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Evaluation of chlorophyll value, protein content and yield of sorghum (*Sorghum bicolor* L.)/ mungbean (*Vigna radiate* L.) intercropping

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Abstract

In order to evaluate the effects of sorghum and mungbean intercropping on yield, chlorophyll value and grain protein, an experiment conducted in 2013 at the Research Farm, Faculty of Agriculture, University of Tabriz, Tabriz, Iran, as randomized complete block design with seven treatments and three replications. The treatments were as follows: sole cropping of sorghum, sole cropping of mungbean 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 chlorophyll index for sorghum and mungbean was obtained in intercropping treatments with (2:1) and (1:2) ratios. The maximum grain yield was achieved for both species in sole cropping treatments. Results indicated that different cropping patterns in all mixture treatments significantly gave higher grain protein content for both plants than monoculture treatments. Land Equivalent Ratio (LER) in all treatments were more than 1 and consequently, its recommended that sorghum and mungbean intercropping is better than monoculture.

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Introduction

If farming activities be conducted based on ecological principles, in addition to preventing the destruction of natural ecosystems, the result is stable condition (Mazaheri *et al.,* 2006). Also agricultural systems must provide needs of people today and future generations; therefore it seems that is essential achieving to sustainable agriculture. One of the key strategies in sustainable agriculture is restoration diversity to agricultural ecosystems, and its effective management. Intercropping is a ways to increase diversity in an agricultural ecosystem. Sustainable agriculture refers to correct agricultural resource management which in addition to the resolving changing needs of human and also it retains environmental quality and capacity of the soil and water resources (Reijntjes *et al.,* 1992). Mixed systems are one of the sustainable systems which by increasing diversity and complexity cause increasing the stability of the farming systems (Zhang and Li, 2003). In intercropping using a variety of plants in the field, production increasing, maintaining soil fertility, erosion control and in total optimal utilization of resources are provided (Mazaheri, 1993). The condition for success in intercropping is that the present species in the mixture use different form of sources and in the other words occupy different ecological niches. This divergent growth leads to act supplement species. So in designing sustainable intercropping systems it should be noted that the plants which have the most differences in the use of resources, are compatible plants in intercropping (Vandermeer, 1989). Intercropping systems high performance in absorbing light, make theme suitable for planting short- leg plants and shade-friendly besides species of long-leg (Elmore and Jakobs, 1986).

After cereal, legumes are considered as the most important source of human food especially in terms of protein and also they are most important protein-rich crops that be grown in the world and they have been adapted in different climatic conditions from mild to hot. Mungbean is one of the most common plants in cereal - legumes cropping systems which is used and has special importance due to the ability of nitrogen fixation in air, short growing season and relatively high product. Mungbean is a legume that is rich in phosphorus and about 24-27% protein (Majnoon-Hoseini, 2004). Among world crops, sorghum is in sixth rank in terms of the importance and its fifth important cereal in the world among cereal such as wheat, rice, maize and barley (Rashed Mohassel *et al.,* 1997). The most important aspects of nutritional in grain sorghum are consist of grain protein content and present phenolic compounds in grain which both structures will fluctuate with changes in agronomic conditions. Changes domain in grain protein content among different cultivars of sorghum is between 8-15% and with increasing in nitrogen from zero to 170 kg ha^{-1}, its value increases (Ajakaiye, 1984).

The amount of chlorophyll in plant depends on soil nitrogen availability and the ability of nitrogen adsorption by plant, and these are important factors in farm management (Jongschaap and Booij, 2004). Rising in leaf chlorophyll content causes improving in photosynthesis, this causes to increase in cell division and cells size by producing more assimilate and finally, the yield increases (Tilak *et al.,* 1992). In experiments conducted in Italy produced corn – soybean mixed with yield similar to control, while protein content were significantly higher than control. Additionally, the protein quality is improved by intercropping (Herbert *et al.,* 1984). In another experiment, evaluation of intercropping grain sorghum and soybean showed that mixture of two plants in all treatments causes increasing LER and the density of 66/7 plant/m^2 and the mixture ratio 33/67 of soybean/sorghum cause to increase in yield up to 30 percent (Beheshti, 1995). Also Abraham and Singh (1984) found that cultivated row for each one of the four species of annual legumes (cowpea forage, grain cowpea, mungbean and soybean) with sorghum increased yield and nitrogen content of sorghum and it controlled weeds less than pollution in sole cropping of sorghum. This experiment was conducted to investigate different ratios of sorghum and mungbean intercropping to achieve maximum yield and grain protein.

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 height of 1360 m above sea level. The experimental design used in this study were 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 used method was the substitute 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 plant/ha in monoculture for sorghum and 200000 plant/ha for mung bean. 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.

The chlorophyll meter SPAD-502 was used to measure leaf chlorophyll index. Measurements carried out at the flowering stage. The measuring method was as follows that 5 plants per plot were randomly selected and chlorophyll content index from in three-point of flag leaf (tip, middle and basal leave) was determined in each plant and the mean of the data was recorded in each specified plot. Protein content of samples was determined by the Kejeldahl method. Kejeldahl method basis is based on measurement of total nitrogen in the experimental sample and assumes that all the available nitrogen is in type of protein. Therefore, after measurement of sample total nitrogen by applying factor 6.25, the protein content is measured in different treatments (Jensen, 1996). Also 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 usefulness of intercropping, it was used from LER index, which this index is determined using the following equation:

$$LER = (Yam/Yas) + (Ybm/Ybs)$$

In this equation Y_{am} is yield of species a in intercropping, Y_{as} is yield of species a in monoculture, Y_{bm} is yield of species b in intercropping and Y_{bs} is yield of species b in monoculture. If LER is greater than one, intercropping would be better than monoculture (Mazaheri, 1993).

Results and discussion

Chlorophyll index

The results of variance analysis table showed that the effects of repeat and pattern of culture on sorghum chlorophyll index were in significant probability levels of (5%) and (1%) respectively (Table 1). The maximum chlorophyll index was obtained in treatment (2:1) with mean of 37.42 (Fig 1). Leaves of plants under low light conditions compared to the leaves that grow under sufficient light conditions, have higher chlorophyll concentrations (Koochecki *et al.,* 2001). Ghosh *et al.* (2006) reported that in intercropping of soybean and sorghum, chlorophyll content of sorghum leaf in all treatments of intercropping was higher than monoculture and its reason attributed to the overcast of plants on each other and nitrogen fixation by legume in intercropping. Therefore, also in the present experiment increasing in sorghum leaf chlorophyll index in some intercropping treatments compared to monoculture attributed to increasing at the canopy

shading, nitrogen fixation by mungbean and in the other hand to higher and optimal usage of available nitrogen in the soil. Hamzei (2012) showed that the barley chlorophyll index in barley with bitter vetch intercropping in some mixed arrangement was higher compared to monoculture.

Table 1. Analysis of variance for grain yield, chlorophyll index and grain protein content of sorghum mixed with mungbean.

		Mean squares		
Source of Variation	df	Grain yield	Chlorophyll index	Grain protein content
Replication	2	7934.78ns	22.38*	0.093ns
Treatments	5	1806613.74**	31.48**	1.914**
Error	10	7831.08	5.16	0.051
CV (%)		4.21	6.79	2.19

*, ** Significant at the 0.05 and 0.01 probability levels, respectively, ns, non-significant.

Table 2. Analysis of variance for grain yield, chlorophyll index and grain protein content of mungbean mixed with sorghum.

		Mean squares		
Source of Variation	df	Grain yield	Chlorophyll index	Grain protein content
Replication	2	3169.91ns	3.45ns	0.532ns
Treatments	5	844971.58**	40.19**	1.776*
Error	10	2441.32	2.66	0.415
CV (%)		3.68	4.07	2.66

*, ** Significant at the 0.05 and 0.01 probability levels, respectively, ns, non-significant.

Mungbean chlorophyll index was significantly influenced by pattern of culture (Table 2). The maximum chlorophyll index was obtained in treatment (1:2) (Fig 1). Apparently the cause of the chlorophyll content in intercropping, is increasing plants shading on one another. In other words, plants under the shade conditions to trap more light to produce photo assimilate, increase their chlorophyll content. Most leaves of plants have higher chlorophyll concentration in the intercropping than monoculture (Ghosh *et al.,* 2006). The experiment was conducted on the intercropping of corn with faba bean, it was reported that the chlorophyll index of corn and faba bean intercropping was higher than monoculture of both species (Rezaei Chianeh *et al.,* 2010). Hamzei (2012) reported that bitter vetch leaf chlorophyll index in monoculture was significantly lower than intercropping with the barley. Also, the results of Tsubo *et al.* (2005) are consistent with these results. They stated that in intercropping containing legume and cereal, due to the increase in leaf chlorophyll and nitrogen fixation by legume, light use efficiency increases.

Grain protein content

Effect of different patterns of culture was significant on sorghum grain protein content (Table 1). Grain protein content in all intercropping treatments was higher than monoculture treatment (Fig 2). It seems that nitrogen fixation by mungbean root nodules and gives it to sorghum has a major role in increasing the availability of sorghum to nitrogen sources and increasing the protein content. In addition to more nitrogen attracting in intercropping, fixing of atmospheric nitrogen by legumes and its transferring to the sorghum can also be other causes in increasing protein in the intercropping campared to monoculture. Brophy *et al.* (1987) concluded that a large proportion of the leaves narrow nitrogen is supplied by legumes. Also Xiao *et al.* (2004)

concluded that more than 5% of the fixed nitrogen of faba bean is transferred to the wheat. Fixed nitrogen by legumes intercropping may be available with cereal in the same season or to be useful as residual nitrogen for the next crop. Both nitrogen transfering appear important and can reduce the cost of the nitrogen supply in legume-based intercropping different systems (Willy, 1990).

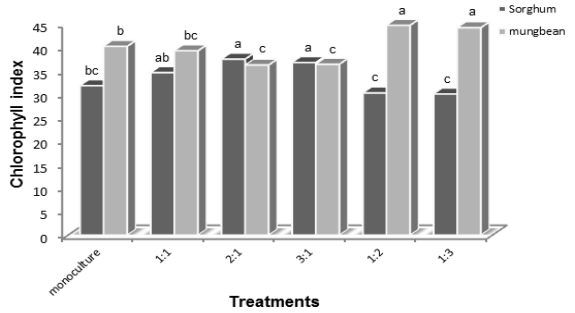

Fig. 1. Mean comparison of sorghum and mungbean chlorophyll index in different patterns of culture.

Mungbean grain protein content was affected by pattern of culture (Table 2). The maximum and minimum grain protein content was related to treatment (1:3) with a mean of 25.08 and treatment (monoculture) with a mean of 23.27 respectively (Fig 2). Considering that the mungbean grain yield declined in intercropping with sorghum, increasing in mungbean grain protein concentration in the intercropping can be attributed to the occurrence of concentration effect (Marschner, 1995). In other words, the grain formation rate was lower than the protein formation rate. Najafi *et al.* (2013) in intercropping of maize, bean and bitter vetch showed that the bean grain protein concentration increased in intercropping compared to bean monoculture.

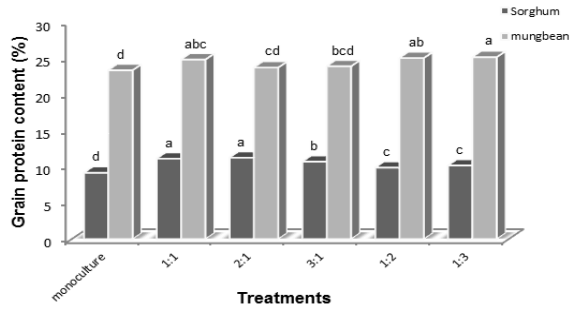

Fig. 2. Mean comparison of sorghum and mungbean grain protein content in different patterns of culture.

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 (Fig 3). It seems that intraspecific competition is less affected in reducing of sorghum grain yield compared to interspecific competition. In the experiment which was conducted on the intercropping of sorghum with legumes, it was reported that sorghum grain yield reduced in intercropping compared to the monoculture (Rashid *et al.,* 2004). Also Pilbeam *et al.* (1994) reported that in intercropping maize with bean, corn grain yield amount in monoculture was more than intercropping. In another experiment, researchers attributed the reason of yield reducing in maize intercropping with grain legumes to compete for absorption of nutrients or lack of nitrogen transfer (Tomar *et al.,* 1988).

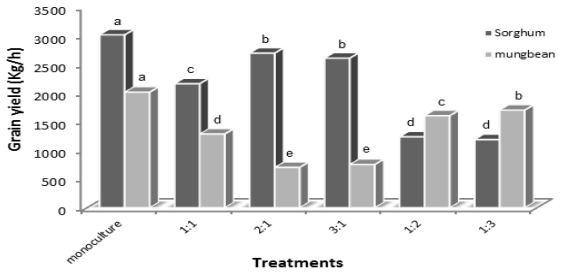

Fig. 3. Mean comparison of sorghum and mungbean grain yield in different patterns of culture.

As can be seen from table (2) the effect patterns of culture were significant on mung bean grain yield. The maximum grain yield was achieved in sole cropping of mungbean treatment (Figure 3). It seems that the main cause of reduction in mungbean grain yield in intercropping to monoculture is placement of mung bean plants canopy under the sorghum plants canopy and lower yield components of sorghum plants in intercropping to monoculture. Gardiner and Craker (1981) reported reduction in bean grain yield in intercropping in evaluation of intercropping maize and bean and found its reason in reducing the number of pod per bean plant in mixture. In another 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.

Land Equivalent Ratio

Land Equivalent Ratio (LER) in all intercropping treatments was more than one. The highest value of LER was observed 1.36 in treatment (1:1) (Fig 4). This subject is a sign of intercropping advantage. Its cause can be morphological differences of two types and thus creating different floor and optimal utilization of resources. The role of morphological differences in access to higher LER by Saleem *et al.* (2003) reported in intercropping of sunflower and mungbean. Mandal *et al.* (1990) surveyed a multi-product intercropping with rice in their study and expressed that planting ratio (2:1) in rice to mungbean is such treatments that showed the highest land equivalent ratio. The researchers attributed this subject to the efficiency of resource usage. Also, Ujjinaiah *et al.* (1991) found that despite the reduction in grain yield of sunflower and pigeon pea in intercropping, totally land equivalent ratio (LER) increased to 1.51 and the highest net profit was obtained.

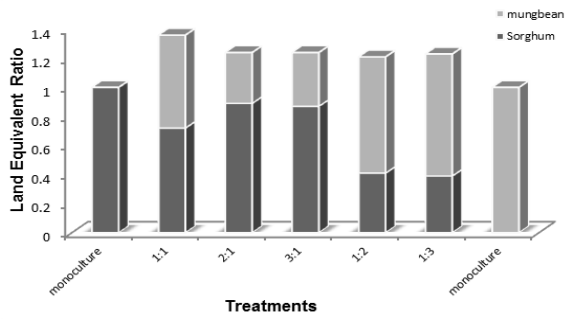

Fig. 4. LER values in different treatments of experiment.

Conclusions

The results clearly showed that intercropping of sorghum with mungbean although the yield of both species in the mixture decreased, but the product quality of both species in grain protein content increased. In fact, mungbean can better tolerate shady conditions and it has additional and assistance effect on sorghum and due to its more compatibility with sorghum, its nitrogen fixation rate is more in the shadows and finally, its transfer to sorghum will lead to increasing in grain production quality. Increasing in sorghum yield in intercropping compensated yield decreasing of mungbean and it increased LER by reducing interspecific competition than intraspecific competition. 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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