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Corm weight or number per unit of land: Which one is more effective when planting corm, based on the age of the field from which corms were selected?

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ABSTRACT

In this study the best corm weight (4–6 g as small-sized and 6–8 g as medium-sized corms) and density (50, 75 and 100 corm m^{-2}) was determined for saffron fields in different ages (1, 2 and 3 years-old). For this purpose, a factorial experiment based on a randomized complete block design with 3 replications was performed during 3 growing seasons from autumn 2015 up to spring 2018, in Ferdowsi University of Mashhad research site. The highest flower number, flower and stigma yields in one- (21.7 flower per m^2, 67 and 0.97 kg ha^{-1}, respectively) and two-years old (70.4 flower per m^2, 214 and 2.92 kg ha^{-1}, respectively) fields were obtained from medium-sized and density of 100 corms per m^2, while in three-years old field, their maximum values (101 flower per m^2, 302 and 4.09 kg ha^{-1}, respectively) were gained when medium-sized corms were planted at density of 75 corms per m^2. The priority of corm weight in lower corm densities was higher, so that, flower yield in medium sized corms was 2.43, 1.87 and 1.62 times more than small-sized corm in 50, 75 and 100 corms per m^2 densities, respectively. Corm weight was prior to corm density, so that, planting of 3.5-ton ha^{-1} medium-sized corm with density of 50 corms per m^2, was produced more flower than planting of 5-ton ha^{-1} small-sized corm with density of 100 corms per m^2 (47.5 vs. 36.7 flower per m^2 and 1.99 vs. 1.50 kg ha^{-1} dry stigma). Corm weight preference in one- and two-years old fields were more than three-years old filed, where larger corms increased flower yield by 1.94, 2.15 and 1.75 times compared with small-sized ones in mentioned fields, respectively. Mean replacement corm weight and number of large replacement corms (> 9 g) decreased when small-sized mother corms were planted and when the farm became elderly. The highest replacement corm yield (52.8-ton ha^{-1}) and number (2034 NO. m^{-2}) were obtained when medium-sized mother corms were planted at density of 100 corms per m^2 and remained in field for three years. Overall, the corm harvesting from one-year-old field was preferable in terms of mean corm weight and production of larger replacement corms.

1. Introduction

Saffron stigma with more than 150 components has numerous applications in the food, cosmetic, health and pharmaceutical industries (Fallahi et al., 2017a,b). Saffron (*Crocus sativus* L.) as a member of Iridaceae is grown in Mediterranean region, from Kashmir in east to Spain in west and currently has about 90,000 ha cultivated area and 336-ton annual stigma production in Iran, which includes near 90% of its world production (Fallahi et al., 2018a). Flowering is the first phase of saffron life cycle which occurs in autumn simultaneously or shortly before the leaves emergence. After flowering, the roots, leaves and replacement corms growth continues during late-autumn and winter and in mid-spring with finalization of replacement corms growth and leaves senescence, the vegetative growth ends and real dormancy of produced corms starts (Behdani et al., 2016; Fallahi et al., 2016). Corm weight is the main factor for determining the capacity of saffron to flower. Small corms (below 6 g) usually do not flower in the first year and also exert a negative effect on the flowering of coming year's when saffron field is used for several years in one planting time (Gresta et al., 2008; De-Juan et al., 2009; Aghhavani-Shajari et al., 2015; Koocheki et al., 2016a,b).

Saffron is an annual herbaceous plant which its perennial cultivation is more common (Fallahi and Mahmoodi, 2018). However, due to failure to comply agronomic requirement mainly plant density and low access to standard mother corms its commercial flowering starts three

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years after corm planting, continues for about four years and then goes down to a lower level than economic production. Accordingly, the yield of field is acceptable only in four middle years in a period of eight years of field use and in other years, capital, time, water and land are not used well (Behdani and Fallahi, 2015). Therefore, it is necessary that research on saffron focus on providing solutions to achieve optimal yield in a shorter time frame. One of this solution is cultivation of saffron as an annual crop but with high corm density (Koocheki et al., 2014a). When saffron is cultivated annually, some of its cultivation principles such as corm size and density will be different from its perennial cultivation (Koocheki et al., 2014b). Therefore, it is necessary to determine the priority of these factors in relation to the number of years of use from saffron field. Probably the change in planting density would change the preference of the corm size, namely the use of bigger mother corms is preferable in lower planting densities. Similarly, when small mother corms are used, the use of higher corm density will be preferable (Behdani and Fallahi, 2015). In addition, the preference of corm size and density can be affected by the number of years that field is used (Koochaki et al., 2012). It seems that decreasing the number of years of saffron fields use especially annual cultivation will probably increase the priority of higher corm density and planting of bigger corms (Behdani and Fallahi, 2015). Although the recommended corm density in perennial cultivation of saffron is 50–75 corm per m^2, in some studies on saffron it has been concluded that in the first and second years after corm planting the highest flower and stigma yields were gained with planting density of 200–400 corms per m^2 (Koocheki et al., 2011; Koochaki et al., 2012; Koocheki et al., 2014a,b).

The main purpose of traditional saffron cultivation as a perennial crop is production of stigma at early years and corm at last year. However, this cultivation method has low efficiency in terms of time and used inputs, as described earlier. Therefore, some researchers believe that the flowering fields must be separated from corm producing ones (Mohammad-Abadi et al., 2011). At flowering fields, the number of years of field usage (field age) must be reduced compared with traditional cultivation, and proper corm size and density also should be considered (Behdani and Fallahi, 2015). So far, the combined effect of these parameters has not been carefully investigated. Accordingly, the aim of this study was to investigate the interaction of mother corm size and planting density and to determine the priority of these factors in order to increase the yield of saffron in different years after planting.

2. Materials and methods

This study was performed at research field of Ferdowsi University of Mashhad during 2015–2018. Mashhad (36 °N, 59°E and 985 m above sea level) is located in northeast of Iran and is characterized by semi-arid climate with average annual precipitation of 233 mm and mean annual temperature of 15.5 °C. The main climatic parameters of research location are shown in Fig. 1.

Table 1
The main chemical and physical properties of soil in experimental station.

pH	EC (dS m^{-1})	Organic matter (%)	N total (ppm)	P ava	K ava	Soil texture
Soil						
7.7	4.7	0.65	650	55	195	Silty loam
Cow manure						
7.3	4.60	97.7	11000	750	4125	–

The aim of this study was to investigate the effect of mother corm size [4–6 g as small-sized (SSMC) and 6–8 g as medium-sized corms (MSMC)], corm density (50, 75 and 100 corms per m^2) and the number of field use years (Field age as 1, 2 or 3 years). For this purpose, a factorial experiment based on a randomized completely block design with three replications was used. All studied plots were fertilized one time before corm planting in September 2015, with 40-ton ha^{-1} rotten cow manure. The main chemical and physical properties of used cow manure and soil in experimental site are presented in Table 1. Corm planting was done in September 10, with density of 50, 75 or 100 corms per m^2 (planting distances of 20 × 10, 20 × 7.5 and 20 × 5 cm, respectively) at the depth of 15 cm in plot with 2 m^2 area. It must be noted that for one-year-old field (OYOF) corm planting was done three times in September 2015, 2016 and 2017, while for two- (TYOF) and three years-old fields (ThYOF) it was done only one time in September 2015 (Fig. 2). Considering planting density and corm weight, the amount of corm used for densities of 50, 75, and 100, when small-sized corms were used was about 2.50, 3.75 and 5-ton ha^{-1} and when medium-sized corms were used was about 3.50, 5.25 and 7-ton ha^{-1}, respectively. In all three growth seasons irrigation was done 5 times during saffron growth cycle (pre- and post-flowering irrigation + 2 irrigations during winter including early February and early March and one irrigation in mid-April). In all plots, hand weeding was done two times in each growing season, one time in mid-winter and another in early spring.

Flower picking up was done from early- to late-November of 2015, 2016 and 2017 in all three field use types. Flowers were harvested, counted and weighted daily and then their stigmas were separated and dried in shade condition and room temperature (~25 °C). The mean data of flowering parameters (flower number, flower yield and stigma yield) during flowering period of three studied years was used for statistical analysis. Corm harvesting was applied at the end of period of field use. Therefore, for OYOF, three times corm harvesting was done (Fig. 2) and then mean data of three years was used for statistical analysis, while in TYOF and ThYOF corms were harvested one time in May 2017 and 2018, respectively (Fig. 2). The measured corm indices were number of replacement corms per m^2, replacement corm yield and mean replacement corm weight. Moreover, the number of replacement corms in weighing groups of < 3, 3–6, 6–9 and > 9 g was counted in all

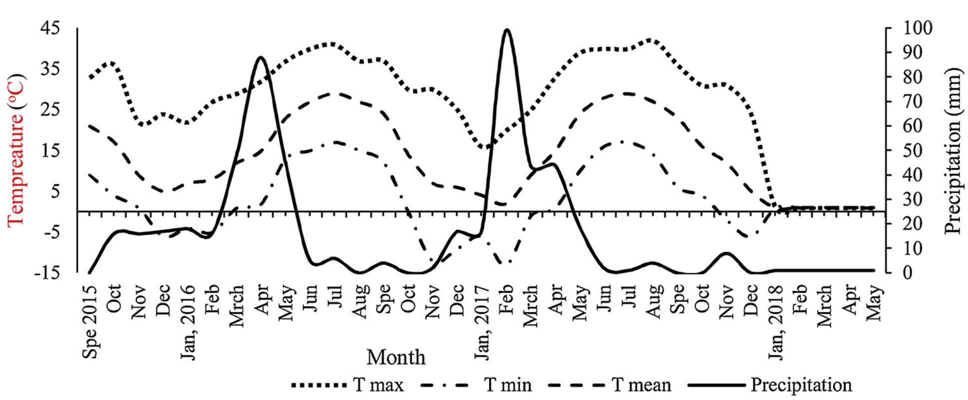

Fig. 1. Trend of temperature and precipitation in study station during experimental period.

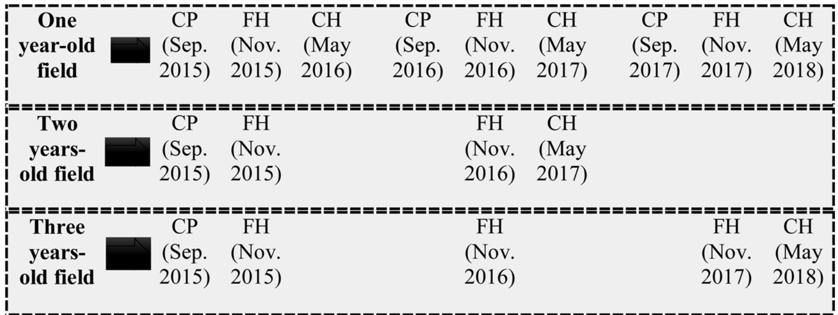

Fig. 2. Agronomic scheduling of three field use types in saffron. CP = corm planting, FH = flower harvesting, CH = corm harvesting.

sampling dates. In saffron during each season replacement corms which are also called daughter corms, develop on the buds of mother corm. Their production starts from late-November to mid-December, continues during winter and even during early spring but at lower rates (Behdani and Fallahi, 2015; Fallahi and Mahmoodi, 2018). In current study, replacement corms of 20 plants were lifted from the soil of each plot separately, at the end of growing season in mid-spring and then the criteria related to replacement corms growth were measured.

At the end of the study, all vegetative and reproductive data were subjected to analysis of variance procedures (using SAS 9.2) and means were compared by LSD test at 5% level of probability.

3. Results and discussion

3.1. Corm growth

Interaction effects of experimental factors were significant on number of replacement corms (RC) in different weight groups, mean RC weight and RC yield (Table 2). Increase in field age and mother corm (MC) weight enhanced the number of replacement corms in groups weight of below 3 and 3–6 g (Table 3). In saffron large corms are considered as one of the most important factors in flowering (Aghhavani-Shajari et al., 2015; Koocheki et al., 2016a,b) and we found that the highest number of this corms (above 9 g) obtained when medium-sized mother corms (MSMC) were planted and the field was used for one-year (Table 3). In similar study planting of large MC caused more RC initiation as well as more root, leaves and RC weight (Fallahi et al., 2017b).

Field age had a considerable effect on number of RC, where their number in one-year old field (OYOF), two-years old field (TYOF) and three-years old field (ThYOF) was 228, 615 and 1107 corm per m^2, respectively (Fig. 3). In all fields in different ages, total number of RC and their number in groups weights of < 3 and 3–6 g increased by increase in corm density, while in group weight of 6–9 g the highest value was obtained at 50 or 75 corm densities. In addition, in all levels of corm density the number of RC in group weight of more than 9 g were gained in OYOF (Table 4). Interaction effect of corm density and corm weight also revealed a positive relation between increased in both mentioned factors with RC production (Table 5) which was similar with those reported previously by Rezvani-Moghaddam et al. (2013) on saffron. Combined effect of all experimental factors showed that RC production in saffron increases when larger MCs are planted in higher densities and when the field becomes elderly. However, production of larger RCs (> 9 g) requires the reduce in field age to one year, the planting of larger MC in density of 75 or 100 corms per m^2 (Table 6).

The highest corm yield was obtained in ThYOF and when MSMC

Table 2
Mean of squares for the effects of mother corm size, corm density and the age of field on saffron flowering and corm growth parameters.

S.O.V	df	Total number of replacement corm	Number of replacement corms in different weight groups			
			< 3 g	3–6 g	6–9 g	> 9 g
Replication	2	17923.5^{ns}	667.4^{ns}	370.3^{ns}	0.74^{ns}	9.3^{ns}
Field age (FA)	2	3497017.4**	2,681,400.9**	81,398.6**	862.6**	3529.9**
Corm size (CS)	1	324646.1**	256,384.2**	3.1^{ns}	320.2**	1758.4**
Corm density (D)	2	3147373.8**	2,325,963.7**	52,583.8**	256.6**	406.2**
FA × CS	2	20209.4^{ns}	54763.9**	13,878.3**	20.7^{ns}	1042.9**
FA × D	4	679731.9**	582,385.5**	12,781.1**	290.3**	760.8**
CS × D	2	94460.1**	79,038.6**	1902.4^{ns}	276.5**	160.5**
FA × CS × D	4	34169.0*	39,763.3**	1894.5*	572.5**	458.8**
Error	34	11411.0	1006.4	651.3	6.94	6.32
Total	53	–	–	–	–	–
C.V. (%)	–	16.4	6.1	23.7	16.8	25.7

SOV	df	Corm yield	Mean weight of replacement corms	Number of flower	Flower yield	Stigma yield
Replication	2	7273043^{ns}	1.167^{ns}	15.5^{ns}	315.1^{ns}	0.030^{ns}
Field age (FA)	2	1729307559**	24.628**	14,515.0**	131,314.1**	23.307**
Corm size (CS)	1	471990413**	3.744*	8332.0**	82,585.7**	15.274**
Corm density (D)	2	2998731317**	0.260^{ns}	877.5**	7044.2**	1.365**
FA × CS	2	49972339**	3.310**	998.3**	9512.4**	1.585**
FA × D	4	224164018**	3.515**	213.6**	1728.4**	0.331**
CS × D	2	134550353**	0.093^{ns}	58.1*	472.7*	0.090^{ns}
FA × CS × D	4	114747267**	1.689*	237.5**	2081.0**	0.328**
Error	34	5405192	0.634	14.06	148.8	0.035
Total	53	–	–	–	–	–
C.V. (%)	–	10.2	19.8	9.0	9.6	10.9

ns: no-significant, * and **: significant at 5% and 1% levels of probability, respectively.

Table 3
mean comparison for the effect of mother corm size and field age on flowering and corm growth of saffron.

Field age (year)	Mother corm size	Number of replacement corm per m^2 in different weight groups			Corm yield (kg ha^{-1})
		< 3 g	3-6 g	> 9 g	
1	Small-sized (4–6 g)	125.9^{d}	30.9^{d}	11.47^{b}	8199^{d}
	Medium-sized (6–8 g)	136.5^{d}	77.3^{cd}	40.34^{a}	17063^{cd}
2	4–6	419.8^{cd}	77.5^{cd}	0.66^{bc}	19776^{bcd}
	6–8	616.0^{bc}	100.3^{bc}	1.55^{bc}	26353^{abc}
3	4–6	799.8^{ab}	213.5^{a}	0.00^{c}	31071^{ab}
	6–8	1006.5^{a}	150.8^{b}	4.48^{bc}	33370^{a}

Field age (year)	Mother corm size	Mean weight of replacement corms (g)	Number of flower per m^2	Flower yield (kg ha^{-1})	Dry stigma yield (kg ha^{-1})
1	4–6	4.47^{b}	9.6^{d}	28.9^{d}	0.41^{d}
	6–8	5.93^{a}	18.1^{cd}	56.3^{c}	0.81^{c}
2	4–6	4.06^{b}	26.0^{c}	77.9^{c}	1.03^{c}
	6–8	3.85^{bc}	54.3^{b}	168.1^{b}	2.29^{b}
3	4–6	2.70^{d}	51.7^{b}	154.8^{b}	2.12^{b}
	6–8	3.03^{cd}	89.4^{a}	271.8^{a}	3.65^{a}

In each column, data with the same letters are not significantly different based on LSD test at 5% level of probability.

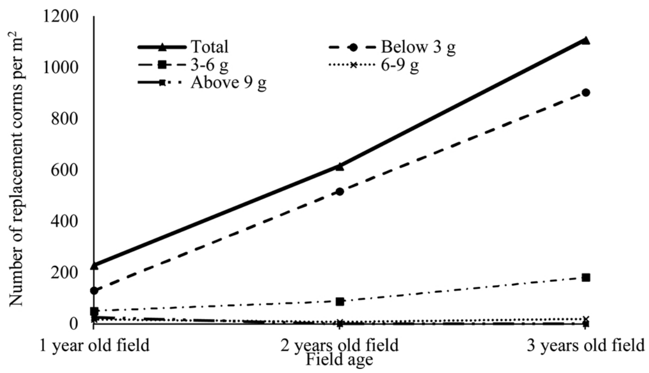

Fig. 3. Relationship of saffron field age with number of replacement corms in different weight groups (Date represents the simple effect of field age; therefore, they are a mean of two mother corms size and three densities).

were planted, which was 4.07 times more than planting of small-sized mother corms (SSMC) in OYOF (Table 3). MC size had a main role in RC yield, so that for example, planting of MSMC in OYOF nearly produced as yield as obtained from SSMC but in TYOF (Table 3). In all fields with different ages, the corm yield increased by increase in corm density and its maximum was obtained in ThYOF and planting of 100 corms per m^2, which was 9.5-fold of OYOF and planting of 50 corms per m^2 (Table 4). Corm yield increased when the density and weight of MC increased, so that, its highest obtained in density of 100 corms m^2 and planting of MSMC which was in same statistic group with SSMC at the same density (Table 5). Overall, the highest corm yield was gained in ThYOF which was cultivated with MSMC in density of 100 corm m^2, that was 13.2 times more than OYOF which was planted with SSMC and corm density of 50 per m^2 (Table 6). The highest and the lowest mean RC weight were obtained at OYOF × MSMC and ThYOF × SSMC, respectively, with 119% difference in amount (Table 3). In contrast with OYOF, increase in corm density in TYOF and ThYOF resulted to decrease in mean RC weight (Table 4). Based on the interaction effects of three experimental factors, the highest mean RC weight was obtained in OYOF that

Table 4
mean comparison for the effect of corm density and field age on flowering and corm growth of saffron.

Filed age (year)	Density (corm per m^2)	Total number of replacement corm per m^2	Number of replacement corms in different weight groups (NO. m^{-2})			
			< 3 g	3-6 g	6-9 g	> 9 g
1	50	133^{f}	87^{e}	28^{f}	12.0^{bcd}	7.20^{b}
	75	212^{ef}	121^{e}	44^{ef}	18.1^{ab}	28.70^{a}
	100	338^{e}	185^{e}	83^{cde}	5.2^{cd}	41.83^{a}
2	50	229^{ef}	164^{e}	59^{def}	27.2^{a}	0.50^{b}
	75	591^{d}	486^{d}	89^{bcd}	14.5^{bc}	1.83^{b}
	100	1026^{b}	903^{b}	119^{bc}	3.3^{d}	1.00^{b}
3	50	528^{d}	387^{d}	114^{bc}	20.1^{ab}	6.72^{b}
	75	823^{c}	668^{c}	128^{b}	26.8^{a}	0.00^{b}
	100	1971^{a}	1653^{a}	305^{a}	13.4^{bcd}	0.00^{b}

Filed age (year)	Density (corm per m^2)	Corm yield (kg ha^{-1})	Mean weight of replacement corms (g)	Number of flower per m^2	Flower yield (kg ha^{-1})	Stigma yield (kg ha^{-1})
1	50	5641^{e}	4.17^{c}	10.5^{e}	33.2^{e}	0.47^{e}
	75	11554de	5.33^{ab}	13.4^{e}	41.0^{e}	0.59^{e}
	100	20698^{c}	6.10^{a}	17.6^{e}	53.6^{e}	0.77^{e}
2	50	10891^{e}	4.44^{bc}	28.3^{de}	88.9^{de}	1.22^{de}
	75	22257^{c}	3.99^{cd}	40.1^{cd}	122.9^{cd}	1.62^{c}d
	100	36045^{b}	3.44^{cde}	52.1^{bc}	157.3^{bc}	2.15^{bc}
3	50	18349^{cd}	2.99^{de}	62.1^{ab}	190.4^{ab}	2.56^{ab}
	75	24528^{c}	2.91^{de}	78.1^{a}	233.7^{a}	3.17^{a}
	100	53784^{a}	2.69^{e}	71.5^{a}	215.9^{ab}	2.92^{ab}

In each column, data with the same letters are not significantly different based on LSD test at 5% level of probability.

Table 5
mean comparison for the effect of corm density and corm weight on flowering and replacement corms growth of saffron.

Corm density (No. m^{2})	Mother corm weight	Total number of replacement corm per m^{2}	Number of replacement corms in different weight groups per m^{2}		
			< 3 g	6-9 g	> 9 g
50	Small-sized (4-6 g)	241^{c}	174^{c}	6.8^{c}	2.5^{b}
	Medium-sized (6-8 g)	354^{bc}	251^{bc}	18.2^{ab}	7.1^{ab}
75	4-6	384^{bc}	281^{bc}	16.3^{abc}	2.3^{b}
	6-8	700^{ab}	570^{ab}	23.3^{a}	10.0^{ab}
100	4-6	1094^{a}	890^{a}	16.5^{abc}	2.3^{ab}
	6-8	1130^{a}	937^{a}	12.7^{bc}	21.2^{a}

Corm density (No. m^{2})	Mother corm weight (g)	Corm yield (kg ha^{-1})	Number of flower per m^{2}	Flower yield (kg ha^{-1})	Dry stigma yield (kg ha^{-1})
50	4-6	8466^{c}	19.8^{c}	60.7^{c}	0.84^{c}
	6-8	14787^{c}	47.5^{ab}	147.6^{ab}	1.99^{ab}
75	4-6	13864^{c}	30.8b^{c}	92.1^{bc}	1.22^{bc}
	6-8	25029^{b}	56.9^{a}	172.9^{a}	2.36^{a}
100	4-6	36716^{a}	36.7^{abc}	108.4^{abc}	1.50^{abc}
	6-8	36968^{a}	57.5^{a}	175.7^{a}	2.40^{a}

In each column, data with the same letters are not significantly different based on LSD test at 5% level of probability.

was planted with MSMC and corm density of 75 or 100 per m^{2}, which was near to planted MCs weight (Table 6).

In a similar study on saffron, Douglas et al. (2014) found that a three-year management cycle is suitable for flower production, but if large RC are desired a two-year management cycle has more profitability. Tavakkoli Kakhki et al. (2016) also reported that planting of 80 MC per m^{2} using large corms (9–12 g) was superior than density of 160 corms per m^{2} using small corm in terms of producing large RC during the first and second growth cycles, although total number of RC was higher in highest corm density. In another study corm size and density of saffron was optimized by central composite design and reported that the optimum level of corm density at the first growing season is 250 corm m^{-2}, when small corms (below 7 g) are used for planting (Nassiri Mahallati et al., 2015). In our research the best treatment for higher corm production was planting of MSMC with high density and harvesting of produced RCs after three years, while the best treatment for production of large RCs (> 9 g) was planting of MSMC with density of 75–100 corm per m^{2} and lifting of produced RCs at the end of the first growing season (Table 6). In saffron cultivation, production of large RC has higher importance than the total number of produced RC (Behdani and Fallahi, 2015), Accordingly, we think that using MSMC it's possible to produce considerable percentage of desired RC only during one growing season (Table 6). However, there is a significant relation between MC weight and the number of years that is needed for production of RCs with desired weight, as results of Fallahi et al. (2018b) showed that when small (< 4 g), medium (4–8 g) and large (8–12 g) MCs were planted, the percentage of RCs with weight of more than 6 g were 47.5, 39.7 and 29% at the end of first growing season, while were 43.4, 43.0 and 47.6%, respectively, at the end of second growing season. Therefore, they concluded that more than one year in needed to reach the small RCs to favorite weight, although we can't confirm their statement based on results presented in Table 3.

3.2. Reproductive growth parameters

Results of analysis of variation (Table 2) indicated a significant different between experimental factors in terms of number of flower (FN), flower yield (FY) and dry stigma yield (SY). Application of MSMC in all three types of fields ages had a high advantage than SSMC in terms of flowering parameters, although this benefit in OYOF and TYOF was more than ThYOF. In confirmation of this statement FN, FY and SY, when MSMC were used in OYOF was 1.88, 194 and 1.97 times more

Table 6
interaction effect of corm density, corm weight and field age on saffron flowering and corm growth.

Filed age (year)	Corm size	Density (corm per m^{2})	Total number of replacement corm per m^{2}	Number of replacement corms in different weight groups per m^{2}				Corm yield (kg ha^{-1})	Mean weight of replacement corms (g)	Number of flower per m^{2}	Flower yield (kg ha^{-1})	Stigma yield (kg ha^{-1})
				< 3 g	3-6 g	6-9 g	> 9 g					
1	Small-sized (4-6 g)	50	97^{i}	69^{k}	15^{k}	6.3^{ij}	7.53^{e}	3994^{h}	4.07^{b-e}	5.7^{n}	17.8^{n}	0.25^{k}
		75	143^{hi}	91^{k}	25^{jk}	21.1^{d}	6.00^{ef}	6103^{h}	4.42^{bc}	9.5^{mn}	28.7^{mn}	0.41^{jk}
		100	311^{gh}	217^{i}	53$^{g\text{-}k}$	19.2^{de}	20.9^{c}	14500^{g}	4.92^{b}	13.5^{lm}	40.1^{lm}	0.57^{ij}
	Medium-sized (6-8 g)	50	170^{hi}	104^{jk}	40^{h-k}	17.8^{def}	6.85^{e}	7287^{h}	4.28^{bcd}	15.3^{lm}	48.7^{klm}	0.69^{hij}
		75	281^{gh}	152^{j}	62^{g-j}	15.1^{efg}	51.4^{b}	17005^{fg}	6.25^{a}	17.3^{kl}	53.2^{kl}	0.77^{ghi}
		100	366^{fg}	152^{j}	113de	35.2^{b}	62.7^{a}	26895^{d}	7.28^{a}	21.7^{jk}	67.0^{jk}	0.97^{gh}
2	Small-sized (4-6 g)	50	91^{i}	55^{k}	36^{ijk}	0.66^{k}	0.00^{g}	4092^{h}	4.14^{bcd}	16.4^{kl}	51.1^{kl}	0.70^{hij}
		75	357^{fg}	274^{h}	68^{f-i}	14.3^{fg}	1.00^{g}	14342^{g}	4.20^{bcd}	27.8^{ij}	82.9^{ij}	1.01^{g}
		100	1063^{b}	931^{c}	127^{cd}	3.6^{jk}	1.00^{g}	40894^{b}	3.85^{b-f}	33.8^{hi}	99.8^{hi}	1.39^{f}
	Medium-sized (6-8 g)	50	366^{fg}	273^{h}	82^{e-h}	9.8^{hi}	1.00^{g}	17691^{efg}	4.75^{bc}	40.2^{g}	126.6^{g}	1.73^{e}
		75	824^{cd}	698^{e}	109^{def}	14.7^{fg}	2.66f^{g}	30171^{cd}	3.77^{b-f}	52.4^{f}	162.9^{f}	2.24^{d}
		100	989^{bc}	876^{d}	109^{def}	3.0^{jk}	1.00^{g}	31196^{c}	2.43^{g}	70.4^{d}	214.88^{d}	2.92^{c}
3	Small-sized (4-6 g)	50	533^{ef}	399^{g}	121^{cde}	13.4^{gh}	0.00^{g}	17313^{efg}	3.03^{d-g}	37.3^{gh}	113.3^{gh}	1.56^{ef}
		75	651de	477^{e}	161^{c}	13.4^{gh}	0.00^{g}	21145^{e}	3.07^{d-g}	55.2^{f}	164.6^{f}	2.25^{d}
		100	1908^{a}	1523^{b}	358^{a}	26.8^{c}	0.00^{g}	54755^{a}	2.61^{fg}	62.7^{e}	186.5^{e}	2.54^{d}
	Medium-sized (6-8 g)	50	524^{ef}	375^{g}	107^{def}	26.8^{c}	13.4^{d}	19384^{ef}	3.54^{c-g}	86.9^{b}	267.5^{b}	3.55^{b}
		75	994^{bc}	860^{d}	94^{d-g}	40.3^{a}	0.00^{g}	27911^{cd}	2.76^{efg}	101.0^{a}	302.7^{a}	4.09^{a}
		100	2034^{a}	1783^{a}	251^{b}	0.00^{k}	0.00^{g}	52813^{a}	2.78^{efg}	80.4^{c}	245.2^{c}	3.31^{b}

In each column, data with the same letters are not significantly different based on LSD test at 5% level of probability.

than SSMC, this values for TYOF were 2.08, 2.15 and 2.22, but for ThYOF were 1.72, 1.75 and 1.71, respectively (Table 3). In previous studies it also has been approved that the corm weight has high important if saffron be cultivated as an annual crop (Koocheki et al., 2016a; Fallahi et al., 2016). For example, in Navelli the RC are lifted up annually at early summer and then large corms are selected for replanting in new fields (Gresta et al., 2008). Fallahi et al. (2017b) also introduced the planting of large MC in light soils as a practical strategy for reducing the gap yield of saffron at the first flowering season. They found that large MC (˜10 g) produced 33 flower per m^{-2} with high flowering rate, while a negligible flowering obtained when small MC (˜ 2 g) were planted at OYOF. In the study of Douglas et al. (2014) also it observed that number of flower increased from 0.45 to 4.5 flower per corm when the MC weight increase from 6 to 10 g to 38–53 g. Moreover, they found that three years is needed for 1 g MC to reach the critical weight for flowering. In another study, the planting of small MC ($<$ 4 g) in the OYOF and TYOF produced 0 and 1.27 kg ha^{-1} dry stigma, respectively, while this values for medium MC (4–8 g), were 0.55 and 3.23 and for large MC (8–12 g) were 1.65 and 4.05 kg ha^{-1}, respectively (Fallahi et al., 2018b). If larger MC be used, the more RC are produced in the annual cycle, which influences flower production in future years (Kumar et al., 2009). Small MC physiological can't produce flower and more than one year is needed for their economical flowering (Sameh Andabjadid et al., 2015). The presence of sufficient food reserves in large MC provides more energy to flower and stigma production (Koocheki et al., 2016b).

In fields with one or two-years old the highest FN was obtained at highest corm density (100 corm m^2), whereas, the best density for ThYOF was 75 corms per m^2. Application of highest corm density was a considerable merit for OYOF and TYOF than ThYOF, so that, the amount of FN in density of 100 compared with density of 50 corms per m^2, for three mentioned age fields were 68, 84 and 13% higher, respectively (Table 4). Increase in corm density from 50 to 100 corm per m^2, in OYOF and TYOF caused an incensement in saffron flower and stigma yields, but in ThYOF the best treatment in terms of mentioned criteria was planting of 75 corms per m^2, although the different between three densities in ThYOF was not statistically significant. Enhancement of corm density from 50 to 75 or 100 corms per m^2 had more preference in OYOF and TYOF than ThYOF. So that, flower yield in three mentioned fields in planting density of 100 corms per m^2, was respectively 61, 76 and 13% more than planting of 50 corms per m^2 (Table 4). Overall, the flower yield showed a positive relation with the field age, where its values for OYOF, TYOF and ThYOF were 43, 204 and 388 kg ha^{-1}, respectively (Fig. 4). In a long-term experiment on saffron the stigma dry yield for 1, 2, 3, 4, 5 and 6-years old farms were 0.4, 5.3, 5.99, 12.8, 12.2 and 7.04 kg ha^{-1}, respectively (Khademi et al., 2014). They stated that corm density was low up to the third year after planting, but in 4- and 5-year old fields the corm density reached to its best value, although more increase in field age caused a high corm density and thereby high competition between them which makes a considerable reduction in produced corms weight. In addition, the accumulation of allelochemicals in soils is another reason for reduction of saffron yield and growth when field becomes too old (Behdani and Fallahi, 2015).

Based on the results of the interaction effect of MC density and size, the best treatment for obtaining the highest flowering was planting of MSMC in density of 75 or 100 corm per m^2, which were produced 187% more flower yield than planting of SSMC with density of 50 corms per m^2 (Table 5). Flowering capacity in saffron is highly dependent on number of flowering buds per corm which itself is affected by MC weight (Mohammad-Abadi et al., 2011; Koocheki et al., 2016a). In accordance with our findings, De-Juan et al. (2009), Khorramdel et al. (2015), Sameh Andabjadid et al. (2015), and Koocheki et al. (2016a) showed that larger MC have more emergence percentage and rate and higher flowering capacity. The preference of MC weight reduced by increase in corm density, so that, bigger MCs in densities of 50, 75 and 100 corms per m^2, respectively, produced 143, 87 and 62% higher flower than smaller ones (Table 5). Combined effects of all experimental factors revealed that the highest and the lowest FN, FY and SY were gained at ThYOF × 75 corm density × MSMC and OYOF × 50 corm density × SSMC, respectively (Table 6). In a study increase in corm density from 55 to 75 per m^2, positively influenced flower production, but it caused a decrease in unitary stigmas weight. However, unitary stigmas weight had a limited effect on final yield, because stigmas yield was more strongly affected by flower number than mean stigma weight (Gresta et al., 2009). Similar results observed by De-Juan et al. (2009) on saffron. Rezvani-Moghaddam et al. (2013) also found that dense planting of saffron using larger MCs is a good strategy for increasing stigma yield in the first and second growing seasons.

4. Conclusion

The main aim of this study was to determine the preference of MC density and weight in saffron fields with different ages from 1 to 3 years. Accordingly, we obtained three main results: 1- larger MCs had more preference when corm density was lower, 2- larger MCs had more preference in OYOF and TYOF than ThYOF and 3- planting of at least 100 corms per m^2 in OYOF and TYOF had more preference while the best density for ThYOF was planting of 75 corms per m^2. Overall, we concluded that saffron can be planted as an annual plant, but it is necessary to use more densities and bigger MCs in annual planting condition. It must be noted that although in current study the highest corm density was 100 corms per m^2, the similar studies recommended the densities between 200 to 400 corms per m^2 for annual cultivation of saffron.

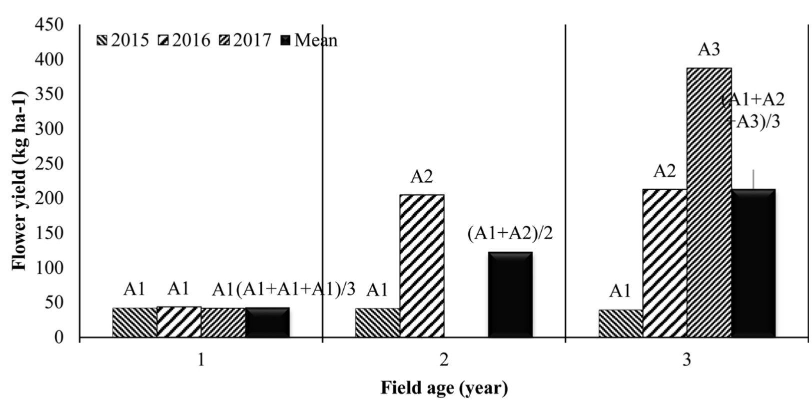

Fig. 4. Flower yield trends in one- two and three-years old fields of saffron (1, 2 and 3 in A1, A2 and A3 represent the age of saffron field).

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