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Original Article

Competition Indices of Safflower and Faba Bean Intercrops as Affected by Fertilizers

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Abstract

Cropping systems of safflower (*Carthamus tinctorius* L.) with faba bean (*Vicia faba* L.) under different fertility were compared with sole cropping of each crop during 2015 and 2016 at the Research Farm of Tabriz University in Iran. The treatments were cropping systems (safflower and faba bean sole croppings, intercropping systems of safflower and faba bean with ratios of 1:1 and 2:1), and nutrient levels (100% chemical fertilizers, 60%, 30% chemical + biofertilizers and no fertilizer). A factorial set of treatments based on a randomized complete block design replicated three times was used. Cropping system and fertility effects were significant for yield and yield components of each crop. Yield and yield components were increased with the integrated use of 60% chemical plus biofertilizers for both years, while seed yield was reduced by intercropping. Maximum land equivalent ratio (LER), relative value total (RVT), system productivity index (SPI) and monetary advantage index (MAI) were achieved in nutritive level of 60% chemical plus biofertilizers as intercropped plants in ratio of 1:1 for both years. The total actual yield loss (AYL) values were positive and greater than zero in all mixtures, indicating an advantage from intercropping over sole crops. Intercropped safflower had a higher relative crowding coefficient (RCC) than intercropped faba bean, indicating that safflower was more competitive than faba bean in intercropping systems. From this study, it is inferred that intercropping (safflower and faba bean) with integrated use of the reduced chemical and biofertilizers may give better overall yield and income than sole cropping of each crop species.

Keywords: biofertilizer; crowding coefficient; intercropping; land equivalent ratio; monetary advantage

Introduction

Intercropping, which is defined as growing more than one species simultaneously in the same field during a growing season, is considered one important strategy in developing sustainable production systems, particularly systems that aim to limit external inputs (Jahansooz *et al.*, 2007; Zhang *et al.*, 2008). Intercropping of grain legumes with non-legume crops have several benefits such as improvement of soil fertility through the addition of nitrogen by fixation and excretion from the component legume (Manjith Kumar *et al.*, 2009), high productivity and profitability (Singh Rajesh *et al.*, 2010), efficient use of resources (Oelbermann and Echarte, 2011), suppressing diseases and weeds (Banik *et al.*, 2006) and yield stability (Nassab *et al.*, 2011). Existing reports indicated that the yield of safflower and or faba bean can be improved in an intercropped system (Singh Rajesh *et al.*, 2010; Zafaranieh, 2015). In intercropping systems, intra and or inter specific competition or facilitation between the system components may occur. Competition is one of the factors that can have significant impact on growth and yield of plant species used in intercropping compared with sole cropping (Caballero *et al.*, 1995). Several indices such as land equivalent ratio, relative crowding coefficient, actual yield loss, relative value total, system productivity and monetary advantage have been used to describe competition and agronomic or economic advantages of intercropping systems (Banik *et al.*, 2000; Fetene, 2003; Ghosh, 2004; Midya *et al.*, 2005).

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Another recent trend is chemical fertilizers being replaced by biofertilizers in global production. Bio-fertilizer (PGPR) represent a specific complex of microorganisms which enable the movement of nutrients from soil to plants through biological process such as N fixation and solubilization of rock phosphate and can improve root system and seed germination (Abou-Khadrah *et al.*, 2000). Biofertilizers are found to have a positive contribution to soil fertility, resulting in an increase in crop yields without causing any environmental, water or soil pollution hazards (Timmusk *et al.*, 1999; Daiss *et al.*, 2008). Azimi *et al.* (2013). This suggested that the yield to components were increasing. It was reported the nitrogen and phosphate biofertilizer application which account for an important benefit, causing a decrease in the inputs of production because of cost deduction compared to chemical fertilizers which increased biological yield. In some studies, it was clearly revealed that biofertilizer application resulted in high productivity for safflower (Mirzakhani *et al.*, 2009; Seyed Sharifi, 2012).

The objectives of this study were: (i) to estimate the effect of competition among the different species used in two intercropping systems, (ii) to evaluate the difference in competition indices in these intercropping systems, (iii) to determine which system is better for resource management with respect to productivity, competition, and economic parameters, (iv) to investigate the effect of biofertilizers on yield to yield components of safflower and faba bean in intercropping systems.

Materials and Methods

Experimental design and crop management

Two field experiments were conducted at the research farm of Tabriz University, Iran, during growing seasons (May-September) of 2015 and 2016. The site is approximately located at North latitude of 38° 05′ and East longitude of 46° 17′ with 1360 m altitude above sea level in Azarbaijan Province, Tabriz -Iran. The Physical and chemical analysis of the top soil (0-25 cm) at the experimental site was carried out in 2015, and revealed the following composition: 15% clay, 20% silt and 65% sand, pH-7.4, organic carbon 0.76%, available N 0.15 %, available P 16 mg kg^{-1} and available K 290 mg kg^{-1} and EC value 1.1 ds m^{-1}. Weather conditions during the experiments (monthly precipitation and mean temperature) are shown in Table 1.

The experiment was laid out in a randomized complete block design arranged in factorial with three replications. The factors were cropping systems which included: sole croppings of safflower (C1) and faba bean (C2), intercroppings of safflower/faba bean with the ratios of 1:1 (C3) and 2:1 (C4), and nutrient levels of application of 100% recommended chemical fertilizer (F1), 30% chemical + biological fertilizers (F2), 60% chemical + biological fertilizers (F3) and no fertilizer (F0). Biological fertilizers consisted of Azoto Barvar-1 (contain free-living nitrogen fixing bacteria) and Phosphate Barvar-2 (contain phosphate dissolving bacteria), and chemical fertilizers consisted of urea (75 kg ha^{-1}) and triple superphosphate (50 kg ha^{-1}). Seeds were inoculated using biofertilizers before having them sowed in both years. The experimental site was deeply ploughed and harrowed in each cropping year and sowing was done manually by planting two seeds using a planting station. The rows were thinned to the required experimental populations at two weeks after planting. In the first year (2015), safflower and faba bean were planted on 16 May, while in the second year (2016), were planted on 14 May. Plant densities of safflower and faba bean were 40 and 20 plant m^{-2}, respectively. For C3, two rows of safflower were intercropped with one row of faba bean (with plot sizes of 4×3 m^2). Also, four rows of safflower were intercropped with two rows of faba bean for C4 (with plot sizes of 4×6 m^2). In sole cropping of each crop, four rows were sown with plot sizes of 4×2 m^2. The plots were weeded manually as required after sowing. Safflower and faba bean were harvested on third of September and on seventh of August in both years, respectively. At maturity, all plants of each crop were harvested separately from the mixtures, and used for seed yield and yield components determinations.

Competitive indices and monetary advantage

The competitive effects and responses of component crops in different safflower and faba bean cropping systems were determined in terms of land equivalent ratio (Willey, 1979), relative value total (Vandermeer, 1989), relative crowding coefficient (Dhima *et al.*, 2007), actual yield loss (Banik, 1996), system productivity index (Agegnehu *et al.*, 2006), intercropping advantage (Banik *et al.*, 2000) and monetary advantage index (Ghosh, 2004) by using the following equations.

Where Y_{ss} and Y_{fs} are the yields of safflower and faba bean as sole crops respectively, and Y_{si} and Y_{fi} are the yields of safflower and faba bean as intercrops, respectively. P_s and P_f are the market prices of safflower and faba bean, respectively. Z_{si} and Z_{fi} were proportions of safflower and faba bean in the intercrops, and Z_{ss} and Z_{fs} were proportions of safflower and faba bean in the sole crops, respectively.

$LER = LER_s + LER_f$	land equivalent ratio (1)
$LER_s = Y_{si}/Y_{ss}$	partial LER of safflower (2)
$LER_f = Y_{fi}/ Y_{fs}$	partial LER of faba bean (3)
$RVT = P_sY_{si} + P_fY_{fi}/ P_sY_{ss} \quad {}_sY_{ss} > P_fY_{fs}$	relative value total (4)
$AYL = AYL_s + AYL_f$	total actual yield loss (5)
$AYL_s = [(Y_{si}/Z_{si}) / (Y_{ss}/Z_{ss})]-1$	actual yield loss of safflower (6)
$AYL_f = [(Y_{fi}/Z_{fi}) / (Y_{fs}/Z_{fs})]-1$	actual yield loss of faba bean (7)
$K = RCC_s \times RCC_f$	relative crowding coefficient (8)
$RCC_s = Y_{si} Z_{si} /(Y_{ss} - Y_{si})\times Z_{fi}$	relative crowding coefficient for safflower (9)
$RCC_f = Y_{fi} Z_{fi} /(Y_{fs} - Y_{fi})\times Z_{si}$	relative crowding coefficient for faba bean (10)
$SPI = (Y_{ss} / Y_{fs}) Y_{fi} + Y_{si}$	system productivity index (11)
$MAI = VCI \times (LER-1/LER)$	monetary advantage index (12)
$VCI = Y_{si} P_s + Y_{fi} P_f$	value of combined intercrops (13)

Statistical analysis

Combined analysis of variance was performed using MSTAT-C software. Means of the treatments were compared, using Duncan's multiple range test at the 5% probability level. The data showed normal distribution and no transformation was required.

Table 1. The mean monthly temperature and rainfall in 2015 and 2016

		May	June	July	August	September	total
2015	M.A.T.(°C)	15.3	22.7	28.2	29.2	23	-
	M.R. (mm)	45.3	1.5	0.9	0	26.4	74.1
2016	M.A.T.(°C)	16.2	21	26.2	28.6	24.5	-
	M.R. (mm)	46.1	29.8	10.3	0	4.7	90.9

Notes: M.A.T. = mean air temperature; M.R. = mean rain.

Results and Discussion

Climate

The weather conditions in both years were different from the norm for research farm. The total precipitations during growing seasons were 74.1 mm and 90.9 mm in 2015 and 2016, respectively (Table 1). All parameters showed an increase in the second year compared to the first year. Conditions of the 2016 cropping season were more favorable for faba bean and safflower production because they were wetter and cooler than in 2015.

Yield components of safflower

Using variance analyzing results it was indicated that the number of seeds per plant head increased and also the weight of 1000 seeds per plant was influenced by the fertilizer and cropping system and by the year. Also the interaction of the year × the fertilizer had a significant effect on the head number per plant and seed number per head ($P \leq 0.01$) (Table 2). The number of head per plant and seed per head increased by 60% after applying the chemical and biological fertilizers (Table 3). Data given in Tables 4 suggest that, two row of safflower with one rows of faba bean (1:1) recorded the highest number of heads per plant and seeds per head compared with the other pattern under the study. These results agreed with those found by Jalilian *et al.* (2017) on safflower intercropped with bitter vetch, and Abdelkader and Hamad (2015) on safflower when intercropped with fenugreek.

The, effect of cropping system × fertilizer was significant on 1000-seed weight. The highest value of this trait was obtained in cropping system of 1:1 with application of 60% chemical plus biological fertilizers (Table 5). Effect of bio-fertilizers on yield components of safflower was positive in this study. In other words, utilizing 60% chemical fertilizer through improving bio-fertilizers activity and providing better nutrient absorption helps in improving photosynthesis (Narula *et al.*, 2000). Farnia and Moayedi (2014) confirmed positive N and P biofertilizers effect on 1000-seed weight.

Table 2. Two-year analysis of variance for yield and yield components of safflower and faba bean affected by different fertilizer treatments and cropping systems

		Safflower				Faba bean			
S.O.V	df	Head per plant	Seed per head	1000-seed weight	Seed yield	Pod per plant	Seed per pod	100-seed weight	Seed yield
Y	1	32.940**	502.128**	355.511**	1810961.2**	2.24**	0.090*	1714.05**	2217519.39**
Y*B	4	0.282**	19.841**	5.549**	5119.36**	0.282**	0.015	75.58**	22617.81**
C.S	2	7.658**	251.137**	86.040**	1760673.41**	7.658**	0.040	485.31**	9040738.59**
F	3	15.775**	307.189**	79.132**	554660.03**	15.775**	0.713**	271.55**	768581.1**
C.S. * F	6	0.117	1.657	2.633**	18793.1 **	0.219**	0.007	0.869	1094.21
Y * C.S	2	0.133	1.966	0.574	2228.04	0.133	0.013	0.423	7609.77
Y* F	3	1.444**	10.449**	0.095	4112.83*	0.138	0.019	0.581	49088.82**
Y*F*C.S	6	0.088	0.829	0.289	1153.13	0.088	0.008	1.942	2468.05
E	44	0.051	0.727	0.349	1025.68	0.051	0.015	2.005	2378.04
C.V. (%)		3.15	1.84	1.44	3.34	3.39	3.75	1.49	3.00

Notes: *Statistically significant at $p \leq 0.05$. **significant at $p \leq 0.01$. Y: year, B: block, C.S.: cropping system, F: fertilizer and E: error.

Table 3. Head per plant, seed per head and seed yield of safflower and faba bean affected by different fertilizer treatments in 2015 and 2016

Treatment		Safflower			Faba bean
		Head per plant	Seed per head	Seed yield(kg.ha^{-1})	Seed yield(kg.ha^{-1})
2015	F0	5.80 e	39.99 f	1774.12 f	1263.53 g
	F1	6.86 cd	46.01 d	2067.36 d	1494.75 e
	F2	6.16 e	41.77 e	1921.09 e	1386.21 f
	F3	7.24 c	47.40 cd	2152.55 c	1647.15 d
2016	F0	6.57 d	43.05 e	2090.83 d	1471.91 e
	F1	8.46 b	51.76 b	2323.07 b	1947.61 b
	F2	7.17 c	47.55 c	2192.09 c	1733.26 c
	F3	9.26 a	53.93 a	2427.03 a	2042.82 a

Notes: Different letter (s) indicates significant difference at $p \leq 0.05$.

Yield components of faba bean

The year and fertilizer effects were significant (P ≤ 0.01) for pod number per plant, seeds number per pod and 100-seeds weight. Except for seeds per pod, cropping system significantly influenced yield components of faba bean (Table 2). Mean yield components were significantly higher in the second year than that in the first year (Table 7). In the second year, climatic conditions, particularly desirable rainfall and temperature during seed filling period, probably, lead to produce large seeds.

In both years, pod number per plant was increased in safflower/faba bean intercropping (1:1) with application of 60% chemical plus biological fertilizers (Fig. 1). Increasing the pod number per plant in 1:1 cropping system is probably the result of different above and below-ground growth habits and the morphological characteristics of the intercrop components, allowing for a more efficient utilization of plant growth resources, i.e., water, light and nutrients. These results are in agreement with those previously found by Xiang *et al.* (2012) and Mahapatra (2011).

Among the different cropping system, the highest 100-seed weight belonged to 2:1 safflower/faba bean intercropping (Table 4). In 2:1 cropping system, due to the lower pod per plant and seed per pod, more photosynthetic materials have been allocated on the seeds and increase seed weight. The highest seed number per pod was obtained from application of 60% chemical plus biofertilizers, while the highest 100-seed weight was observed at no application of fertilizers and the lowest value was observed in application of 60% chemical plus biofertilizers (Table 6). Presumably, utilizing 60% chemical plus biofertilizers, cause to increasing seed number per pod and pod number per plant, which leads to an increase in competition between the seeds to receive photosynthetic materials, as a result 100-seed weight was reduced.

Seed yield

Seed yields of safflower and faba bean were affected by year, cropping system and biofertilizer (Table 2). Mean seed yields of each crops were higher in the year 2016 than in 2015 (Table 3). This could be attributed to higher rainfall and lower temperature in 2016 compared to 2015.

In both years, seed yields of both crops were significantly lower in intercrops due to interspecific competition for light, water and nutrients (Tables 4 and 5). The yield of cowpea intercropped with sorghum in the sole cropping system was higher than the intercropping system. It showed that the intraspecific competition in the sole cropping system was lower than the interspecific competition in the intercropping system (Chimonyo *et al.*, 2016). In addition, these results agree with those reported by Lal *et al.* (2017). The highest safflower and faba bean seed yields belonged to application of 60% chemical plus biofertilizers in the second year (Table 3). Similar findings were also reported by Seyed Sharifi *et al.* (2017), who stated that biofertilizer alone, or in combination with synthetic fertilizers have significantly increased grain yield. Biofertilizers are good tools to reduce the application of chemical fertilizer and reduce its negative environmental effects also improves seed yield because of the increase in metabolic activities of biologic fertilizers and production of growth stimulating hormones by bacteria (Uhart and Andrade, 1995). Also, these results agree with those reported by Jahan *et al.* (2013) and Kumar *et al.* (2009).

Land equivalent ratio (LER)

Land equivalent ratio is the most commonly used indices for assessing competition in intercropping system in contrast to pure stands (Agegnehu *et al.*, 2006). The LER is the relative area of sole crop required to produce the yield achieved in intercropping (Khan, 1988).

Table 4. Yield and yield components of safflower and faba bean in sole and intercropping systems

Cropping system	Safflower		Faba bean	
	Head per plant	Seed per head	Seed yield (kg.ha^{-1})	100-seed weight (gr)
C1	-	-	2320.73 a	95.24 b
C2	6.569 b	43.378 c	-	-
C3	7.672 a	49.822 a	1165.22 c	90.49 c
C4	7.331 a	46.100 b	1384.26 b	99.48 a

Notes: Different letter (s) indicates significant difference at p ≤ 0.05

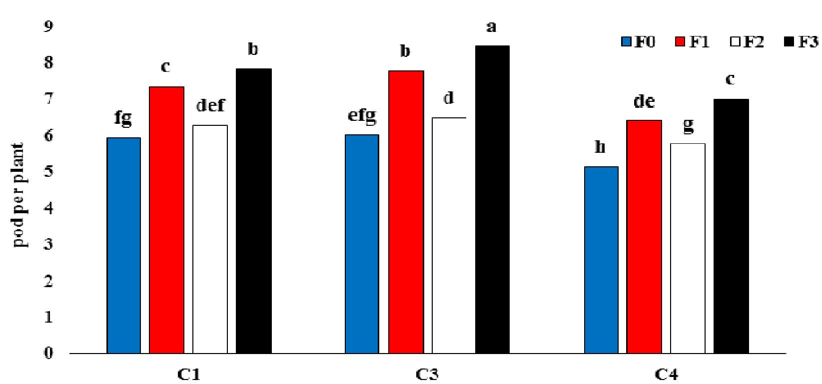

Fig. 1. Pod per plant in faba bean at different cropping systems with fertilization

Table 5. 1000-seed weight and seed yield of safflower affected by different fertilizer treatments in cropping systems

Treatment		1000-seed weight (gr)	Seed yield(kg.ha^{-1})
C2	F0	37.218 i	2505.73 d
	F1	40.213 fg	2689.70 b
	F2	38.723 h	2580.53 c
	F3	40.947 ef	2792.92 a
C3	F0	39.533 gh	1816.08 g
	F1	44.477 b	2230.10 e
	F2	42.147 cd	2022.35 f
	F3	46.052 a	2342.75 e
C4	F0	38.812 h	1475.61 i
	F1	41.625 de	1665.85 h
	F2	40.248 fg	1566.90 hi
	F3	43.010 c	1733.70 gh

Notes: Different letter (s) indicates significant difference at $p \le 0.05$.

Table 6. Seed per pod and 100-seed weight of faba bean in different fertilizer treatments

Fertilizer	Seed per pod	100-seed weight (gr)
F0	3.039 c	97.13 a
F1	3.430 ab	93.08 b
F2	3.259 b	99.34 a
F3	3.47 a	90.73 c

Notes: Different letter (s) indicates significant difference at $p \le 0.05$.

Table 7. Yield components of safflower and faba bean in the 2015 and 2016 growing seasons

Treatment	Safflower	Faba bean		
	1000-seed weight (gr)	Pod per plant	Seed per pod	100-seed weight (gr)
2015	43.79 b	6.514 b	3.266 b	90.19 b
2016	49.07 a	6.867 a	3.337 a	99.95 a

Notes: Different letter (s) indicates significant difference at $p \le 0.05$

The partial LER of safflower (LER_s) in 1:1 cropping system with 60% chemical plus biological fertilizers was higher than those of other treatment combinations in both years (Table 9). This indicates that there was an advantage for safflower in this cropping system. The partial LER of faba bean (LER_f) was higher in 2:1 cropping system with 60% chemical plus biofertilizers in both years (Table 9).

The value of LER appears to be greater than 1.00 under all intercropping systems for both years (Table 9), which indicates a total yield advantage of intercrops compare to sole crops (Mead and Willey, 1980). In addition, LER values in the second year were higher than that of the first year in all treatment combinations. The highest LER (1.41) was obtained from cropping system of 1:1 with applying of 60% chemical plus biofertilizers in 2016 (Table 9). These results represent the role of biofertilizers in increasing LER and an advantage from intercropping over sole cropping in terms of the use of environmental resources for plant growth and better land utilization. In this context, the higher LER value regardless of the crops for intercropping than sole cropping system was reported by various researchers (Dhima *et al.*, 2007; Imran *et al.*, 2011; Chimonyo *et al.*, 2016).

Relative Value Total (RVT)

For both years, relative value total for all intercrops was more than one, which indicates the economic advantage of intercropping over the pure one (Table 8). The highest RVT values were observed in cropping system of 1:1 with applying of 60% chemical plus biofertilizers in 2016 (Table 8). Intercropping resulted in economic advantage; RVT was between 1.01 and 1.22, showing 1-22% economic advantage. These results are in good agreement with those reported by Rezaei Chianeh *et al.* (2011) on maize/faba bean and Imran *et al.* (2011) on sunflower/mung bean. According to Table 8, regardless to fertilizer sources, fertilizer application more improved safflower and faba bean yields (LER) and economical outputs (RVT) as intercropped compare to sole cropping of them.

Relative crowding coefficient (RCC)

Relative crowding coefficient is used as a measure of interspecific competition. Willey and Rao (1980) reported that where the relative crowding coefficient of a particular crop species is less than, equal to or greater than 1, then that species produced less yield, the same yield or more than 'expected' yield, respectively. RCC values for safflower (RCC_s) were greater than one, whereas, it was less than one for faba bean (RCC_f) in most intercrops (Table 8). The intercropped safflower had higher RCC values than the intercropped faba bean, indicating that safflower was more competitive than faba bean in the intercropping systems. Hence, safflower due to its stronger rooting system and high nitrogen uptake was able to obtain more resources than faba bean, which makes it a superior crop in intercropping treatments. In general, non-legume crop is intended to be a dominant crop in annual legume/non-legume intercrop system (Wahla *et al.*, 2009), for instance in safflower/fenugreek (Abdelkader and Hamad, 2015), mustard/legume (Banik *et al.*, 2000) and safflower/bitter vetch (Jalilian *et al.*, 2017) intercrops. The maximum value of K was observed in 1:1 row ratio, which indicated a yield advantage as for this cropping system (Table 8). This result is supported by the findings of Banik *et al.* (2000) in chickpea/wheat intercropping.

Actual yield loss (AYL)

Actual yield loss for safflower (AYL_s) had positive values in 1:1 cropping systems while the negative values were obtained from cropping system of 2:1 (Table 10). Actual yield loss index gave more accurate information than the other indices on inter and intraspecific competitions and the behavior of each species in intercropping systems (Banik *et al.*, 2000). Partial yield loss also demonstrates the proportionate yield loss or gain by its sign and as its value (Dhima *et al.*, 2007). Thus, there was a 68% (AYL_s = + 0.68) increase in yield of safflower in 1:1 cropping systems with 60% chemical plus biological fertilizers, when compared to its sole crop yield. However, in 2:1 cropping system, the AYL_s ranged from -0.14 to -0.06 indicating a yield loss of 14-6%, compared to sole crop yield. In the first year, actual yield loss for faba bean (AYL_f) had negative values in 1:1 cropping system under all fertilizer treatments except application 60% chemical plus biofertilizers, indicating a yield loss of faba bean compared to sole crop yield (Table 10). The positive values of AYL_f were obtained from other treatment combinations in both years. In both years, total actual yield loss values were more than zero in all intercrops which suggests an advantage of intercropping over sole crops (Table 10).

Monetary advantage index (MAI)

The positive monetary advantage index values in most cropping patterns indicated the profitability of intercrops compared with sole cropping system (Sadeghpour *et al.*, 2013). MAI values were positive in all intercropping systems in both years (Table 9). The result showed positive yield and economic advantages of the intercropping system over their sole cropping. The highest MAI was obtained in the 1:1 cropping system with 60% chemical plus biological fertilizers, which implied that this cropping system was highly economical and advantageous for the mixtures. Ghosh (2004) reported that if LER and K values were higher, there was an economic benefit expressed with MAI values such as obtained in the present study. Krantz *et al.* (1976) also reported higher monetary returns from systems involving intercropping of legumes and non-legumes compared to sole non-legume cropping which was attributed to better utilization of resources.

Table 8. Effect of cropping systems and fertilization on relative value total (RVT) and relative crowding coefficients (RCC) of safflower and faba bean in two years

Treatment		RCC_s		RCC_f		RCC (K)		RVT	
		1:1	2:1	1:1	2:1	1:1	2:1	1:1	2:1
2015	F0	2.74	2.37	0.65	0.54	1.55	1.48	1.01	1.00
	F1	4.62	3.19	0.89	0.62	4.09	1.99	1.14	1.06
	F2	3.17	3.03	0.79	0.57	2.51	1.75	1.07	1.03
	F3	5.16	3.30	1.03	0.66	5.41	2.18	1.16	1.07
2016	F0	2.90	3.06	0.98	0.73	2.86	2.23	1.16	1.10
	F1	5.08	3.41	1.26	0.91	6.38	3.12	1.19	1.13
	F2	4.13	3.24	0.99	0.79	4.59	2.56	1.17	1.12
	F3	5.25	3.34	1.36	0.92	7.03	3.44	1.22	1.15

Table 9. Effect of cropping systems and fertilization on land equivalent ratio (LER) and monetary advantage index (MAI) of safflower and faba bean in two years

Treatment		LER_s		LER_f		LER		MAI	
		1:1	2:1	1:1	2:1	1:1	2:1	1:1	2:1
2015	F0	0.70	0.57	0.40	0.52	1.11	1.10	155.74	141.75
	F1	0.82	0.61	0.47	0.56	1.29	1.17	460.59	274.48
	F2	0.76	0.60	0.44	0.54	1.20	1.14	305.30	212.26
	F3	0.84	0.62	0.51	0.57	1.35	1.19	576.51	327.10
2016	F0	0.74	0.60	0.50	0.60	1.24	1.20	384.19	319.72
	F1	0.84	0.63	0.56	0.65	1.39	1.28	717.16	521.79
	F2	0.80	0.61	0.53	0.62	1.33	1.23	568.72	405.93
	F3	0.83	0.62	0.58	0.68	1.41	1.30	786.81	584.54

Table 10. Effect of cropping systems and fertilization on System productivity index (SPI) and Actual yield loss (AYL) of safflower and faba bean in two years

Treatment		AYL_s		AYL_f		AYL		SPI	
		1:1	2:1	1:1	2:1	1:1	2:1	1:1	2:1
2015	F0	0.41	-0.14	-0.21	0.58	0.20	0.44	2567.10	2563.51
	F1	0.64	-0.09	-0.06	0.69	0.59	0.61	3293.44	2982.31
	F2	0.52	-0.11	-0.12	0.63	0.40	0.53	2937.61	2779.69
	F3	0.67	-0.08	0.01	0.74	0.69	0.66	3538.13	3130.14
2016	F0	0.49	-0.10	0.01	0.81	0.50	0.70	3316.72	3203.16
	F1	0.67	-0.06	0.11	0.97	0.78	0.90	3940.73	3613.61
	F2	0.61	-0.08	0.05	0.87	0.66	0.78	3619.12	3345.41
	F3	0.68	-0.07	0.15	1.05	0.83	0.98	4185.91	3843.82

System Productivity Index (SPI)

System productivity index presents the most productive and stable cropping system (Agegnehu *et al.*, 2006; Lithourgidis *et al.*, 2011a). According to Lithourgidis *et al.* (2011b), SPI values are generally conform the LER and K values. In our study, the SPI was found in 1:1 cropping system with 60% chemical plus biological fertilizers. Contrary, the lowest SPI was observed in 2:1 cropping system with no fertilizer in both years (Table 10). According to the results of this research, safflower and faba bean are cooperative and beneficial crops to be intercropped together. The advantages of the intercropping systems found in this study can be attributed to the better utilization of growth resources (Ofori and Stern, 1987). Similar results were recorded by Jalilian *et al.* (2017) when intercropped safflower with bitter vetch and Raei *et al.* (2015) when intercropped potato with green bean. Inoculation of intercropped plant species with biofertilizers could increase yield as a result of more efficient use of resources by crops. In this research, intercrops that inoculated with biofertilizers improved the seed yield of safflower and faba bean, which supported by the findings of Jalilian *et al.* (2017).

Conclusions

In general, the results indicate that cropping system and fertilizer treatments significantly affected yield components of safflower and faba bean. Seed yields of both crops were increased with the integrated use of chemical and biofertilizers in the intercropped plants for both years. When plant species are fertilized with chemical and biological fertilizers, it is likely that yield advantages occur as a result of more nutrient accessibility for growth of safflower and faba bean. LER values along with RVT, SPI and MAI values demonstrated the economic feasibility of cropping systems particularly, in 1:1 cropping system with 60% chemical plus biological fertilizers, where the highest LER, RVT, SPI, and MAI values were recorded. Safflower was the dominant crop in the safflower/faba bean combination, and had higher RCC in comparison with faba bean. Overall, 1:1 cropping system with 60% chemical plus biological fertilizers could be a better intercropping system.

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