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Saffron-pumpkin/watermelon: A clean and sustainable strategy for increasing economic land equivalent ratio under limited irrigation

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A B S T R A C T

Generally, from the onset of dormancy to flowering, saffron farms are free of vegetation. Therefore, nutrients loss due to soil erosion, increased soil temperature and reduced land use efficiency are the most obvious problems of sole saffron cultivation, occurring over this period. Herein the intercropping advantage of saffron with watermelon or pumpkin and its effects on growth, yield and economic land equivalent ratio under limited irrigation were evaluated as a three-year field experiment (2014–2017) with a randomized complete blocks design arranged in factorial with three replicates. In this study, limited irrigation regimes on pumpkin and watermelon (14 and 28 days intervals) and cropping systems (saffron, pumpkin, watermelon, saffron + pumpkin and saffron + watermelon) were considered as the first and the second factors, respectively. Except for 2014, the individual effects of irrigation scheme and cropping systems on flower number and dried stigma yield were significant. In 2015, 2016, in comparison to saffron monoculture, intercropping significantly increased flower number and dried stigma yield. Moreover, in these years, increase in irrigation interval from 14 to 28 days significantly reduced average fruit weight in pumpkin and watermelon. The maximum land equivalent ratio and economic land equivalent ratio of saffron were found in saffron-pumpkin intercropping system with 14 days irrigation interval. Intercropping could positively affect saffron corms growth and N and P concentrations in the corms. In sum, considering the water shortage in arid and semi-arid regions, saffron-pumpkin or saffron-watermelon intercropping increases land efficiency and improves farmers' income during perennial life cycle of saffron.

1. Introduction

Saffron, a member of the Iridaceae family, is a spice derived from the flower stigma of *Crocus sativus* (Halvorson, 2008). It is cultivated in arid and semi-arid regions of the world, especially in Iran (Khanali et al., 2016; Sepaskhah and Kamgar-Haghighi, 2009). In 2016, Iran's saffron cultivation area and production were 105,000 ha and 336 ton, respectively, which mainly are concentrated in Northeast of the country in Khorasan-Razavi Province (Agricultural statistics, 2017). Accordingly, Iran is known as the most important saffron producer in the world as 89% of world's production is grown in Iran. The average saffron yield in Iran is about 3.2 kg ha^{-1} (Agricultural statistics, 2017).

Saffron plays a vital role in the agricultural economy of the province where drought effects are most severe (Bouzarjmehri et al., 2016; Nasabian and Jafari, 2016). Low water requirement, specific growing cycle which is mainly during winter and having some unique morphological characteristics such as narrow and tough leaves make saffron compatible with arid regions (Azizi-Zohan et al., 2009; Koocheki and Seyyedi, 2016b, Koocheki et al., 2014; Mirsafi et al., 2016; Yarami et al., 2011).

Saffron as a crop has a perennial life cycle (Koocheki and Seyyedi, 2015). Saffron is propagated through vegetative means using mother corms (Gresta et al., 2008; Rajaei et al., 2009). In botanical point of view, mother corms are modified underground stems with several buds (Kumar et al., 2009; Rubio-Moraga et al., 2014). These buds form new corms during growing season which called daughter corms (Koocheki and Seyyedi, 2015). After flowering in autumn, daughter corms start to form (Gresta et al., 2016; Koocheki et al., 2016a). In March saffron growth reaches to its maximum and in the middle of May daughter corms formation completed. At this stage, above ground parts dry out and daughter corms remain dormant until environmental conditions are

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favorable for it to flower again (Kumar et al., 2009; Renau-Morata et al., 2012).

Nutrients loss due to soil erosion and reduced land use efficiency are the most obvious problems of saffron cultivation, occurring over saffron dormancy period (Koocheki et al., 2014; 2016b; Maleki et al., 2017). Since soil surface is free of any vegetation for four months (Seyyedi et al., 2018), leaving the land unused would reduce farmers' annual income per unit area. In addition, increased soil temperature due to decreased canopy shading would negatively affect flower induction in daughter corms (Hosseini et al., 2008).

Generally, intercropping is a solution to deal with adverse effects of sole cropping in conventional production systems (Amani Machiani et al., 2018; Himmelstein et al., 2017). In fact, biodiversity and sustainability are among the most important consequences of intercropping (Nassiri Mahallati et al., 2015; Yin et al., 2017), especially when it is combined organic farming that can lead to the provision of clean products and services (Jones and Gillett, 2005; Theunissen, 1997). On the other hand, production of clean products from medicinal plants such as saffron is very important; because the products of these plants are directly used in pharmaceutical industry (Christodoulou et al., 2015; Shahabzadeh et al., 2013). Hence, saffron intercropping with other crops may economically and environmentally be feasible and can be considered to neutralize some of the above mentioned adverse impacts (Naderi Darbaghshahi et al., 2013; Koocheki et al., 2009, 2016b). However, from the total cultivation area of saffron in Iran, only about 10–12% is managed based on intercropping systems (including cumin, sunflower and wheat) and other 88–90% of saffron is sole system (Agricultural statistics, 2017).

The success in saffron intercropping depends on choosing appropriate species to be intercropped with the saffron (Asadi et al., 2016; Mesgaran et al., 2008). In other words, the candidate species should be able to cover the surface of the soil and reduce the negative effects of heat stress during the summer (Koocheki et al., 2016b). In this regard, watermelon (*Citrullus lanatus*) and pumpkin (*Cucurbita pepo*) are the two most commonly cultivated crops in semi-arid regions (Choopan et al., 2014; Erdem and Yuksel, 2003; Wang et al., 2004) so that in 2015, total production of watermelon and pumpkin in Khorasan-Razavi Province, obtained from irrigated and rain-fed land, reached to 211200 and 68400 ton, respectively. In the Province rain-fed watermelon fruit yield and pumpkin seed yield were reported as 5200 and 298.7 kg ha^{-1}, respectively (Agricultural statistics, 2017). These crops are suitable to be intercropped with saffron as their life cycle is not coincident with that of the saffron. In fact, according to region's climate, saffron above ground parts start to wilt in May and plants enter into dormancy (Koocheki and Seyyedi, 2015; Seyyedi et al., 2018). Watermelon and pumpkin are usually planted one month before initiating saffron dormancy, so that the maximum growth and fruit formation take place during this period of time (Jahan et al., 2013; Jalali and Jafari, 2013). After saffron flowering and with the onset of the cold season, watermelon and pumpkin above ground parts life end whereas saffron vegetative growth starts. Furthermore, watermelon and pumpkin make an excellent groundcover (Fandika et al., 2011; Olasantan, 2007; Soltani et al., 1995) that acts as a live mulch to hold moisture in the soil and keep the soil cool during warm seasons. Consequently, intercropping saffron with watermelon or pumpkin would provide considerable profitability in both spatial and temporal dimensions.

According to author's knowledge, some information are available about saffron-ajwain, saffron-black seed (Koocheki et al., 2009), saffron-chamomile (Naderi Darbaghshahi et al., 2013) and saffron-cumin (Koocheki et al., 2016b) intercropping under semi-arid conditions. However, there is no study that investigated the intercropping of saffron with Cucurbitaceae family. On the other hand, according to our hypothesis, watermelon and pumpkin cultivation during saffron dormancy period no only conserve corms against heat stress through covering soil surface, but also increase land use efficiency and farmers income. Hence, the current study was designed to quantify land productivity of saffron, watermelon and pumpkin under limited irrigation conditions and to evaluate its effects on growth, yield and economic land equivalent ratio. These objectives are consistent with the principles of sustainable agriculture and clean products provision towards elimination of all the chemical inputs.

2. Materials and methods

2.1. Site description

The current experiment was conducted during 2014–2017 in experimental station, Faculty of Agriculture, Ferdowsi University of Mashhad, Iran (latitude: 36°15′ N; longitude: 59°28′E; elevation: 985 m altitude). The region is classified as semi-arid, where water shortage is the most important limiting factor for crop production. Monthly rainfall and average temperature data during these years are given in Fig. 1. The soil of the experimental site was classified as clay with low organic matter. Some physical and chemical properties of the soil are listed in Table 1. The history of previous crops on experimental site included cultivation without reliance on chemical inputs.

2.2. Experimental design and field management

The experimental plots were arranged as a factorial randomized complete block design with three replicates. Limited irrigation regimes on pumpkin and watermelon (14 and 28 days intervals) and cropping systems (saffron, pumpkin, watermelon, saffron + pumpkin and saffron + watermelon) were considered as the first and the second factors, respectively.

The field was prepared according to the local practice for saffron production. Before corm planting, composted cattle manure (25 ton ha^{-1}) was scattered onto the soil surface and then mixed into the soil using plow and disk and then plots were established. Each plot was 6 m^2 (3 m long and 2 m width) and 1.5 m apart. The blocks were separated by a 2 m buffer zone.

Saffron mother corms were planted using basin method on 4th of July 2014 at 100 corms m^{-2} and 25 cm distance between planting rows (Figs. 1 and 2). Due to the high soil fertility of experimental site, there was no need to use N, P and K fertilizers. The other reason for not using chemical inputs was to focus on providing clean products and services from intercropping systems.

Pumpkin (cv. Local population) and watermelon (cv. Crimson Sweet) seeds were sown (30th April in 2015 and 28th April in 2016)

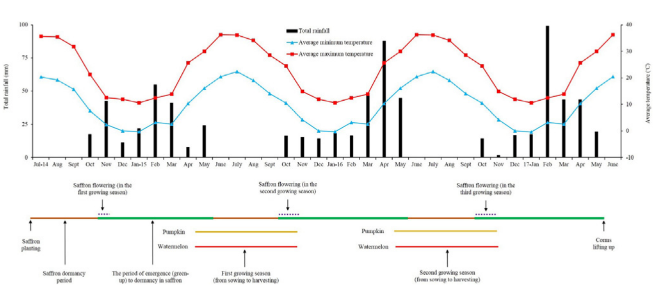

Fig. 1. Monthly rainfall and average temperature during the experimental periods from 2014 to 2017 at the experimental station, Faculty of Agriculture, Ferdowsi University of Mashhad, Iran.

Table 1
The soil physic-chemical characteristics of the experimental site during three years.

Soil analysis	2014	2015	2016
Physical *			
Clay (%)	47.20	49.81	45.71
Silt (%)	30.27	31.05	33.56
Sand (%)	22.53	19.14	20.73
Chemical			
OC (%)	0.58	0.81	0.76
Available N (mg kg^{-1})	16.36	15.98	13.56
Olsen-P (mg kg^{-1})	21.79	20.84	18.43
Available K (mg kg^{-1})	198.43	184.20	182.98
pH	8.39	8.11	8.01
EC (dS m^{-1})	1.04	0.87	0.85

Soil texture class (0–30 cm): clay (US system).

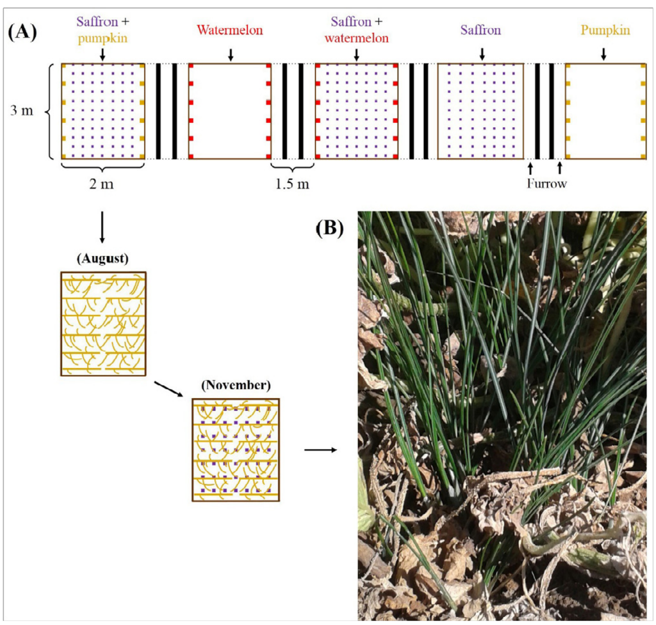

Fig. 2. A sample from experimental treatments based on randomized complete block design arranged in factorial manner (A), saffron growth (17th of Nov 2015) onto the pumpkin residues (B).

on both sides of the plots (Fig. 1). These cultivars are drought tolerant and suitable for production in the area. According to local irrigation patterns, when more water is available, pumpkin and watermelon fields are irrigated every two weeks, but when water is a limiting factor, the irrigation of these plants is done every four weeks. Seedlings were thinned at four-true leaf stage based on 0.5 m spacing between plants within the rows (12 plant $plot^{-1}$).

Irrigation scheme of saffron (flooding method), pumpkin and watermelon (furrow method) during the growing season are given in Table 2. In the second and third years, the irrigation dates were similar between saffron and pumpkin/watermelon (Table 2). Polyethylene pipelines and water counters were installed to control irrigation. All crops were kept free of weeds by hand hoeing and no herbicide or pesticide was applied over growing seasons.

2.3. Sampling and measurements

2.3.1. Saffron

In the first, second and third years of the experiment, saffron flowers were manually picked up daily from the first to 19th of November 2014, from 2nd of October to 8th of November 2015 and from 30^{th} of September to 9th of November 2016, respectively. During three years of the experiment, flower number and dried stigma yield were recorded by harvesting 2 m^2 of the central part of each plot. Stigmas were dried in an oven (at 30 °C for 48 h) to a constant weight (Gresta et al., 2009).

At the end of third growing season (1st of June 2017), daughter corms were lifted up in a 2 m × 1 m quadrate per plot and related indices such as number and weight in each group (≤5 g or small-sized, 5.1–10 g or mid-sized and >10 g or large-sized) were determined. The sorting criterion was carried out according to the previous experiment (Koocheki et al., 2016a). Moreover, N and P concentrations (g kg^{-1}) in daughter corms (plus corm tunics) were determined using Kjeldahl (AOAC, 2000) and Murphy and Riley (1962) methods, respectively. Accordingly, N and P content in saffron daughter corms were calculated according to Eqn. (1):

$$\begin{aligned} \text{N(P)content in daughter corms}\left(\text{gm}^{-2}\right) &= \text{N(P) concentration in daughter corms}\left(\text{gkg}^{-1}\right) \\ &\times \text{weight of daughter corms}\left(\text{gm}^{-2}\right) \end{aligned} \tag{1}$$

It should be noted that the daughter corms were not measured at the end of first and second growing season, because the removal of daughter corms from the soil could change the competition between the remaining corms and cause an experimental error.

2.3.2. Pumpkin and watermelon

At harvesting time (from 21st of August to 5th of October 2015 and from 30^{th} of August to 16th of October 2016), all ripe fruits were harvested from each plot, counted and weighed. It should be noted that, very small, infirm and rotted fruits were discarded as they are unacceptable for markets. In addition, 1000-seed weight (dried weight), grain yield and seed oil content of pumpkin were measured. Pumpkin seed oil content was measured using soxhlet method (Allen et al., 1986).

2.3.3. Land equivalent ratio (LER) and economic LER

For the saffron-pumpkin/watermelon intercropping, partial and total land equivalent ratio (LER) were calculated according to Eqns. (2)–(6) (Rao and Willey, 1980):

$$LER_S = Y_{SI}/Y_{SS} \tag{2}$$

$$LER_P = Y_{PI}/Y_{PS} \tag{3}$$

$$LER_W = Y_{WI}/Y_{WS} \tag{4}$$

$$LER_{S+P} = LER_S + LER_P \tag{5}$$

$$LER_{S+W} = LER_S + LER_W \tag{6}$$

where Y_{SI} is saffron dried stigma yield in intercropping. Y_{SS} is saffron dried stigma yield in sole cropping. Y_{PI} is pumpkin grain yield in intercropping. Y_{PS} is pumpkin grain yield in sole cropping. Y_{WI} is watermelon fruit yield in intercropping. Y_{WS} is watermelon fruit yield in sole cropping. LER_S, LER_P and LER_W are partial LER of saffron, pumpkin and watermelon, respectively. Moreover, partial economic LER were calculated using Eqns. (7)–(11):

$$ELER_S = Y_{SI} \times \text{monetary value}/Y_{SS} \times \text{monetary value} \tag{7}$$

$$ELER_P = Y_{PI} \times \text{monetary value}/Y_{PS} \times \text{monetary value} \tag{8}$$

Table 2
Irrigation schemes for saffron, pumpkin and watermelon during years of the experiment.

	Saffron			Pumpkin/watermelon [a]			
	First growing season	Second growing season	Third growing season	First growing season		Second growing season	
				14 days	28 days	14 days	28 days
	7th of Aug 2014	3th of Aug 2015 [b]	3th of Aug 2016 [b]	11th of May 2015	11th of May 2015	11th of May 2016	11th of May 2016
	28th of Sep 2014	28th of Sep 2015 [b]	28th of Sep 2016 [b]	25th of May 2015	8th of Jun 2015	25th of May 2016	8th of Jun 2016
	16th of Nov 2014	17th of Nov 2015	16th of Nov 2016	8th of Jun 2015	6th of Jul 2015	8th of Jun 2016	6th of Jul 2016
	9th of Mar 2015	5th of Mar 2016	7th of Mar 2017	22th of Jun 2015	3th of Aug 2015 [b]	22th of Jun 2016	3th of Aug 2016 [b]
	5th of Apr 2015	7th of Apr 2016	6th of Apr 2017	6th of Jul 2015	31th of Aug 2015	6th of Jul 2016	31th of Aug 2016
				20th of Jul 2015	28th of Sep 2015 [b]	20th of Jul 2016	28th of Sep 2016 [b]
				3th of Aug 2015 [b]	26th of Oct 2015	3th of Aug 2016 [b]	26th of Oct 2016
				17th of Aug 2015		17th of Aug 2016	
				31th of Aug 2015		31th of Aug 2016	
				14th of Sep 2015		14th of Sep 2016	
				28th of Sep 2015 [b]		28th of Sep 2016 [b]	
				12th of Oct 2015		12th of Oct 2016	
				26th of Oct 2015		26th of Oct 2016	
Total irrigation amount (mm)	286	397	411	1220	610	1220	610

[a] Irrigation schemes for pumpkin and watermelon were begun after plant thinning at four-true leaf stage.
[b] In the second and third growing seasons, the irrigation dates were similar between saffron and pumpkin/watermelon.

$$ELER_W = Y_{WI} \times \text{monetary value}/Y_{WS} \times \text{monetary value} \tag{9}$$

$$ELER_{S+P} = ELER_S + ELER_P \tag{10}$$

$$ELER_{S+W} = ELER_S + ELER_W \tag{11}$$

where $ELER_S$, $ELER_P$ and $ELER_W$ are partial economic LER of saffron, pumpkin and watermelon, respectively. Monetary values (per kg) were calculated based on export prices of saffron dried stigma (1 kg = 58000000 rial), pumpkin grain (1 kg = 300000 rial) and watermelon fruit (1 kg = 7000 rial) in Iran (1 $ = 38000 Iran's rial). The export prices of harvested crops were obtained from the Central Bank of the Islamic Republic of Iran (Central Bank of the Islamic Republic of Iran, 2017).

2.4. Statistical analysis

All the data were analyzed from analysis of variance (ANOVA) using SAS software version 9.3 (SAS, 2011). The least significant difference (LSD) at 5% probability level was used to measure statistical differences between treatments.

3. Results

3.1. Saffron flower

Analysis of variance on flower number and dried stigma yield are shown in Table 3. Except for the first year, interaction between irrigation scheme and cropping systems was significant on flower number and dried stigma yield. For saffron monoculture, in the second and the third years, there was no significant difference between 14 and 28 days irrigation intervals in terms of flower number and dried stigma yield (Figs. 3 and 4).

Except for the first year, in comparison to saffron monoculture, intercropping significantly increased flower number and dried stigma yield (Figs. 3 and 4). For example, in the third year, under 14 days irrigation interval treatment, dried stigma yield increased by 36% due to saffron-pumpkin intercropping compared with saffron monoculture (Fig. 4B).

In the second and the third years, in both irrigation schemes, flower number and dried stigma yield in saffron-pumpkin system was more than saffron-watermelon system (Figs. 3 and 4). Moreover, in these years, increase in irrigation interval from 14 to 28 days significantly reduced pumpkin average fruit weight, 1000-seed weight and yield (Table 4) and watermelon average fruit weight and fruit yield (Table 5). However, pumpkin seed oil content increased when increased irrigation interval.

3.2. Pumpkin grain and watermelon fruit

Pumpkin average fruit weight, 1000-seed weight, seed yield and oil content didn't increase significantly when pumpkin intercrop with saffron compared with sole system (Table 4). Similar results were found when watermelon-saffron system was compared with watermelon monoculture system (Table 5).

3.3. LER and ELER

Except for the first year, increase in irrigation interval significantly decreased LER_S. However, LER_P and LER_W were not affected by irrigation schemes. On the other hand, similar to LER_S, LER_{S+P} and LER_{S+W} decreased due to increased irrigation interval, however this reduction was significant only in the second year (Table 6).

In the second and the third years, significant difference was observed between intercropping systems in terms of LER_S, LER_{S+P} and LER_{S+W}. In addition, interaction between irrigation scheme and intercropping system was found to be significant on these indexes. In these years, the maximum LER_S was found in saffron-pumpkin intercepting system with 14 days irrigation interval (Table 6).

The effect of irrigation interval was significant on $ELER_S$, $ELER_{S+P}$ and $ELER_{S+W}$ only in the second year. In the second and the third years, the effect of cropping systems and interaction between irrigation interval and cropping systems were significant on $ELER_S$, $ELER_{S+P}$ and $ELER_{S+W}$ (Table 7). In these years, the maximum $ELER_S$ was found in saffron-pumpkin intercropping system with 14 days irrigation interval (Table 7). In addition, in the second year, when 28 days irrigation interval was applied, $ELER_S$ in saffron-pumpkin and saffron-watermelon intercropping systems was found to be 1.68 and 1.44, respectively. Under similar conditions in the third year, $ELER_S$ was recorded as 1.71 and 1.53 (Table 7).

Table 3
Analysis of variance for flower number and dried stigma yield of saffron.

S.O.V	Flower number			Dried stigma yield		
	2014	2015	2016	2014	2015	2016
Irrigation intervals	NS	**	*	NS	**	**
Cropping systems	NS	**	**	NS	**	**
Irrigation intervals × cropping systems	NS	**	**	NS	**	**

*, Statistical differences at $p \leq 0.05$.
**, Statistical differences at $p \leq 0.01$. *NS*, Non-significant.

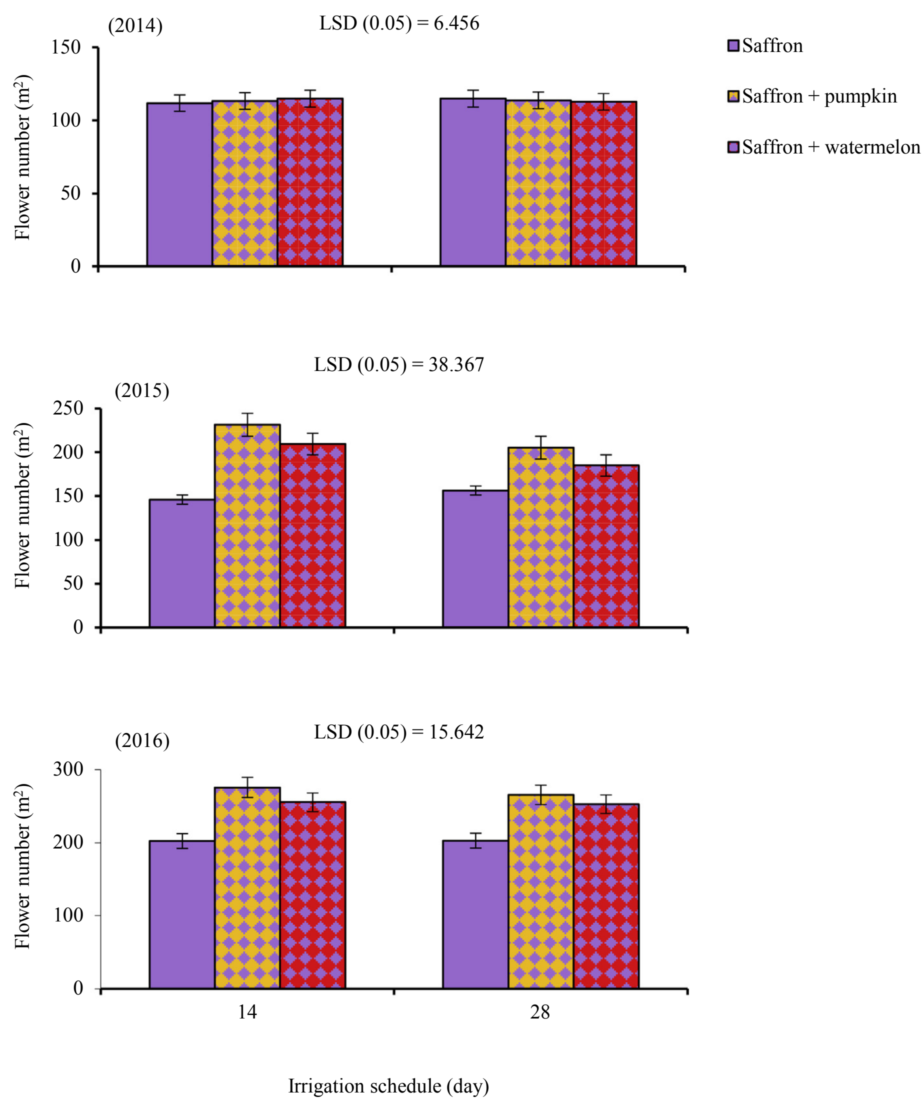

Fig. 3. Flower number of saffron in relation to irrigation intervals and cropping systems during years of the experiment (2014–2016).

3.4. Daughter corms behavior

According to the results, irrespective of size, daughter corms number and weight were significantly affected by irrigation rounds and planting patterns (Table 8).

Regardless of intercropping, reduction in irrigation rounds significantly increased small-sized daughter corms number and weight per m^2 whereas decreased mid or large-sized daughter corms. For example, in saffron monoculture treatment, change in irrigation intervals from 14 days to 28 days, increased small-sized daughter corms number by 16%, by contrast, mid or large-sized daughter corms number decreased by 36 and 25%, respectively (Table 8).

Based on the obtained results, intercropping played a considerable role in increasing saffron daughter corms growth and yield (Table 8). For instance, large-sized daughter corms number doubled when saffron was intercropped with pumpkin (74.7 corms m^{-2}) and irrigated with 14 days irrigation interval treatment compared with saffron monoculture (36 corms m^{-2}). Furthermore, intercropping could increase large-sized daughter corms number to total number of daughter corms ratio (Table 8).

Irrespective of irrigation treatments, saffron + pumpkin was more effective in increasing mid and large-sized daughter corms number and weight compared with saffron + watermelon (Table 8).

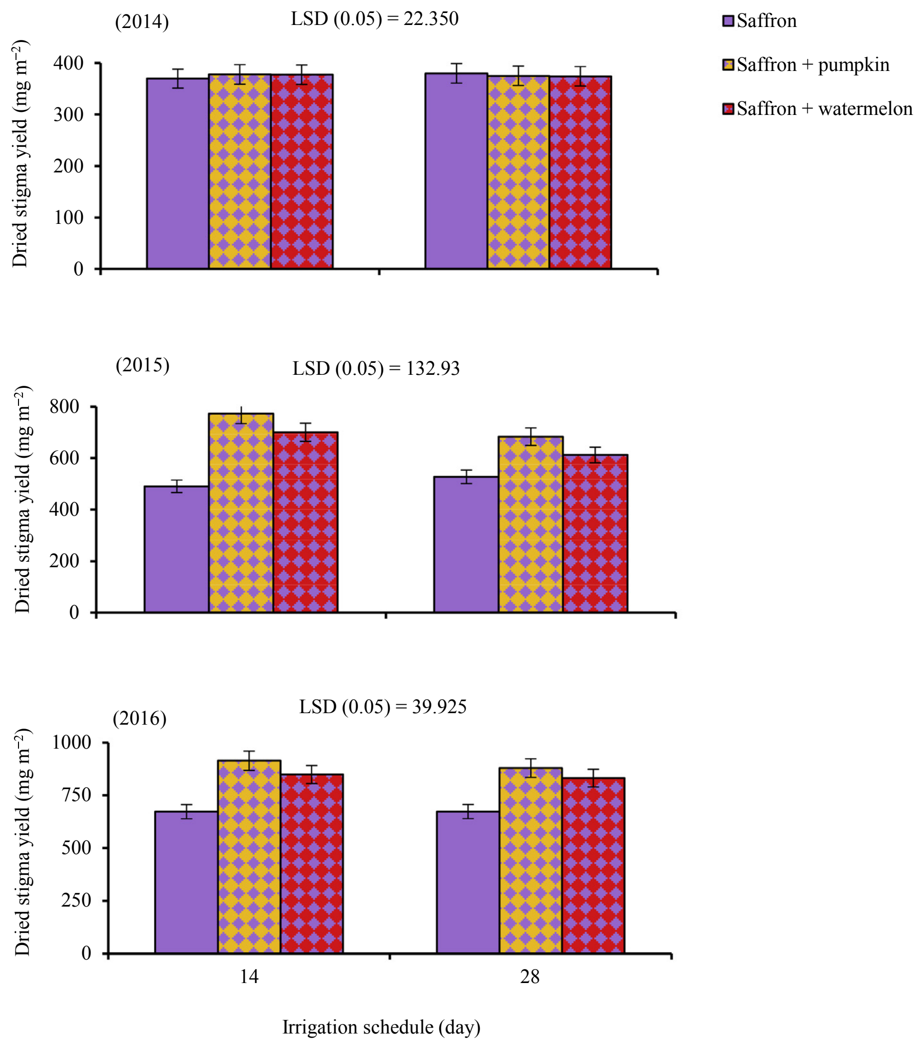

Fig. 4. Dried stigma yield of saffron in relation to irrigation intervals and cropping systems during years of the experiment (2014–2016).

Table 4
Mean single fruit weight, 1000-seed weight, seed yield and seed oil content of pumpkin in relation to irrigation intervals and cropping systems during growing seasons.

Experimental treatments	Mean single fruit weight (kg)		1000-seed weight (g)		Seed yield (kg ha^{-1})		Seed oil content (%)	
	2015	2016	2015	2016	2015	2016	2015	2016
Irrigation intervals (day)								
14	2.80	2.78	175.75	178.21	776.12	731.44	38.34	38.34
28	1.67	1.50	135.81	129.70	369.46	344.84	44.17	45.34
LSD (P = 0.05)	*0.037*	*0.030*	*6.276*	*6.445*	*24.814*	*14.785*	*0.740*	*0.538*
Cropping systems								
Pumpkin	2.23	2.15	159.21	156.85	581.05	544.15	41.00	41.83
Saffron + pumpkin	2.25	2.13	152.34	151.06	564.52	532.13	41.50	41.83
LSD (P = 0.05)	*0.058*	*0.047*	*8.599*	*8.284*	*39.234*	*23.377*	*1.169*	*0.851*
Irrigation intervals (day) × cropping systems								
14 × Pumpkin	2.78	2.80	180.11	181.56	783.81	737.59	38.00	38.67
14 × Saffron + pumpkin	2.82	2.75	171.39	174.86	768.42	725.29	38.67	38.00
28 × Pumpkin	1.67	1.49	138.31	132.13	378.29	350.70	44.00	45.00
28 × Saffron + pumpkin	1.67	1.50	133.30	127.26	360.63	338.97	44.33	45.67
LSD (P = 0.05)	*0.083*	*0.066*	*10.089*	*10.230*	*55.486*	*33.059*	*1.654*	*1.204*
Irrigation intervals	*	*	*	*	*	*	*	*
Cropping systems	NS	NS	NS	NS	NS	NS	NS	NS
Irrigation intervals × cropping systems	*	*	*	*	*	*	*	*

*, Statistical differences at $p \leq 0.01$. *NS*, Non-significant.

On the other hand, due to saffron + pumpkin in comparison with saffron + watermelon, small-sized daughter corms number and weight decreased by 6.2% and 5.5%, respectively (Table 8). Among experimental treatments, the minimum small-sized daughter

Table 5
Mean single fruit weight and fruit yield of watermelon in relation to irrigation intervals and cropping systems during growing seasons.

Experimental treatments	Mean single fruit weight (kg)		Fruit yield (t ha^{-1})	
	2015	2016	2015	2016
Irrigation intervals (day)				
14	2.54	2.57	59.16	65.69
28	1.41	1.46	19.72	21.92
LSD (P = 0.05)	*0.021*	*0.041*	*1.031*	*1.905*
Cropping systems				
Watermelon	1.97	2.03	39.90	43.91
Saffron + watermelon	1.97	2.00	38.98	43.70
LSD (P = 0.05)	*0.032*	*0.065*	*1.630*	*3.013*
Irrigation intervals (day) × cropping systems				
14 × Watermelon	2.53	2.59	59.69	65.65
14 × Saffron + watermelon	2.54	2.55	58.63	65.72
28 × Watermelon	1.41	1.47	20.10	22.16
28 × Saffron + watermelon	1.40	1.44	19.33	21.68
LSD (P = 0.05)	*0.046*	*0.092*	*2.305*	*4.261*
Irrigation intervals	*	*	*	*
Cropping systems	NS	NS	NS	NS
Irrigation intervals × cropping systems	*	*	*	*

*, Statistical differences at $p \le 0.01$. *NS*, Non-significant.

corms percentage (39.2% of total daughter corms) was related to saffron + pumpkin intercropping and 14 days irrigation interval treatment (Table 8).

3.5. N and P uptake in daughter corms

According to the results, N and P concentrations and content in small, mid and large-sized daughter corms were significantly affected by interaction between irrigation regimes and planting patterns (Tables 9 and 10).

Under both irrigation intervals, the minimum N and P concentrations in mid and large-sized daughter corms were observed when saffron was cultivated as single crop (Tables 9 and 10). Similar results were found in case of N and P content. For instance, N content in large-sized daughter corms increased three times when saffron was intercropped with pumpkin and irrigated with 14 days irrigation interval treatment compared with saffron monoculture (Tables 9 and 10).

In all three cropping patterns, 28 days irrigation interval treatment in comparison with 14 days irrigation interval treatment could increase N and P concentrations in saffron daughter corms. For example, N concentration in large-sized daughter corms increased by 13.7% on account of 28 days irrigation interval treatment (Tables 9 and 10).

Although N and P concentrations increased, 28 days irrigation interval treatment played a significant role in decreasing N and P content in saffron daughter corms (Tables 9 and 10). According to Eqn. (1), reduction in N and P content in saffron daughter corms, grown under 28 days irrigation interval treatment, might be due to reduction in corms weight.

Based on the results, N and P concentrations increased with increasing daughter corms size. For example, N and P concentrations in large-sized daughter corms increased more than two times compared with small-sized daughter corms (Tables 9 and 10).

4. Discussion

4.1. Saffron flower

The lack of effect of irrigation schemes (14 or 28 days intervals) on flower number and dried stigma yield is justifiable according to

Table 6
Partial land equivalent ratios (LER) in relation to irrigation intervals and cropping systems during growing seasons.

Experimental treatments	LER_S			LER_P		LER_W		LER_{S+P}			LER_{S+W}		
	2014	2015	2016	2015	2016	2015	2016	2014	2015	2016	2014	2015	2016
Irrigation intervals (day)													
14	1.01	1.34	1.21	1.00	1.00	0.99	1.01	1.01	1.52	1.45	1.01	1.47	1.42
28	0.99	1.15	1.18	0.98	0.99	0.98	0.99	1.00	1.42	1.42	1.00	1.37	1.40
LSD (P = 0.05)	*0.025*	*0.052*	*0.024*	*0.053*	*0.026*	*0.024*	*0.037*	*0.025*	*0.069*	*0.049*	*0.025*	*0.079*	*0.049*
Cropping systems													
Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
Saffron + pumpkin	1.01	1.44	1.34	0.98	0.98	–	–	1.01	2.41	2.31	–	–	–
Saffron + watermelon	1.00	1.29	1.25	–	–	0.97	0.99	–	–	–	1.00	2.26	2.24
LSD (P = 0.05)	*0.040*	*0.078*	*0.069*	*0.084*	*0.041*	*0.038*	*0.058*	*0.040*	*0.204*	*0.078*	*0.040*	*0.204*	*0.078*
Irrigation intervals (day) × cropping systems													
14 × Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
14 × Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
14 × Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
14 × Saffron + pumpkin	1.02	1.58	1.36	0.99	0.99	–	–	1.02	2.57	2.35	–	–	–
14 × Saffron + watermelon	1.02	1.43	1.27	–	–	0.98	1.01	–	–	–	1.02	2.41	2.27
28 × Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
28 × Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
28 × Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
28 × Saffron + pumpkin	0.99	1.30	1.31	0.96	0.97	–	–	0.99	2.26	2.27	–	–	–
28 × Saffron + watermelon	0.99	1.15	1.24	–	–	0.96	0.98	–	–	–	0.99	2.11	2.21
LSD (P = 0.05)	*0.057*	*0.151*	*0.098*	*0.119*	*0.059*	*0.054*	*0.082*	*0.057*	*0.288*	*0.082*	*0.057*	*0.288*	*0.082*
Irrigation intervals	NS	*	*	NS	NS	NS	NS	NS	*	NS	NS	*	NS
cropping systems	NS	**	**	NS	NS	NS	NS	NS	**	**	NS	**	**
Irrigation intervals × cropping systems	NS	**	**	NS	NS	NS	NS	NS	**	**	NS	**	**

*, Statistical differences at $p \le 0.05$.
**, Statistical differences at $p \le 0.01$. *NS*, Non-significant. LER_S, LER_P and LER_W are partial LER of saffron, pumpkin and watermelon, respectively. LER_{S+P}: $LER_S + LER_P$. LER_{S+W}: $LER_S + LER_W$.

Table 7
Partial economic land equivalent ratios (Economic LER) in relation to irrigation intervals and cropping systems during growing seasons.

Experimental treatments	$ELER_S$			$ELER_P$		$ELER_W$		$ELER_{S+P}$			$ELER_{S+W}$		
	2014	2015	2016	2015	2016	2015	2016	2014	2015	2016	2014	2015	2016
Irrigation intervals (day)													
14	1.03	1.85	1.50	1.00	0.99	0.99	1.01	1.03	1.83	1.62	1.03	1.67	1.54
28	0.99	1.37	1.41	0.98	0.97	0.97	0.99	1.00	1.54	1.55	0.99	1.46	1.50
LSD (P = 0.05)	*0.052*	*0.258*	*0.115*	*0.107*	*0.052*	*0.048*	*0.071*	*0.052*	*0.192*	*0.115*	*0.052*	*0.172*	*0.115*
Cropping systems													
Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
Saffron + pumpkin	1.02	2.09	1.79	0.97	0.96	–	–	1.02	3.06	2.75	–	–	–
Saffron + watermelon	1.01	1.75	1.58	–	–	0.95	0.99	–	–	–	1.01	2.69	2.57
LSD (P = 0.05)	*0.082*	*0.407*	*0.182*	*0.169*	*0.082*	*0.076*	*0.113*	*0.082*	*0.461*	*0.182*	*0.082*	*0.461*	*0.182*
Irrigation intervals (day) × cropping systems													
14 × Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
14 × Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
14 × Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
14 × Saffron + pumpkin	1.05	2.51	1.87	0.99	0.98	–	–	1.05	3.50	2.85	–	–	–
14 × Saffron + watermelon	1.05	2.05	1.62	–	–	0.98	1.01	–	–	–	1.05	3.02	2.63
28 × Saffron	1.00	1.00	1.00	–	–	–	–	1.00	1.00	1.00	1.00	1.00	1.00
28 × Pumpkin	–	–	–	1.00	1.00	–	–	–	1.00	1.00	–	–	–
28 × Watermelon	–	–	–	–	–	1.00	1.00	–	–	–	–	1.00	1.00
28 × Saffron + pumpkin	0.99	1.68	1.71	0.95	0.94	–	–	0.99	2.63	2.65	–	–	–
28 × Saffron + watermelon	0.97	1.44	1.53	–	–	0.93	0.97	–	–	–	0.97	2.37	2.50
LSD (P = 0.05)	*0.115*	*0.576*	*0.257*	*0.239*	*0.116*	*0.108*	*0.159*	*0.115*	*0.652*	*0.257*	*0.115*	*0.652*	*0.257*
Irrigation intervals	NS	*	NS	NS	NS	NS	NS	NS	*	NS	NS	*	NS
Cropping systems	NS	**	**	NS	NS	NS	NS	NS	**	**	NS	**	**
Irrigation intervals × cropping systems	NS	**	**	NS	NS	NS	NS	NS	**	**	NS	**	**

*, Statistical differences at $p \leq 0.05$.
**, Statistical differences at $p \leq 0.01$. *NS*, Non-significant. $ELER_S$, $ELER_P$ and $ELER_W$ are partial economic LER of saffron, pumpkin and watermelon, respectively. $ELER_{S+P}$: $ELER_S + ELER_P$. $ELER_{S+W}$: $ELER_S + ELER_W$.

Table 8
Number and weight of saffron daughter corms in relation to irrigation intervals and cropping systems.

Experimental treatments	Number of daughter corms (m^2)				Weight of daughter corms (m^2)			
	5 g and lower	5.1–10 g	Over 10 g	Total	5 g and lower	5.1–10 g	Over 10 g	Total
Irrigation intervals (day)								
14	213.8	122.0	76.5	412.3	647.5	1006.5	993.4	2647.4
28	239.6	95.9	62.8	398.2	678.7	750.5	811.1	2240.3
LSD (P = 0.05)	*9.29*	*7.55*	*4.39*	*13.32*	*14.83*	*54.63*	*58.26*	*92.9*
Cropping systems								
Saffron	349.9	78.2	42.0	470.0	822.7	585.7	471.6	1879.9
Saffron + pumpkin	159.9	129.4	87.0	376.2	566.9	1054.3	1192.4	2813.5
Saffron + watermelon	170.4	119.4	80.0	369.7	599.9	995.6	1042.8	2638.2
LSD (P = 0.05)	*14.69*	*11.94*	*6.94*	*21.06*	*23.44*	*86.38*	*92.11*	*146.88*
Irrigation intervals (day) × cropping systems								
14 × Saffron	324.0 (69.2)	95.0 (20.3)	48.0 (10.2)	467.0	816.9 (39.8)	703.1 (34.2)	541.1 (26.0)	2061.1
14 × Saffron + pumpkin	153.7 (39.2)	142.0 (36.3)	96.3 (24.6)	392.0	543.4 (17.8)	1195.2 (39.2)	1311.2 (43.0)	3049.7
14 × Saffron + watermelon	163.7 (43.3)	129.0 (34.1)	85.3 (22.6)	378.0	582.2 (20.7)	1121.2 (39.6)	1127.9 (39.7)	2831.3
28 × Saffron	375.7 (79.4)	61.3 (12.9)	36.0 (7.7)	473.0	828.4 (48.8)	468.2 (27.7)	402.0 (23.4)	1698.7
28 × Saffron + pumpkin	166.0 (46.2)	116.7 (32.2)	77.7 (21.6)	360.3	590.3 (23.0)	913.3 (35.3)	1073.6 (41.7)	2577.2
28 × Saffron + watermelon	177.0 (49.1)	109.7 (30.1)	74.7 (20.7)	361.3	617.5 (25.4)	869.9 (35.4)	957.7 (39.2)	2445.1
LSD (P = 0.05)	*20.78*	*16.88*	*9.81*	*29.78*	*33.15*	*122.16*	*130.26*	*207.72*
Irrigation intervals	*	**	**	*	*	**	**	*
cropping systems	*	*	**	*	*	*	**	*
Irrigation intervals × cropping systems	*	**	**	**	*	**	**	**

*, Statistical differences at $p \leq 0.05$.
**, Statistical differences at $p \leq 0.01$. Daughter corms' size: ≤ 5 g or small-sized, 5.1–10 g or mid-sized and >10 g or large-sized. Number in parenthesis indicated percentage of each group of daughter corms (based on number or weight).

irrigation schedule. In other words, watermelon and pumpkin were irrigated by furrow method whereas saffron was irrigated using flooding method (Table 2).

According to saffron phenological cycle, saffron fields are free of vegetation from May to October and daughter corms are passing their dormancy period (Renau-Morata et al., 2012). However, flower induction is occurring during this time (Koocheki and Seyyedi, 2016b). On the other hand, optimum temperature for saffron flowering induction is 23 °C (Molina et al., 2005) so lack of vegetation during summer season not only increases soil erosion but also damages dormant corms through increasing soil temperature (Rezvani Moghaddam et al., 2013).

According to Fig. 1, no precipitation was recorded during summer seasons in 2014, 2015 and 2016. Furthermore, average maximum temperature were recorded as 35.0, 33.9 and 34.7 °C during these periods, respectively. Therefore, increase in flower

Table 9
N uptake in saffron daughter corms in relation to irrigation intervals and cropping systems.

Experimental treatments	N concentration (g kg^{-1})			N content (g m^{-2})			
	5 g and lower	5.1–10 g	Over 10 g	5 g and lower	5.1–10 g	Over 10 g	Total
Irrigation intervals (day)							
14	7.6	13.6	16.9	4.9	13.9	17.4	36.2
28	9.5	16.5	19.3	6.5	12.6	16.0	35.1
LSD (P = 0.05)	*0.25*	*0.27*	*0.71*	*0.23*	*1.03*	*1.37*	*2.04*
Cropping systems							
Saffron	8.7	13.5	16.6	7.2	7.8	7.8	22.7
Saffron + pumpkin	8.4	16.2	19.6	4.8	16.9	23.3	44.9
Saffron + watermelon	8.6	15.4	18.3	5.2	15.2	19.1	39.4
LSD (P = 0.05)	*0.40*	*0.42*	*1.12*	*0.36*	*1.62*	*2.16*	*3.23*
Irrigation intervals (day) × cropping systems							
14 × Saffron	7.6	12.2	15.1	6.3 (27.3)	8.6 (37.5)	8.3 (35.2)	23.1
14 × Saffron + pumpkin	7.4	14.6	18.5	4.0 (8.9)	17.5 (38.3)	24.3 (52.8)	45.8
14 × Saffron + watermelon	7.7	13.9	17.2	4.5 (11.4)	15.7 (39.7)	19.5 (48.9)	39.6
28 × Saffron	9.8	14.8	18.0	8.1 (36.4)	6.9 (31.3)	7.2 (32.3)	22.3
28 × Saffron + pumpkin	9.4	17.8	20.6	5.5 (12.6)	16.3 (36.9)	22.2 (50.5)	44.0
28 × Saffron + watermelon	9.4	16.9	19.4	5.8 (15.0)	14.7 (37.3)	18.6 (47.7)	39.1
LSD (P = 0.05)	*0.57*	*0.60*	*1.59*	*0.52*	*2.30*	*3.06*	*4.57*
Average	8.5	15.0	18.1	5.7	13.3	16.7	35.6
Irrigation intervals	*	**	**	*	*	*	*NS*
cropping systems	*NS*	**	**	**	**	**	*
Irrigation intervals × cropping systems	*	**	**	**	**	**	**

*, Statistical differences at $p \leq 0.05$.
**, Statistical differences at $p \leq 0.01$. *NS*, Non-significant. Daughter corms' size: ≤ 5 g or small-sized, 5.1–10 g or mid-sized and >10 g or large-sized. Number in parenthesis indicated percentage of N content in each group of daughter corms.

Table 10
P uptake in saffron daughter corms in relation to irrigation intervals and cropping systems.

Experimental treatments	P concentration (g kg^{-1})			P content (g m^{-2})			
	5 g and lower	5.1–10 g	Over 10 g	5 g and lower	5.1–10 g	Over 10 g	Total
Irrigation intervals (day)							
14	2.1	4.4	6.2	1.4	4.4	6.3	12.1
28	2.8	5.5	7.1	1.9	4.2	5.9	11.9
LSD (P = 0.05)	*0.05*	*0.06*	*0.06*	*0.05*	*0.13*	*0.26*	*0.38*
Cropping systems							
Saffron	1.7	3.1	4.2	1.4	1.8	2.0	5.1
Saffron + pumpkin	1.7	3.4	4.6	1.0	3.6	5.5	10.0
Saffron + watermelon	1.6	3.4	4.5	1.0	3.3	4.7	8.9
LSD (P = 0.05)	*0.10*	*0.09*	*0.10*	*0.08*	*0.36*	*0.41*	*0.60*
Irrigation intervals (day) × cropping systems							
14 × Saffron	1.4	2.7	4.0	1.1 (22.0)	1.9 (36.9)	2.2 (41.1)	5.3
14 × Saffron + pumpkin	1.4	3.0	4.3	0.8 (7.7)	3.6 (35.8)	5.6 (56.5)	10.0
14 × Saffron + watermelon	1.4	3.0	4.1	0.8 (9.6)	3.3 (37.8)	4.7 (52.6)	8.8
28 × Saffron	1.9	3.5	4.4	1.6 (31.5)	1.6 (33.3)	1.8 (35.2)	4.9
28 × Saffron + pumpkin	1.9	3.8	4.9	1.1 (11.2)	3.5 (34.9)	5.3 (54.0)	9.9
28 × Saffron + watermelon	1.8	3.7	4.8	1.1 (12.9)	3.2 (35.8)	4.6 (51.4)	8.9
LSD (P = 0.05)	*0.11*	*0.13*	*0.13*	*0.11*	*0.51*	*0.57*	*0.85*
Average	1.6	3.3	4.4	1.1	2.9	4.0	8.0
Irrigation intervals	*	*	**	*	*	*	*NS*
cropping systems	*NS*	*	*	**	*	**	*
Irrigation intervals × cropping systems	**	*	**	**	**	**	**

*, Statistical differences at $p \leq 0.05$.
**, Statistical differences at $p \leq 0.01$. *NS*, Non-significant. Daughter corms' size: ≤ 5 g or small-sized, 5.1–10 g or mid-sized and >10 g or large-sized. Number in parenthesis indicated percentage of P content in each group of daughter corms.

number and dried stigma yield under intercropping systems might be due to covering the soil surface by watermelon and pumpkin canopy which could reduce soil temperature, evaporation and nutrients loss during saffron dormancy period (Fig. 5). Increase in soil water content and reduced soil temperature from June to August have been reported by Olasantan (2007) who studied yam and pumpkin intercropping.

Balanced nutrients availability is one of the most important factors in improving daughter corms growth and saffron final yield (Behnia et al., 1999; Koocheki and Seyyedi, 2015, 2016a). Hence, gradual degradation of watermelon and pumpkin residues during autumn and winter, when saffron corms are active again, can help the saffron plants to uptake more nutrients during flowering stage. In this regard, it has been reported that, keeping wheat residue on the soil surface not only reduce soil temperature and evaporation but also improves soil physical and chemical characteristics, which leads to increased flowering and dried stigma yield (Rezvani Moghaddam et al., 2013). Similar results have been reported by Koocheki et al. (2016b) who investigated the positive effects of cumin (*Cuminum cyminum* L.) residue in summer season. On the other hand, increase in flower number and dried stigma yield in saffron-pumpkin intercropping system compared with saffron-

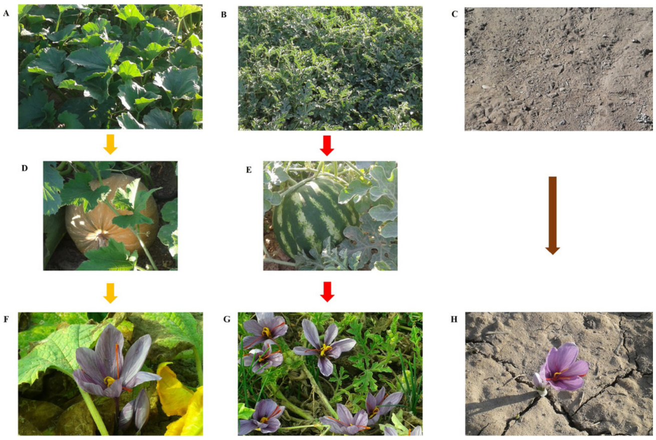

Fig. 5. Covering soil surface with pumpkin (A) and watermelon (B) canopy during saffron dormancy period (summer season), sole saffron during dormancy period (C), growing fruits of pumpkin (D) and watermelon (E), saffron flowers emergence (3rd of October 2015) onto pumpkin (F) and watermelon (G) above ground parts, flowers emergence in saffron monoculture system (H). Generally, saffron flowers appeared before its leaves emergence.

watermelon system might be due to higher leaf area in pumpkin compared with watermelon which cover more area of the soil surface and thus causes lower temperature and less evaporation (Fig. 5).

4.2. Pumpkin grain and watermelon fruit

As mentioned before, increase in irrigation interval from 14 to 28 days significantly reduced pumpkin seed yield and watermelon fruit yield. In this regard, the negative effects of drought stress on watermelon seed weigh and fruit yield have been reported (Erdem et al., 2001).

Although there are some reports stating that water deficit stress reduces pumpkin seed oil content (Eskandarizanjani et al., 2011; Yousefi, 2012), the results indicated that pumpkin seed oil content increased by increasing irrigation interval from 14 to 28 days (Table 4). In general, increase in seed oil content in response to increased irrigation interval may be considered as a physiological mechanism which increases plants ability in absorbing water under drought conditions. In other words, under water shortage conditions, increasing oil content probably regulates osmotic pressure and improves fruit growth through more water absorption. In this regard, increase in pumpkin seed oil content due to increased irrigation interval from 7 to 21 days has been reported (Yavuz et al., 2015b).

Although watermelon and pumpkin yield decreased due to extended irrigation interval (28 days), the yield was still acceptable. For instance, in the third year, watermelon monoculture with 28 days irrigation interval produced 22.2 ton fruit. In addition, seed yield in pumpkin monoculture with 28 days irrigation interval (350.7 kg ha^{-1}) decreased by 52.5% compared with 14 days irrigation interval (737.6 kg ha^{-1}). The results suggest that watermelon (Crimson Sweet cultivar) and pumpkin are partially drought resistant and can be intercropped with saffron in arid and semi-arid regions. Relative drought resistance in Crimson Sweet cultivar has been previously approved (Jafari and Jalali, 2015).

4.3. LER and ELER

As mentioned already, watermelon and pumpkin traits were not affected by intercropping (Tables 4 and 5), which might be due to this fact that watermelon and pumpkin were sown when saffron corms were passing their dormancy period (Fig. 1). Since during this period, saffron above ground parts are dried, watermelon or pumpkin cultivation won't be affected by positive or negative aspects of saffron. However, LER_S decreased due to increased irrigation interval from 14 to 28 days. Since, watermelon and pumpkin were sown to cover soil surface during summer season and considering the reduced yield on account of increased irrigation interval, reduction in LER_S might be due to negative effect of drought on vegetative growth and yield which in turn leads to reduced flowering in saffron. On the other hand, increase in LER_S due to saffron-pumpkin intercropping compared with saffron-watermelon intercropping may be due to higher leaf area in pumpkin which covers more soil surface during summer seasons.

With increasing LER_S, efficiency per unit of saffron field would increase which in turn increases $ELER_S$. Furthermore, considering the role of irrigation in improving pumpkin (Babayee et al., 2012; Yavuz et al., 2015a) and watermelon (Erdem et al., 2001; Wang et al., 2004) growth and yield, it can be concluded that water availability during summer season would increase LER_S and $ELER_S$. From the literature, increasing crop yield and farmers' income, improving resource use efficiency (Himmelstein et al., 2017) and promoting ecological services (Naudin et al., 2014; Norris et al., 2018) are among the most implications of proper intercropping patterns.

4.4. Daughter corms behavior

As mentioned before, saffron farms are bare and free of vegetation during dormancy period. (Koocheki and Seyyedi, 2015). The dormancy has two phases: true and apparent dormancy. Until mid of July, meristematic cells of the tip of the buds have detained activity, which is called true dormancy (Abrishamchi, 2003; Ahrazem et al., 2015). Apparent dormancy is also divided into two stages; during the first stages (until early August) vegetative organs start to develop, whereas during the second stage (until late August) reproductive organs differentiate (Abrishamchi, 2003; Molina et al., 2005; Gresta et al., 2009). Hence, loss of vegetation, especially in summer, increases soil erosion and soil overheating risk which is strongly linked to dormant corms damages. Accordingly, reduction in irrigation rounds hinders watermelon or pumpkin vegetative growth and left more area uncovered which means more sunlight and heat received by the soil which finally lead to damage to saffron flowering processes.

As mentioned already, the positive effect of intercropping on saffron production is related to the broader concept of vegetation in the fields. In other words, the complete coverage of the soil surface increase resource use efficiency and system productivity (Yadav et al., 2018), moderate soil temperature and reduce the evaporation and nutrients loss (Ebrahimian et al., 2016; Murungu et al., 2011), especially during saffron dormancy period (Koocheki et al., 2016b; Rezvani Moghaddam et al., 2013).

Generally, in arid and semi-arid regions, increase in soil organic matter, nutrients cycle recovery and reduced soil temperature are known as the most important results of conserving vegetation cover by a companion crop on soil surface (Mazzoncini et al., 2011; Zibilske and Makus, 2009). As shown in Fig. 5, higher leaf area of pumpkin, in comparison with watermelon, covers more soil surface area and reduce sunlight exposure which in turn reduces soil temperature and evaporation in summer season when saffron corms are passing dormancy period.

4.5. N and P uptake in daughter corms

As mentioned above, conserving vegetation in summer season is among the most effective solutions to reduce soil erosion and temperature (Unger, 1988; Koocheki et al., 2016b). On the other hand, nutrients availability, especially N and P, is a crucial factor in increasing saffron daughter corms formation and growth (Amiri, 2008; Khorramdel et al., 2015), therefore, gradual decomposition of pumpkin or watermelon residue during autumn and winter release micro and macro-nutrients which are necessary for saffron daughter corms formation and growth. In this context, the positive effects of wheat residues in improving soil organic matter and increasing large-sized daughter corms number has been reported by Rezvani Moghaddam et al. (2013).

In general, soluble and metabolites accumulation in plant cells are known as a defensive mechanism against drought and heat stress (Martínez et al., 2007; Rivero et al., 2001). Hence, it appears that, 28 days irrigation interval treatment causes less vegetative growth and left more soil area uncovered which in turn increases soil temperature and evaporation. In addition, it seems that saffron plants tolerate heat stress through increasing N and P concentration in the tissues. Similar results have been found by Koocheki et al. (2014) who stated that reduction in saffron water requirement from 100 to 50% increases P concentration in saffron daughter corms.

Generally, more nutrients will be stored in the corms when sink size (corm size) is increased (Gresta et al., 2008; Renau-Morata et al., 2012). Increase in nutrients concentration improves plants ability in absorbing other nutrients and eventually increases larger daughter corm formation at the end of the growing season. In this regard, Koocheki et al. (2014) have reported that increase in N and P concentrations might be due to daughter corms size. In a similar study, it has been reported that N and P uptake efficiency increased with increasing mother corms size (Koocheki and Seyyedi, 2015).

5. Conclusion

Because of no watermelon and pumpkin in the first year, LER_S was not affected by intercropping, however, in the second and the third years, covering soil surface with watermelon and pumpkin canopy during saffron dormancy period (summer season) accelerated saffron flowering, improved dried stigma yield, daughter corms growth and increased LER_S and $ELER_S$. In addition, in comparison with saffron monoculture, saffron intercropping with pumpkin or watermelon could increase N and P concentration in all sized daughter corms. Accordingly, the applicable outlooks for this research are affected by water availability during saffron dormancy period. In fact, as long as water is available during summer, saffron-watermelon or saffron-pumpkin intercropping in arid and semi-arid regions increases land efficiency and improves farmers' income during perennial life cycle of saffron. Overall, considering water shortage in arid and semi-arid regions, saffron-pumpkin or saffron-watermelon intercropping, as an agronomic strategy that can lead to clean and sustainable saffron production, is highly recommended.

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