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Evaluation of yield and advantage indices of sorghum (*Sorghum bicolor* L.) and mungbean (*Vigna radiate* L.) intercropping systems

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ABSTRACT

Intercropping is considered for increasing and stability of yield per unit. In order to study the effects of different intercropping arrangements on sorghum and mungbean yield and to find the land use advantage in the intercropping system, an experiment was carried out based on a randomized complete block design with seven treatments and three replications at the Research Farm, Faculty of Agriculture, University of Tabriz in 2013. The treatments were as follows: sole cropping of sorghum, sole cropping of mung bean and five intercropping patterns of sorghum: mungbean with replacement ratios ((1:1), (2:1), (3:1), (1:2), (1:3)) respectively. The results showed that the maximum grain yield was obtained from both species in monoculture treatment. The highest intercropping advantage (3.22) was related to treatment (1:3). Also, the highest value of RYT was observed 1.36 in treatment (1:1). Land equivalent ratio (LER) in all evaluated treatments was more than one. Thus, according to economic evaluation indices, sorghum and mungbean intercropping was economically justified in comparison with their sole cropping in Tabriz.

Key words: Actual yield loss (AYL); Intercropping; Relative value total (RVT); Relative yield totals (RYT)

INTRODUCTION

Given the increasing global demands for food and the relationship of enhanced food production with food security, and the need to conserve the natural resources, diversification of planting system is necessary (Banik and Sharma, 2009). Sustainable agriculture is a type of agriculture that is more efficient in use of resources, for the benefit of humanity, and is in balance with the environment (Gruhn et al., 2000). Intercropping is a cropping system which integrates crop production with soil conservation. Intercropping, the cultivation of two or more crops at the same time in the same field is a common practice, especially in the tropics and in the developing countries. Benefits of intercropping may be briefed as: better use of resources, improvement of soil fertility by legume components of the system, soil

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preservation through covering the bare land between the rows, reduction of biotic and abiotic risks by increasing diversity and suppression of weed infestation (Emam, 2003). In the tropical and sub-tropical region, cereal - legumes intercropping is the most popular practice because of its many additional advantages (Willey, 1979). When legumes are used as intercrops, they provide the beneficial effect on soil fertility by fixing atmospheric nitrogen. Best utilization of nutrients, moisture, space and solar energy can be derived through mixed/intercropping system (Donald, 1963). However, the advantage of intercropping is obtained when correspondent species are differences in the form and spatio-temporal of natural resources in which different physiological and morphological characteristics will be able to make optimal use of environmental factors when cropped in the vicinity of each other (Nurbakhsh et al., 2013). Sorghum (*Sorghum bicolor* L.) is the fifth most important cereal in the world followed by wheat, rice, maize and barley and a major staple diet of people of semi-arid tropics. Besides its use as an energy source for human consumption, it draws its great value as a source of grain and straw that is used for animal feed (El Naim et al., 2012). Mungbean (*Vigna radiata* L. Wilczek) also called green gram, it is an important summer annual legume crop grown widely in South East Asia. Mungbean seeds are primarily used for food purposes. They are a rich source of lysine and proteins, and thus can supplement cereal-based human diet (Anjum et al., 2006). TohidiNejad et al. (2004) reported that, intercropping of maize (*Zea maize*) and sunflower (*Helianthus annuus*), led to an improvement in performance of both species due to more use of light. Also, Rahimi et al. (2003) reported that LER in intercropping is higher than monoculture intercropped corn and soybean. This experiment was conducted to investigate different ratios of sorghum and mungbean intercropping to achieve maximum yield and higher land equivalent ratio.

2- MATERIALS AND METHODS

This experiment was carried out in the spring of 2013 at the Research Farm, Faculty of Agriculture, University of Tabriz, Located eight kilometers from the East of Tabriz city with longitude and latitude 46° 17′ and 38° 5′ respectively and with a height of 1360 meters above sea level. The experimental design used in this study was a randomized complete block design with three replications with seven treatments as follows: sole cropping of sorghum, sole cropping of mungbean and five sorghum: mungbean intercropping pattern with replacement ratios ((1:1), (2:1), (3:1), (1:2), (1:3)) respectively.

Before planting, super phosphate and nitrogen fertilizer added to the soil with values of 180 and 30 kg ha^{-1} respectively as starter fertilizer. The method used was the substitution method according to constant densities and changing ratios. Each plot consisted of eight rows of 4 meters long with row spacing 50 cm which were away 50 cm from the adjacent plot. The row spacing for sorghum seed was considered 25 cm and 10 cm for the mungbean. As a result, the final density obtained 80000 plants/ha^{-1} in monoculture for sorghum and 200000 plants/ha^{-1} for mungbean. Planting was done manually and clumped. To perform desired density, after plants establishment and in three to four leaf stage, the thinning act was conducted. The first irrigation was conducted one day after planting and next irrigations were conducted once a week. During the growing season, there was no use of chemical toxins and weed control was manually done twice. For measuring the grain yield of the two species, in each plot five plants of sorghum and mungbean accidently were selected after removing marginal effects (lateral rows and half-meter of rows sides) and traits were measured. Obtained results were analyzed using SPSS software and graphs plotted in Excel. Duncan test was used for means comparison.

Also to evaluate the intercropping, indices such as land equivalent ratio (LER) (Equation 1), relative yield totals (RYT) (Equation 2), relative value total (RVT) (Equation 3), actual yield loss or gain (AYL) (Equation 4) and intercropping advantage (IA) (Equation 5) were used.

$$LER = (Yam/Yas) + (Ybm/Ybs) \quad (1)$$

Where, Yam and Ybm are the yields of two crops in intercropping, and Yas and Ybs are the yields of each crop in a monoculture system. If LER is greater than one, intercropping would be better than monoculture (Mazaheri, 1993).

$$RYT = P_1/M_1 + P_2/M_2 = RY_1 + RY_2 \quad (2)$$

P_1 and P_2 are the yields of two crops in intercropping, and M_1 and M_2 are the yields of each crop in a monoculture system. Values of RYT > 1 indicate that the species make different demands on resources or avoid competition in some way, while values of RYT < 1 imply mutual antagonism, RYT values of 1 indicate that the components fully share the same limiting resource (Harper, 1977).

$$RVT = (aP_1 + bP_2) / aM_1 \quad (3)$$

In this equation, a is the price of the main crop, b the price of the secondary crop, p_1 the yield of the main crop of intercropping, p_2 the yield of the secondary crop of intercropping, M_1 the yield of the pure cropping of the main species.

$$AYL = AYL_a + AYL_b \quad (4)$$

$$AYL_a = [LER \times (100/Z_{ab}) - 1]$$

$$AYL_b = [LER \times (100/Z_{ba}) - 1]$$

Where, AYL_a is sown partial actual yield loss or gain of species a, AYL_b is sown partial actual yield loss or gain of species b, Z_{ab} is sown proportion of species a in intercropping and Z_{ba} is sown proportion of species b in intercropping.

$$IA = [(P_a/P_a+P_b) \times AYL_b] + [(P_b/P_a+P_b) \times AYL_a] \quad (5)$$

In this equation, P_a is the price of species a, P_b is the price of species b, AYL_a is the partial actual yield loss or gain of species a and AYL_b is the partial actual yield loss or gain of species b.

3- RESULTS AND DISCUSSION

3-1- Grain yield

Sorghum grain yield was significantly affected by different patterns of culture (Table 1). The mean comparison of culture different patterns effect on grain yield showed that the maximum sorghum grain yield obtained in sole cropping of sorghum treatment (Figure 1). It seems that intraspecific competition is less affected in reducing of sorghum grain yield compared to interspecific competition. Angadi et al. (2004) revealed that grain yield of sorghum was reduced considerably in intercropping system as compared to sole crop. Also, Subramanian and Rao (1988) in a field experiment consisting intercropping of sorghum with pigeonpea and mungbean reported that both component crops of sorghum and pigeonpea recorded less grain yield as compared to sole crop yields of sorghum and pigeonpea.

As can be seen from table 1 the effect patterns of culture were significant on mungbean grain yield. The maximum grain yield was achieved in sole cropping of mungbean treatment (Figure 1). It seems that the main cause of reduction in mungbean grain yield in intercropping to monoculture is placement of mungbean plants canopy under the sorghum plants canopy and lower yield components of sorghum plants in intercropping to monoculture. In study which conducted on intercropping of wheat and chickpea, it observed that the chickpea yield in mixture significantly decreased (Banik et al., 2006). Allen and Ebura (1983) found that soybean yield losses in intercropping with maize due to direct competition for light, space and nutrients.

Table 1. Analysis of variance for grain yield and 1000 seed weight in intercropping sorghum and mungbean

		Mean square			
		Grain yield		1000 seed weight	
S.O.V	df	Sorghum	Mungbean	Sorghum	Mungbean
Replication	2	7934.78ns	3169.91ns	0.147ns	0.568ns
Treatments	5	1806613.74**	844971.58**	1.006ns	11.981**
Error	10	7831.08	2441.32	0.624	0.182
CV (%)		4.21	3.68	2.97	0.75

** Significant at the 0.05 and ns, non-significant

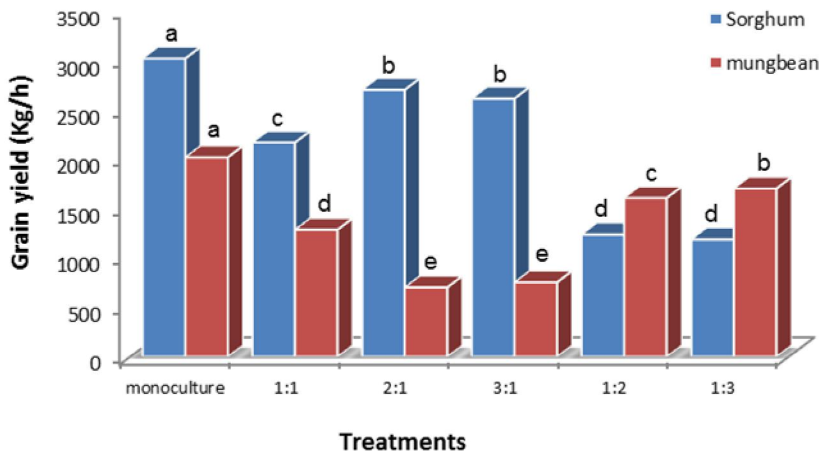

Figure 1. Mean comparison of sorghum and mungbean grain yield in different patterns of culture

3-2- Seed weight

Effect of different patterns of culture were not significant on sorghum 1000-seed weight (Table 1). However, sole cropping of sorghum treatment was with a mean of 27.21 (gr) of the highest seed weight than all the intercropping patterns (Figure 2). Gary and Francies (1999) reported that in intercropping maize, soybean and sorghum, soybean seed weight was not significant. Manjith Kumar et al. (2009) stated that different ratios of intercropping did not significant effect on chickpea seed weight.

The results of variance analysis showed that the effect of patterns of culture on mungbean 1000-seed weight was significant probability levels of (1%) (Table1). The maximum and minimum seed weight were related to treatment (3:1) and sole cropping of mung bean treatment, respectively (Figure 2). The reason of this result was due to the greater number of pod and the number of seeds per pod in monoculture compared to intercropping patterns, plants available in monoculture should be saved themselves assimilate in more reservoirs and this leads to reduced seed weight in monoculture than other treatments. In intercropping of rice with greengram, blackgram and pigeonpea the 100-seed weight of legumes increased in different intercropping systems (Mandal et al., 2000).

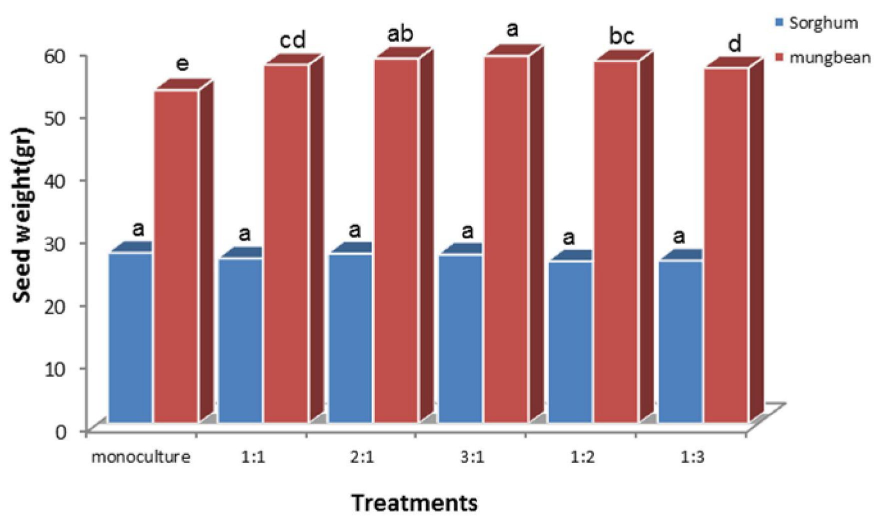

Figure 2. Mean comparison of sorghum and mungbean seed weight in different patterns of culture

3-3- Land equivalent ratio

The highest amount of LER was observed in treatment (1:1) with 1.36 (Table 2). However, all treatments had higher LER than monoculture which indicated the superiority of intercropping over monoculture. The reason the amount of LER is more than one is perhaps because of fixing and absorbing nitrogen in intercropping sorghum and mungbean. Koocheki et al. (2009) found similar results in intercropping corn and beans, which is consistent with the results of present experiment. Also, in intercropping of wheat and lentil, the maximum LER (1.52) was achieved in lentil and 40% wheat as mixed cropping system (Akter et al., 2004).

Table 2. Relative yield (RY), Relative yield totals (RYT), land equivalent ratio (LER), relative value total (RVT), actual yield loss (AYL) and intercropping advantage (IA) of sorghum(s) intercropping with mungbean(m)

Treatment	RYs	RYm	RYT	LER	RVTs	RVTm	AYL	IA
1:1	0.72	0.64	1.36	1.36	2.28	0.93	3.44	1.71
2:1	0.89	0.35	1.24	1.24	1.75	0.71	3.6	1.25
3:1	0.87	0.37	1.24	1.24	1.78	0.72	4.56	1.34
1:2	0.41	0.8	1.21	1.21	2.36	0.96	3.46	2.26
1:3	0.39	0.84	1.23	1.23	2.46	0.98	4.61	3.22

3-4- Relative yield total

The most important index of biological advantage is the relative yield total (RYT) that was used to quantify the yield advantages in a replacement series (Mead, 1986). Relative yield total in all intercropping treatments was more than one. The highest value of RYT was observed 1.36 in treatment (1:1). The maximum and minimum relative yield (RYs) of sorghum was related to treatment (2:1) with 0.89 and treatments (1:3) to 0.39, respectively. Also, the highest relative yield (RYm) of mungbean was obtained in the treatment (1:3) with a mean of 0.84 (Table 2). A relative yield total greater than one indicate partial resource complementarities between competing species. It means the competing species use partially different growing resources or utilize the same resources, but more efficiently due to differences in plant architecture, physiology or growing cycle (Bulson et al., 1997). Ghaderi et al. (2008) showed that the best RYT for alfalfa and wheatgrass intercropping was 1.15 and the maximum R (yield in intercropping/yield in single cropping) for alfalfa and wheatgrass was 1.02 and 0.36, respectively.

3-5- Relative value total

The problem with LER is that such calculation does not account for the value of the crops that are being sown. The solution to this problem is provided in calculating relative value total (RVT) of the crop mixtures. Such calculation is relevant for the farmer that has monetary value as his farming goal (Vandermeer, 2004). If RVT is bigger than 1, the intercropping is economically preferable; whereas if RVT is smaller than 1, the pure cropping is preferable. Provided that RVT is equal to 1, neither of the methods is economically superior to the other. The results showed that the relative value total of mungbean in all intercropping treatments was lower than sole cropping of mungbean. Also, RVT of sorghum in all intercropping treatments was more than one (Table 2). This subject indicates the economical advantage of sorghum and mung bean intercropping more than the sole cropping of sorghum. One reason for the preference of the intercropping over the pure cropping, is the lesser interspecific competition of the crops of intercropping compared to the intraspecific competition of the crops of pure cropping. Similar results were also reported by Rahimi et al. (2011).

3-6- Actual yield loss

Actual yield loss or gain (AYL) index, gave more accurate information about the competition than the other indices among components of intercropping system. The AYL is the proportionate yield loss or gain of intercrops compared to sole crop (Banik, 1996). The amount of AYL in all patterns of intercropping was positive (Table 2). Consequently, an AYL positive coefficient indicates the advantage of intercropping over monoculture. In this study, the highest amount of AYL was obtained in treatment (1:3) with 4.61. Similar results were also reported by Mansouri et al. (2013).

3-7- Intercropping advantage

According to Banik et al. (2000), this index, in addition to expressing the advantage or disadvantage of intercrops, can be an indicator of the economic feasibility of intercropping systems. The maximum intercropping advantage (IA) was related to treatment (1:3) with 3.22 (Table 2). The reason of this result was due to better use of resources such as light, water and nutrients in this treatment, probably.

4- CONCLUSION

The results indicated that all intercropping systems produced greater gross income than monoculture. As regards the LER in all intercropping treatments were more than one so as a result sorghum and mungbean intercropping is recommended for similar conditions with this study.

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