results aforementioned demonstrated that intercropping had yield advantage over sole cropping and maize-soybean combination was to be more productive both with rainfed and supplementary irrigation. Egbe (2010) also reported LEC values above 25% in maize intercropping systems.

Relative crowding coefficient (K)

Relative crowding effect was another coefficient used in the study and it is the relative dominance of one species over the other (Banik et al., 2006). The relative crowding

Table 3. The relative crowding coefficient (K) for mixtures of maize and legumes under rain fed and supplementary irrigation in Tselemti, Ethiopia in 2016/2017.

Treatment	Relative competition coefficient (K)					
	Maize + Soybean			Maize + Mungbean		
	Kw	Kl	K	Kw	Kd	K
Rainfed	-16.67	3.33	-55.56	3.55	0.85	3.02
SI	-3.12	10	-31.21	-3.63	1.08	-3.93

Kw: coefficient of wheat; Kl: coefficient of lentil; Kd: coefficient of dekoko; K: product of coefficient.

Table 4. The MAI for maize-legume intercropping in Tselemti, Ethiopia.

Treatment	Monetary advantage index (MAI) (ETBr)	
	Rainfed	Supplementary Irrigation
Maize + Soybean	7.937.2	20.642
Maize + Mungbean	4.983.9	22.500

coefficient (K) was significantly affected ($p < 0.05$) by intercropping wheat with the legumes. The partial K values indicated that the legumes were more species to maize in the crop mixtures (Table 3).

Soybean exhibited greater dominance in both rainfed and supplementary irrigation conditions. The study also showed that the partial K for maize was greater than one (3.55) in maize-mungbean intercropping under rainfed conditions. However, it was less than one in the soybean intercropping scenario (Table 3). Under supplementary irrigation, the partial K for maize was less than one in both maize-soybean and maize-mungbean intercropping. Overall, the product of K was less than one in both intercropping scenarios under the two water regimes, except for the case of maize-mungbean intercropping under rainfed conditions.

It can be inferred that intercropped legumes utilized resources more competitively than maize hence were more dominant. Additionally, partial K values for soybean were higher than that of mungbean which is an indication that soybean was more competitive than mungbean in the maize-legume mixtures. This finding was in line with the findings of Yilmaz et al. (2008) who reported that legumes become more competitive than the cereals when planted in equal proportions. However, it contradicts with the findings of Banik et al. (2006) who reported more competitiveness of maize in maize-chickpea intercropping, which was attributed to better resource utilization by the cereal than the component legume. The negative values indicated yield disadvantages of maize intercropping with soybean and mungbean.

Similar findings were reported by Dhima et al. (2007) and Tahir et al. (2003) who reported yield disadvantages in wheat-vetch and wheat-canola intercropping systems respectively over the respective monocultures. This index however did not provide a more realistic comparison of yield advantage and was relatively indifferent to LER and LEC (Table 3).

Economic advantage of intercropping

Monetary advantage index (MAI)

Most intercropping indices mainly give the agronomic and yield advantages of intercropping, and do not take into account the economic and absolute yield comparisons (Tamado and Mulatu, 2000; Yayeh et al., 2014b). Nevertheless it is necessary to perform some monetary evaluations to satisfactorily compare the value of the yield advantage (Willey, 1979).

The study demonstrated that intercropping wheat with legumes significantly affected the MAI ($p < 0.05$). It showed that MAI was positive in all the intercropping systems and higher above one (Table 4). This indicates that the intercropping systems were more economically feasible weighed compare to sole cropping. This conforms to similar results by Dutta et al. (1994) on maize-rapeseed combinations.

MAI was higher in maize-soybean in the absence of supplementary irrigation (ETBr 7,937.2). However, with application of supplementary irrigation, Maize – mungbean intercropping had higher values of MAI (ETBr 22,500) (Table 4). These results imply that it was more economically viable to intercrop maize with lentil under rainfed conditions in the study area, whereas Maize-mungbean intercrop demonstrated economic advantage under supplementary irrigation. This signifies unsuitability of mungbean in maize intercropping under rainfed conditions and entails that maize-soybean intercropping systems is more suitable for the rainfed farming systems of the study area. These results followed a similar trend as the LER and LEC competitive indices (Table 2). It was reported by Dhima et al. (2007) that when LER and LEC values are higher, there is also economic advantage in terms of MAI. Intercropping lupine-wheat and lupine-finger millet also gave more economic returns compared to sole cropping (Yayeh et al., 2014a).

CONCLUSION AND RECOMMENDATIONS

LER was greater in both maize-soybean and maize-mungbean intercropping and as well, the LEC was greater than 25%. MAI was also positive showing that intercropping was more efficient in terms of resource utilization in the environment than sole cropping. Moreso, LER demonstrated that 24 and 83% more land in maize-mungbean and maize-soybean respectively would be required in sole cropping to produce the same yields as in intercropping under rainfed conditions. Therefore, intercropping would serve as a more sustainable way of improving soil productivity among the low-input farmers in Tselemti area and similar agro ecologies. It also suggests maize-soybean as the most economical combination for maize intercropping in the area. Besides, these leguminous are new crop to the study area but in short time accepted they use those for local consumption and market. Therefore, introducing intercropping to the areas gives more advantages to the farmers. However, this study considered only a single ratio of combination of maize and the legumes, and in only one location. We recommend that a similar study should be conducted using different seeding ratios and with different intercropping patterns in different agro-ecologies to come with conclusive recommendations. In addition, a cost-benefit analysis of the different intercropping combinations and patterns would lead to the most economically feasible combination and agronomic management to be recommended for the smallholder farmers in the area.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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