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Studying the Effects of Irrigation Management, Organic Fertilizer and Nano composite Superabsorbent Polymers on Some Quantitative and Qualitative Characteristics of Daughter Corms of Saffron (Crocus Sativus L.)

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Abstract

Corm plays a pivotal role in the life cycle of saffron plant. In order to find and recommend a method for improving the growth of daughter corms using soil organic amendments in semi-arid areas, a split plot experiment in randomized complete block design including three irrigation intervals of 30, 50 and 70 days as main plots and three factors of vermicompost, Terracottem, and Bolourab-A as sub plots was conducted for two years (2014-2016). The results showed that the highest number of daughter corms was observed in Bolourab-A and irrigation interval of 50 days in the second year, and the highest average weight (14.8 g) was related to Terracottem and 30-day irrigation round in the first year. The highest percentage of standard and non-standard daughter corms in the first year was obtained in combined vermicompost + Bolourab-A and 50-day irrigation interval, control and 30-day irrigation interval treatments, respectively. The highest amount of nitrogen uptake was in Terracottem + Bolourab-A and 50-day irrigation interval treatments also phosphorus and potassium were in vermicompost + Terracottem and irrigation in 50 and 70 days in the first year, respectively. The highest dry matter content was obtained in treatment of vermicompost + Bolourab-A and 30-day irrigation, also the highest yield daughter corms (36.4 $ton.ha^{-1}$) and water use efficiency (5.2 $kg.m^{-3}$) were observed in irrigation interval of 70 days and Bolourab-A + Terracottem,vermicompost + Terracottem treatments, respectively. In general, soil organic amendments can be used in combination to increase the efficiency of available water resources and improve some characteristics of daughter corms of saffron in semi-arid regions.

Keywords: Bolourab-A, daughter corms, Terracottem, vermicompost, water use efficiency.

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Introduction

Crocus sativus L. is an herbaceous, perennial and rosette plant, which belongs to Iridaceae family. As the commercial and expensive spice, stigmaof saffron has a wide range of uses in food and pharmaceutical industries. It has also sedative and anticancer effects and can be used for the reduction of joint pain (Abdullaev *et al.*, 2004, Xi *et al.*, 2007). The plant is genetically sterile (2n = 3x = 24), and thus propagated asexually by using undergrowth stem called corm. Selection of proper mother corm is the most important factor when planting saffron because plant flowering capacity and stigma function depend to a large extent on the weight of the mother corm planted (Rezvani-moghadam *et al.*, 2013). Saffron flowering decreased by cultivating corms less than 8 gr (non-standard), while the percentage of flowering and stigma yield increased significantly by planting corms 8 and more than 8 gr (standard) (Aghhavani shajari *et al.* 2015, Sadeghi *et al.*, 2014). During the annual growing season of the plant and after the flowering period, daughter corms develop on meristematic buds of the mother corm, and then photosynthetic activity of the leaves and nutritional storage of mother corms cause their growth continuation until the end of the growing season (Renau morata *et al.* 2012). Factors such as climate, soil texture and structure, planting date of mother corm, available nutrition, and proper irrigation management are the most important factors affecting the growth of daughter corms of saffron (Koocheki *et al.*, 2014). Lack of soil moisture is one of the most important factors in reducing the yield of saffron, because the growth of leaves and daughter corms is strongly influenced by soil moisture and soil conditions (Kafi *et al.*, 2006). Application of organic fertilizer had the greatest effect on the significant increase of yield in saffron daughter corm (Koocheki *et al.*, 2014). Mokhtari *et al.* (2018) reported that among the individual fertilizer studies, organic fertilizer had the highest impact on saffron dry weight (g= 1.493) at 95% confidence interval. Masumi *et al.* (2012) reported that application of vermicompost and sulfur increased vegetative growth and production of flowering and standard daughter corms (w≥ 8 g) saffron. Studying the effect of irrigation rounds and different fertilizers on the yield of saffron stigma, Mohammadpour *et al.* (2013) reported that the highest stigma yield was obtained in the treatment of vermicompost and irrigation interval of 14 days. Super absorbent polymers, in addition to having high water absorption capacity, caused an increase in the maintenance of moisture in rhizosphere, improvement in the ventilation and texture of soil increase in the irrigation interval, increase in the penetration of water and reduction of erosion and runoff, and reduction of surface evaporation (Abedi Koupai *et al.*, 2008). Superabsorbent hydrogels are highly hydrophilic and have great potential for soil restoration and storing water and nutrients for plant growth (Jahan *et al.* 2015). Khorramdel *et al.* (2014) reported that increase of super absorbent polymer levels from zero to 0.8% improved vegetative and reproductive growth, such as increasing the production of daughter corm and improving the yield of saffron stigma. Fallahi *et al.* (2016) reported that application of super absorbent polymers increased the vegetative growth of saffron and produced standard daughter corms (w≥ 8 g.) in semi-arid regions. Reducing available water resources in many countries including Iran, due to the excessive harvesting of these resources and climate changes, has led to adequate water scarcity for the desired growth of saffron and decline in its yield per unit area. In such conditions, use of soil organic amendments and water preservatives such as vermicompost and Nano composite super absorbent polymers, which contain various nutritional elements, can be a useful way to increase the growth of daughter corm and increase the yield of saffron in semi-arid regions. Therefore, to find and recommend a method for improving the growth of daughter corms using soil organic amendments in semi-arid areas, this study was aimed at studying the effects of irrigation management along with the application of organic fertilizer and Nano composite super absorbent polymers on yield and some quantitative and qualitative characteristics of saffron doughter corms.

Materials and Methods

Experimental Farm Characteristics

This experiment was conducted to study the effect of irrigation management, vermicompost organic fertilizer and super absorbent polymers of Bolourab-A and Terracottem on some quantitative and qualitative characteristics of daughter corms of saffron in Saffron Research Institute of Torbat Heydarieh University. The area was located at 35° 18´ N latitude, 59° 11´ E longitude, and elevation of 1430 m above sea level. The annual mean evaporation of the area was 360.5 mm, mean participation 175.8 mm, and maximum and minimum annual mean temperatures 8.5 and 23.8, respectively (Iran Meteorological organization, 2016). The experiment was carried out for two years of 2014 to 2016.

Experimental Design

The experiment was performed as split plot based on Randomized Complete Block Design with three replications. Main plots included irrigation at three intervals of 30, 50 and 70 days, and sub plots included 4 g vermicompost per kg dry weight of soil

(12000 kg. ha^{-1}), super absorbent polymers of Bolourab-A and Terracottem each at the rate of 0.4 g per kg dry weight (1200 kg. ha^{-1}) and their interactions, along with control.

Field Crop Operations

After preparing the ground and during the true dormancy stage of the corms, corms with the weight of 8-12 g were first disinfected with Captan fungicide at 4 ppm. Then based on the density, 50 corms per m^2 were planted at the space of 25 cm × 8 cm apart and the depth of 20 cm in plots with the dimensions of 6 m^2 in June. Vermicompost and super absorbent polymers of Bolourab-A and Terracottem were distributed in rows before planting of corms. To begin the annual growth and development in both growing seasons, the first irrigation was performed on October 20 in all the experimental plots, and the rest of irrigation treatments until the end of the growing season was performed according to the schedule at the rate of 800 m^3 per ha per irrigation interval. One week after the first irrigation, all of the experimental plots were subjected to crust-breaking operation. Furthermore, weeds were removed manually at end of each growing season. Physical and chemical characteristics of vermicompost, soil, water and super absorbent polymers are described in Table 1.

Table 1: The main properties of soil, vermicompost, and irrigation water and Nano composite superabsorbent polymers

Soil and vermicompost

Properties	Texture: clay (%)	loam (%)	sand (%)	N (%)	P (ppm)	K (ppm)	EC ($ds.m^{-1}$)	pH	O.C (%)
Field soil	24	52	24	.06	2.6	220	1.51	8.16	0.058
Vermicompost	-	-	-	1.6	1.9	1.54	1.42	7.27	24.13

Irrigation water

pH	EC ($ds.m^{-1}$)	S.A.R	T.D.S ($mg.lit^{-1}$)	CL^- ($meq.lit^{-1}$)	$HCO3^-$ ($meq.lit^{-1}$)	Ca^{2+} ($meq.lit^{-1}$)	Mg^{2+} ($meq.lit^{-1}$)	K^+ ($meq.lit^{-1}$)	Na^+ ($meq.lit^{-1}$)
7.51	0.8	3.74	512	4.37	3	1.8	2.1	0.04	5.22

Nano composite superabsorbent polymers

N.S.A.P	Appearance	Career	Density ($gr.cm^{-3}$)	pH	Particle Size (µm)	Maximum Durability (year)	Nutrient elements content: N (%)	P (%)	K (%)	Potential of deionized water absorption ($g.g^{-1}$)	Potential for solution absorption of 0.2% NaCl ($g.g^{-1}$)
Terracottem	Granul and brown	lava	0. 8	7	63−40	8	15	10	15	450	250
Bolourab-A	Powder and pink	Zeolite	0. 85	6.5	25-45	5	3.75	6.6	19	320	220

Measuring Growth Indicators of Daughter Corms

In order to study the formation and growth stages of daughter corms and calculate their growth indices, after the germination and the end of the flowering period of the mother corms, destructive sampling was carried out every 15 days from the beginning of December and continued until the full yellowing of the leaves. In each sampling, three plants were randomly selected from each experimental unit and transferred to the laboratory for measuring quantitative and qualitative characteristics of daughter corms. The number of daughter corms per plant and their fresh weight were measured and recorded after their removing from the mother plant. To determine the dry weight of daughter corms, they were dried in oven at 105 ° C for 48 hr and their dry weight was measured, and the percentage of dry matter of the daughter corms was calculated using equation 1 as follows (Khorramdel *et al.*, 2014):

(1) % Biomass = DW/FW×100

Where DW is the dry weight of the plant sample and FW is the fresh weight of the plant sample. Furthermore, the amount of some macro elements absorbed by daughter corms including nitrogen, phosphorus and potassium were measured. In order to measure the amount of nitrogen, phosphorus and potassium, Kjeldahl method (Cottenie *et al.*, 1989), vanadate-molybdate method (Page *et al.*, 1982) using a spectrophotometer at the wavelength of 660 nm and photometer film device (model PFP 7, Jenway) were used, respectively. At the end of the vegetative growth period, and after full yellowing and drying of leaves and the beginning of the true dormancy period of the corms in mid-June, corms were harvested at the area of one m^2 from each experimental plots, and the daughter corms produced were classified according to their number and the average weight. Subsequently, the percentages of standard (daughter corms with the weight of 8 g and more) and non-standard (daughter corms with the weight of less than 8 g) daughter corms were determined by using the equations 2 and 3 (Fallahi *et al.*, 2016):

(2) Percentage of standard corms (%)
$$= \frac{\text{standard corm yield}(\text{ton.ha}^{-1})}{\text{total cormy ield}(\text{ton.ha}^{-1})} \times 100$$

(3) Percentage of no - standard corms (%)
$$= \frac{\text{no−standard corm yield}(\text{ton.ha}^{-1})}{\text{total corm yield}(\text{ton.ha}^{-1})} \times 100$$

Moreover, water use efficiency was calculated by using equation 4 as follows (Fallahi *et al.*, 2016):

$$(4)\ \text{Wue}\ (\text{kg.m}^{-3}) = \frac{\text{Total corm yield}(\text{Kg.ha}^{-1})}{\text{water consumption}(\text{m}^3.\text{ha}^{-1})}$$

Statistical Analysis

The data obtained was subjected to a compound analysis by using SAS.9.2 software. Duncan's multiple test was used for means comparison ($P \leq 0.01$), and Excel software was used to draw the graphs.

Results

Number of Daughter Corms

The results of analysis of variance (Table 2) showed that all treatments had a significant effect on the number of produced daughter corms ($p \leq 0.01$). Based on the results of means comparison (Tables 3 and 4) and the effect of treatments, the highest average number of daughter corms was 346.7 per m^2 which was related to 50-day irrigation interval and Bolourab-A treatment in the second year, and the lowest average number of daughter corms was observed in control treatment during the two experiment years.

Fresh and Dry Weights of Daughter Corms

The average fresh and dry weights of daughter corms were significantly influenced by some of the treatments ($p \leq 0.01$) (Table 2). Application of combined treatments of vermicompost, Bolourab-A and Terracottem at 70 day irrigation interval in the second year was the best treatment and resulted in 66.4% and 68.9% increases in fresh (3625.3 gr) and dry (1241.1 gr) weights of daughter corms, respectively, compared to the control at the same irrigation interval (Tables 3 and 4). It was expected that the above treatments and 50- or 30 day irrigation intervals with less drought stress have maximum fresh and dry weights of daughter corms, while increase in the average weight of daughter corms was observed at 70 day irrigation interval and more drought stress.

The Percentage of Non-Standard (With the Weight Less Than 8 G.) And Standard (With the Weight Equal to 8 G. And More Than 8 G.) Daughter Corms

The results of the experiment revealed that some of the treatments had significant effects on the production of standard ($w \geq 8$ g.) and non-standard ($w < 8$ g.) daughter corms ($p < 0.01$) (Table 2). Furthermore, comparison of the means showed that, unlike other traits, the highest percentage of non-standard daughter corms produced ($w < 8$ gr) was 66.3%, which was observed in control and irrigation interval of 30 days in the first year (Tables 3 and 4). On the other hand, the highest percentage of standard and valuable daughter corms production ($w \geq 8$ g) was related to the combined treatments of organic compounds including vermicompost + Bolourab-A and Bolourab-A + Terracottem at irrigation periods of 30, 50 and 70 days in the first year and the lowest percentage of the production was related to the control treatment during the two experiment years.

The Average Weight of Daughter Corms

The results of the experiment showed that the treatments had a significant effect on the average weight of the produced daughter corms ($P \leq 0.01$) (Table 2). Furthermore, means comparison showed that all treatments, except for control, improved the size and weight of daughter corms, and the highest average weight of daughter corms (14.8 g) was related to the treatment of Terracottem and irrigation interval of 30 days in the first year (Tables 3 and 4), which showed 48% increase in weight relative to the control treatment.

Nutritional Elements Absorbed By Daughter Corms

Supply of the required nutrients of corm, as a source of nutrients supply for regrowing of saffron, can play an important role in the emergence of the highest number of flower, because the initiation and development of the reproductive organs of saffron occurs under the ground and inside the corms buds, and only a small part of plant growth takes place on the surface of the soil (Poggi *et al.*, 2009, Sabet Teimouri *et al.*, 2010). The results of this experiment showed that the absorption of macro nutrients including nitrogen, phosphorus and potassium was significantly influenced by different treatments ($P \leq 0.01$) (Table 5).

Nitrogen

Means comparison of the treatments showed that maximum nitrogen uptake was related to combined treatments of Bolourab-A + Terracottem and 50- and 30-day irrigation rounds, respectively, and the lowest nitrogen uptake occurred in control treatment during two experiment years (Tables 6 and 7).

Phosphorus

Investigating the amount of phosphorus adsorbed in different treatments indicates the improvement of phosphorus absorption due to the application of different treatments, so that the combined treatment of vermicompost + Terracottem at 50-day irrigation round in the first year was the best treatment and showed significant difference from the control treatment during two years of the experiment (Tables 6 and 7).

Potassium

The amount of potassium absorbed in different treatments showed that the highest rate of its absorption by daughter corms was due to the combined application of vermicompost + Terracottem and irrigation interval of 70 days in the first year and the lowest amount of its absorption was related to control treatment during the two years of the experiment (Tables 6 and 7).

Percentage of Dry Matter of Daughter Corms

The amount of dry matter produced in daughter corms was influenced by some treatments ($P \leq 0.01$) (Table 5). Based on the results of means comparison of the treatments, the highest dry matter content (46.5%) was observed in combined treatment of Vermicompost + Bolourab-A and irrigation interval of 30 days in the second year, while the effects of treatments were not significant in the first year (Tables 6 and 7).

Table 2: ANOVA results of experimental factors on different traits of saffron daughter corms

Source of variation	DF	D. C. number	D. C. fresh weight	D. C. dry weight	D. C.less than 8 g	D. C.8 and more than 8 g	D. C. average weight
Replication	2	185.5^{ns}	6812^{ns}	13330.8^{ns}	24.7^{ns}	52.9^{ns}	0.08^{ns}
Year	1	583314.1**	67087020.4**	8066594**	6119.2**	6439.5**	3.5^{ns}
Year error	2	723.6	122884.5	2430.1	21.2	37.4	0.3
Irrigation	2	4089.2**	225935.1*	19304.3**	17.3^{ns}	47.5^{ns}	28.9**
Year * Irrigation	2	5266.6**	744200**	102623.5**	36.9^{ns}	42.3^{ns}	11.8**
Irrigation error	4	279.7	51526.7	4845.1	29.7	33.3	.94
Nutrition†	7	15195.7**	4967241.3**	629994.3**	743.8**	712.3**	47.9**
Year * Nutrition	7	2491.1**	587557.2**	70228.5**	100.2**	111.8**	3.7*
Irrigation * nutrition	14	2624**	130167.5^{ns}	9344.2^{ns}	47.4*	39.9*	3.6*
Year * Irrigation * Nutrition	14	2521.1**	133059.7^{ns}	14481.9*	39.9*	32.4*	3.7*
Nutrition error	88	643.4	85366.6	7841.9	23.2	26.6	1.7
Coefficient of variation	-	13.2	13.5	12.1	10.3	9.7	11.5

Ns: not significant, * and ** represent significant at probability levels of 5 and 1%, respectively.
† include svermicompost + Terracottem + Bolourab-A, D.C.: Daughter corm

Table 3: Means comparison of different treatments on traits of saffron daughter corms in the first year

Year	Irrigation interval	Nutrition	D.C. number (no.m^2)	D.C. fresh weight (g.m^{-2})	D.C. dry weight(g.m^{-2})	D.C. <8 g (%)	D.C. ≥8 g (%)	D.C. average weight (g)
1 (2014-15)	30 days	Control	89.7^{o}	693.7^{ij}	211.5^{kl}	66.3^{a}	33.7^{m}	7.7^{g-j}
		Vermicompost	119.7^{mno}	1655.3^{d-g}	549.5^{g-j}	41.8^{h-p}	58.2^{a-f}	13.9^{a-d}
		Bolourab-A	111.7^{mno}	1380.3^{e-h}	504.3^{hij}	41.6^{h-p}	58.4^{a-f}	12.9^{a-f}
		Terracottem	125^{mno}	1848^{d-g}	585.4^{g-j}	38.5^{j-p}	61.5^{a-e}	14.8^{a}
		Vermi. + Bolour.	164.3^{j-m}	1983de	616.8^{gh}	31.7^{p}	67.7^{a}	12.1^{a-f}
		Vermi. + Terraco.	134^{l-o}	1923^{def}	569.8^{g-j}	37^{l-p}	62.9^{a-d}	14.3^{ab}
		Bolour. + Terraco.	157.7^{klm}	1903.7^{d-g}	623.7^{gh}	31.9^{p}	68.1^{a}	12.1^{a-f}
		Vermi. + Bolour. + Terraco.	117.7^{klm}	1648^{d-g}	605.1^{ghi}	40.5^{i-p}	59.5^{a-f}	13.9^{abc}
	50 days	Control	76.7^{o}	565.7^{j}	175.4^{l}	55.2^{a-g}	44.8^{g-m}	7.4^{hij}
		Vermicompost	111.3^{mno}	1270^{e-i}	445.3^{hij}	40.6^{i-p}	59.4^{a-f}	11.4^{b-f}
		Bolourab-A	120.3^{mno}	1420^{efg}	488.4^{hij}	40.1^{i-p}	59.9^{a-f}	11.8^{a-f}
		Terracottem	144.7^{lmn}	1571.7^{d-g}	576.1^{g-j}	35.4^{m-p}	64.6^{abc}	11.8^{a-f}
		Vermi. + Bolour.	135^{l-o}	1460.3^{efg}	558.9^{g-j}	33.8^{p}	66.2^{ab}	10.9^{c-g}
		Vermi. + Terraco.	127^{mno}	1326.3^{e-i}	512.5^{hij}	40.5^{i-p}	59.5^{a-f}	10.4^{e-h}
		Bloor. + Terraco.	155^{klm}	1746.3^{d-g}	604.9^{ghi}	31.6^{p}	68.4^{a}	11.3^{b-f}
		Vermi. + Bolour. + Terraco.	122.7^{mno}	1550.7^{d-g}	491.4^{hij}	37.6^{k-p}	62.4^{a-e}	12.5^{a-f}
	70 days	Control	64.2^{o}	430.3^{k}	135.2^{kl}	56.8^{a-f}	43.2^{h-m}	6.7^{ij}
		Vermicompost	128^{mno}	1550^{d-g}	486.6^{hij}	38.2^{j-p}	61.8^{a-e}	12.3^{a-f}
		Bolourab-A	126.7^{mno}	1520^{d-g}	502.8^{hij}	38.4^{j-p}	61.6^{a-e}	12.1^{a-f}
		Terracottem	149^{lmn}	1521^{d-g}	483.8^{hij}	38.7^{i-p}	61.3^{a-e}	10.3^{e-h}
		Vermi. + Bolour.	136.3^{l-o}	1650.3^{d-g}	570.7^{g-j}	34.1^{nop}	65.9^{ab}	12.3^{a-f}
		Vermi. + Terraco.	155^{klm}	1522^{d-g}	522.3^{g-j}	43.4^{g-p}	56.6^{a-h}	9.8^{e-i}
		Bolour. + Terraco.	167.7^{i-m}	1763.7^{d-g}	575.8^{g-j}	32.2^{p}	67.8^{a}	10.5^{e-h}
		Vermi. + Bolour. + Terraco.	125.7^{mno}	1466.7^{efg}	468.2^{hij}	42.7^{h-p}	57.3^{a-g}	11.7^{a-f}

Common letters in every column indicate not significant difference according to Duncan's test at ($P\leq 0.01$), D.C.: Daughter corm

Table 4: Means comparison of different treatments on traits of saffron daughter corms in the second year

Year	Irrigation interval	Nutrition	D.C. number (no.m^2)	D.C. fresh weight (g.m^{-2})	D.C. dry weight (g.m^{-2})	D.C. < 8 g (%)	D.C. ≥ 8 g (%)	D.C. average weight (g)
2 (2015-16)	30 days	Control	175.3^{h-n}	1292.7^{f-j}	386.5^{ijk}	63.2^{ab}	36.8^{klm}	7.4^{g-j}
		Vermicompost	195.7^{g-l}	2221.3^{cd}	739.6^{fg}	50.8^{c-j}	49.2^{i-m}	11.4^{b-f}
		Bolourab-A	231.3^{d-h}	2951^{ab}	994.7^{cde}	53.5^{b-h}	46.5^{f-m}	12.8^{a-e}
		Terracottem	214.7^{f-k}	2683.3^{bc}	931.1^{ef}	51.1^{c-g}	48.9^{e-l}	12.5^{a-e}
		Vermi. + Bolour.	228^{d-i}	3169^{ab}	1096.5^{a-e}	40.6^{i-p}	59.4^{a-e}	13.9^{abc}
		Vermi. + Terraco.	268.7^{c-f}	3396.7^{ab}	1154.5^{a-d}	56.2^{a-f}	43.8^{g-m}	12.7^{a-e}
		Bolour. + Terraco.	307.3^{abc}	3240^{ab}	1073.5^{a-e}	58.9^{a-e}	41.1^{i-m}	10.5^{d-h}
		Vermi. + Bolour. + Terraco.	290.7^{a-d}	2843.3^{bc}	920.5^{ef}	57.7^{a-f}	42.3^{i-k}	10.1^{e-i}
	50 days	Control	171.3^{h-m}	1153.3^{g-j}	372.8^{jkl}	62.7^{abc}	37.3^{klm}	6.7^{j}
		Vermicompost	335^{ab}	3307.7^{ab}	1103.6^{a-e}	60.7^{a-d}	39.3^{j-m}	10^{e-i}
		Bolourab-A	346.7^{a}	3205.3^{ab}	1057.9^{a-e}	55.8^{a-f}	44.2^{g-m}	9.2^{f-j}
		Terracottem	258^{c-f}	2952.7^{ab}	1009.8^{b-e}	49.1^{d-k}	50.9^{d-k}	11.5^{b-f}
		Vermi. + Bolour.	277.7^{b-e}	3019^{ab}	1077.6^{a-e}	49.7^{d-k}	50.3^{d-k}	10.9^{c-g}
		Vermi. + Terraco.	259^{c-f}	2991^{ab}	1019.7^{b-e}	56.9^{a-f}	43.1^{i-m}	11.6^{a-f}
		Bolour. + Terraco.	306.3^{abc}	3041.3^{ab}	1043.4^{a-e}	51.2^{c-i}	48.8^{e-l}	9.9e-i
		Vermi. + Bolour. + Terraco.	239.3^{d-g}	2913.3^{ab}	988.6^{cde}	48^{e-k}	52^{c-j}	12.2^{a-f}
	70 days	Control	154^{k-m}	1012.3^{f-j}	286.1^{jk}	65.1^{ab}	34.9^{lm}	6.6^{j}
		Vermicompost	284^{b-e}	2984^{ab}	1060.1^{a-e}	51.2^{c-i}	48.8^{e-l}	10.6^{c-g}
		Bolourab-A	249^{c-g}	3070^{ab}	1078.1^{a-e}	50.3^{c-j}	49.7^{d-k}	12.3^{a-f}
		Terracottem	312^{abc}	3381.3^{ab}	1163.8^{a-d}	49.6^{c-i}	50.4^{g-m}	10.5^{b-g}
		Vermi. + Bolour.	268^{c-f}	3378.7^{ab}	1193.2^{abc}	42.6^{e-m}	57.4^{f-m}	12.6^{a-f}
		Vermi. + Terraco.	290.7^{a-d}	3621.7^{a}	1241.1^{a}	41.4^{c-j}	58.6^{a-e}	12.5^{a-f}
		Bolour. + Terraco.	259.7^{c-f}	3625.3^{a}	1221.8^{ab}	44.1^{f-o}	55.9^{b-f}	13.9^{abc}
		Vermi. + Bolour. + Terraco.	224.3^{e-j}	2782.3^{bc}	960.3^{de}	46.5^{e-n}	53.5^{b-i}	12.4^{a-f}

Common letters in every column indicate not significant difference according to Duncan's test at (P≤ 0.01), D.C.: Daughter corm

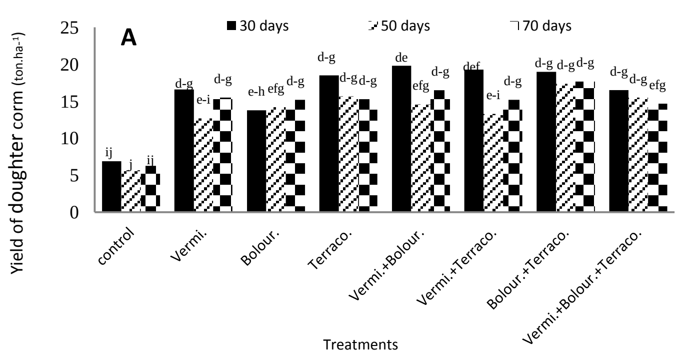
Table 5: ANOVA results of experimental factors on different traits of saffron daughter corms

Source of variation	Degree of freedom	Nitrogen	Phosphorus	Potassium	Dry matter	Yield of D. C.	Water use efficiency
Replication	2	0.12^{ns}	77854.8^{ns}	66409.9^{ns}	0.89^{ns}	0.69^{ns}	0.16^{ns}
Year	1	9.6^{**}	8440477.6^{**}	23434474.2^{**}	61102.1^{**}	6708.9^{**}	71.2^{**}
Year error	2	0.008	20274.5	821112.1	0.68	12.2	0.04
Irrigation	2	0.28^{*}	505878.4^{ns}	808426.1^{ns}	3.5^{ns}	22.2^{*}	44.3^{**}
Year * Irrigation	2	0.04^{ns}	1265732.3^{**}	1136934.1^{ns}	3.6^{ns}	74.4^{**}	8.8^{**}
Irrigation error	4	0.39	145637.8	16350.2	0.3	5.2	0.08
Nutrition†	7	0.79^{**}	4084757.7^{**}	4029557.9^{**}	25.3^{**}	496.4^{**}	5.2^{**}
Year * Nutrition	7	0.14^{*}	633695.2^{*}	667351.6^{*}	24.8^{**}	58.6^{**}	0.63^{**}
Irrigation * nutrition	14	0.15^{**}	1439468.1^{**}	745430.9^{*}	3.5^{ns}	13^{ns}	0.47^{**}
Year * Irrigation * Nutrition	14	0.1^{*}	802212.9^{**}	403208.7^{*}	3.5^{ns}	13.3^{ns}	0.17^{**}
Nutrition error	88	0.06	235950.1	486616	4.6	8.5	0.06
Coefficient of variation	-	19.6	16.5	12.9	10.2	13.5	11.8

Ns: not significant, * and ** represent significant at probability levels of 5 and 1%, respectively.
† include vermicompost + Terracottem + Bolourab-A, D.C.: Daughter corm

Yield of Daughter Corms

Yield of daughter corms was significantly affected by different treatments (P <0.01) (Table 5). The esults of means comparison showed that the highest yield of daughter corm was 36.4 and 36.2 ton per ha which was related, respectively, to the combined treatments of Bolourab-A +Terracottem and Bolourab-A + vermicompost at irrigation interval of 70 days in the second year, and the lowest yield was related to the control in both experiment years (Fig 1).



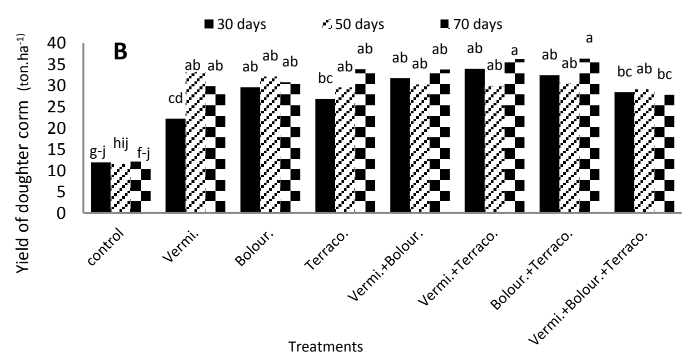


Fig 1: Interaction effects of nutrients and irrigation interval on yield of doughter cormsin the first (A) and secound (B) years in saffron

Water Use Efficiency of Daughter Corms

According to the results of variance analysis, the effect of all treatments on water use efficiency was significant (P <0.01) (Table 5). Means comparison suggests that the highest water use efficiency (5.2 kg/m^3) was associated to the combined application of vermicompost + Terracottem at irrigation interval of 70 days in the second year, which showed significant difference from the control treatment during two experiment years (Tables 6 and 7).

Table 6: Means comparison of different treatments on traits of saffron daughter corms in the first year

Year	Irrigation interval	Nutrition	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)	Dry matter (%)	Water use efficiency (kg.m^{-3})
1 (2014-15)	30 days	Control	1^{fgh}	3016.7^{b-h}	5016.7^{b-h}	0.3^{g}	0.3^{x}
		Vermicompost	1.5^{a-g}	2483.3^{d-h}	5410^{a-h}	0.33^{g}	0.9^{t-x}
		Boloурab-A	1.3^{c-h}	2800^{c-h}	5463.3^{a-h}	0.37^{g}	0.9^{t-x}
		Terracottem	1.4^{b-g}	3233.3^{b-f}	5816.7^{a-e}	0.32^{g}	1^{q-v}
		Vermi. + Bolour.	1.5^{a-g}	4243.3^{b}	5220^{b-h}	0.32^{g}	1.1^{q-v}
		Vermi. + Terraco.	1.5^{a-g}	2966.7^{c-h}	5843.3^{a-e}	0.33^{g}	1^{q-v}
		Bolour. + Terraco.	2^{ab}	3483.3^{b-e}	6216.7^{a-d}	0.33^{g}	1.1^{q-v}
		Vermi. + Bolour. + Terraco.	1.6^{a-f}	3266.7^{b-f}	5833.3^{a-e}	0.37^{g}	1^{q-v}
	50 days	Control	1.3^{c-h}	2800^{c-h}	4750^{c-h}	$.31^{g}$	0.4^{wx}
		Vermicompost	1.5^{a-g}	3316.7^{b-f}	5333.3^{a-h}	0.35^{g}	1.1^{q-v}
		Bolourab-A	1.5^{a-g}	2966.7^{c-h}	5616.7^{a-e}	0.34^{g}	1.2^{p-v}
		Terracottem	1.8^{a-e}	3300^{b-f}	6316.7^{abc}	0.38^{g}	1.4^{n-u}
		Vermi. + Bolour.	1.6^{a-f}	3150^{b-f}	5753.3^{a-e}	0.39^{g}	1.4^{n-u}
		Vermi. + Terraco.	1.9^{abc}	6016.7^{a}	6066.7^{a-e}	0.39^{g}	1.3^{p-v}
		Bolour. + Terraco.	2.1^{a}	3250^{b-f}	6346.7^{abc}	0.35^{g}	1.5^{l-t}
		Vermi. + Bolour. + Terraco.	1.5^{a-g}	2466.7^{d-h}	5526.8^{a-g}	0.32^{g}	1.2^{p-v}
	70 days	Control	1.2^{d-h}	903.3^{i}	4993.2^{b-h}	0.29^{g}	0.8^{u-x}
		Vermicompost	1.3^{c-h}	3433.3^{b-e}	5716.7^{a-f}	0.31^{g}	2^{f-m}
		Bolourab-A	1.3^{c-h}	2520^{d-h}	5923.3^{a-e}	0.33^{g}	2.1^{e-l}
		Terracottem	1.3^{c-h}	2966.7^{c-h}	5933.3^{a-e}	0.32^{g}	2^{f-m}
		Vermi. + Bolour.	1.8^{a-e}	3883.3^{bc}	6050^{a-e}	0.35^{g}	2.4^{d-i}
		Vermi. + Terraco.	1.6^{a-f}	3866.7^{bc}	7076.8^{a}	0.34^{g}	2.2^{d-k}
		Bolour. + Terraco.	1.6^{a-f}	2696.7^{c-h}	6803.3^{ab}	0.33^{g}	2.4^{d-i}
		Vermi. + Bolour. + Terraco.	1.5^{a-g}	3636.7^{bcd}	6070^{a-e}	0.32^{g}	1.9^{i-o}

Common letters in every column indicate not significant difference according to Duncan's test at (P≤ 0.01)

Table 7: Means comparison of different treatments on traits of Saffron daughter corms in the second year

Year	Irrigation interval	Nutrition	Nitrogen (%)	Phosphorus (ppm)	Potassium (ppm)	Dry matter (%)	Water use efficiency (kg.m^{-3})
2 (2015-16)	30 days	Control	0.4^{ij}	1771.7^{hi}	3831^{gh}	35.8^{f}	0.7^{vwx}
		Vermicompost	0.7^{hij}	2225.3^{e-h}	4535^{c-h}	40.4^{b-f}	1.3^{p-v}
		Bolourab-A	1^{fgh}	2258^{e-h}	5553.3^{a-g}	43.2^{abc}	1.8^{j-p}
		Terracottem	1.1^{fgh}	2902.6^{c-h}	5279.7^{a-h}	41.6^{a-d}	1.7^{k-q}
		Vermi. + Bolour.	1.3^{c-h}	3155^{b-f}	5000^{b-h}	46.5^{a}	1.9^{i-o}
		Vermi. + Terraco.	1^{fgh}	2423.3^{d-h}	5423.8^{a-h}	44.3^{abc}	2.1^{e-l}
		Bolour. + Terraco.	1.5^{a-g}	2897^{c-h}	5950.7^{a-e}	41.1^{b-e}	1.9^{i-o}
		Vermi. + Bolour. + Terraco.	1.2^{d-h}	2641^{c-h}	5540^{a-g}	44.3^{abc}	1.6^{k-s}
	50 days	Control	0.7^{hij}	1850.3^{ghi}	3690^{h}	37.4^{def}	0.9^{t-x}
		Vermicompost	1.2^{d-h}	3057.7^{b-g}	5236.3^{b-h}	43.2^{abc}	2.8^{d}
		Bolourab-A	1.1^{fgh}	2667.3^{c-h}	4687^{c-h}	41.3^{a-e}	2.6^{def}
		Terracottem	1.1^{fgh}	3092.7^{b-g}	4704.7^{c-h}	43.1^{abc}	2.5^{d-h}
		Vermi. + Bolour.	1.1^{fgh}	2804.7^{c-h}	5919.3^{a-e}	42.9^{abc}	2.7^{d-e}
		Vermi. + Terraco.	1.2^{d-h}	2952^{c-h}	5110^{b-h}	41.7^{a-d}	2.5^{d-h}
		Bolour. + Terraco.	1.3^{c-h}	2288.3^{e-h}	4974.7^{b-h}	39.1^{c-f}	2.6^{def}
		Vermi. + Bolour. + Terraco.	1.1^{fgh}	2795.7^{c-h}	4392^{d-h}	41.3^{a-e}	2.5^{d-h}
	70 days	Control	0.4^{ij}	1844^{ghi}	3921.3^{fgh}	36.2^{ef}	1.3^{k-s}
		Vermicompost	1^{fgh}	2569.3^{d-h}	5389.7^{a-h}	41.9^{a-d}	4.4^{bc}
		Bolourab-A	1.3^{c-h}	2725.3^{c-h}	5203.6^{b-h}	40.5^{b-f}	4.5^{ab}
		Terracottem	1.2^{d-h}	3045.6^{b-g}	4622.8^{c-h}	39.2^{c-f}	4.8^{ab}
		Vermi. + Bolour.	1.1^{fgh}	3434.7^{b-e}	5724^{a-f}	44.9^{ab}	5^{a}
		Vermi. + Terraco.	1^{fgh}	3492.3^{b-e}	6225.7^{a-d}	42.3^{a-d}	5.2^{a}

Bolour. + Terraco.	1.1[fgh]	2772.8[c-h]	4284.3[e-h]	42.4[a-d]	5.1[a]
Vermi. + Bolour. + Terraco.	1.2[d-h]	3144[b-f]	4744[c-h]	41.8[a-d]	4[c]

Common letters in every column indicate not significant difference according to Duncan's test at ($P\leq 0.01$)

Discussion

Number of Daughter Corms

These results indicate that the formation of daughter corms was significantly affected by water and soil nutrient availability also in the second year, saffron produce more network of roots able to increase the absorption of mineral nutrient, compared to the first year. Therefore, increase in plant growth and daughter corm formation as well as expanded root system enables the plants absorb nutrients efficiently from the soil. This increment due to life cycle of saffron as a perennial plant, in other words, saffron growth continues to develop from year to year (Koocheki *et al.*, 2014). By increasing water holding capacity in the soil (Islam *et al.*, 2011), improving porosity and ventilation of soil (Wu *et al.*, 2008) and providing the essential nutrients needed in the rhizosphere environment, super absorbent polymer provides suitable conditions for the production of more daughter corms. Increasing the rate of super absorbents led to a significant increase in the growth rate of leaves and the production of daughter corms of saffron plants, as Khorramdel *et al.* (2014) reported.

Fresh and Dry Weights of Daughter Corms

The results of the experiment showed the improvement of physical structure, appropriate soil moisture content and the supply of essential nutrients produced daughter corms with heavier weight. Drought stress in saffron plant causes vegetative buds to be less active, so the transfer of nutrients from mother corms to daughter ones occurs less due to the lack of moisture, so the weight of these corms, in comparison with sufficient moisture conditions, reduced less due to the lack of nutrients consumption (Sabet Teimouri *et al.*, 2010). In fact, number of daughter corms decreased as a result of drought stress, but the weight of these corms increased compared to the ones produced under more irrigation conditions. Increase in the rate of super absorbents from zero to 0.8% based on dry weight ofsoil caused 41% increase in dry weight of daughter corms compared to the control (Khorramdel *et al.*, 2014).

The Percentage of Non-Standard (With the Weight Less Than 8 G.) And Standard (With the Weight Equal to 8 G. And More Than 8 G.) Daughter Corms

This was due to the lack of sufficient nutrient availability to the plant, given the presence of suitable moisture in the rhizosphere. Findings of the researchers have shown that the production of these corms reduced the economic yield of the crop per unit area, thus reducing the efficiency of water, fertilizer and other inputs. Daughter corms weighing less than 8 g usually do not have the ability of producing flowers, but they only store photosynthetic materials and do not spend their energy on the production of new daughter corms (Sabet Teimouri *et al.*, 2010, Omidbaigi *et al.*, 2002). These results demonstrate the importance of using soil organic amendments containing different nutrients, as well as the positive relationship between proper fertilization of the plant in the presence of sufficient moisture and increase of the vegetative growth and the production of larger daughter corms. Application of super absorbent polymer caused a reduction in the production of non-standard daughter corms and an increase in the production of standard daughter corms and their application is an appropriate strategy for production of standard saffron corms in semi-arid regions (Fallahi *et al.*, 2016). Results of a research showed that increasing weight of daughter corms from 2 - 4 g to more than 8 g led to a significant increase in the yield of saffron stigma ($P\leq 0.01$) (Tookalloo and Rashed Mohassel, 2009). Therefore, the use of correct management operations especially water availability is essential for the production of saffron standard corms in corm production fields.

The Average Weight of Daughter Corms

By providing moisture and essential nutrients required by the plant in the rhizosphere, super absorbent polymer provides good environment for the growth and production of large daughter corms. Poggi *et al.* (2009) found in their studies that 1 cm increase in corm diameter caused a threefold increase in saffron yield. At the present, study of the production methods of daughter corms with high weight but fewer numbers on mother corms is one of the main goals of the researchers of saffron. Cell division and growth of leaves in larger corms, compared to smaller ones, occur earlier. Rapid growth and greater level of leaves allow the plant to use inputs and environmental conditions efficiently, and provide the conditions for increasing the production of more and heavier daughter corms by producing more photosynthetic materials and transferring and storing them in corms (Molina *et al.*, 2005).

Nutritional Elements Absorbed By Daughter Corms

Nitrogen

Daughter corms produced during the growing season store photosynthetic materials produced in leaves. Therefore, the higher the amount of assimilates produced by the leaves, the heavier and higher daughter corms produced. Through direct influence on photosynthesis and cell division processes, nitrogen can increase vegetative growth and plant's green surface (Saikia *et al.*, 2010). In geophyte plants such as saffron, besides producing and transferring photosynthetic materials from leaves, nutritional elements are also transferred from aerial parts to underground organs at the end of the growing season (Chaji *et al.*, 2013).

Phosphorus

The availability of phosphorus element along with sufficient moisture in combination with vermicompost and Terracottem organic matters improved its absorption by the plant saffron. Phosphorous plays specific role in cell division, production of ATP molecules, chlorophyll synthesis and improvement of qualitative and quantitative yield of saffron (Naghdi Badi *et al.*, 2011). Researchers have shown that up to 80% of saffron yield changes depend on soil-related variables, and meanwhile the availability of organic matter and phosphorus is of high importance (Chaji *et al.*, 2013). Application of organic fertilizers (cow manure, vermicompost and garbage compost) significantly increased the concentration of phosphorus in saffron daughter corms (Koocheki *et al.*, 2015). Rezvani Moghaddam *et al.* (2013) observed an increase in the number and weight of the daughter corms as a result of organic fertilizer application and associated it to the availability of most nutrients, in particular nitrogen and phosphorous, and improvement of physical and biological properties of the soil due to increased organic matter. Chaji *et al.* (2013) reported that increasing phosphorus levels enhanced the weight of saffron daughter corms and decreased their number, while increase in nitrogen consumption had opposite effect.

Potassium

Since potassium ion (K^+) is often absorbed on negative charged particles and organic matters become negatively charged after water absorption and hydration, organic matters prevent potassium ion leaching by its adsorption. Therefore, due to the adequate ventilation (70 day irrigation interval) around the root, the ground for maximum absorption of potassium is provided. Addition of Vermicompost to soil increases the absorption of phosphorus, potassium, calcium and magnesium by plants (Renato *et al.*, 2003). Application of organic fertilizer can, besides improving physical and chemical properties, play effective role in improving the action exchange capacity and increasing soil nutrient (Amiri, 2008). The results of physicochemical analysis of Saffron Research Farm soil using artificial neural network showed that the values of electrical conductivity parameters, zinc, nitrogen, pH, phosphorus, potassium and soil gravel percentage, respectively, were the most important characteristics affecting dry weight of saffron corm (Zarghani *et al.*, 2016). The most important soil chemical properties affecting dry weight of saffron cormaccording to stepwise regression analysis were determined potassium and phosphorus with available contents of 0.561 and 0.264, respectively (Rezvani Moghaddam *et al.*, 2015).

Percentage of Dry Matter of Daughter Corms

An increase in plant ability to absorb (N), (P) and (K) cause the increase of dry matter production. Nutritional elements existing in organic compounds such as vermicompost and Bolourab-A are gradually released. Thus, in the second year, the availability of most nutrients released from organic matters in soil solution and the presence of sufficient moisture caused nutrients to be absorbed more in comparison with the first year, leading to the increase of dry matter. However, water requirement of saffron is relatively low compared to other plants, but applying moisture stress and lack of soil moisture has a direct negative effect on dry matter yield and growth of saffron daughter corms (Kafi *et al.*, 2006). Application of high levels of superabsorbent increased the percentage of root dry matter and its development (Huttermann *et al.*, 1999). Use of super absorbent polymers had a positive effect on traits such as plant height and dry matter accumulation (Torabi *et al.*, 2012).

Yield of Daughter Corms

This issue indicates that the gradual degradation of organic matters added to the soil and the increase of available nutrients in the soil in the presence of adequate humidity and appropriate ventilation (70-day irrigation interval) as well as the increase in the activity of microorganism increased the amount of nutrients available to the corm and improved the yield of daughter corms in the second year compared to the first year. The results of the researches conducted by Allah Dadi *et al.* (2005) showed that application of super absorbent polymer under drought stress and low irrigation resulted in an increase in yield and some yield components. Increasing drought stress and decreasing available water content enhanced the effect of super absorbent hydrogels on the increase of yield, so the effect of super absorbent polymers is more pronounced at lower levels of moisture (Koohestani *et al.*, 2009). As mentioned before, this result might be due to more growth and expansion of the roots network during the second year.

Water Use Efficiency of Daughter Corms

In general, low irrigation is an optimal strategy for crop production under water scarcity conditions that always reduce the product yield, and its main objective is to increase water use efficiency. According to the results of this study, use of combined treatment of Vermicompost and Terracottem under stress conditions, due to the increase of irrigation intervals, could reduce stress levels by increasing available water and plant nutrients absorption and improve the yield of daughter corms by increasing water use efficiency. This high efficiency and reduction of water consumption is very valuable and useful for producing a suitable amount of daughter corms in semi-arid areas. Abedini and Kupayi (2016) reported that Aquasorbhydrogel in 21-day irrigation treatment compared to 14-day treatment showed higher production of saffron daughter corms than that of Stockosorb and Bolourab-Aunder the same water consumption. Water use efficiency in saffron daughter corms due to the application of superabsorbent polymer (6.1 kgm^{-3}) was higher than that of control (4.34 $kg.m^{-3}$) in the second year of the experiment (Fallahi *et al.*, 2016). Overall, appropriate water availability especially by organic compounds application is a suitable strategy for increasing corm production and water use efficiency.

Conclusion

Saffron, like other plants, needs appropriate agronomic management and new technologies for optimum use of environment potential, achievement of high yields and increase of the farm exploitation period. The results of this study showed that use of super absorbent polymers combined with vermicompost organic fertilizer was effective against moisture loss between two irrigations by improving water holding capacity in soil, delaying moisture stress in plant and providing a buffering state. Furthermore, they reduce plant water requirement by increasing irrigation efficiency, an issue which is of high importance in arid and semi-arid regions of Iran, where limitation of water resources is an important problem. Combined application of super absorbent polymers and vermicompost improved ventilation, increased porosity, prevents leaching, maintained and supplied essential nutrients of plant, increased permeability and, by adjusting soil temperature, created more favorable conditions for plant growth, thereby increasing vegetative growth and daughter corms yield. Taking into account economic conditions, combined application of vermicompost organic fertilizer (6000 kg ha^{-1}), super absorbent polymer of Bolouraba (600 kg ha^{-1}) and Terracottem (600 kg ha^{-1}) in planting time of corms and 50-day irrigation round during the growing period of saffron could increase water use efficiency and improve the yield of daughter corms compared to control.

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