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RESEARCH ARTICLE

Influence of Superabsorbent Polymer Rates on Growth of Saffron Replacement Corms

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Abstract

Mother corm size is the most important factor for production of replacement corms, flower, and stigma yield in saffron. In semi-arid regions, water shortage is a deterrent agent for appropriate corm growth of saffron. Therefore, in this experiment the effects of six levels of superabsorbent polymer (SAP) including 0, 10, 20, 30, 40, and 50 kg ha^{-1} was investigated on growth indices of replacement corms of saffron. For this purpose, an experiment was evaluated at the research farm of the Saffron Research Group, Sarayan Faculty of Agriculture, University of Birjand, Iran, during 2013-2015. Results showed that SAP application did not considerable effect on corm growth indices in the first life cycle of saffron. Nevertheless, consumption of 30-40 kg ha^{-1} SAP somewhat improved the number and total weight of replacement corms per clone. In the second life cycle of saffron, the positive impact of SAP was clearly observed on the growth of replacement corms. The application of 40 kg ha^{-1} SAP increased the amount of number of replacement corms per clone by 13%, total weight of replacement corms per clone by 36%, and scale weight of corms per clone by 50% compared with control. In addition, the amount of mean weight of replacement corms and mean number of buds per corm in treatment of application of 40 kg ha^{-1} SAP were 29 and 27% higher than the control treatment, respectively. SAP application decreased the amount of non-standard (< 8 g) corm production while significantly increased the percentage of corms with standard weight. Overall, the increasing effect of SAP application on corm weight, bud number, and standard corm yield was higher than the number of produced corms per clone. In addition, water-use efficiency in SAP application treatments (6.1 kg standard corm m^{-3}) was more than the control (4.34 kg m^{-3}) treatment. In total, SAP application is an appropriate strategy for production of standard saffron corms in semi-arid regions.

Key words : bud, drought stress, flower, stigma, water-use efficiency

Introduction

Saffron (*Crocus sativus* L.) is a spicy and medicinal plant with 210 tons annual production in Iran, which includes about 90% of its world production (Fallahi et al. 2014a). Saffron is a geophyte herbaceous plant belonging to the Iridaceae family. This plant is a triploid (2n = 3x = 24) and sterile species and does not produce seed. Therefore, the crop is propagated by corms which are underground stems (Gresta et al. 2008; Kumar et al. 2009). In saffron, during each season replacement corms develop on the buds of the mother corm and the photosynthetic activity of the leaves and mother corm reservoir contributes to the formation of these new corms (Kumar et al. 2009; Renau-Morata et al. 2012).

Bulb and corm size is the main agent for determining the capacity of bulbous plants to flower (Kumar et al. 2009; Rezvani-Moghaddam et al. 2014). Selection of suitable corms is an important factor in saffron cultivation because the flowering capacity of the plant depends heavily on the weight of planted corms. Small corms usually do not flower

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Table 1. Some climatic indices of experimental site during two saffron growth cycles.

Months	Average monthly temperature (°C)		Monthly rainfall (mm)		Monthly evaporation (mm)	
	2013-14	2014-15	2013-14	2014-15	2013-14	2014-15
October	23.3	22.4	0.2	0	236.1	238
November	13.4	11.7	15.9	26.5	89.3	94.2
December	9.7	8.7	9.7	10.8	57.1	25.1
January	2.3	8	9.6	7.5	-	-
February	5.3	10	4.3	9.4	-	-
March	11.1	8.5	20.3	43.6	-	-
April	15.7	18.4	13	12	~230	135.8
May	22.6	24	7.2	5.3	259.8	297.2
June	27.6	28.5	0.1	0	381.4	417.6
July	29.9	-	0	-	461.7	-
August	29.8	-	0	-	425.2	-
September	26.3	-	0	-	329	-

in the first year and thus the planting of them is not affordable (Fallahi et al. 2015). Saffron flowering can be limited when mother corms below 8 g are used, while the percentage of flowering and stigma yield increase significantly with enhancement of corm weight (Aghhavani-Shajari et al. 2015; Koocheki et al. 2015b).

Therefore, similar to many conventional crops it is essential that appropriate reproductive organs of saffron be provided to farmers for the construction of new flowering fields. For this purpose, it is necessary to specific corm fields be considered for multiplication and production of standard corms (Fallahi et al. 2015; Mohammad-Abadi et al. 2011). In these fields, suitable corms can be produced with a weight of more than 8 g through improved crop management over a short period from October to May (Sadeghi et al. 2014). This will prevent the waste of 2 years of cost, time, and water for the enlargement of small corm in flowering fields. Therefore, in the new cycle of saffron production, corm-producing farmers grow small corms in old saffron fields and sell them to flower-producing farmers to increase plant yield during the first 2 years after planting (Koocheki et al. 2015a ; Sadeghi et al. 2014).

The most important factors that affect the growth of saffron replacement corms include climatic factors, soil texture and structure, planting date, good availability of nutrients, and suitable irrigation management (Aghhavani-Shajari et al. 2015; Koocheki et al. 2015b). Appropriate water availability during the saffron vegetative growth cycle especially in low rainfall years and in particular at the beginning of spring can increase the average weight of produced corms (Koocheki 2013; Koocheki et al. 2015b; Sadeghi et al. 2013). However, reduced availability of water resources in many arid countries such as Iran in response to the indiscriminate harvesting of water reservoirs and climate change has led to inadequate water for optimum growth of saffron. Therefore, the use of water-retaining compounds such as synthetic super absorbent polymers (SAP) can be a useful strategy to increase the growth and yield of saffron in arid areas (Fallahi et al. 2014a ; Razavi and Davary 2014) since SAPs are highly hydrophilic and have great potential for soil restoration and storing water and nutrients for plant growth (Shooshtarian et al. 2012; Jahan et al. 2015).

So far, few studies reported the positive effects of water absorbent materials such as zeolites and SAP on emergence, corm growth and flower yield of saffron (Khorramdel et al. 2014; Ahmadee et al. 2014; Fallahi et al. 2014a). In a greenhouse study, it was reported that by increasing in SAP rate from 0 to 0.8%, saffron corm dry weight was enhanced 40% (Khorramdel et al. 2014). In another study, it was concluded that the use of K zeolite water absorbent increases the percentage and rate of emergence of saffron corms (Ahmadee et al. 2014).

Due to the positive effect of appropriate water availability on corm growth indices of saffron, the aim of this study was to investigate the effects of different levels of SAP on growth indices of saffron replacement corm during two life cycles.

Materials and Methods

Aims and experimental site

For investigating the influence of superabsorbent polymer (SAP) on corm growth indices of saffron this experiment was carried out at the Research Farm of the Sarayan Faculty of Agriculture, University of Birjand, Iran during 2013 - 2015. Sarayan (33 °N, 58 °E, and 1450 masl) is one of the main saffron producing areas in Iran, with annual long-term rainfall and temperature of 150 mm and 17°C, respectively. The main climatic characteristics of the experimental site during the study conducting are presented in Table 1.

Experimental materials and treatments

In this experiment six levels of SAP (0, 10, 20, 30, 40, and 50 kg ha^{-1}) was used based on a randomized complete block design with three replications. The consumed SAP was made of potassium polyacrylate and polyacrylamide copolymers (Table 2). Water and soil quality are two important factors for water absorbing capacity of SAP and saffron corm growth. Therefore, some physico-chemical indices of soil and irrigation water of experimental site are shown in Table 2.

Agronomic practices

Saffron planting was made on October 14, 2013 using

Table 2. The main properties of soil, irrigation water, and superabsorbent polymer.

superabsorbent properties							
Appearance	Density (g cm^{-3})	Grain size (mm)	pH	EC (μm)	Moisture (%)	Maximum durability (year)	Water holding capacity (g g^{-1})
White granule	1.1-1.5	0.5-1	7.4	1754	11.6	7	330
Irrigation water properties							
EC (μm)	pH	TDS (ppm)	Ca^{2+} (ppm as $CaCO_3$)	Mg^{2+} (ppm as $CaCO_3$)	Na^+ (ppm)	K^+ (ppm)	Cl^- (ppm)
1300	7.81	8510	48	51.5	156.4	0.45	170.4
Soil properties (0 - 40 cm)							
Sand (%)	Clay (%)	Silt (%)	Soil texture	pH	EC(ms cm^{-1})	SP	SAR
53.5	19.4	27.1	Loam	7.62	8.85	28.3	13.2
OC (%)	N_{total} (%)	P_{ava} (ppm)	K_{ava} (ppm)	$CaCO_3$ (%)	Gyp (%)	Ca (meq lit^{-1})	TDS
0.25	0.021	6.27	249	14.9	1.55	14.9	5660

corms with an average weight of 5.95 g in plots with size of 1.5 × 1.5 m^2. In each plot, 900 g of corm was planted in rows with 20 cm distances and planting depth of 20 cm. SAP was used below and beside of mother corms. For plant nutrition, 30 t ha^{-1} cow manure, 100 kg ha^{-1} potassium sulfate, and 50 kg ha^{-1} urea was used as pre-planting. The first irrigation was done after corm planting. Other irrigations were conducted five times during two growth cycles with almost monthly intervals (Nov. 6, Dec. 6, Jan. 6, Feb. 6, and April 6). In addition, one-time summer irrigation was applied on August 6, 2014.

Plant sampling

Corm lifting from soil was carried out after leaf withering in early May 2014 and 2015. For this purpose, four clones were selected randomly in each plot and then all replacement corms were removed. Corm measured indices included the number of replacement corms per clone, total corms weight per clone, corms weight without scale per clone, scale weight per clone, mean replacement corms weight, and number of buds per replacement corm. For better understanding of the effects of SAP application on corm growth of saffron, sampled replacement corms were classified in five weight categories (3 >, 3 - 6, 6 - 9, 9 - 15, and > 15 g) and the number of replacement corms was determined in each category. In addition, the corm yield (ton ha^{-1}) was measured in different weight groups and the percentage of standard corms (corms with weight of more than 8 g) was determined using equation 1 (Aghhavani-Shajari et al. 2015).

$$\text{Percentage of standard corms}=\frac{\text{Standard corm yield(tan } ha^{-1})}{\text{Tatal corm yield (tan } ha^{-1})}\times 100 \quad (1)$$

Finally, water-use efficiency based on total (WUEt) and standard (WUEs) produced corms in the second life cycle of saffron was measured using equations 2 and 3. The amount of consumed water including one summer irrigation and six irrigations during the vegetative growth of saffron was estimated about 4200 m^3 ha^{-1}. This amount was equal in all plots.

$$WUEt=\frac{\text{Tatal corm yield (kg } ha^{-1})}{\text{Water cosumption (} m^3 ha^{-1})} \quad (2)$$

$$WUEs=\frac{\text{Standard corm yield (kg } ha^{-1})}{\text{Water cosumption (} m^3 ha^{-1})} \quad (2)$$

Data analysis

Data analysis was made using SAS 9.1. In addition, means were compared using Duncan's multiple range test at 5% level of probability.

Results

Super absorbent polymer (SAP) application had no significant effect on most of the saffron replacement corms growth indices in the first growth cycle (FSGS), but its effect was considerable on all indices in the second saffron growth cycle (SSGS) (Table 3). In the FSGS, the number of replacement corms per clone increased by SAP application; however, in the SSGS this index decreased some in most SAP levels compared with the control. Application of 40 kg ha^{-1} SAP was the best treatment regarding corm production in a sum of two years. Moreover, the number of replacement corms in all SAP levels in SSGS was significantly higher than FSGS (Table 4). Different rates of SAP application had a remarkable positive effect on the total corms weight per clone, especially in the SSGS. The highest amount of this index was obtained in treatment of 40 kg ha^{-1} SAP application, which was 37% more than the control treatment. Similar results were observed in corm weight without the scale per clone. In addition, SAP application increased the amount of scale weight per clone in both saffron growth cycles, but this enhancement was more significant in the SSGS. Also, the amount of corm weight per clone increased significantly in SSGS, especially in SAP application treatments (Table 4).
Different levels of SAP had a significant positive effect on

Table 3. Analysis of variance (sum of squares) for effect of superabsorbent rates on growth of saffron replacement corms.

Source of variation	df	Number of replacement corms per clone		Total weight of replacement corms per clone		Replacement corms weight without scale per clone	
		2014	2015	2014	2015	2014	2015
Superabsorbent	5	3.26^{ns}	33.3*	44.3^{ns}	2003.7*	32.8^{ns}	1557.0*
Replication	2	0.88^{ns}	1.1^{ns}	19.9^{ns}	773.5^{ns}	10.2^{ns}	204.1^{ns}
Error	10	2.38	18.3	71.9	1266.6	27.4	968.8
Total	17	6.53	52.8	136.2	4043.9	70.5	2730.1
C.V	-	11.4	13.2	13.3	17.8	9.3	16.8

Source of variation	df	Scale weight per clone		Mean replacem ent corm weight		Average number of buds per replacement corm	
		2014	2015	2014	2015	2014	2015
Superabsorbent	5	3.20**	29.8**	1.5^{ns}	8.1**	32.8^{ns}	17.4**
Replication	2	0.03^{ns}	0.2^{ns}	3.3**	2.7**	10.2^{ns}	8.4**
Error	10	0.73	07.8	1.8	2.1	27.4	6.5
Total	17	3.97	37.9	6.7	12.9	70.5	32.4
C.V	-	10.9	18.9	8.5	7.5	9.3	11.4

*and**: signficant at 5 1% levels of probability, respectively. ns-significant

Table 4. Results of means comparison for effect of superabsorbent levels on growth of saffron replacement corms.

Superabsorbent rates (kg ha^{-1})	Number of replacement corms per clone		Total weight of replacement corms per clone(g)		Replacement corms weight without scale per clone(g)	
	2014	2015	2014	2015	2014	2015
0	3.9^{b}	11.0^{ab}	19.1^{a}	54.7^{b}	16.7^{ab}	50.9^{b}
10	4.5^{ab}	10.5^{ab}	20.1^{a}	60.9^{b}	17.0^{ab}	56.7^{b}
20	4.0^{ab}	09.8^{b}	21.2^{a}	60.7^{b}	18.7^{a}	55.9^{b}
30	4.9^{a}	08.3^{b}	21.9^{a}	55.3^{b}	19.2^{a}	51.4^{b}
40	4.5^{ab}	12.6^{a}	21.1^{a}	86.0^{a}	18.8^{a}	78.5^{a}
50	3.7^{b}	09.2^{b}	17.2^{a}	61.6^{b}	15.5^{b}	57.6^{b}

Superabsorbent rates (kg ha^{-1})	Scale weight per clone(g)		Mean replacem ent corm weight(g)		Average number of buds per replacement corm	
	2014	2015	2014	2015	2014	2015
0	2.3^{b}	3.7^{b}	5.2^{ab}	4.8^{c}	-	5.5^{d}
10	3.2^{a}	4.1^{b}	4.9^{ab}	5.7^{b}	-	6.3^{cd}
20	2.5^{b}	4.7^{b}	5.4^{a}	6.1^{ab}	-	8.3^{a}
30	2.8^{ab}	3.8^{b}	4.5^{b}	6.3^{ab}	-	6.6^{bcd}
40	2.3^{b}	7.4^{a}	5.0^{ab}	6.8^{a}	-	7.5^{abc}
50	1.8^{c}	4.0^{b}	5.0^{ab}	6.7^{a}	-	8.0^{ab}

*In each column means followed by the same letters are not significantly different based on Duncan's test (*P* 0.05).

mean weight of replacement corms particularly in the SSGS. The amount of this index increased with enhancement in the rate of SAP, so that the mean replacement corm weight in levels of 10, 20, 30, and 40 kg ha^{-1} SAP application was 16, 21, 24, and 30% higher than the control, respectively. All levels of SAP consumption also had a positive effect on the mean number of buds per replacement corm. The average amount of this index in SAP application treatments was 25% higher than the control treatment (Table 4).

The effect of SAP application was significant on the number of replacement corms per clone, in all weight categories (Table 5). The highest amount of number of small replacement corms (< 3 and 3 - 6 g) was obtained in the no-application SAP treatment, while the number of large replacement corms (9 - 15 and > 15 g) per clone, in all rates of SAP was significantly higher than in the control. The average number of replacement corms with weight of < 3 and 3 - 6 g in SAP consumption treatments was 29 and 9% lower than in the control, while the amount of this criteria in weight categories of 9 - 15 and > 15 g in SAP application treatments was 32 and 37% more than in the control, respectively (Table 6).

SAP affected significantly replacement corms yield in all corm weight groups (Table 7). The yield of very small corms (< 3 g) in the control treatment was significantly higher than all SAP application treatments. SAP consumption had a positive effect on the medium and large corm yields. The amount of corm yield in 9 - 15 and > 15 g weight groups for SAP application treatments was on average 33 and 36% higher than the control, respectively (Table 8). In addition, the effect of SAP application was significant on total corm yield and also yield and percentage of standard corms (Table 7). Different levels of SAP increased the yields of total and stan-

Table 5. Analysis of variance (sum of squares) for effect of superabsorbent levels on the number of saffron replacement corms per clone in different weight categories

Source of variation	df	< 3 g	3 - 6 g	6 - 9 g	9 - 15 g	> 15 g
Superabsorbent	5	8.2**	4.98**	3.799**	6.28**	2.50*
Replication	2	0.2^{ns}	0.06^{ns}	0.006^{ns}	0.31^{ns}	0.45^{ns}
Error	10	1.5	1.83	1.055	0.83	1.55
Total	17	10.0	6.89	4.861	7.44	4.51
C.V	-	11.7	15.0	19.6	20.7	43.4

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

Table 6. Results of means comparison for effect of superabsorbent levels on the number of saffron replacement corms per clone in different weight categories

Superabsorbent rates (kg ha^{-1})	< 3 g	3 - 6 g	6 - 9 g	9 - 15 g	> 15 g
0	4.37^{a}	3.08^{ab}	1.62^{ab}	1.00^{c}	0.62^{b}
10	2.91^{cd}	2.50^{bc}	2.16^{a}	2.58^{a}	0.55^{b}
20	3.16^{bc}	3.08^{ab}	1.33^{bc}	1.33^{bc}	0.75^{b}
30	2.25^{d}	3.08^{ab}	0.91^{c}	0.83^{c}	0.83^{b}
40	3.87^{ab}	3.50^{a}	1.62^{ab}	1.62^{b}	1.62^{a}
50	3.25^{bc}	1.87^{c}	2.25^{a}	1.00^{c}	1.12^{ab}

* In each column means followed by the same letters are not significantly different based on Duncan's test (*P* 0.05).

dard corms compared with the control. The highest amount of standard corm yield was obtained at 40 kg ha^{1} SAP application treatment, which was nearly two times more than the control. Furthermore, the percentage yield of standard corms in all levels of SAP was considerably higher than in the no-SAP application treatment (Table 8).

The effect of SAP application was significant on water-use efficiency based on both total (WUEt) and standard (WUEs) produced corms (Table 7). The highest and the lowest amounts of WUEt obtained at 40 and 0 kg ha^{-1} SAP application treatments, respectively. Moreover, WUEs in SAP application treatments was on average 29% higher than in the control. In total, the positive effect of SAP on increasing of WUEs was more than WUEt (Table 8).

Discussion

Drought stress is one of the main problems for appropriate crops production in semi-arid regions. Although saffron is very compatible to semi-arid areas due to its low water requirement, however, the availability of adequate moisture will lead to its more growth and flowering (Fallahi et al. 2014a ; Khorramdel et al. 2014). Saffron is irrigated only four to five times due to shortage water resources in many parts of Iran in a year with normal rainfall (Fallahi et al. 2015). This amount of irrigation considered to be low precipitation (Table 1) is not favorable for appropriate saffron corm growth. Therefore, the use of superabsorbent polymer is a suitable strategy for a better use of scarce water resources and improving the saffron corm growth and flower yield in low rainfall areas (Fallahi et al. 2014a; Khorramdel et al. 2014). The results of the current experiment showed that SAP application significantly improved the saffron replacement corm growth indices (Table 4, 6). These beneficial effects are related to the improvement of plant viability and emergence, preventing nutrient leaching, reduction in water stress, improvement in ventilation, increase in soil porosity, increase in the rainfall-use efficiency, and enhance soil microbial communities' activity (Shooshtarian et al. 2012; Khorramdel et al. 2014). However, SAP application had lower effects on saffron corm growth in the first growth cycle than in the second one (Table 4). It seems that this phenomenon is because saffron replacement corm growth in the first cycle mainly is dependent on mother corm nutrient reservoirs and is less affected by agronomic management such as corm density and water availability (Mohammad-Abadi et al. 2011).

SAP application accelerates cell division in corm by providing more moisture. Moreover, these materials can enhance leaf growth and consequently more photo-assimilates partitioning to corms. These processes increase the growth indices of saffron replacement corms (Fallahi et al. 2014a ; Khorramdel et al. 2014). Depending on the structure of the polymer and water quality, SAP can absorb significant amounts of irrigation water and rainfall. For example in the current experiment, the amount of soil water content in the treatment of the application of 30 kg ha^{-1} SAP was 8% higher than in the control treatment (data are not shown). In addition, SAP absorbs fertilizers and when the plants need nutrients, they supply plants through exchange interaction (Gao et al. 2013; Shahid et al. 2012). It seems that many benefits of SAP application especially increase in soil water-holding capacity is responsible for better growth of saffron replacement corms. So far, the positive effect of appropriate water availability on corm growth and yield of saffron has been reported by Azizi-Zohan et al. (2006), De-Juan et al. (2009), Behdani (2011), and Koocheki et al. (2014). Accordingly, in semi-arid regions standard saffron corms can be produced by sufficient water provided through SAP application.

Saffron is a sterile plant that produces annual replacement

Table 7. Analysis of variance (sum of squares) for effect of superabsorbent rates on the saffron replacement corm yields and water-use efficiency

Source of variation	df	Yield of < 3 g replacement corms	Yield of 3 - 6 g replacement corms	Yield of 6 - 9 g replacement corms	Yield of 9 - 15g replacement corms	Yield of > 15 g replacement corms
Superabsorbent	5	7.8**	42.66**	90.28**	382.48**	271.29*
Replication	2	0.2^{ns}	0.57^{ns}	0.15^{ns}	19.27^{ns}	48.81ns
Error	10	1.43	15.73	25.09	51.06	168.63
Total	17	9.52	58.97	115.54	452.83	488.75
C.V	-	11.7	15.0	19.6	20.7	43.4

Source of variation	df	Yield of standard replacement corms	Yield of total replacement corms	Percentage yield of standard corms	Water-use efficiency based on standard corms	Water-use efficiency based on total corms
Superabsorbent	5	652**	850**	616*	37.0**	48.2**
Replication	2	110^{ns}	123^{ns}	173^{ns}	06.2^{ns}	06.9^{ns}
Error	10	240	241	383	13.6	13.6
Total	17	1004	1215	1172	56.9	68.8
C.V	-	20.1	12.2	10.3	20.1	12.2

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

Table 8. Results of means comparison for effect of superabsorbent levels on the saffron replacement corms yields and water-use efficiency

Superabsorbent rates (kg ha^{-1})	Yield of < 3 g replacement corms (ton ha^{-1})	Yield of 3 - 6 g replacement corms (ton ha^{-1})	Yield of 6 - 9 g replacement corms (ton ha^{1})	Yield of 9 -15 g replacement corms (ton ha^{-1})	Yield of > 15 g replacement corms (ton ha^{-1})
0	4.26^{a}	9.01^{ab}	7.90^{ab}	07.80^{c}	06.48^{b}
10	2.84^{cd}	7.31^{bc}	10.56^{a}	20.15^{a}	05.20^{b}
20	3.08^{bc}	9.01^{ab}	6.50^{bc}	10.40^{bc}	07.80^{b}
30	2.19^{d}	9.09^{ab}	4.46^{c}	06.50^{c}	08.66^{b}
40	3.77^{ab}	10.23^{a}	7.91^{ab}	12.66^{b}	16.88^{a}
50	3.16^{bc}	5.48^{c}	10.96^{a}	07.80^{c}	11.68^{ab}

Superabsorbent rates (kg ha^{-1})	Yield of standard replacement corms (ton ha^{-1})	Yield of total replacement corms (ton ha^{-1})	Percentage yield of standard corms	Water-use efficiency based on standard corms(kg m^{-3})	Water-use efficiency based on total corms (kg m^{-3})
0	18.24^{c}	35.47^{c}	49.6^{b}	4.34^{c}	08.4^{c}
10	30.63^{ab}	46.06^{ab}	66.2^{a}	7.29^{ab}	10.9^{ab}
20	21.45^{bc}	36.80^{bc}	57.6^{ab}	5.10^{bc}	08.7^{bc}
30	17.40^{c}	30.84^{c}	55.7^{ab}	4.14^{c}	07.4^{c}
40	33.50^{a}	51.47^{a}	65.1^{a}	7.97^{a}	12.2^{a}
50	24.96^{abc}	39.10^{bc}	63.4a	5.94^{abc}	09.3^{bc}

* In each column means followed by the same letters are not significantly different based on Duncans test (P 0.05)..

corms and is propagated solely by these corms (De-Juan et al. 2009). In many studies, it has been reported that the mother corm size of saffron is an important factor on replacement corm and flower production (Alipoor Miandehi et al. 2015; De-Juan et al. 2009; Koocheki et al. 2015c). This opinion also is supported by local knowledge of the saffron agronomy. However, high proportions of saffron corms that are used for establishing new fields in Iran are not practical in terms of weight (Fallahi et al. 2015). The corm weight is more important if saffron can be cultivated as an annual crop, as in Navelli where the corms are lifted up annually at the beginning of the summer and then corms with diameter greater than 2.5 cm are selected for re-planting in new fields (Gresta et al. 2008). Therefore, the use of correct management operations especially water availability is essential for the production of saffron standard corms in corm production fields. The results of this experiment showed that SAP application is a good strategy for increasing the weight of saffron corms so that the amount of corm yield in > 9 g weight group in SAP application treatments was on average 35% more than in the control (Table 8). These findings are supported by the results of Khorramdel et al. (2014) and Ahmadee et al. (2014) who reported that saffron fields in semi-arid areas have inappropriate soil texture with relatively low moisture content. Therefore, SAP application might increase corm growth and yield of saffron.

SAP application had a positive significant impact on water-use efficiency of saffron based on produced total (WUEt) and standard (WUEs) corms (Table 8). Although saffron is native to semi-arid regions, sever water stress could negatively affect replacement corm formation (Koocheki et al. 2014). As Behdani (2011) reported that for higher saffron corm and flower yields, short irrigation intervals are needed. Based on the results of our experiment, it is possible to decrease water need and increase WUE of saffron by reducing the amount of water consumption during its life cycle, if SAP is used. Saffron as a summer dormant and winter active species is one of the most efficient plants in terms of water consumption (Fallahi et al. 2014b). The results of the current experiment revealed that WUE of saffron was considerably high for corm-producing fields than other conventional crops. It has been reported that water requirement of saffron is low (3000 m^3 per year in Iran) and can have a satisfied yield by scarce rainfall and several low irrigations, when it is cultivated in semi-arid conditions (Gresta et al. 2008; Koocheki 2004; Koocheki et al. 2014). In addition, the higher effect of SAP application on WUEs than WUEt (Table 8) shows that water availability is a main factor for the production of standard corms in saffron. Overall, although saffron is drought tolerant, appropriate water availability especially by SAP application is a suitable strategy for increasing corm production and water-use efficiency.

Conclusion

Super absorbent polymer had a positive effect on corm growth indices particularly in the second life cycle of saffron. Although different levels of SAP application decreased the number of replacement corms per clone by 10% compared with the control, the amount of total corms weight per clone in those treatments was on average 16% higher. In addition, SAP application had a considerable positive effect on mean replacement corm weight and average number of buds per corm. SAP consumption also decreased the number and yield of small corms and increased the number and yield of large standard corms. Moreover, water-use efficiency increased on average by 30% in SAP application treatments. Overall, application of SAP at the rate of 40 kg ha^{-1} is recommended for saffron corm production in semi-arid regions.

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