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Mother corm weight and soil amendment improves the vegetative and reproductive growth of saffron (*Crocus sativus* L.)

Introduction

Saffron is a geophyte herbaceous annual plant, which its stigmas are used as a spice in food, as a dye, in perfumes and cosmetics preparation and for medicinal purposes (Gresta et al. 2008). Iran is the main saffron producer in the world with more than 88,000 hectares of cultivated area and annual production of 280 tons dried stigma. Mean stigma yield for the country is 3.2 kg ha^{-1}, which is low compared with other countries with similar levels of production technology (Ebadzade at al., 2016; Koocheki et al. 2016a). However, some Iranian leading farmers have produced up to 20 kg ha^{-1} stigma, which shows a high gap yield for saffron. Poor soil texture and structure, low soil organic matter and application of small mother corms are the main reasons for the high differences between potential and actual saffron yields (Behdani and Fallahi, 2015; Aghhavani Shajari et al. 2015).

Bulb and corm size is the main factor to determine the flowering capacity in bulbous plants (Rezvani Moghaddam et al. 2014). Saffron yield in is very low in the first growing season, mainly due to inappropriate planting date and use of small corms (Behdani and Fallahi, 2015). Application of standard mother corms in saffron cultivation is a useful strategy to solve this problem, which also will prevent the waste of two years of cost, time, and water for the enlargement of small corms in flowering fields (Fallahi et al. 2016). Results of Koocheki et al. (2016b) showed that number of flowers (84 %), flower yield (66 %) and stigma dry yield (154 %) were higher for the larger mother corm (9–10 g) than small ones (4–5 g). Likewise, Sameh Andabjadid et al. (2015), Khorramdel et al. (2015) and Koocheki et al. (2016c) showed that bigger mother corms have more emergence percentage, flowering capacity, flower weight and stigma yield.

Growing media also is one of the main factors for saffron flower and corm formation (Turhan et al. 2007). Soil amendments such as organic manure, super absorbents and sand are good choices for better growth and flowering in saffron. These materials act as a soil conditioner which are added to soil to improve its physical qualities, nutrient content and water holding capacity (Rezvani Moghaddam et al. 2014; Aghhavani Shajari et al. 2015; Fallahi et al. 2016). In a study on saffron reported that the flower and stigma yield and replacement corm growth improved when a mixture of 70 % sand + 30 % field soil + cow manure was used as corm bed (Aghhavani Shajari et al. 2015). Rezvani Moghaddam et al. (2014) also reported that the use of organic manures in corm bed of saffron is an appropriate method for increase in corm weight and flowering capacity. Results of Turhan et al. (2007) revealed that a growing media including soil + sand + manure applied as a double layer above and bottom of corm bed, had a positive effect on the flower and stigma weight of saffron. Similarly, Korramdel et al. (2014) reported that the highest stigma yield was obtained in sandy loam soil which was higher than loam and clay loam with 30 and 49 %, respectively. In addition, by increasing in super absorbent from 0 to 0.8 % enhanced dry weight of stigma. Fallahi et al. (2016) in a study on saffron also found that application of 40 kg ha^{-1} super absorbent, increased the number of replacement corms (13 %), mean weight of replacement corms (29 %) and number of buds per corm (27 %), compared with the control. Due to the key role of mother corm weight and soil physical properties to obtain satisfactory yield in saffron, the aim of this study was to investigate the combined effects of mentioned factors on flowering and initial vegetative growth of saffron in the first growing season.

Abstract

Low yield of saffron in the first growing season is a main problem which is closely linked to poor soil physical properties and application of non-standard mother corms for planting. Therefore, this study aimed to investigate the effects of mother corm weight (<4 g or small sized, 4–8 g or medium-sized and 8–12 g or large-sized) and soil amendment [heavy (HSA) and light (LSA) amendments using cow manure (CM), sand (S) and super-absorbent polymer (SAP)] on saffron flowering and its initial vegetative growth parameters. The amounts of CM, S and SAP, in LSA and HSA were, 4.5 vs 9 kg m^{2}, 30 vs 60 kg m^{-2} and 30 vs 60 kg ha^{-1}, respectively. Planting of large mother corms resulted in more replacement corms initiation as well as more root and replacement corm weight. The highest biomass production was obtained at large corms and HAS treatment, while its lowest was gained at small corm and LSA (2.49 vs 0.69 g per plant). Similar results were obtained about leaf number and dry weight. Combined treatment of large corm and HSA produced the highest amounts of number of flower (43.1 flower per m^{-2}), flowering rate (12.27 day^{-1}), flower yield (144.2 kg.ha^{-1}) and pistil yield (2.16 kg.ha^{-1}), while there was no flowering in both combinations of small corms. Overall, it was concluded that planting of large corms in light soils is an appropriate strategy for reduction of gap yield of saffron at the first flowering period.

Keywords

Cow manure, Flowering rate, Corm initiation, Soil texture, Stigma, Super absorbent polymer.

Materials and Methods

This study was carried out at research field of Sarayan faculty of agriculture (33 ºN, 58 ºE and 1450 msl), univer-

sity of Birjand. The experimental site has semi-arid climate with an average annual precipitation and mean annual temperature of 110 mm and17 °C, respectively. In this study the effects of soil amendment and mother corm weight was studied on some vegetative and reproductive growth of saffron. For this purpose, a factorial experiment based on a randomized complete block design with three replications was used. Experimental factors were: 1- mother corm weight (<4 g or small-sized, 4–8 g or medium-sized and 8–12 g or large-sized) and 2- soil physical properties amendment including heavy (HSA) and light (LSA) amendment. Soil amendment was done by simultaneous application of cow manure (CM), sand (S) and super-absorbent polymer (SAP). The amounts of CM, S and SAP in HSA were, 9 kg m^2, 60 kg m^{-2} and 60 kg ha^{-1}, respectively, while in LSA, half the amounts used in the HSA were applied. All CM, S and SAP were used before corm planting. The consumed SAP was made of potassium polyacrylate and polyacrylamide copolymers (density= 1.1–1.5 g cm^{-3}, grain size= 0.5–1 mm, pH= 7.4, maximum durability= 7 years and water holding capacity= 330 $g.g^{-1}$).
The soil of experimental field had 48.5% sand, 22.5% silt and 29% clay, which is classified as a loam soil. In addition, the soil had 0.13% organic carbon, 0.016% total nitrogen, 2.07 ppm available phosphorous and 195 ppm available potassium. Soil preparation was done in the late of summer and then saffron corm planting was done on 1th October, 2016. Planting rows space, corm space within the row and planting depth were 20, 5 and 20 cm, respectively. First irrigation was performed four weeks after corm planting and the second one after flowering. Saffron flowers harvesting was made daily during autumnal flowering phase (8–25 November). In each harvesting date the flowers were counted and weighed separately in each plot. In addition, flower and stigma lengths were determined in each flower picking date. Flowering rate also calculated using equation 1, that has been presented by Koocheki et al. (2016a). After flower harvesting, the petals were separated from pistil (stigma and style). Then, drying of main saffron flower parts was made at ambient temperature (25 °C) and shade condition for 14 days. Finally, dry pistil and petal weights were determined with accuracy of 0.001 g.

$$\text{Flowering rate} = \sum_{i=1}^{n} \frac{NF}{DAFF}$$

Equation 1

NF= *Number of flower in each harvesting date*

DAFFD = *Number of days after the first flowering date*

n= *harvesting date*

For evaluation of the effects of experimental factors on initial vegetative growth of saffron, five plants were lifted from soil, on 12th December. Then number of initiated replacement corms per plant, total weight of replacements corms per plant, mean replacement corm weight, scale weight, leaf number, leaf length, leaf dry weight, root dry weight and total plant dry weight (replacement corms + roots + leaves) were measured. Finally, all data were subjected to analysis of variance procedures (using SAS 9.2) and means were compared by LSD test at P=0.05.

Results and Discussion

Initial vegetative growth

Mother corm weight (MCW) affected significantly all initial vegetative growth indices of saffron, while soil amendment (SA) and combined effects of MCW and SA was significant only on leaf and total plant dry weights (Tab. 1). Number of initiated replacement corm enhanced by increase in MCW, so that this index was 2.33 for large-sized corms (LC) and 1.15 corm per plant for small-sized corms (SC). This is due to the fact that LC contains more buds and each sprouting bud creates a replacement corm (Husaini et al. 2010). Total weight of replacement corms in LC treatment was about 5 times more than SC. Accordingly, mean replacement corm weight increased by 55% when LC were used for saffron planting. MCW and scale weight per plant in LC also were more than two other treatments. Consider to MCW before planting and after production of roots, leaves and replacement corms, it was observed that 82, 86 and 80% of mother corms reservoirs were transferred to new sinks in SC, middle-corm sized (MC) and LC, respectively (Tab. 2). Improvement of corms growth in LC treatment is due to well development of root system and leaf area which leads to increase in nutrient uptake capacity by roots and more photoassimilates production by leaves (Khorramdel et al. 2014).
Application of LC improved the growth of root system and leaves of saffron. Number of leaf per plant in LC increased by 64 and 14%, compared with SC and MC, respectively. Likewise, application of LC increased leaf length by 17% and leaf weight per plant by 65% compared with SC. Root development also enhanced significantly by plantation of LC, where this trait for LC, MC and SC was 0.2, 0.12 and 0.07 g per plant, respectively. Finally, total dry weight (leaf + replacement corm + root) was higher in LC treatment, followed by MC and SC (Tab. 2). It has been reported that primary growth of saffron depends strongly on the food reserves in the mother corms (Koocheki et al. 2016c). Therefore, better extension of roots, leaves and initial replacement corms during early stage of saffron growth cycle mainly is related to mother corm characteristics (Fallahi et al. 2016).
Heavy soil amendment (HSA) using super absorbent polymer, cow manure and sand, increased the leaf and total dry weight of saffron by 18 and 13%, compared with light soil amendment (LSA), respectively (Tab. 3). These results are in good agreement whit findings of Aghhavani Shajari et al. (2016), which reported that a mixture of sand + cow manure + soil is a suitable media for better leaf and corm development in saffron. They attributed their observation to easier and quick exit of leaves from soil and appropriate nutrient uptake by the root system, which leads to better development of aerial parts. Combined effects of experimental factors revealed that leaf dry weight in plants produced from LC and managed by HSA was 3.4 times more than those produced from SC and were managed by LSA. Similarly, there was a considerable difference between exprimental treatments in terms of total dry weight, where this trait in LC × HSA was 3.6 time more than SC × LSA (Tab. 6). As a general rule the propagation, root extension and leaf development in bulbous plants such as saffron is strongly influenced by soil texture and MCW.

Tab. 1: Mean squares for the effects of corm weight and soil amendment on vegetative growth traits of saffron

Tab. 4: Mean squares for the effects of corm weight and soil amendment on flowering traits of saffron

Source of variation	df	Number of flower per m²	Flowering rate	Flower mean weight	Flower mean length
Replication	2	2.03^{ns}	0.16^{ns}	0.0019^{ns}	1.67^{ns}
Corm size	2	1732.3**	113.9**	0.1560**	48.18**
Soil amendment	1	112.5**	17.7**	0.0014^{ns}	0.73^{ns}
Corm size× soil amendment	2	218.9**	29.4**	0.0021^{ns}	2.36^{ns}
Error	10	1.56	0.26	0.0022	1.78
Source of variation	**df**	**Stigma length**	**Flower yield**	**Pistil dry yield**	**Petal dry yield**
Replication	2	0.86^{ns}	62.1^{ns}	0.0184^{ns}	0.08^{ns}
Corm size	2	16.06**	19950.4**	4.280**	305.0**
Soil amendment	1	0.14^{ns}	1408.0**	0.333**	24.03**
Corm size× soil amendment	2	1.02^{ns}	2379.8**	0.638**	16.48**
Error	10	0.628	38.9	0.0065	1.38

*ns: no-significant; *, ** significant at 5% and 1% probability level, respectively*

Tab. 5: Means comparison for the effects of corm weight on reproductive growth traits of saffron

Corm size	Number of flower per m²	Flowering rate (day⁻¹)	Flower mean weight (g)	Flower mean length (cm)
Large (8–12 g)	33.7^{a}	8.73^{a}	0.33^{a}	6.02^{a}
Medium (4–8 g)	12.6^{b}	4.42^{b}	0.27^{b}	5.59^{a}
Small (0.1–4 g)	0.06^{c}	0.02^{c}	0.03^{c}	0.91^{b}
Corm size	**Stigma length (cm)**	**Flower yield (kg ha⁻¹)**	**Pistil dry yield (kg ha⁻¹)**	**Petal dry yield (kg ha⁻¹)**
Large (8–12 g)	3.41^{a}	112.6^{a}	1.65^{a}	13.90^{a}
Medium (4–8 g)	3.35^{a}	34.3^{b}	0.55^{b}	04.22^{b}
Small (0.1–4 g)	0.55^{b}	0.11^{c}	0.00^{c}	0.000^{c}

Means with the same letter(s) within a column are not significantly different ($P \leq 0.05$) based on LSD test

fron reported the important role of mother corm weight on plant emergence, number of produced flower, flowering period and flower yield. They stated that small corms are not able to produce flower from physiological aspect and in order to produce economically, more than one year is needed for plant establishment. Koocheki et al. (2016c) also reported that larger mother corms have more food reserves content and thus provide more energy to flower and stigma.

Number of flower and flowering rates increased by 28 and 36%, respectively, when HSA was used (Tab. 3). The higher saffron flowering in light soils is attributed to decrease in physical resistance against bud's and flowers emergence (Khorramdel et al. 2014). Furthermore, hard crust produced in heavy clay soils after irrigation, is a major obstacle against saffron flowers emergence (Aghhavani Shajari et al. 2016). Flower, pistil and petal yields in HSA enhanced by 31% compared with LSA (Tab. 3). Our results are accordance with findings of Rezvani Moghaddam et al. (2015) which observed that the highest and the lowest saffron yield were observed in sandy loam and clay textures, respectively. It has been reported that saffron requires a well-ploughed sandy-loamy soil or a well-drained clay soil (Gresta et al. 2008). Besides sand, we used also from cow manure for soil amendment. Cow manure, provides essential nutrients and improves soil structure and water holding capacity which leads to better saffron growth and flowering (Husaini et al. 2010).

Combined effects of MCW and SA revealed that the highest and the lowest produced flowers (43.1 vs 0 flower per m⁻²) and flowering rate (12.27 vs 0 day⁻¹) were obtained at LC × HSA and SC × LSA or HSA, respectively. In addition, saffron sowing using LC and utilization of HSA produced the highest flower yield (144 kg ha⁻¹), pistil yield (2.16 kg ha⁻¹) and petal yield (16.96 kg ha⁻¹), while there was no flowering for SC in both levels of SA (Tab. 6). Douglas et al. (2015) found that it took three years for the corms of a 1 g to attain the critical weight to flower. Since saffron fields in arid and semiarid climatic conditions have clay texture with relatively low moisture content, sand, cow manure and super absorbent application might increase growth and yield due to accelerating in initiation and emergence of flowers (Khaorramdel et al. 2014).

Cow manure increases soil organic matter and decreases soil bulk density which are suitable for corm propagation and flowering (Rezvani Moghaddam et al. 2014). Yarami and Sepaskhah (2015) reported that cow manure application (60 tons' ha⁻¹) enhanced saffron stigma yield by 23%, due to improving soil fertility and providing the nutrient requirements of plant. However, it seems that the nutritional function of organic manure does not appear at the first growing season (Behdani and Fallahi, 2015), like our study that cow manure had been consumed 45 days before flowering period. Nevertheless, cow manure by improving soil physical properties especially decrease in soil bulk density can affect the leaf and flower emergence during first flowering phase (Behdani and Fallahi, 2015). Super absorbent polymers also improve saffron growth and yield by mechanisms like improvement of plant viability and emergence, preventing nutrient leaching, reduction in water stress, improvement in ventilation and increase in soil porosity (Fallahi et al. 2016).

Conclusion

In Iran, mean stigma yield in perennial cultivation of saffron is 3.2 kg ha⁻¹ and below 0.5 kg ha⁻¹ in the first flowering year. In addition, there is a high gap yield between mean stigma yield of ordinary farmers and the production of leading farmers. Our results showed

Tab. 6: Means comparison for the combined effects of corm weight and soil amendment on vegetative and reproductive growth traits of saffron

Mother corm size	Soil amendment	Leaf dry weight per plant (g)	Total dry weight per plant (g)	Number of flower per m²	Flowering rate (day⁻¹)
Large (8–12 g)	Heavy soil amendment	1.50[a]	2.49[a]	43.1[a]	12.27[a]
	Light soil amendment	1.12[b]	2.03[b]	24.3[b]	5.20[b]
Medium (4–8 g)	Heavy soil amendment	0.89[c]	1.34[c]	11.0[d]	3.89[c]
	Light soil amendment	0.79[c]	1.23[d]	14.5[c]	4.95[b]
Small (0.1–4 g)	Heavy soil amendment	0.46[d]	0.70[e]	0.00[e]	0.00[d]
	Light soil amendment	0.44[d]	0.69[e]	0.13[e]	0.04[d]
Mother corm size	**Soil amendment**	**Flower yield (kg.ha⁻¹)**	**Pistil yield (kg.ha⁻¹)**	**Petal yield (kg.ha⁻¹)**	
Large (8–12 g)	Heavy soil amendment	144.2[a]	2.16[a]	16.96[a]	
	Light soil amendment	80.9[b]	1.15[b]	10.85[b]	
Medium (4–8 g)	Heavy soil amendment	29.3[c]	0.45[d]	4.64[c]	
	Light soil amendment	39.3[c]	0.65[c]	3.81[c]	
Small (0.1–4 g)	Heavy soil amendment	0.00[d]	0.00[e]	0.00[d]	
	Light soil amendment	0.23[d]	0.00[e]	0.00[d]	

Means with the same letter(s) within a column are not significantly different ($P \leq 0.05$) based on LSD test

that with application of standard mother corms and soil amendment practices can achieve 2.16 kg ha⁻¹ dry pistil, which is a considerable yield for the first growing season.

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