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Reaction of the Green Bean- Safflower Intercropping Patterns to Different Nitrogen Fertilizer Levels

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ABSTRACT- In order to investigate the effects of nitrogen fertilizer levels and intercropping ratios on yield and other morphological traits of two crops, field experiments were conducted during two years (2010-2011) in the research field of the school of Agriculture, Shiraz University, Shiraz, Iran. The study was carried out in a factorial experiment laid out based on a completely randomized block design (RCBD) with three replications where the factors were intercropping in seven different ratios of green bean (B) and safflower (S) (including green bean sole cropping, safflower sole cropping, intercropping of green bean/safflower with 1/1, 1/3, 2/3, 3/1 and 3/2 proportions) and nitrogen fertilizer rates (0, 75 and 150 kg per ha). Overall results indicated that different intercropping systems and N-fertilizer levels significantly affected the yield and other traits measured in both green bean and safflower. Optimal treatments in terms of economic importance for the farmers were intercropping B2S3 or B3S2 with 75 kg N/ha for safflower and B2S3 or B3S1 intercropping ratios under any or 75 kg N per ha for green bean (17.82g/plant) and the highest total LER (1.3). In order to obtain the highest total product amount, which is of prime importance to the farmers, B2S3 intercropping with no N-fertilizer application is recommended. Based on the results of this study, green bean and safflower are compatible and profitable crops and can be recommended to farmers for intercropping.

Keywords: Green bean, Intercropping systems, Nitrogen fertilizer, Safflower

INTRODUCTION

Intercropping is the practice of growing more than one crop in the same field simultaneously (2). Diversity of the plants' physical structure in an intercropping system has many benefits. Increased leaf coverage in intercropping systems helps reduce weed populations in the field (2). Coexistence of different root systems in the soil reduces water loss and also increases water uptake as well as transpiration. Increased transpiration may make the microclimate cooler, which along with increased leaf coverage, helps to cool down the soil and reduce soil evaporation (7). This is important in periods of water stress because as compared to sole cropping,

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intercropped plants use a larger percentage of available water from the field. Increased plant diversity in intercropped systems may reduce the impact of pest and disease outbreaks by providing more habitats for predatory insects and increasing the distance between plants of the same crop (2). Other ecological benefits of intercropping include less land needed for crop production, reduction of pesticide use and soil erosion (2). One of the main benefits of intercropping is an increase in yield per unit area of land. To compare yields of sole cropping and intercropped systems, the Land Equivalent Ratio (LER) was developed. The LER can be calculated by dividing the amount of the intercropped yield by the amount of the sole cropping yield for each crop in the field using any units of measurement (19). Another advantage of intercropping is related to the vertical distribution of the crops (2). When rows of tall crops such as safflower are intercropped in a field with a shorter crop such as bean, they reduce the wind speed above the shorter crops and thus help reduce desiccation (19).

Safflower (*Carthamus tinctorius* L.) is a deep-rooted annual crop which can be grown in rotation with other crop species such as the common bean, a legume that can fix nitrogen into soil. Safflower yield responds very well to nitrogen (6), thus a good field management option for growers is intercropping these crops (11).

Most studies on intercropping have focused on legume-cereal intercropping, which is considered a productive and sustainable system, but other intercropping systems such as green bean-safflower intercropping has rarely been investigated. The objectives of this study were to compare different density ratios of safflower-green bean intercropping and their response to various nitrogen fertilizer levels.

MATERIALS AND METHODS

Field experiments were conducted during the 2010-2011 growing seasons in the research field of the School of Agriculture, Shiraz University, located near Shiraz, Fars province, south of Iran (29°43´ N and 52°35´ W). Soil characteristics of the experimental area are presented in Table 1. The soil was amended through the application of 80 kg phosphate/ha and 100 kg potassium/ha just prior to sowing. A factorial experiment based on a completely randomized block design (RCBD) with three replications was used in the study where the first factor was the ratio of safflower-green bean (in seven ratios including safflower sole cropping (7 Plants per m^2), green bean sole cropping (7 Plants per m^2), intercropping of green bean / safflower with the ratios of 1/1, 1/3, 2/3, 3/1 and 3/2) and the second factor was nitrogen (N) fertilizer (0, 75 and 150 kg per ha N). The N-fertilizer levels were applied just before sowing the two crops. Each plot of sole safflower cropping consisted of four rows with a row distance of 60 cm, 3 m long. Experimental plots were irrigated and hand weeded as required. For intercropping systems, the treatments were applied: as follows:

Green bean / safflower; B1/S1= 1 seeds of green bean on a row with equal distance and 1 Seed of safflower

Green bean / safflower; B1/S3= 1 seeds of green bean on a row with equal distance and 3 seeds of safflower

Green bean / safflower; B2/S3= 2 seeds of green bean on a row with equal distance and 3 seeds of safflower

Green bean / safflower; B3/S1= 3 seeds of green bean on a row with equal distance and 1 seeds of safflower

Green bean / safflower; B3/S2= 3 seeds of green bean on a row with equal distance and 2 seeds of safflower. Mature green bean and safflower were respectively harvested about 110 and 190 days after planting.

Table 1. Soil properties in the depth of 0-30 cm of the research field prior to sowing

OC (%)	pH	Sand (%)	Silt (%)	Clay (%)	Soil texture	EC (dSm^{-1})	P (mg kg^{-1})	K (mg kg^{-1})	Total N (%)
0.70	7.2	7	66.7	26.3	Silty loam	0.01	16.7	472	0.06

Plant parameters such as leaf area, plant height, shoot dry weight, 100-seed weight, biological Yield and grain yield for both crops were measured. Stem diameter, numbers of primary and secondary branches and number of heads per plant for safflower and number of pods per plant and seeds per pod and leaf area for green bean were also measured. The land equivalent ratio (LER) was calculated to assess the performance of a crop mixture relative to the corresponding sole crop using the following formulas (Mead and Willey, 1980):

$$LER= Y_i/Y_j \quad (1)$$

$$\text{Total LER}= LER_s + LER_b \quad (2)$$

Where Yi is the yield of different intercropping in safflower or green bean and Yj is yield of related sole cropping. Total LER was calculated by adding up LER values for both safflower and green bean crops. In order to better understand the differences among intercropping systems and also the effect of N-fertilizer, the effect of cropping system × N-fertilizer interaction on yield was evaluated.

The test of homogeneity of variance for combined data of two years was carried out to verify variance homogeneity across treatments and a combined analysis of variance using the general linear model (GLM) procedure of SAS statistical software was run. In this model, the effect of year was considered as random while intercropping and weed management were fixed effects. Normality of all variables was investigated in Minitab14 using residuals, and where a variable deviated from normality, appropriate transformations were attempted to deal with non-normality. The least significant difference (LSD) method ($P<0.05$) was used to evaluate mean differences between weed management and cropping system means.

RESULTS AND DISCUSSION

Results of combined variance analysis showed significant effects of nitrogen fertilizer, cropping systems and their interactions on most of the parameters measured in both crops (Table 2 and 3).

Table 2. Analysis of variance and mean comparison of cropping systems for safflower

Sources	DF	Number Secondary branches per plant	Leaf area (cm^2)	Plant height (cm)	Dry weight (g/plant)	Number of primary branches per plant	Head numbers Per plant	Stem diameter (cm^2)	100-seeds weight (g/plant)	Biological yield (g/plant)	Yield (g/plant)
Year	1	140.75**	2541.3	270.75	14.8	12.00	108.0	1.00	0.42	26759.3**	112.65
R(year)	4	17.97	265157.3	47.44	2756.7	30.56	728.0	0.28	0.56	548.6	34.66
N	2	66.33**	1362961.6**	415.36**	5186.1**	21.00**	928.0**	0.16	0.68**	10979.2**	2927.09**
I	5	64.88**	914736.8**	442.75**	7053.3**	66.40**	938.2**	0.12	4.33**	12526.5**	1443.96**
N x I	10	95.53**	2704640.8**	260.36**	9946.1**	262.60**	950.2**	0.28**	2.65**	12558.6**	733.27**
Year x N	2	13.00**	12204.1	84.25	223.8	0.57	169.0	0.08	0.03	1759.3	28.46
Year x I	5	52.35**	13404.1	28.75	233.7	2.87	49.1	0.07	0.03	1425.9	45.29
Year x N x I	10	33.40**	14223.1	37.25	383.6	1.99	769.2**	0.04	0.03	2092.6	62.13
Error	68	1.77	200510.2	41.41	811.5	2.61	56.7	0.08	0.07	1759.8	105.39
CV		7.19	39.5	9.05	32.14	9.51	15.21	25.28	12.29	26.93	39.26
R-Square		0.96	0.7	0.71	0.74	0.95	0.94	0.66	0.92	0.69	0.75
N0		17.75	1178.7	69.25	86.11	16.33	53.83	1.05	2.02	138.10	15.98
N75		18.08	921.1	68.89	78.06	17.83	40.83	1.10	2.09	156.07	29.27
N150		20.25	1302.5	74.94	101.67	16.83	53.83	1.19	2.29	173.02	33.19
LSD		0.63	210.61	3.03	13.40	0.76	3.54	ns	0.12	19.73	4.83
Mean comparison											
B1S1		16.67	1326.1	66.17	81.39	15.67	24.33	1.00	2.40	132.93	17.09
B1S3		19.67	1007.4	68.44	85.83	16.67	37.67	1.14	1.74	133.03	15.03
B2S3		20.00	859.9	79.61	98.06	19.00	71.33	1.20	3.00	191.79	32.45
B3S1		21.33	1039.1	68.83	57.50	18.33	47.33	1.12	1.88	142.93	23.24
B3S2		17.00	1097.7	68.94	91.39	18.33	66.33	1.18	2.00	186.00	36.37
S		17.50	1474.2	74.17	117.50	14.00	50.00	1.03	1.77	147.70	32.70
LSD		0.88	297.85	4.28	18.95	1.08	5.01	ns	0.17	27.90	6.83

B1S1, 1 rows of green bean+ 1row of safflower; B1S3, 1 row of green bean +3 rows of safflower; B2S3, 2 rows of green bean + 3 rows of safflower; B3S1, 3 rows of green bean + 1 rows of safflower; B3S2, 3 rows of green bean + 2 rows of safflower; S, safflower sole cropping

Most parameters showed increase as the N-fertilizer increased. When N-fertilizer is added to the field, despite fixing the nitrogen from nature, the legume bean can uptake N directly from the N-fertilizer source and save energy to support growth; therefore, yield responds very well to nitrogen (6). Abundant N sources in the soil can be readily absorbed by safflower to supply its growth. Highest plant height, number of primary branches and heads per 100-seeds weight and biological yield were recorded for the B2S3 intercropping system. Sole safflower cropping recorded the maximum leaf area, plant height and dry weight and also minimum number of primary branches of safflower. The highest and lowest mean yields of safflower were observed in B3S2 and B1S3 respectively (Table 2). Green bean sole cropping had the highest leaf area, plant height, number of seeds and pods per plant, and yield while it had lowest branches and dry weight. Minimum mean yield and number of branches in green bean were observed in B1S1 (Table 3). Silwana and Lucas (2002) showed in their study that intercropping affects vegetative growth of component crops. It was also found that using different crop species in intercropping increases the capturing of growth limiting resources. In radish-vegetable amaranths intercropping, the higher density of vegetable amaranths resulted in increased LAI in radish (3). Prasad and Brook (2005) reported that increasing safflower plant density had significant positive effects on LAI in safflower-soybean intercropping. Maluleke et al (2005) reported a negative correlation between safflower dry matter and lablab population. Chui (1988) observed that dry matter yields at maturity in intercrops was reduced by 24.4 and 11.6 percent over sole safflower when safflower and French bean were grown in the same row and French green bean was grown between two safflower rows.

Table 3. Analysis of variance and mean comparison of cropping systems for green bean

Sources	DF	Number of Branches per plant	Leaf area (cm^2)	Plant height (cm)	Dry weight (g/plant)	Pods per plant	Seeds per pod	100-seeds weight (g)	Biological yield (g/plant)	Yield (g/plant)
year	1	834.4**	535221.7	147.0	53.5	147.00	261.33	614.47**	34276.35*	3.20
R(year)	4	27.1	211344.2	249.4	1469.9	162.44	146.61	10.14	2104.93	12.87
N	2	108.1	396903.7	2411.1**	1736.1	1039.0**	3387.11**	13.50	1301.49	220.32**
I	5	775.7**	1924269**	5550.5**	348.3	565.60**	4544.69**	29.40**	3135.62**	178.72**
N x I	10	192.4**	717111.7*	548.2**	3536.1**	459.80**	3889.07**	11.42*	515.41	240.00**
Year x N	2	62.9	401456.4	225.0**	23.1	19.30	12.44	12.34	216.10	17.20
Year x I	5	44.8	320070.9	48.6	23.1	1.55	4.62	35.85**	1208.99	52.63*
Year x N x I	10	52.7	327450.3	225.0**	23.1	15.67	6.40	10.15	832.26	43.36**
Error	68	53.3	395361.7	54.2	785.6	17.62	34.61	5.71	699.05	16.00
CV		28.73	34.87	9.54	37.6	21.16	13.59	50.71	28.59	25.22
R-Square		0.71	0.67	0.92	0.7	0.90	0.97	0.76	0.63	0.81
N0		23.55	843.7	72.11	29.167	23.50	23.17	4.09	86.04	14.16
N75		25.72	635.6	72.67	36.111	22.33	45.06	4.73	93.49	14.74
LSD		ns	ns	3.46	ns	1.97	2.77	ns	ns	1.88
Mean comparison										
B1S1		33.87	585.9	64.50	40.28	17.17	42.67	4.29	89.23	12.31
B1S3		26.53	628.9	62.72	34.17	26.50	56.11	5.18	78.86	15.83
B2S3		21.80	413.9	78.72	35.28	13.17	16.56	3.75	108.05	17.75
B3S1		31.97	725.2	72.17	42.50	18.83	37.00	4.29	105.87	17.82
B3S2		21.28	767.0	73.72	33.61	16.50	45.67	3.85	76.95	11.90
B		17.07	1365.7	110.83	30.83	26.83	61.67	4.92	95.95	19.59
LSD		4.86	418.2	4.90	ns	2.79	3.91	1.59	17.59	2.66

B1S1, 1 rows of green bean + 1row of safflower; B1S3, 1 row of green bean + 3 rows of safflower; B2S3, 2 rows of green bean + 3 rows of safflower; B3S1, 3 rows of green bean + 1 rows of safflower; B3S2, 3 rows of green bean + 2 rows of safflower ;B, green bean sole cropping

Since the comparison of sole crops yield with intercropping systems alone can not provide such knowledge, the land equivalent ratio (LER) for either crop and the combined LER for both crops were calculated (Figures 1, 2 and 3). Safflower recorded the highest yield under B2S3 and B3S2 intercropping systems with 0, 75 and 150 kg per ha N application rates respectively. These results indicate that different crop density in intercropping systems affect safflower yield. Similar results for LER value for safflower were obtained in these three intercropping densities with an LER greater than unity (LER>1) while other sole safflower cropping recorded LER values were lower than unity. Overall, the application of 75 kg N per ha yielded maximum LER in safflower and also among intercropping systems practiced for safflower B2S3 and B3S2 performed more superior to others. For green bean, B2S3 and B3S1, green bean sole cropping and B1S3, and B3S1 the recorded maximum yields were found to be under 0, 75 and 150 Kg N per ha application rates respectively. The cropping system and N-fertilizer level also affected green bean yield and LER in a similar pattern as the safflower. When green bean yield and LER was considered, B2S3 and B3S1 intercropping systems showed higher yield and LER values than others with LER values near unity (=1). Significantly higher LER values for green bean were recorded when no N-fertilizer was applied, indicating that the application of N-fertilizer in intercropping systems may not be a suitable method to achieve higher green bean yield.

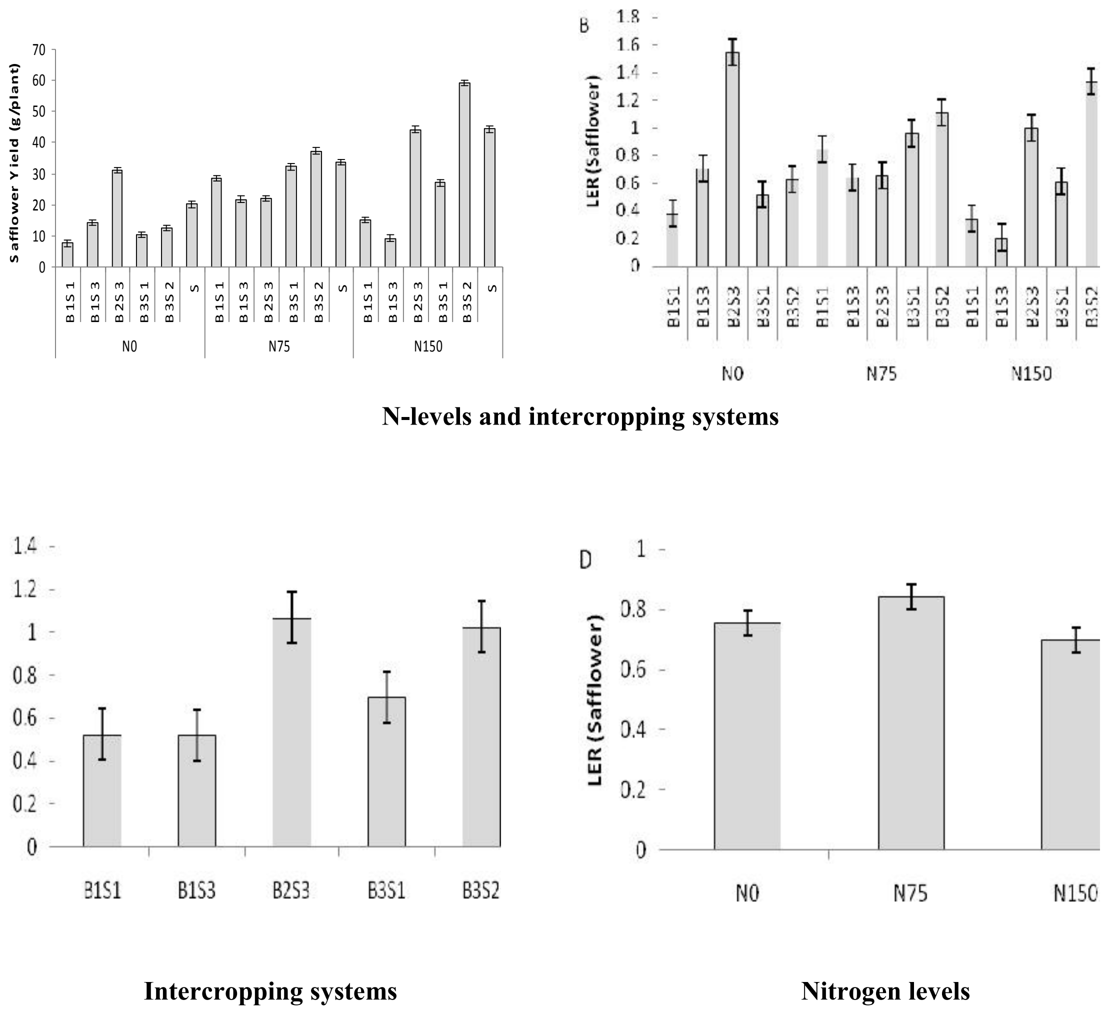
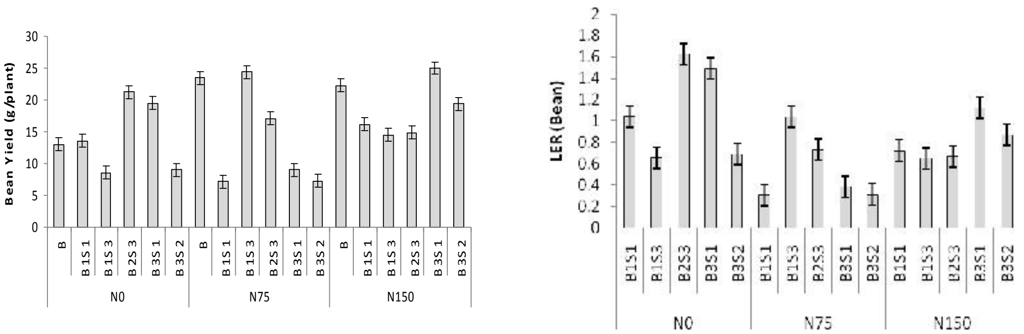
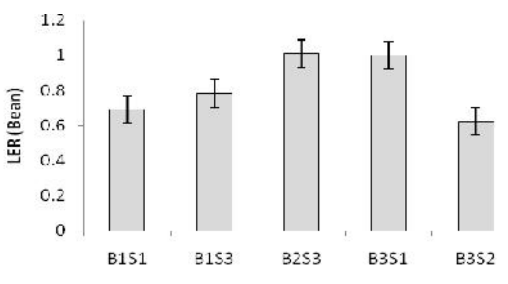


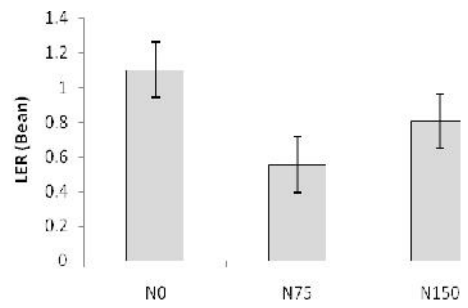
Fig. 1. Yield of safflower and its land equivalent ratio in different nitrogen levels and intercropping systems. B1S1, 1 rows of bean+ 1row of safflower; B1S3, 1 rows of bean +3row of safflower; B2S3, 2 rows of bean + 3 rows of safflower; B3S1, 3 rows of bean + 1 rows of safflower; B3S2, 3 rows of bean + 2 rows of safflower; S, safflower sole cropping

When nitrogen fertilizer is added to the field, the intercropped legumes use the inorganic nitrogen instead of fixing nitrogen from the air and thus compete with other crops for nitrogen. However, when nitrogen fertilizer is not applied, intercropped legumes fix most of their nitrogen from the atmosphere and therefore do not compete with other crops for nitrogen resources (1). Higher LER in the no N-fertilizer application for green bean and 75 kg N per ha for safflower is due to this characteristic of the green bean legume. When N-fertilizer is not applied, green bean fixes nitrogen from the atmosphere and has no competition with safflower. By applying low concentrations of inorganic nitrogen (75 kg N per ha), green bean decreases the rate of nitrogen fixing but still its competition with safflower is not very fierce, because the plant responds to low nitrogen concentrations and begins nitrogen fixation. On the other hand, at high concentrations of inorganic nitrogen (150 kg N per ha), green bean competes more severely with safflower for nitrogen, resulting in the final reduction of LER value of safflower. The highest total LER (1.3) for both crops was observed in B2S3 intercropping with no N-fertilizer. B1S3 intercropping with 75 kg N per ha and B3S2 intercropping with 150 kg N per ha recorded a higher total LER than other intercropping systems and N-fertilizer regimes. According to the total LER for intercropping systems (Figure 3), B2S3 had a significantly higher LER than the others and is thus considered a more suitable intercropping system to practice in the field. Selecting compatible crops for intercropping depends on the plant's growth habit, water and fertilizer utilization (3).



N-levels and intercropping systems

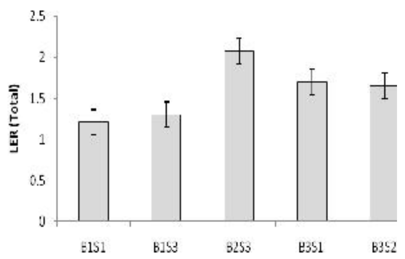




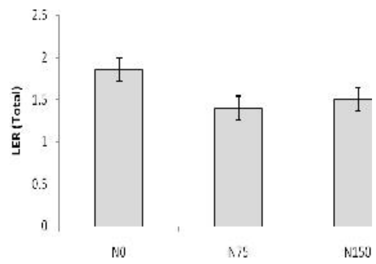
Intercropping systems **Nitrogen levels**

Fig. 2. Yield of bean and its land equivalent ratio in different nitrogen levels and intercropping systems. B1S1, 1 rows of bean+ 1row of safflower; B1S3, 1 rows of bean +3 row of safflower; B2S3, 2 rows of bean + 3 rows of safflower; B3S1, 3 rows of bean + 1 rows of safflower; B3S2, 3 rows of bean + 2 rows of safflower; B, bean sole cropping

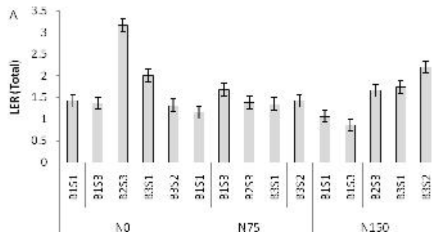
Based on the results of this study, safflower and green bean are compatible and profitable crops to be intercropped together. Higher yield, in terms of total biomass and grain production per unit area in a given season, without the use of costly inputs under an intercropping system, is attributed to better use of growth resources, namely, light, moisture and nutrients (8; 14). Also, different root and leaf systems are able to get more nutrients more efficiently as compared to the time that the roots and leaves of only one species are present (17). Vesterager et al (2008) found maize and cowpea intercropping to be a more beneficial system to practice on nitrogen poor soils. In another study, Maize-cowpea intercropping showed to increase the amount of nitrogen, phosphorus and potassium content as compared to maize monocroping (5). Also Suryanta and Harwood (1976) found more efficient nutrient uptake and utilization in maize-rice and maize-soy bean than in those crops as monocrop. Pandey et al. (1999) obtained higher total yields, maize equivalent yield and LER values in paired rows of maize (30/90 cm) + 2 rows of soybean. There are similar studies showing that intercropping significantly increases maize grain equivalent yield and N uptake over sole cropping (15).



Intercropping systems



Nitrogen levels



N-levels and intercropping systems

Fig. 3. Total land equivalent ratio in different nitrogen levels and intercropping systems. B1S1, 1 rows of bean + 1row of safflower; B1S3, 1 rows of bean + 3 row of safflower; B2S3, 2 rows of bean + 3 rows of safflower; B3S1, 3 rows of bean + 1 rows of safflower; B3S2, 3 rows of bean + 2 rows of safflower

CONCLUSIONS

Overall results indicate that an intercropping system and N-fertilizer levels significantly affected yield and other measured traits in both green bean and safflower. With respect to crop importance for farmers, the use of B2S3 intercropping systems or B3S2 with 75 kg N per ha for safflower and B2S3 or B3S1 intercropping systems under no or 75 kg N per ha for green bean are recommended. When the total product and agreement with organic agriculture is important for the farmer, B2S1 with no N-fertilizer application may be practiced. Based on the results of this study, safflower and green bean are compatible and profitable crops to be intercropped together.

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واکنش سیستم کشت مخلوط لوبیا سبز- گلرنگ به سطوح مختلف کود نیتروژن

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چکیده- به منظور بررسی اثر سطوح نیتروژن و سیستم کشت مخلوط بر عملکرد و خصوصیات مورفولوژیکی دو گیاه زراعی آزمایش مزرعه‌ای طی دو فصل رشد در سال‌های ۱۳۸۹ و ۱۳۹۰ در مزرعه تحقیقاتی دانشکده کشاورزی انجام شد. آزمایش به صورت فاکتوریل و در قالب طرح بلوک کاملا تصادفی در سه تکرار انجام گردید و فاکتورها شامل ۷ نسبت مختلف کشت مخلوط لوبیا و گلرنگ شامل کشت خالص لوبیا و گلرنگ و کشت مخلوط لوبیا و گلرنگ با نسبت‌های ۱ به ۳، ۱به ۱، ۲به ۳ ، ۳ به ۲ و ۳ به ۱ و سه سطح نیتروژن (صفر، ۷۵ و ۱۵۰ کیلوگرم نیتروژن در هکتار) بودند. به طور کلی نتایج نشان داد که سیستم کشت مخلوط و نیتروژن، عملکرد و تمام صفات هر دو گیاه گلرنگ و لوبیا را به طور معنی داری تحت تاثیر قرار داد. نتایج نشان دادند که نوع سیستم کشت مخلوط B2S3 یا B3S2 و مصرف ۷۵ کیلوگرم نیتروژن در هکتار برای گلرنگ و سیستم کشت مخلوط B2S3 یا B3S1 با مصرف ۷۵ کیلوگرم نیتروژن در هکتار و یا بدون مصرف نیتروژن برای لوبیا دارای بالاترین عملکرد (۱۷/۸۲ گرم در هر بوته) و نسبت برابری سطح زمین(۳/۱) می‌باشد. به‌منظور دستیابی به حداکثر تولید، سیستم کشت مخلوط B2S3 بدون مصرف نیتروژن قابل توصیه است. با توجه به نتایج به دست آمده سیستم کشت مخلوط لوبیا و گلرنگ قابل اختلاط و سودمند خواهد بود و قابل توصیه برای کشاورزان می‌باشد.

واژه‌های کلیدی: سیستم کشت مخلوط، کود نیتروژن، گلرنگ، لوبیا

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