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ORIGINAL PAPER

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AGRONOMIC AND QUALITATIVE TRAITS OF SAFFRON AND CUMIN IN RESPONSE TO INTERCROPPING

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ABSTRACT

As well as the expansion of land use due to the short period of saffron growth, its intercropping can also enhance yields and agronomic traits, which usually happens through weed control, shading, and the reduction of soil temperature and growth climate. Therefore, the effects of cumin seed rates in an intercropping on quantitative and qualitative characteristics of saffron were studied in a Randomized Complete Block Design (RCBD) with three replications in Zaveh, Torbat-E Heydariyeh, Iran, during 2016–2017. Treatments included five levels of cumin seed proportions (25, 50, 75 and 100% of the optimum density). The results of the study indicated the significant effect of cumin seed rates on all the measured traits of saffron except the number of flowers, daughter corms and leaves, as well as safranal value. The minimum and maximum weight of dry stigma was associated with the ratios of 100 and 25% of cumin seed, respectively. Any increase in the ratio of cumin seed by over 25% reduced the amount of other quantitative traits. The cumin seed ratio showed significant effects on the number of umbels per plant, the number of seeds per plant, and seed yield. Since the increase in the number of seeds per plant as a result of low ratios of cumin seed cannot compensate for the reduction of plants, therefore, lower yields would be attained. Totally, increasing shading and less competition, due to lower ratios of seed, improves physical, chemical and biological conditions of the soil, and helps to save more water. Such conditions improve the traits of corm, flower, and photosynthetic area, and so results in an economical saffron yield.

Key words: cover crop, cumin, qualitative traits, saffron, yield

INTRODUCTION

Crocus sativus L. belongs to the *Iridaceae* family, and Iran is known as its habitat [Koocheki et al. 2013]. Recently, more than 95% of the global saffron is produced in Iran, where Khorasan provinces account for most of the production [Kafi et al. 2002, Paseban 2006]. Saffron is the most valuable agricultural and medicinal crop applied in different industries such as nutrition, cosmetics, medicine, dyeing, aromatization and art. With increasing the lands under saffron cultivation in Khorasan provinces and Iran, its mean yield has been reduced to about 3.5 kg ha^{-1} [Mollafilabi and Shoorideh 2009]. The efficiency of saffron production can be enhanced through intercropping. In addition to effective ecological stability, the intercropping of saffron with other plants can increase land productivity, and hence, it results in increasing the yield [Naderi et al. 2009]. Since saffron falls asleep within some times of the year, intercropping can increase the yield of both

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plants through the appropriate use of environmental factors for the whole year and the improvement of soil conditions [Asadi et al. 2016].

The canopy structure of saffron causes water (through evaporation) and light loss. Only its roots use the top soil and other parts of the soil are not optimally used. Making another crop to grow with saffron as a cover or companion plant improves their efficiency [Khorramdel et al. 2017]. In this regard, there are some benefits such as effective weed control, more shading, land coolness, nitrogen fixation, and the improved use of water and nutrition sources of the soil provided by intercropping which enhances saffron agronomic traits [Farhoodi et al. 2014, Asadi et al. 2016].

The weed biomass is reduced because of the cover plants used in intercropping with saffron prevent its seed germination. Moreover, like other glandular plants, saffron acts at a specific depth of soil, and hence results in the incomplete use of nutrition and water sources. Saffron, with narrow leaves, which are mostly flaccid, does not properly use the solar radiation [Fallahi and Behdani 2016]. Impact of high temperature during the summer on saffron flower induction as well as the delay in its flowering decrease the economical production of the crop. Yet, growing companion plants like cumin (*Cuminum cyminum*) with saffron helps to stabilize the production through the decreasing the negative effects (Galavi et al. 2008, Khoramdel et al. 2017).

Due to the ecological and physiological traits of saffron and its inactivity for one-half of the year, it is considered as the best option for intercropping. In addition to improving saffron agronomic and qualitative traits through filling in its production gaps, a companion plant with its different needs has economical yields [Aqhavani Shajari 2017].

Since saffron is a crop with little need of water, and frequent irrigation can even negatively influence its yield, choosing a companion plant with similar needs is of great importance [Farhoodi et al. 2004]. Cumin is an important medicinal plant whose good adaptation to drought has led to the increase in the area of the lands under cultivation in Khorasan provinces so that these provinces account for 90% of its production throughout the country. With its limited period of growth, its intercropping with other plants can improve the attraction and consumption of sources and enhance the stability of agronomic system yield [Zarifpour et al. 2014].

In an experiment in Mashhad, Iran, a study on the effects of cumin intercropped with saffron showed that the weight of dry flower and economical yield significantly affected by cumin seed rates. The mentioned study indicated that the highest economical yield of saffron (1.98 gr m^{-2}) was related to the treatment of 60% of cumin seed rate [Khorramdel et al. 2017]. Other studies, also in Mashahd, Iran, indicated the positive effects of marjoram [Koocheki et al. 2013] and pea [Asadi et al. 2016] in different densities on saffron and the improvement of the measured traits. Koocheki et al. [2013] stated that the 1 : 1 planting combination, e.g. one row of marjoram and one row of saffron, had the highest stigma yield per unit of area (2 gr m^{-2}). In their study, the lowest amount of economical yield was associated with 1 : 0 planting combination (pure stand of saffron). According to these researchers, the increase in the economical yield of saffron in intercropping was due to the increased number of flowers obtained as a result of the improved soil temperature.

Asadi et al. [2016] in Mashhad, Iran concluded that the maximum saffron fresh flower and economical yield in mono cropping were 48.02 and 2.29 gr m^{-2}, respectively. However, mono cropping resulted in better saffron traits, and an 80% of increase in the seed pea ratio (from 20% to 100%) resulted in 142% of increase in the weight of saffron fresh flower and stigma.

Another report showed that intercropping of cumin with saffron increased the number of flowers, the weight of dry stigma, and the number of corms per the unit of area [Koocheki et al. 2016].

Saffron intercropping with other adapted plants can, through microclimate change, provide suitable conditions for lowering temperature and increasing the period of photosynthetic activity of saffron in spring and thus increase its economic yield. The present study was conducted under intercropping conditions at Zaveh, Iran, to investigate the effects of using different ratios of cumin on different saffron traits concerning corm, leaf, flower, and economical yield.

MATERIALS AND METHODS

This experiment was conducted in a farm located in Zaveh, Torbat-e Hedariye, Iran during 2016–2017. Altitude, longitude and latitude of Zaveh are

1470 m, 59°26'42" and 35°21'42", respectively. The experiment was conducted based on a randomized complete block design with three replications. The treatment consisted different cumin rates (0, 25, 50, 75 and 100% of appropriate seeding rate). Ten kilograms per hectare was considered as the appropriate seeding rate of cumin.

In the experiment, a uniform four-year saffron farm was selected. The size of each experimental plot was 2 × 2 m (4 m^2). The saffron rows were separated with 20 cm distance. Furthermore, distance between the two saffron plants on one row was 5 cm (density of 100 plants m^{-2}). In order to control weeds, hand--weeding was applied. The irrigation and fertilization were carried out based on regional routines. In order to determine physical and chemical traits of the farm soil, prior to cultivation of cumin, some sample was taken from 0–20 cm depth. Table 1 shows the results of the sample soil analysis.

Table 1. Results of physical and chemical soil analysis

Texture	EC (ds m^{-1})	pH	OC (%)	N (%)	P (ppm)	K (ppm)	Zn (ppm)	Fe (ppm)
Sandy Loam	0.81	7.98	0.58	0.05	16	285	1.65	5

Cumin was cultivated in relevant densities on February 15, 2017. The saffron measured traits included corm traits (number and weight of daughter corms and mean diameter of corms), quantitative properties of the flower (the number and weight of fresh and dry flower and the weight of fresh and dry stigma), leaf specification (the number and weight of leaf and height of plant), and the flower qualitative properties (crocin, picrocrocin and safranal values).

In order to measure the corm traits, 5 plants of each plot were randomly selected, and the relevant traits were specified on May, 2017. To specify flower traits, 1 m^2 area from every plot was harvested in October, 2017. After counting the flowers and determining the fresh weight, the stigma was also separated and weighed. To specify dry weight, the relevant organs were put in an oven for 48 h at 70°C. Furthermore, after counting the leaves of five plants, the number of saffron leaves was obtained for each plant. Finally, to determine the dry weight of leaves, 1 m^2 area from every plot was randomly harvested in March, 2018 and was weighed after being dried.

To specify the qualitative properties of the flower, the samples harvested in October, 2017 were used. Iso method was used to qualify saffron. Picrocrocin, safranal, and crocin were measured based on an absorption of 1% aqueous solution at wavelength of 254, 330 and 440 nm per dry material, respectively according to the 259/2 national standard method [Iran National Standard 259-2. 2010].

Upon a random harvest of 1 m^2 area of every cumin plot and separating the seeds on July, 2017, its yield was specified. In addition, after counting 1000 seeds, their weight was measured. Cumin yield attributes, including the number of umbels per plant, the number of seeds per umbel and the number of seeds per plant, were determined by calculating the mean of 5 plants.

To analyze the data (ANOWA 2-way), the SAS software was used, furthermore, the means were compared by the LSD Test.

RESULTS AND DISCUSSION

Cumin yield. The results of analysis of variance show that seeding rate of cumin significantly influenced the number of umbels per plant as well as the number of seed per plant and seed yield (Tab. 2).

As the seed ratio was increased, the number of umbels per plant was decreased, and hence it reached to 17.73 at the seed ratio of 100% compared to 27.93 at that of 25% (Tab. 3). The effect of seed ratio on the number of seeds per plant was significant. The highest seeds number per plant (820.9) was related to treatment seed ratio set at 25% that was 85% more than treatment seed ratio set at 100% (Tab. 3). Seed yield in the treatment seed ratio at 100% (941.99 kg ha^{-1}) was 54% more than treatment seed ratio at 25%. On the other hand, the seed ratio at 75% and 100% were not significantly different. The seed ratios set at 50% and 25% showed the minimum yield and were not significantly different (Tab. 3). The number of seeds per plant seems to be the most important component of yield since it was influenced significantly by the seed ratio.

Mashayekhi et al. [2011] in their study on cumin in Kerman, Iran showed that an increase in its plant density from 44 to 148 per 1 m^2 results in a decreased number of umbels per plant. In addition, in their study, the plant density did not influence the weight of 1000 seeds significantly. Generally, the weight of 1000 seeds is one of the most constant components of yield, which is controlled genetically, and hence is less likely to be influenced by environmental conditions unless severe stresses occur.

As seed ratio per unit of area increased, the number of umbels per plant decreased, and so it leads to the decrease in the number of seeds per plant due to an increased competition among plants [Mashayekhi et al. 2011]. Heidari Zolleh et al. [2009] in an experiment in Kermanshah, Iran indicated that cumin seed yield is determined mainly by the number of umbels and seeds per plant. Therefore, any factor that enhances these traits can increase the yield. In that experiment, the density of 200 plants per m^2 on the first planting date had the highest seed yield, which was positively correlated with the number of seeds per plant. However, at low planting densities, increasing seed number per plant could not offset the decrease in yield. Also in this experiment the treatment seed ratio of 25% had the lowest seed yield.

Traits of saffron

Weight, number and diameter of daughter corms. The results of the analysis of variance indicated a significant effect of cumin seed ratio on weight and diameter of the daughter corm. However, the number of these corms was not significantly affected by the cumin seed ratio (Tab. 4).

The maximum weight (17.9 g) and diameter (25.26 mm) of daughter corms were related to cumin seed ratio of 25%, which was not significantly different from those obtained for ratios at 0 and 50%. Also, the treatment cumin seed ratio of 100% had the lowest weight (8.95 g) and diameter (17.52 mm) of the daughter corms (Tab. 5). The observed high correlation (0.7) between the weight of daughter corms and dry weight of stigma (economical yield) at 1% level indicates high importance of this trait (Tab. 6).

Koocheki et al. [2016] in Mashhad, Iran found out that the diameter and weight of saffron daughter corms were influenced significantly by cover plants. In their study, the weight and diameter of daughter corms were increased by 10% as a result of using *Lathyrus sativus* and *Trifolium* sp. as cover plants, compared to control treatment. The growth status of saffron corms is a function of leaves photosynthesis. Each factor boosting leaves efficiency and increasing photosynthesis in saffron can improve the weight and size of its corms, and hence resulting in an increase in its final yield [Molina et al. 2005]. It seems that covering and/or mulch provided by cover plants as well as their direct and indirect effects on the increased shading, improved physical – chemical properties and fertility of soil, decreased leaching and balanced temperature and moisture have led to the development of bigger corms in saffron [Sainju et al. 2006, Fallahi et al. 2014, Koocheki et al. 2015]. In another study, the maximum planting distance of watermelon (*Citrullus lanatus*) as a cover plant (40 cm) showed the minimum number of corms (10.57) and minimum weight of fresh (47.18 g) and dry (13.87 g) corm. If cover plants are appropriately positioned in the spring, they can improve traits of saffron daughter corms through improving soil conditions during hot months and through helping saffron to compete with weeds [Rouhi et al. 2012].

Number and weight of fresh and dry flower. Weight of fresh and dry flower were influenced significantly by the cumin seed ratio. However, the effect of treatment on the number of flowers per 1 m^2 was not significant (Tab. 4). Fresh and dry flower yield in the treatment cumin seed ratio of 25% (Tab. 5), showing an increase of 23.6% and 27.9%, respectively, compared to the saffron mono cropping. The weight of dry flower is positively and significantly correlated with important traits such as the number of flowers, weight of dry leaf, and most importantly, economical yield (Tab. 6), and so it is of paramount importance in physiological research.

Table 2. The result of analysis of variance related to the effect of cumin seed ratios on its yield and components

Source of variation	df	Number of umbels per plant	Number of seeds per umbel	Number of seeds per plant	Weight of 1000 seeds	Seed yield
Treatment	3	202.9**	16ns	271054**	0.8ns	224914*
Replication	2	206.2**	321*	149026**	2.42*	340687**
Error	6	28.8	26.6	14420	0.92	65524
C. V. (%)		10.23	7.5	8.52	14.17	13.92

*, ** show the significance levels at 5% and 1%, respectively; ns non-significant

Table 3. Effect of cumin seed ratio on its yield and components

Ratios of cumin seed	Number of umbels per plant	Number of seeds per umbel	Number of seeds per plant	Weight of 1000 seeds (g)	Seed yield (kg ha^{-1})
25	27.93 a	29.36 a	820.9 a	3.17 a	612.59 b
50	22.03 b	29.03 a	573.1 b	2.73 a	621.49 b
75	18.06 b	27.6 a	426.4 c	2.7 a	803.14 ab
100	17.73 b	26.4 a	443.9 c	2.46 a	941.99 a

Means followed by at least one same letter within each column are not significantly different (p = 0.05)

Table 4. The result of analysis of variance related to the effect of cumin seed ratios on some traits of saffron corm and flower

Source of variation	df	Weight of each daughter corm	Number of daughter corm	Diameter of corm	Number of flowers	Weight of fresh flower	Weight of dry flower	Number of leaves
Treatment	4	165.1*	4.82ns	154.28*	23839ns	702069*	18648**	1.26ns
Replication	2	109.35*	0.94ns	160.53**	6950ns	403852*	812ns	1.72*
Error	8	82.95	11.49	57.7	22442	358527	1566	1.19
C.V. (%)		24.33	24.74	12.15	25.11	20.49	9.62	7.79
Source of variation	**df**	**Weight of dry leaf**	**Height of plant**	**Crocin**	**Picrocrocin**	**Safranal**	**Weight of wet stigma**	**Weight of dry stigma**
Treatment	4	80494*	630.4*	125.7**	52.9*	19.7ns	1894**	74.7**
Replication	2	22120ns	288.6ns	22.5ns	19.6ns	12.9ns	2349**	90.6**
Error	8	29911	310.9	27.4	23.06	15.06	4705	20.7
C.V. (%)		25.34	12.06	0.69	1.89	3.86	13.39	14.27

*, ** indicate significance levels at 5% and 1 %, respectively; ns non-significant

Koocheki et al. [2016] showed that cover plants like *Trifolium resupinatum* and *Vicia* sp. increase saffron flowering through control of received radiation and soil physical-biological traits. In another study in Mashhad, Iran [Koocheki et al. 2013], it was shown that intercropping of saffron with *Origanum majorana* increased the weight of fresh flower and the economical yield of saffron. In this study, with an increase in *Origanum majorana* density, the weight of fresh flower was increased; however, in a 7-day irrigation interval, the highest density of *Origanum majorana* resulted in the minimum weight of fresh flower (5.6 g m^{-2}). In addition, shading resulted from cover crop and better growth of corms has led to an increase in flower production, which are in line with the findings of the present study [Galavi et al. 2008].

Number and weight of dry leaves and plant height of saffron. The number of leaves at different treatments was 5, which was not statistically significant (Tab. 4). However, the effect of cumin seed ratio on the weight of dry leaf and plant height was significant. The control treatment (mono crop of saffron) showed the lowest plant height (40.7 cm) – Table 5. As cumin seed ratio was increased, an increase was also shown in the plant height. Probably, an increased competition as a result of shading caused by high density of cumin caused an increase in the height of saffron plants.

The highest weight of saffron dry leaves (351.7 g m^{-2}) was observed in cumin seed ratio set at 25%, which was not significantly different from the saffron mono cropping and the cultivation ratio of 50% (Tab. 5). More increase in the cumin seed ratio in intercropping decreased the weight of saffron dry leaves per unit of area due to the increase in the interspecific competition so that the cumin seed ratio set at 100% resulted in a decrease in the weight of dry leaves by 44%, compared to the saffron mono cropping. The growth status of saffron leaf is crucial in determining its yield [Bayat et al. 2016].

The weight of dry leaves as a crucial index of saffron leaf specification is effective by 80% in filling up the daughter corms and is more effective than mother corms. Obviously, an increase in the weight of daughter corms leads to the increase in the flower traits, and hence it boosts the economical yield of saffron [Lundmark et al. 2009, Andabjadid et al. 2015]. The positive and high correlation coefficient obtained for the weight of dry leaf and economical yield (dry weight of stigma) of saffron (Tab. 6) supports this claim. According to Khorramdel et al. [2017], each factor that improves soil fertility traits and increases its water holding capacity improves corms and enhances photosynthetic area and yield of saffron.

The amount of crocin, picrocrocin and safranal. Saffron crocin and picrocrocin content were influenced significantly by cumin seed cultivation ratio (Tab. 4). The safranal values showed no significant difference among different treatments. The maximum values of Crocin (270 mg g^{-1}) and Picrocrocin (93 mg g^{-1}) were observed for cumin seed cultivation ratio of 100% (Tab. 5). Secondary metabolites in saffron determine the quality and each one plays a part. Crocin, Picrocrocin and Safranal account for the saffron color, flavor, and odor, respectively [Lage and Cantrell 2009, Srivastava et al. 2010].

In an experiment, picrocrocin value was increased significantly through protective plowing which was attributed to the improvement of soil conditions. In that experiment, the values of safranal and crocin were not influenced by irrigation and plowing [Feizi et al. 2014]. In line with the present study, Khorramdel et al. [2017] found out that the safranal value was not influenced significantly by the cover crop such as cumin. Among agronomic traits, the effective role of biologic fertilizers in significant increase of crocin, picrocrocin and safranal values has been taken into consideration [Omidi et al. 2009]. However, the role of agronomic factors such as plowing and/or irrigation in increasing picrocrocin is not clear. It is generally stated that an increase in saffron flower induction and yield may be effective in improving the quality of saffron.

In the present study, the further shading caused by high density of cumin probably has balanced soil temperature, and has improved the growth status of leaves, which has influenced the crocin and picrocrocin values.

Economical yield of saffron (weight of wet and dry stigma). The effect of cumin seed ratio on the weight of fresh and dry stigma (economical yield) was significant (Tab. 4). The maximum weight of fresh and dry stigma (75.06 and 14.88 kg ha^{-1}, respectively) was obtained for the seed cultivation ratio of 25% and the minimum values (39.8 and 8.03 kg ha^{-1}, respectively) were found for the cumin cultivation ratio of 100%. The weight of

Table 5. Effect of cumin seed ratios on some traits of saffron corm and flower

Cumin seed ratio (%)	Weight of each daughter corm (g)	Number of daughter corms per plant	Diameter of corm (mm)	Number of flowers per 1 m^2	Weight of fresh flower (kg ha^{-1})	Weight of dry flower (kg ha^{-1})	Number of leaves per plant
0	13.86 abc	4.88 a	23.41 ab	212.2 a	1062 ab	148.2 bc	5.1 a
25	17.39 a	5.69 a	25.26 a	287.8 a	1313.1 a	189.6 a	5.4 a
50	15.36 ab	5.18 a	25.21 a	235.9 a	1163.3 a	169.1 ab	4.7 a
75	10.07 bc	4.34 a	19.02 bc	183 a	987 b	134.1 c	4.6 a
100	8.95 c	4.12 a	17.52 c	179.2 a	664.5 b	85.6 d	4.7 a
Cumin seed ratio (%)	**Weight of dry leaves (g m^{-2})**	**Plant height (cm)**	**Crocin (mg g^{-1})**	**Picrocrocin (mg g^{-1})**	**Safranal (mg g^{-1})**	**Weight of fresh stigma (kg ha^{-1})**	**Weight of dry stigma (kg ha^{-1})**
0	261.9 ab	40.7 b	261.3 c	87.3 b	37 a	59 b	11.64 b
25	351.7 a	49.8 ab	263.6 bc	89.6 b	26.3 a	75.06 a	14.88 a
50	270.7 ab	51.2 ab	266.3 b	89.3 b	35.6 a	55.5 b	11.57 b
75	175.5 bc	59 a	266 b	88.6 b	34.3 a	54.3 b	10.18 bc
100	146.4 c	57.3 a	270 a	93 a	34 a	39.8 c	8.03 c

Means followed by at least one same letter within each column are not significantly different (p = 0.05)

Table 6. Correlation coefficient among some important traits of saffron

	Weight of daughter corm	Weight of dry flower	Number of flowers	Weight of dry stigma	Number of leaves	Weight of dry leaves	Crocin	Picrocrocin	Safranal
Weight of daughter corm	1	0.47^{ns}	0.35^{ns}	0.7^{**}	0.51^{*}	0.82^{**}	-0.2^{ns}	0.03^{ns}	0.38^{ns}
Weight of dry flower		1	0.59^{*}	0.64^{**}	0.4^{ns}	0.72^{**}	-0.66^{**}	-0.4^{ns}	0.32^{ns}
Number of flowers			1	0.74^{**}	0.69^{**}	0.6^{*}	-0.28^{ns}	-0.08^{ns}	0^{ns}
Weight of dry stigma				1	0.86^{**}	0.86^{**}	-0.33^{ns}	-0.15^{ns}	-0.03^{ns}
Number of leaves					1	0.76^{**}	-0.31^{ns}	0.01^{ns}	0.06^{ns}
Weight of dry leaves						1	-0.46^{ns}	-0.19^{ns}	0.3^{ns}
Crocin							1	0.66^{**}	-0.36^{ns}
Picrocrocin								1	-0.25^{ns}
Safranal									1

*, ** show the significance levels at 5% and 1%, respectively; ^{ns} non-significant

fresh and dry stigma in the cumin cultivation ratio of 25% showed an increase of 27% and 28% respectively, compared to saffron mono cropping (Tab. 5).

Different ratios of cumin-saffron intercropping in the study by Khorramdel et al. [2017] in Mashhad, Iran influenced significantly on the weight of dry flower, which can influence economical yield so that the average density of cover crop brings maximum economical yield of saffron (1.98 g m^{-2}). In addition, in the study by Koocheki et al. [2013] in Mashhad, Iran, a farm with alternate rows of *Origanum majorana* and saffron resulted in the maximum yield of stigma per unit of area (0.2 g m^{-2}). In this study, the lowest economical yield was associated with pure stand of saffron. According to these researchers, the increase in the saffron economical yield by intercropping was due to the increase in the number of flowers as a result of soil temperature improvement. Because of the soil temperature adjustment, daughter corms grow well and hence boosting economic yield due to the increase in flowering. In this study, the weight of dry stigma was significantly and positively correlated with all the important quantitative traits (Tab. 6).

CONCLUSION

Generally, the results indicated that, using cumin low densities in the saffron intercropping, compared to the saffron mono cropping, results in the improvement of yield and growth traits of saffron probably through the improvement of micro climate conditions of farm. On the other hand, all of the densities used in the intercropping of saffron with cumin, compared to mono cropping of saffron, improved saffron qualitative traits. Therefore, it is recommended that saffron can be intercropped with average densities of cumin plant.

REFERENCES

Andabjadid, S., Pasban, B., Sadeghi Bakhtavari, A., Mohammadi, H. (2015). Effects of corm size and plant density on Saffron (*Crocus sativus* L.) yield and its components. Inter. J. Agron. Agric. Res., 6(3), 20–26.

Aqhavani Shajari, M. (2017). Feasibility study of corm size and improved yield of saffron through agricultural management. PhD thesis. Ferdowsi University of Mashahd, Iran [in Persian].

Asadi, G., Khoramdel, S., Hatefi, M. (2016). The effects of cultivation ratios of pea and saffron row intercropping on yield and some growth traits. J. Saffron Agron. Tech., 4(2), 93–103 [in Persian].

Bayat, M., Tajbakhsh, M., Ramezani, M. (2016). Evaluation of saffron ecotypes for stigma yield and yield components using different maternal corm weights. J. Plant Physiol. Breed., 6(1), 53–64 [in Persian].

Fallahi, H., Behdani, M. (2016). Technical knowledge based on research approaches. Mashhad University Jihad Publications, pp. 412.

Fallahi, H., Paravar, A., Behdani, M.A., Aghhavani-Shajari, M., Fallahi, M.J. (2014). Effects of saffron corm and leaf extracts on early growth of some plants to investigate the possibility of using them as associated crop. Not. Sci. Biol., 6(3), 282–287.

Farhoodi, R., Rahnama, A., Esmailzadeh, H. (2014). Status of saffron planting in intercropping. 3rd National Conference on Saffron, Ferdowsi University of Mashhad.

Feizi, H., Mollafilabi, A., Sahabi, H., Ahmadian, A. (2014). The effect of summer irrigation and conservation tillage on flower yield and qualitative indexes of saffron (*Crocus sativus* L.). J. Saffron Agron. Tech., 2(4), 255–263 [in Persian].

Galavi, M., Soloki, M., Mousavi, S.R., Ziyaie, M. (2008). Effect of planting depth and soil summer temperature control on growth and yield of saffron (*Crocus sativus* L.). Asian J. Plant Sci., 7, 747–751. DOI: 10.3923/ajps.2008.747.751

Heidari Zolleh, H., Bahraminejad, G., Maleki, A., Papzan, H. (2009). Response of cumin (*Cuminum cyminum* L.) to sowing date and plant density. Res. J. Agric. Biol. Sci., 5(4), 597–602.

Kafi, M., Rashed Mohassel, M.H., Koocheki, A., Mollafilabi, A. (2002). Saffron (*Crocus sativus* L.), Production and Processing. Faculty of Agriculture, Ferdowsi University of Mashhad, Iran, 50–60 [in Persian].

Khorramdel, S., Koocheki, A., Rezvani Moghaddam, P. (2017). Evaluation of the effects of saffron-cumin intercropping ratios on quality and yield under semi-arid conditions. Acta Hortic., 1184, 179–184 [in Persian]. DOI: 10.17660/ActaHortic.2017.1184.26

Koocheki, A. (2013). Research on production of Saffron in Iran; past trend and future prospects. Saffron Agron. Tech., 1(1), 3–21 [in Persian].

Koocheki, A., Shabahang, J., Khorramdel, S., Azimi, R. (2013). The effect of irrigation intervals and intecropped marjoram (O*riganum vulgare*) with saffron (*crocus sativus*) on possible cooling effect of corms for climate change adaptation. Iran. J. Field Crops Res., 11(3), 390–400.

Koocheki, A., Rezvani Moghaddam, P., Fallahi, H.R. (2015). Effects of planting dates, irrigation management and cover crops on growth and yield of saffron (*Crocus sativus* L.). Agroecol., 8(3), 435–451. DOI: 10.22067/jag.v8i3.51323.

Koocheki, A., Seyyedi, S.M., Gharaei, S. (2016). Evaluation of the effects of saffron-cumin intercropping on growth, quality and land equivalent ratio under semi-arid conditions. Sci. Hortic., 201, 190–198. DOI: 10.1016/j.scienta.2016.02.005

Lundmark, M., Vaughan, H., Lapointe, L. (2009). Low temperatures maximize growth of *Crocus vernus* (L.) Hill, via changes in carbon partitioning and corm development. J. Exp. Bot., 60, 2203–2213. DOI: 10.1093/jxb/erp103

Mashayekhi, A., Shirzadi, M., Naghavi, H. (2011). Effect of planting date and plant density on yield and yield components of cumin (*Cuminum cyminum* L.). Middle East J. Sci. Res., 9(6), 773–777.

Molina, R., Valero, M., Navarro, Y., Guardiola, L., Garsia, A. (2005). Temperature effect on flower formation in saffron. Sci. Hortic., 103, 361–379. DOI: 10.1016/j.scienta.2004.06.005

Mollafilabi, A., Shoorideh, H. (2009). The new methods of saffron production. Fourth National Festival of Saffron, Khorasan–Razavi, Iran, 27–28 October [in Persian].

Omidi, H., Naghdibadi, H.A., Golzad, A., Torabi, H., Fotoukian, M.H. (2009). The effect of chemical and bio-fertilizer source of nitrogen on qualitative and quantitative yield of saffron (*Crocus sativus* L.). J. Med. Plant., 8, 98–109.

Paseban, F. (2006). Effective factors on exporting Iranian saffron. Econ. Res., 6(2), 1–15.

Rouhi, M., Kordnaeij, A., Amirshekari, H. (2012). The effects of corm density and cultivation date of watermelon as a living mulch on quantitative and qualitative yield of saffron. J. Crop Prod. Res., 6(1), 29–42 [in Persian].

Sainju, U.M., Singh, B.P., Whitehead, W.F., Wang, S. (2006). Carbon supply and storage in tilled and non-tilled soils as influenced by cover crops and nitrogen fertilization. J. Environ. Qual., 35, 1507–1517. DOI: 10.2134/jeq2005.0189

Zarifpour, N., Naseripouryazdi, M., Nasirimahalati, M. (2014). The effect of different intercrop-combinations on quantitative and qualitative traits of *Cuminum cyminum* L., and agronomic traits of *Cicer arietinum* L. Iran. J. Field Crops Res., 12(1), 34–43 [in Persian].