African Journal of Agricultural Research Vol. 6(7), pp. 1786-1793, 4 April, 2011
Available online at http://www.academicjournals.org/AJAR
DOI: 10.5897/AJAR10.288
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

Intercropping of maize (*Zea mays* L.) and faba bean (*Vicia faba* L.) at different plant population densities

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Accepted 24 June, 2010

In order to determine the best combination and efficiency of resource utilization in intercropping of maize (*Zea mays*) and faba bean (*Vicia faba*), a field experiment was conducted as factorial on the bases of randomized complete block design with three replications. Treatments were intercropped combinations of maize densities (6, 7 and 8 plant/m^2) and faba bean densities (30, 40 and 50 plant/m^2) and 6 sole-cropped treatments. Two species were intercropped as additive series. The biological and grain yields of maize and faba bean were significantly affected by maize and faba bean densities. Maximum land equivalent ratio (1.97) was attained by 6 maize plants/m^2 with 40 and 50 plants/m^2 of faba bean intercropping combinations indicating that the area on which monocultures were planted would need to be 97% greater than the area allotted to the intercrop for the two produced the same combined grain yield. The highest standard land equivalent ratio (LERs) produced by intercropping of 8 maize plants with 50 faba bean plants/m^2. Maximum RVT (1.31) was obtained in maize and faba bean intercropping with 8 maize and 50 faba bean plants/m^2. Whereas, intercropping monetary advantage in comparison with mono cropping was 30%. The combination of 8 maize and 50 faba bean plants/m^2 showed the highest profitability and could be introduced as best intercropping system.

Key words: Faba bean, grain yield, intercropping, land equivalent ratio, maize.

INTRODUCTION

Food supply is one of the most important problems the world is enduring nowadays; intercropping is used in many parts of the world for the production of food and feed crops (Carruthers et al., 2000). The amount of cultivable land is gradually decreasing, mainly because of rapid urbanization and industrialization due to the global population explosion. The limited land areas are facing pressure to meet basic demands, especially for food, fiber and oil since most growers own very small plots of land, especially in the developing countries of Asia and Africa. In view of this, there is need for not only increased production, but also the ability to grow multiple crops in small areas. Intercropping as a method of sustainable agriculture is the simultaneous growing of two or more crops during the same season on the same area, which utilize common limiting resources better than the species grown separately as an efficient resource use method (Gosh et al., 2006; Sobkwicz, 2006). Intercropping of cereals with legumes has been popular in humid tropical environments (Tusbo et al., 2005) and rain-fed areas of the world (Gosh et al., 2004) due to its advantages for yield increment, weed control (Poggio, 2005), insurance against crop failure, low cost of production and high monetary returns to the farmers (Ofori and Stern, 1987), improvement of soil fertility through the addition of nitrogen by fixation and transferring from the legume to the cereal (Gosh et al., 2006), improving yield stability, socio-economic and some other advantages (Willey, 1979).

Several functions or parameters such as monetary advantage, aggressiveness, cash return, land equivalent ratio (LER) (Willey, 1990), standard land equivalent ratio (LERs), relative value total (RVT) (Vandermeer, 1989) and equivalent yield have been used to assess the efficiency of intercrops or mixed crops. However, LER is

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Table 1. Experimental treatments as maize and faba bean densities.

Treatments	Maize density (plants/m^2)	Faba bean density (plants/m^2)
Monocropped maize (a_1)	6	0
Monocropped maize (a_2)	7	0
Monocropped maize (a_3)	8	0
Monocropped faba bean (b_1)	0	30
Monocropped faba bean (b_2)	0	40
Monocropped faba bean (b_3)	0	50
intercropping (a_1b_1)	6	30
intercropping (a_1b_2)	6	40
intercropping (a_1b_3)	6	50
intercropping (a_2b_1)	7	30
intercropping (a_2b_2)	7	40
intercropping (a_2b_3)	7	50
intercropping (a_3b_1)	8	30
intercropping (a_3b_2)	8	40
intercropping (a_3b_3)	8	50

considered as the most appropriate in combination with the absolute yields of the crops.

Maize-faba bean intercropping is used in many parts of the world, especially in the high lands of east and South Africa, and in Mexico (Minal et al., 2001; Mbah et al., 2007). Maize as a third cereal product of the world has been recognized as a common component in most intercropping systems (Adeniyan et al., 2007). It is used as food, feed and forage. Faba bean, due to its shade tolerance (Nasrullahzadeh et al., 2007) and symbiotically atmospheric nitrogen fixation capacity which adds valuable nitrogen to the soil (Wenxue et al., 2005) and also due to its high amount of protein among the legumes (Matthews and Hary, 2003) is a valuable crop for intercropping with maize.

In our hypothesis, we tested intercropping of maize and faba bean in regard to plant and growing traits to see if the combination can use resources more efficiently compared to sole cropping and so produce higher profitability. Maize and faba bean are in the list of compatible crops that can be produced in research location. Thus, in this research the maize and faba bean intercropping is assessed to determine the best combination and efficiency of resource utilization by determining advantageous indices.

MATERIALS AND METHODS

Field experiment was carried out at the research station of Faculty of Agriculture, University of Tabriz, Iran (latitude of 38°, 5' and longitude of 46°, 17' at an altitude of 1360 m above mean sea level) in 2007. Mean annual temperature and rainfall in 2007 were 10°C and 271 mm, respectively. The soil was clay-loam with a pH of 7.3.

The experimental were factors arranged as a factorial based on randomized complete block design with three replications. Each plot size was 3 m×4 m involving 5 rows with inter–row spacing of 0.6 m. Factors included cropped maize (Zea maize var, 704, with 120 - 150 days growing period) with mono- six, seven, and eight plants/m^2, and faba bean (Vicia faba, with 90 - 120 days growing period) with thirty, forty and fifty plants/m^2 and intercropping of two species based on additive series (Table 1). These are very close to the optimum populations of these crops.

Seed bed preparation included ploughing, disk harrowing and cultivation. Before sowing, seeds were treated with 2 g/kg benomyl. Sowings were performed manually by planting twice more seeds than the expected plant densities and then, rows were thinned to the required densities. For mono and intercropped maize treatments, a basal application of nitrogen and phosphorous were carried out at sowing time, using urea and P_2O_5 fertilizers at the rate of 60 kg ha^{-1} and 100 kg ha^{-1}, respectively. About 60 kg ha^{-1} urea was also added to the soil when maize plants were 40 - 50 cm height. The remaining urea 60 kg ha^{-1} was added to the soil when maize was in anthesis – silking interval. The sole-cropped faba bean received 50 kg ha^{-1} of P_2O_5 during planting. Soil moisture was kept at an adequate level to prevent water deficiency stress during growing. Plots were irrigated as at when needed. Weed control was performed manually. Maize was harvested at complete maturity and faba bean plants were harvested when the most pods fully matured. Maize and faba bean plants were cut from ground surface and vegetative parts of plants oven dried at 78°C for 48 h and dry weight was recorded as biological yield. Seeds were detached from the cubs and pods and weighed after adjusting the seeds moisture constants levels to 14% in maize and to 15% in faba bean.

In order to evaluate the competitive effects among component crops and to determine intercropping performance in mixture and sole crop, different indices as relative yield (RY), relative yield total (RYT) of grain and biomass of species were calculated, using the equations described by Willey (1979):

$$RY_i = \frac{Y_{ij}}{Y_{ii}}, \quad RY_j = \frac{Y_{ji}}{Yjj}$$

$$RYT = RY_i + RY_j$$

where Y_{ii} is the yield of maize in pure stand, Y_{ij} is the yield of maize

Table 2. Analysis of variance of biological and grain yields of sole and intercropped maize at different maize and faba bean densities.

Source of variance	MS		
	d.f	Grain yield of maize	Biological yield of maize
Replication	2	370/60 ^{ns}	21013/37 *
Maize density	2	37415/13 **	322338/2 **
Faba bean density	3	317609/ 50 **	420228/61**
Interaction	6	11211/73 **	18909/26 **
Error	22	839/09	5588/88
CV (%)		13/30	15/43

ns, *, **: Non significant and significant at $p \leq 0.05$ and $p \leq 0.01$, respectively.

inter-cropped with faba bean, Y_{jj} is the yield of faba bean in pure stand and Y_{ji} is the yield of faba bean inter-cropped with maize.

In the additive design RY is the response of a species that occupies a certain space to the addition of plants of another species to that space. According to (50) different values of RY having different meanings: RY < 1.0 shows competition, RY = 1.0 indicates lack of interaction and RY > 1.0 shows stimulation. Relative yield total (RYT) is a measure of resource complementarily and indicates to what extent species compete for limiting resources. If the species completely share common limiting resources RYT = 1.0. Relative yield total greater than 1.0 indicates partial resource complementarities between competing crops.

The most basic tool that agricultural scientists generally use to evaluate intercrop efficiencies in grain yield, dry matter, and mass density of a crop with respect to sole crops is the land equivalent ratio (LER). LER values are calculated according to Willey (1979):

$$LER = \frac{P_1}{M_1} + \frac{P_2}{M_2}$$

Where, P_1 and P_2 are the yields of two different crops in intercropping and M_1 and M_2 are the yields of these crops in mono-cropping. LER > 1 shows intercropping advantage and LER < 1 means mono-cropping advantage. To remove the faults relating to LER, we used LERs in which the maximum of mono-cropping yield was applied.

Relative value total (RVT) was estimated by the following equation (Vandermeer, 1989):

$$RVT = \frac{aP_1 + bP_2}{aM_1}$$

where P_1, P_2 and M_1 are defined as in equation 3, a and b are the market prices of crops 1 and 2, respectively.

Analysis of variance of the data appropriate to the experimental design and comparison of means at $p \leq 0.05$ were done using M-STAT C software. Word and Excel softwares were used to draw tables and figures.

RESULTS

Biological and grain yields of maize

The effects of maize and faba bean densities and their interactions on biological yield of maize were significant (Table 2). The highest biological yield of maize was obtained in mono-cropping of maize with 7 and 8 plants/m^2, compared with other treatments (Figure 1). Biological yield in mono-cropping of 6 plants/m^2 was statistically similar to that of intercropping combinations of 6+30, 6+40, 7+30, 7+40 plants/m^2 of maize and faba bean, respectively.

The results revealed that the maize grain yield was significantly ($p \leq 0/01$) influenced by maize and faba bean densities and their interaction (Table 2). The highest grain yield of maize was obtained by sole cropping at 7 and 8 plants/m^2, compared with all other treatments (Figure 2). Intercropping of maize in association with faba bean resulted in significant reduction of maize yield. There was a significant increase in yield with increasing plant population in sole cropping.

Biological and grain yields of faba bean

The results indicated that the biological yield of faba bean was not significantly affected by faba bean densities (Table 3). But the effect of maize density on biological yield of faba bean in intercropping was significant. Biological yield of faba bean in pure stand was greater than in intercropping (Figure 3). The maximum biological yield of faba bean was obtained under mono-cropping, while the minimum biological yield was produced under inter-cropping with higher maize density (8 plants/m^2).

Statistical analysis showed that the effects of maize densities and the interactions of maize and faba bean densities on grain yield of faba bean were significant (Table 3). There was a general reduction in the yield of faba bean under intercropping system. The highest grain yield of faba bean was recorded in mono-cropping with maximum density (50 plants/m^2). Grain yield of 30 and 40 plants/m^2 in mono-cropping was similar to that of different densities in intercropping (Figure 4).

Land equivalent ratio (LER)

Results showed that LER values were greater than one in

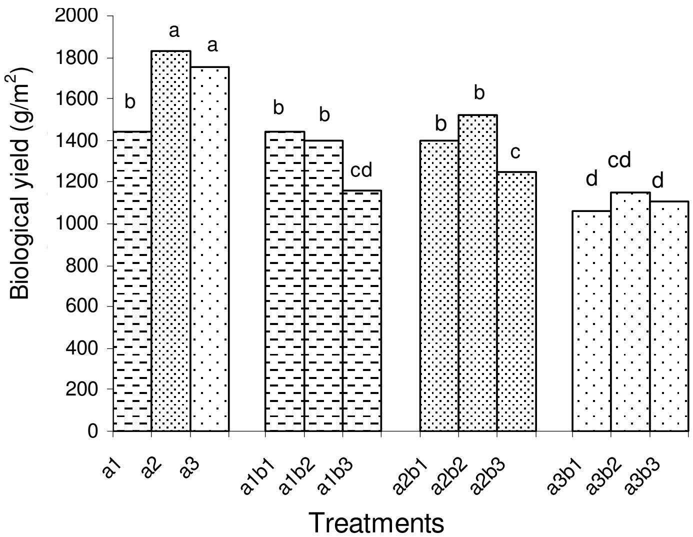

Figure 1. Biological yield of sole and intercropped maize at different intercropping densities. a_1, a_2: and a_3: 6, 7 and 8 maize plants per m^2, respectively; b_1, b_2 and b_3: 30, 40 and 50 faba bean plants per m^2, respectively.

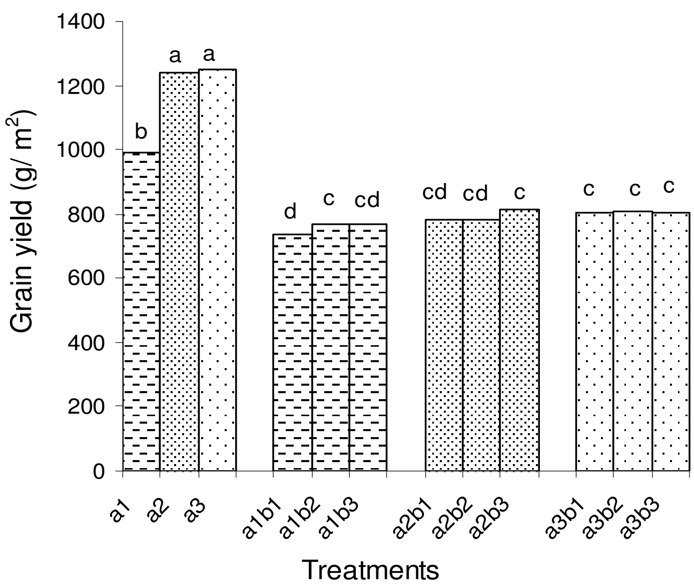

Figure 2. Grain yield of sole and intercropped maize at different intercropping densities. a_1, a_2: and a_3: 6, 7 and 8 maize plants per m^2, respectively; b_1, b_2 and b_3: 30, 40 and 50 faba bean plants per m^2, respectively.

all the intercropping combination of maize and faba bean (Table 4). The highest LER value (1.97) was recorded at intercropping of 6 maize plants with 40 and 50 faba bean plants/m^2, indicating additional 0.97 unit of land would have been needed to get equal yield to planting maize and faba bean in pure stands. The lowest LER (1.22) was obtained from intercropping of 8 maize plants/m^2 with 30 and 40 faba bean plants/m^2, in which intercropping had 0.22 ha profitability in land usage.

Standard land equivalent ratio (LERs)

The value of LERs appears to be greater than unity under all intercropping treatments (Table 4). Maximum and minimum LERs of 1.34 and 1.04 were attained by

Table 3. Analysis of variance of biological and grain yields of sole and intercropped faba bean at different maize and faba bean densities.

Source of variance	MS		
	d.f	Grain yield of faba bean	Biological yield of faba bean
Replication	2	12061.41**	38041.57**
maize density	3	7972.88**	75595.35**
Faba bean density	2	2542.45^{ns}	7329.22^{ns}
Interaction	6	3643. 91*	1897.34 ^{ns}
Error	22	1341.11	4288.77
CV(%)		20.22	15.40

ns, *, **: No significant and significant at p≤0.05 and p≤0.01, respectively.

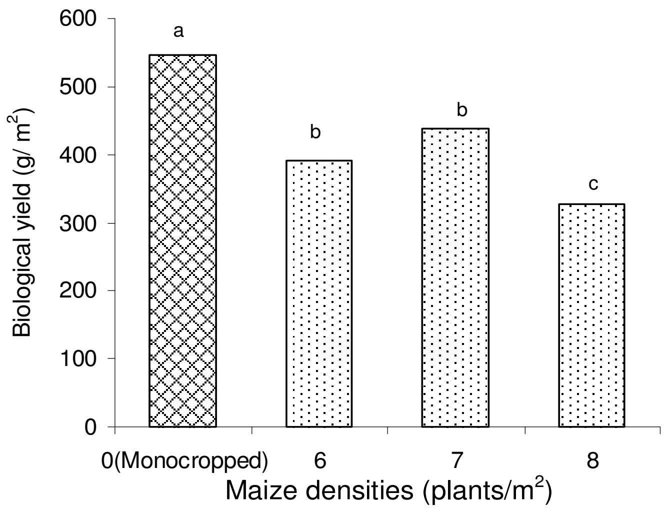

Figure 3. Biological yield of faba bean in mono-cropping and intercropping at different densities of maize.

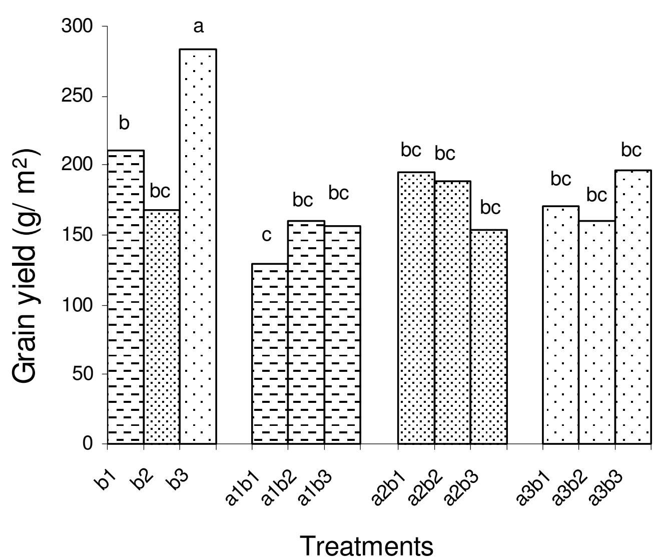

Figure 4. Grain yield of sole and intercropped faba bean at different intercropping densities.b_1, b_2 and b_3: 30, 40 and 50 faba bean plants per m^2, respectively; a_1, a_2: and a_3: 6, 7 and 8 maize plants per m^2, respectively.

Table 4. Relative yields (RY), land equivalent ratio (LER), standard land equivalent ratio (LERs) and relative value of total (RVT) for grain yields of maize and faba bean at different intercropping densities

Treatments	RY Maize	RY Faba bean	RYT=LER	LERs	RVT
(a_1b_1)	0.74	1.17	1.91	1.04	1.02
(a_1b_2)	0.78	0.19	1.97	1.08	1.05
(a_1b_3)	0.78	0.19	1.97	1.08	1.05
(a_2b_1)	0.63	0.19	1.82	1.32	1.30
(a_2b_2)	0.63	1.10	1.73	1.27	1.25
(a_2b_3)	0.65	0.78	1.43	1.1	1.08
(a_3b_1)	0.64	0.58	1.22	1.22	1.19
(a_3b_2)	0.64	0.58	1.22	1.22	1.20
(a_3b_3)	0.64	0.7	1.34	1.34	1.31

b_1, b_2 and b_3: 30, 40 and 50 faba bean plants per m^2, respectively; a_1, a_2: and a_3: 6, 7 and 8 maize plants per m^2, respectively.

intercropping of 8 maize with 30 faba bean plants/m^2 and 6 maize with 50 faba plants/m^2, respectively. This means that sole culture of maize or faba bean requires 34% more land to produce equal yield.

Relative value total (RVT)

The RVT values of all treatments were greater than one (RVT > 1), (Table 4). The highest RVT (1.31) was obtained in maize and faba bean intercropping with 8 maize and 50 faba bean plants/m2. Intercropping resulted in economic advantage; the relative value total (RVT) was between 1.02 and 1.31, showing 2 - 31% economic advantage.

DISCUSSION

The reduction in maize biological yield in the intercropping system in comparison with mono-cropping at 7 and 8 plants/m^2 (Figure 1) can be attributed to inter-specific competition of faba bean with maize. Similar results were reported for intercropping of common vetch with oat (Tuna and Orak, 2007) and gram with mustard (Patel et al., 1991).

Intra-specific and inter-specific competition of faba bean with maize reduced grain yield of maize similar to those reported for intercropping of other crops (Carruthers et al., 2000; Gosh, 2004; Amanullah et al., 2006; Mbah et al., 2007; Alhaji, 2008; Lingaraju et al., 2008; Jayakumar et al., 2008; Yilmaz et al., 2008), nitrogen fixing ability of faba bean roots and transfer of N fixed by faba bean to maize, extensive root system of maize for absorption of water and nutrients (Chen et al., 2004) and less competition of faba bean with maize resulted in no significant change in grain yield of maize at different densities of intercropping (Figure 2).

Al-Dalain (2009) reported that the total biomass of plants depends directly on the quantum of light intercepted by the plants. The intercropping decreased biological yield of faba bean (Figure 3) due to inter-species competition for light, water and nutrients, particularly nitrogen (Gosh, 2004). Ofori and stern (1987) indicated that the biological yield of bean decreased by 13% in the intercropping with maize. Gosh et al. (2006) reported that the plant biomass of soybean was reduced by 30% in the intercropping with sorghum. These results are in agreement with those reported for other intercrops (Santalla et al., 1994; Akman and Sencar, 1999; Agegnehu et al., 2006; Al-Dalain, 2009).

The grain yield potential of legumes is generally low when compared with cereals like maize even when optimal agronomic practices are fully adopted (Alhaji, 2008). Results of this investigation showed that faba bean is quite compatible to cultivate with maize, because the grain yield of faba bean was not significantly reduced when intercropped with maize, compared with pure stand of faba bean at 30 and 40 plants/m^2 (Figure 4). Faba bean via N_2 fixation could secrete H^+ in soil (Tang et al., 1997). This acidification of the rhizosphere could enhance dissolution of phosphorus in high pH soils (Hinisinger, 2001). Therefore, faba bean provides nitrogen and phosphorus for itself and maize in intercropping. This can increase total grain yield of two crops in intercropping system.

Land equivalent ratio reflected the extra advantage of intercropping system over sole cropping system. Intercropping resulted in yield advantage; the total land equivalent ratio was between 1.22 and 1.97 showing 22 - 97% yield advantages due to intercropping compared with sole cropping of both faba bean and maize (Table 4).

Therefore, 22 to 97% more land should be used in sole cropping in order to obtain the same yield of intercropping, which indicates the superiority of the intercrops over pure stands in terms of the use of environmental resources during plant growth and development (Dhima et al., 2006). Ghanbari (2000) reported that LER greater than one was due primarily to the increase in nitrogen absorption. The LER greater than

1 in intercropping systems have also been reported by other researchers (Minale et al., 2001; Abbas et al., 2004; Adeniyan et al., 2007; Mbah et al., 2007; Raji, 2007; Bingcheng et al., 2008; Javanmard et al., 2009) .

The standard land equivalent ratio (LERs) of higher than 1.0 (Table 4) indicates that higher productivity per unit area was achieved by growing the crops together rather than separately. This is an indication of the biological efficiency of these systems over the sole cropping system which was previously reported by Vandermeer (1989). LERs ranged from 1.04 to 1.34, suggesting 4 to 34% grain yield increase for intercrops compared with sole crops. The LERs, greater than one in this experiment may have resulted from morphological differences of these two species and creating various floors and better operation of environmental sources as light and humidity, or different horizons of soil. The higher LERs in intercropping than mono-cropping have been reported by Haymes and Lee (1999), Adeniyan et al. (2007) and Bingcheng et al. (2008).

The relative value total (RVT) of 1.31 (Table 4) shows that intercropping of maize and faba bean can increase net income (NI) by 31%. This confirms the advantage of this type of intercropping system to get more benefit. Therefore, intercropping of maize and faba bean with high production stability can considerably increase economical revenues and the profitability of the farmlands. Alabi and Esobhawan (2006) reported 10% higher profit based on relative value of intercropping index in maize-okra intercrop compared to mono-crops. Liben et al. (2001) reported that the highest LER and monetary advantage was obtained by 1 maize:1 faba bean intercrop. Intercropping of maize-groundnut produced higher LER and monetary advantage (>1) than sole crops (Ghosh, 2004).

Regarding monetary advantage and land resource utilization efficiency, the combination of 8 maize and 50 faba bean plants/m^2 showed the highest profitability and land use efficiency and could be introduced as best intercropping system.

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