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Original Article

Effect of Different Irrigation Systems and Fertilizer Types on Saffron Corm Production

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ABSTRACT

In order to investigate the effect of irrigation method and fertilizer type on saffron corm production, a split-plot experiment was carried out in the research field of Islamic Azad University, Birjand Branch, Birjand, Iran during 2016-2018 years based on a randomized complete block design with three replications. Three irrigation methods (flooding, surface drip, subsurface drip) were as the main plots. Also, six fertilizer levels (1-cattle manure at 25 t/ha, 2-chemical fertilizer including 150, 100, and 150 kg/ha urea, triple superphosphate and potassium sulfate, respectively, 3-biological fertilizer at 200, 300 and 300 g/ha including nitrogen, phosphorus and potassium, respectively, 4-the combination of 50% cattle manure and 50% chemical fertilizer, 5-the combination of 50% biological fertilizer and 50% chemical fertilizer and 6-non-fertilizer application) were the subplots. The results showed that the simple and interaction effects of irrigation method and fertilizer type on the corms number and yield was significant. In general, the results indicated superiority of treatment subsurface drip irrigation and combination of 50% cattle manure with 50% chemical fertilizer. It seems that reducing the use of chemical fertilizers and replacing them with livestock manure can lead to sustainable agriculture and reduce environmental pollution. On the other hand, using of subsurface drip irrigation under the conditions of increasing drought stress in the region will be an effective step in increasing saffron yield.

INTRODUCTION

Saffron *(Crocus sativus* L.) is a perennial, herbaceous plant belonging to the Iridaceae family [1] which is considered one of the most valuable medicinal species and the most expensive crop in the world. Its main economic aspect is the three-branched stigma derived from the flowers; however, today the production of saffron corms may also lead to high income for farmers [2]. This plant mainly grows in the Mediterranean region, west asia, and low rainy regions of Iran with cold winter and hot summer [3]. Special features of this product, including the possibility of several year exploitations through one-period planting, need for low water, irrigation in non-critical seasons of water needs of other plants, as well as suitable domestic and foreign markets have made it the first choice of farmers for planting pattern in south Khorasan province [4].

The quality of saffron corm and its weight are very important in the economic yield of this crop. Therefore, the role of managerial and agronomical factors such as irrigation and nutrition in the production of high quality saffron corm is very important [2].

Water scarcity is one of the most important issues in agriculture throughout the world, especially in arid and semi-arid regions such as Iran. At present, to compensate for water shortage in the agricultural sector (i.e. the largest and most important water consumer in Iran with more than 90% of total water consumption), it is necessary to change cultivation patterns, improve irrigation efficiency, and increase water productivity. In this regard, selection of suitable irrigation method and plants should be considered in the planting pattern [5]. Proper management of irrigation systems is essential to achieve maximum irrigation water use efficiency. The use of underground drip irrigation systems (subsurface drip irrigation) in agriculture can increase water use efficiency. These systems provide irrigation water directly to the plant underground, instead of surface [6]. Drip irrigation is an efficient method of delivering water to the plant root without loss, which leads to saving water consumption by 50-66% and increasing yield by 30-40% in comparison with flood irrigation [7, 8]. Various studies were performed on the effects of subsurface drip irrigation systems on the yield of agricultural products. In an experiment the results showed that in addition to saving water consumption compared to traditional methods, drip irrigation with a 24-days cycle, produced larger corms [9]. In another study in Qaen, Iran, the results showed that although irrigation methods (rain, drip, furrow, and basin irrigations) did not any significant effect on the growth and yield of saffron corm in the first year, the highest and lowest yields of saffron corm in the third year were related to the basin irrigation and rain irrigation, respectively [10]. Meanwhile, another researcher [11] in the study of three irrigation methods (flooding, drip and sprinkling) observed the highest dry weight and number of saffron replacement corms was related to drip irrigation method. In the study, drip irrigation of saffron increased the number of replacement corms by 10 and 34% compared to rain and basin irrigation methods, respectively.

In the study of the subsurface drip irrigation method at a depth of 40 cm and furrow irrigation method on Alfalfa (*Medicago sativa* L.), the results showed that crop yield increased by 20% and water consumption decreased by 6% in subsurface drip irrigation method compared to furrow irrigation method [12]. Also, in another study reduction of evaporation, surface runoff and deep infiltration and better weed control and increase herbicide efficiency have been stated as special advantages of the subsurface drip irrigation method [13].

Several agricultural operations including the use of chemical fertilizers have been carried outto increase the production of agricultural crops.These operations causeenvironmental pollution, especially of soil and water resources, and affect the health of human communities by entering human food resources. Hence, the use of modern agricultural techniques and fertilizer management is very important in the production of agricultural crop with a sustainable agricultural approach [14]. Plant nutrition is one of the most effective agronomic strategies to increase the yield of medicinal plants [15]. Unfortunately, Iran is one of the countries facing a crisis of chemical fertilizers application. One of the proposed methods to reduce the harmful effects of excessive use of chemical fertilizers is the use of biofertilizers [16, 17].

In an experiment, the effect of organic and chemical fertilizers on the production of saffron replacement cormwas investigated. The lowest total weight of corms was observed in non-fertilizer treatment, which did not differ significantly fromthe treatment of NPK chemical fertilizer [18].These researchers reported that the use of cattle manure produced corms more with heavier than eight grams. On the other hand using chemical fertilizers increased the number of smaller replacement corms, especially corms less than one gram. In another study, it was found that in the early years of farmingoperation, the availability of nutrients more led to an increase in the number of replacement corms, but in the later years, the weight of replacement corms enhanced [19]. In another study increasing phosphorus levels, caused an increase in the weight of saffron replacement corms, but their number decreased. However, with increasing nitrogen consumption, the weight of replacement corms decreased and their number increased [20]. Little research was done on comparing different methods of drip irrigation (surface and subsurface) with flooding irrigation and their effects on saffron corm production. Thus, little information is available about the response of saffron to different irrigation methods. Hence, given the increasing importance of organic production and the need to reduce the use of chemical fertilizers, the present study was conducted to evaluate the effect of different irrigation methods and fertilizer sources on the capability of producing saffron corm in Birjand.

MATERIALS AND METHODS

This research was conducted during two production seasons from 2016 to 2018 at the experimental station of agricultural college, Birjand branch, Islamic Azad University, Birjand, Iran. Longitude, latitude and altitude of the experiment location are 32 degrees and 53 minutes north and 59 degrees and 13 minutes east, and 1491 m above the mean sea level, respectively. The long-term average minimum and maximum temperatures in Birjand are 4.6 and 27.5 degrees Celsius, respectively; the average annual rainfall is 152 mm; and the average minimum and maximum relative humidity are 23.5 and 59.6%, respectively. The climate of this desert region is hot and dry. Important climatic indicators during the growing season are presented in Table 1.Before applying the treatments, a depth of 0-30 cm in the soil was sampled andits physical and chemical properties were determined (Table 2).

This experiment was carried out as split plot in a randomized complete block design with three replications. Irrigation system at three levels (flooding, I1; surface drip, I2; subsurface drip, I3) were considered as the main factor. Also, fertilizer types at six levels (cattle manure at 25 t/ha,F1; chemical fertilizer including 150, 100 and 150 kg/ha urea, triple superphosphate, and potassium sulfate, respectively,F2; biological fertilizer or Barvar-2 at 200, 300, and 300 g/ha including nitrogen, phosphorus and potassium, respectively,F3; the combination of 50% cattle manure and 50% chemical fertilizer,F4; the combination of 50% biological fertilizer and 50% chemical fertilizer,F5; and non-fertilizer application,F6) considered as the secondary factor. In each experimental plot, ten planting rows with a length of 5 meters and a distance between rows of 20 cm, a distance on rows of 10 cm, and a density of 50 corms per square meter were created.

In the summer of 2016, initial plowing was done by plough to prepare the planting bed, and then, in order to soften the lumps (of earth) in late August, the farm was diskedand leveled with leveler. To prevent the transfer of water and fertilizer to adjacent plots, a distance of half meter was embedded between two plots, in a 60 cm deep canal with a thick plastic in it, which was covered with soil on both sides. In this design, 16 mm pipes were used in which drippers were embedded in the line with a flow rate of 4 liters per hour at distances of 20 cm, and a tape pipe was placed next to each row of saffron. Just like the surface drip irrigation, 16mmpipes were placed under of the soil surfacewith the difference that the thickness of pipes was greater. pipes were installed at a depth of 15 cm, in the vicinity of saffron corm. In order to reduce the risk of dripper clogging, soft and washed sand was positioned under the pipes. In each main plot, a volumetric water meter of 1/2 was installed at the water entrance to the pipe, the irrigation of each plot was controlled, and the amount of water consumption was measured and recorded by a volumetric water meter. The In flood irrigation plots, water was transferred to the plot by polyethylene pipe and the amount of incoming water was measured with a water meter. In general, irrigation rate per year in each irrigation method was constant and equal to 4800 m^3. In each turn, irrigation was fixed for all treatments, in accordance with the farming custom of 70-120 liters per square meter.

Table 1 Monthly meteorological data for the growing season of saffron (2016-2018)

Date	Precipitation (mm)	Mean temperature (°C)	Mean humidity (%)	Sum of evaporation (mm)
Sep-16	0	25.3	15.2	356.3
Oct-16	0	17.7	18.4	242.5
Nov-16	3.4	9.4	29.8	120.9
Dec-16	2	9.2	31.6	0
Jan-17	18.6	4.5	44.5	0
Feb2017	42.2	6.5	55.5	0
Mar-17	17.8	12.2	38.7	161.6
Apr-17	0.8	19.2	23.1	302.1
May-17	5.1	24.9	20.9	378.2
Jun-17	0	29	13.2	506.6
Jul-17	0	27.7	14.4	518.4
Aug-17	0	25	14.7	444.8
Sep-17	0	21.6	15.6	349.1
Oct-17	0	18	15.2	267.7
Nov-17	0.3	11.1	27.3	94.7
Dec-17	0.1	5.2	27.4	0
Jan-18	8.1	4.9	35.5	0
Feb-18	23.3	8.6	38	0
Mar-18	12.8	15.1	32.5	195.7
Apr-18	31	18	35.4	255.5
May-18	13.2	21	26.9	317.7
Jun-18	0	28.2	13.8	488.2
Jul-18	0	29.1	13	558.7
Aug-18	0	26.4	16.3	481.9
Sep-18	1.5	22	15.6	332.6
Oct-18	21.2	16	31	208.6
Nov-18	7.7	10.7	45.8	109.2
Dec-18	0.7	6.7	37.9	47.3

Table 2 Physico-chemical properties of the soil at experimental site

Soil texture	EC (dS/m)	OC (%)	Total N (%)	P (ppm)	K (ppm)	pH
Sandy loam	3.49	0.04	0.006	3.8	236	7.45

Water was supplied by a pressure irrigation network. In order to prevent fungal infection, the cleaned corms were placed in fungicide solution for 5 minutes, and subsequently, were planted on 2016-09-04.

The first irrigation was performed on 2016-10-16, according to the farming tradition, and the flowers appeared on 2016-12-10. The entrance water was carefully controlled and recorded by volumetric water meter. In order to investigate the effect of experimental treatments on replacement corms in mid-June and after complete drying of the leaves and confidence the beginning of the corms dormancy period, the underground part of 10 complete plants was removed from the soil with regard to the edge effect. After separating the soil particles from the corms, corms traits including the number of corms, the fresh and dry weight of the whole corms, and also the number and weight of the replacement corms less than 4 g (small corm), between 4-8 g (medium corm), and more than 8 g (large corm) were examined and measured.Then, the corms of each weight group were cut into pieces, and by placing them in the oven for 48 hours at a temperature of 72°C, their dry weights were determined.The obtained data were analyzed using SAS software, version 9.1. It is necessary to explain that given the perennial nature of the saffron and the differences in the studied traits in the first and second years due to the growth nature of this plant, the data were analyzed separately each year, and the means were compared using Duncan's multivariate range test at the 5% probability level. Excel software wasused to draw the figures.

RESULTS

Number of Replacement Corms per Square Meter

Analysis of variance indicated that the simple and interaction effects of irrigation method and fertilizer level on thenumber of replacement corms during two years were significant at the level of 1%; except the simple effect of irrigation method on the number of corms more than 8 g in the second year which was not significant (Table 3). The largest number of small corms in the first and second years with means of 186.51 g and 476.67 g per square meter, respectively, were related to I1F2 treatment. In the second year, I1F2 and I3F2 treatments were included in the same statistical group in terms of the mentioned trait (Table 4). The largest number of small corms in I2 irrigation level was obtained in I2F1 treatment for the first year, and in I2F4 and I2F5 treatments for the second year; and in I3 irrigation level, in I3F2 treatment for both years. Medium corms of I1F4 treatment with a mean of 67.1 corms per square meter for the first year and I3F2 and I1F2 treatments for the second year had a significant advantage over other treatments. I3F2 treatment with a mean of 190 corms per square meter had the largest number of medium corms, which was only in the same statistical group with I1F2 treatment.

In addition, the largest number of medium corms produced per unit area in I2 irrigation level in both years was related to I2F2 treatment (Table 4). I3F4 treatment with a mean of 86.33 corms per square meter produced the largest number of corms heavier more than 8 g in the first year. However, in the second year, I1F4 and I3F4 treatments with a mean of 220 corms per square meter had the largest number of large corms. Moreover, the largest number of corms weighing more than 8 g in I2 irrigation level in both years was related to I2F2 treatment and in all three irrigation methods in the second year, the most number of large corms was observed in I3F4 fertilizer level.

In terms of the total number of corms per square meter, in the first year, I1F2 treatment with a mean of 301.72 corms per square meter had a significant advantage over other treatments. In the second year, I3F2 and I1F2 treatments with means of 790 and 764 corms per square meter respectively had a significant advantage over other treatments (Table 4). The lowest total number of corms per square meter was observed in I1F6 treatment in both years, which showed a decrease of 64% and 62.5% compared to the superior treatment (I3F2, I1F2). The largest total number of corms per square meter in I2 irrigation level was obtained in I2F1 treatment in the first year and in I2F4 treatment in the second year, which were placed in the same statistical group with I2F2 and I2F5 treatments (Table 4).

Yield of Replacement Corms per Square Meter

The results of analysis of variance showed that the simple and interaction effects of irrigation methods and fertilizer sources on corm yield per unit area were significant at the level of 1% in both years (Table 3). The comparison of means in the first year showed that the treatments of I2F1 and I2F3 with 284 and 29.4 g/m^2, respectively, had the highest and lowest yields of small corm. In the flood irrigation method (I1), I1F4 treatment had the highest yield of small corm, which did not differ significantly with I1F2 and I1F1 treatments (Table 4). In the subsurface drip irrigation (I3), the highest yield of small corm was observed in I3F2 treatment, which had a significant advantage of 2.27 times compared to I3F1 treatment. In the second year, I3F2 treatment with the product of 925 g/m^2 produced the highest yield of small corm, which was included in the same statistical group with I1F2 treatment (Table 4). I1F3 treatment produced the lowest yield of small corm and was included in the same statistical group with I1F6, I2F3, and I3F6 treatments (Table 4). The highest and lowest yields of small corm in the flood irrigation (I1) were obtained in I1F2 and I1F3 treatments, respectively; in the surface drip irrigation system (I2) were obtained in I2F4 and I2F6 treatments, respectively, and in the subsurface drip irrigation system (I3) were obtained in I3F2 and I3F6 treatments, respectively (Table 4). The highest and lowest yields of 4-8 g corms in the first year were obtained in I1F4 and I3F3 treatments, respectively. In I2 irrigation level, the highest yield of medium corm in the first year was obtained in I2F2 treatment, which included in the same statistical group with I2F5 treatment, and had a significant advantage of 2.07 times compared to I2F6 control treatment (Table 4). In the second year, the highest yield of 4-8 g corm was observed in I3F2 and I1F2 treatments and the lowest yield in I3F6 and I1F6 treatments. The results also showed that in the non-fertilized treatment (F6), I2 irrigation level had a significant advantage of 1.39 and 1.47 times, respectively, compared to I1F6 and I3F6 treatments in the second year (Table 4).

The highest yields of corm with weight of more than 8 g in the first and second year were obtained in I3F1, I3F4 and I3F4 treatments, respectively. The lowest yield for this trait in the first and second year observed in I2F6, I1F6 and I1F6 treatments, respectively. Also, the largest amount of this trait in I1 irrigation level in the first year was achieved in I1F1 with 3.13 times superiority to I1F6 treatment, and in the second year was obtained in I1F4 treatment with 4.08 times superiority to I1F6 treatment (Table 4). The highest total fresh yields of corms in the first year were obtained with a mean of 1515.8 g/m^2 in I1F1 treatment, which included in the same statistical group with I3F1 and I3F4 treatments and had a significant advantage of 4.3 times over I2F6 treatment (the lowest total fresh yield of corms) (Table 4). In the second year, I3F4 treatment with a mean of 3858.53 g fresh corm per square meter had a significant advantage over other treatments. However, in I1 irrigation level, I1F2 and I1F4 treatments, and in I2 irrigation level, I2F4 treatment had a significant advantage compared to other treatments. The highest total dry yield of corms in the first year was obtained in all three irrigation levels under the application of rotten cattle manure (F1), which was not significantly different from F4 fertilizer level in I1 and I3 irrigation levels. However, the highest total dry yield of corms in the second year was observed in all three irrigation levels, in the fertilizer level of F4, which had a statistically significant advantage over other treatments.

In both years, the lowest total dry yield of corms was obtained in all three irrigation levels in non-fertilizer treatment (F6); except for the first year in the subsurface drip irrigation (I3), in which the lowest total dry yield was obtained in F3 fertilizer treatment. It should be noted that in the second year, the application of 50% cattle manure and chemical fertilizer (F4) in the irrigation levels of I1, I2, and I3 caused a significant increase 2.42, 2.33 and 2.14 times compared to the non-fertilizer treatment (F6), respectively (Table 4).

DISCUSSION

In a study [19] on the two methods of basin and drip irrigation, the highest dry weight of corm and leaf, number of replacement corms, and number and length of leaves were observed in the drip irrigationmethod; in addition, drip irrigation of saffron increased the number of replacement corms by 34% compared to the basin irrigation method. Similarly, in another research [21] the highest average weight and total dry weight of replacement corm were obtained in subsurface drip irrigation.

The results of some studies have shown that although saffron has relatively less demands for nutrients, it seems that providing an appropriate amount of nutrients in the growing environment may play a beneficial role in the allocation of photosynthetic materials and the improvement of corm growth and yield [2]. Increasing the amount of soil organic matter is effective in accelerating and increasing the number and yield of saffron corm through affecting the physicochemical properties of soil including temperature adjustment, greater availability of water and moisture, and reducing soil hardness [22]. In another study, it was observed that the effect of cattle manure on saffron yield was more than that of chemical fertilizers of nitrogen, phosphorus, and potassium. It was also found that with increasing the age of farms, the effect of cattle manure on the plant yield increased [23]. Organic fertilizers improve the growth and yield of crop plants, especially bulbs, through increasing organic matter, strengthening microbial communities, and creating granulation in soil, along with increasing access to water and nutrients [24]. Balanced supply of nutrients plays a very important role in improving the growth of saffron mother corms [17,25,26]. In saffron plant, the reproduction and growth of the underground organs that have the largest portion of the total weight are affected by soil physical properties including apparent specific gravity, texture, and porosity [18].On the other hand, in addition to providing a balanced supply of micronutrients and macronutrients throughout the growing season [24], the use of organic fertilizers in saffron cultivation improves the physical properties of soil [27]. Therefore, the use of rotten cattle manure improves the growth of saffron underground organs. As an organic nutrient source, cattle manure plays a beneficial role in improving the growth and development of saffron. It probably improves the weight of saffron corm due to increased soil moisture retention and allocation of more photosynthetic material to storage organs. In a study, it was reported that in the early years of the farm operation, the availability of nutrients more leads to an increase in the number of replacement corms and in later years, more leads to weight gain [19]. Studies have shown that there is a positive and high correlation between soil organic matter and saffron yield [28] and that the cattle manure is the most important factor in increasing saffron production [29]. The results of another study [16] also showed an 11% increase in the number of replacement corms as a result of using cattle manure compared to not use of it, led to an increase in corm yield. The combined application of organic and chemical fertilizers increases the soil moisture content due to an increase in specific surface area and cation exchange capacity (CEC) of soil particles [30]. However, it should be noted that although the use of organic manure fertilizes the farm soil and improves its physicalproperties, some nutrients may not be supplied sufficiently for the plant, and hence, the need for chemical fertilizers may be felt [20, 31, 32]. Another researcher [33] found that the use of cattle manure produced the largest number of corms above 8 g, and the use of chemical fertilizer increased the number of replacement corms, especially corms less than one gram; which may be related to increasing the availability of nutrients in chemical fertilizers. It seems that the use of chemical fertilizers may be an effective factor in accelerating the growth and yield of saffron corm, due to the rapid release of nutrients rather than the gradual decomposition of organic manure [34].

On the other hand, the use of fertilizer sources leads to stimulation of cell division in more meristematic points (buds) on the mother corm and stimulates corm production. Nitrogen is one of the most important elements necessary for plant growth, and adding it to the soil can stimulate vegetative growth and cell development; so, the rapid and easy availability of nutrients through chemical fertilizers may be the main reason for the considerable increase in the total number of corms in treatments containing chemical fertilizer compared to non-fertilizer treatment. Organic fertilizers (such as cattle manure) are rich in micro-nutrients such as iron and zinc, which are the precursors of the synthesis of S-amino levulinic acid, which is also the precursor for the synthesis of chlorophyll. Therefore, with the use of cattle manure, chlorophyll synthesis may increase and cause an increase in chlorophyll and photosynthesis in the plant [35].

Table 3 Analysis of variance of experimental factors on the traits tested of saffron in the first (2016–2017) and second (2017–2018) growing seasons

S.O.V	df	Number of daughter corms: Small (0.1-4g) 2016–2017	Small (0.1-4g) 2017–2018	Medium(4-8g) 2016–2017	Medium(4-8g) 2017–2018	Large(>8g) 2016–2017	Large(>8g) 2017–2018	Yield of daughter corms: Small (0.1-4g) 2016–2017	Small (0.1-4g) 2017–2018	Medium(4-8g) 2016–2017	Medium(4-8g) 2017–2018	Large(>8g) 2016–2017	Large(>8g) 2017–2018	Total Corm: Number 2016–2017	Number 2017–2018	Fresh weight 2016–2017	Fresh weight 2017–2018	Dry weight 2016–2017	Dry weight 2017–2018
Block	2	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	*	**	ns	ns	ns	**	ns	**
Irrigation (I)	2	**	**	**	**	**	ns	**	**	**	**	**	**	**	**	**	**	**	**
Error I	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fertilizer (F) (F)	5	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
I×F	10	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**	**
Error II	30	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
CV (%)	-	4.23	13.31	10.64	8.53	13.52	13.29	11.51	11.94	8.17	5.96	7.8	3.5	4.45	7.71	5.78	3.14	6.18	5.59

*, **, and ns indicate statistical differences at $p \leq 0.05$, $p \leq 0.01$ and non-significant, respectively

Table 4 Interaction effects of Irrigation method and type of fertilizer on the traits tested of saffron in the first (2016–2017, 1) and second (2017–2018, 2) growing seasons

Value followed by the same letter are not significantly different at p≤0.05 (DMRT) ,I1(Basin), I2(Surface Drip Irrigation), I3(Subsurface Drip Irrigation), F1(Cow Manure), F2(Chemical), F3(BARVAR2), F4(50%:F1+F2),

Experimental treatments /Year		Number of daughter corms (m^2): Small (0.1-4g) 1	Small (0.1-4g) 2	Medium (4-8g) 1	Medium (4-8g) 2	Large (>8g) 1	Large (>8g) 2	Yield of daughter corms (g m^2): Small (0.1-4g) 1	Small (0.1-4g) 2	Medium (4-8g) 1	Medium (4-8g) 2	Large (>8g) 1	Large (>8g) 2	Total Corm: Number (m^2) 1	Number (m^2) 2	fresh weight (g m^2) 1	fresh weight (g m^2) 2	dry weight (g m^2) 1	dry weight (g m^2) 2
	F1	133.3 d	307 bc	51.7b	120 d	74.67 bc	110 de	204 bc	613.7 bc	336.6 b	789.6 c	975.2 b	1228.9 g	259.7bc	537 cde	1515.8 a	2632.2 g	779.7 a	959 d
	F2	186.5 a	476.7 a	50.1b	176.3ab	65.11 cd	111.6 de	220.3 b	888.2 a	267.8 c	1017.8 a	701.1 c	1317 f	301.7 a	764.6 a	1189.2 c	3223 d	656.2 c	1125.3 b
I	F3	55.6 ij	153.3 g	22.1 fgh	63.3gh	34.2 ghi	100 def	76.5 ef	178.4 h	151.4 efg	362.7 g	329.7 fg	1081.5 h	111.8 j	316.7 f	557.5 hi	1622.6 ij	321 ghi	634.5 g
1	F4	150 c	180 fg	67.1 a	93.3 ef	50.3 ef	220 a	223.6 b	341.7 ef	401.5a	558.1 e	733.8 c	2412.2 b	267.4 b	493.3 de	1358.9 b	3312 cd	741.4 ab	1245.3 a
	F5	77.8 h	260 cde	22.9 fgh	113.3d	28.7 ij	100 def	131 d	590.7 bcd	133.9 fgh	645.8 d	254.5 gh	1266 fg	129.3 i	473.3 e	519.4 ij	2502.5 g	294.9 hi	998.6 cd
	F6	44.4 k	163 g	21.9 fgh	53.3 h	28.3 ij	70.4 gh	54.78 fg	207.7 gh	119.1 h	346.8 g	241.5 hi	685.6 j	94.6 k	286.8 f	415.3 kl	1240.1 l	226.7 jk	515.6 i
	F1	166.7 b	232.5 def	38.4 c	140 c	58. 9 de	120 cd	284.06 a	368.1 e	230.1 d	792.7 c	755.4 c	1105.1 h	264 bc	492.5 de	1269.5 bc	2265.9 h	684 c	858.5 e
	F2	105.6 f	280.3 cd	50 b	163.3 b	41. 4fgh	126.2 cd	128.94 d	627.2 bc	276. 8 c	917 b	448.7 de	1427.3 e	197 f	569.9 bc	854. 4 e	2971.4 e	461.7 e	1129.2 b
I	F3	48.7 jk	170 fg	21.1 gh	76. 7 g	28.8 ij	70 gh	29.4 g	200.5 gh	128 gh	488.5 f	294.3 gh	884.4 i	98. 6 jk	316. 7 f	451.7 jk	1573.4 j	275.9 ij	632.6 g
2	F4	40.8 l	310 bc	38.1 c	106.7de	61. 1 de	160 b	63.06 f	681.3 b	229.9 d	614.5 d	769. 2 c	2091.1 c	140 i	576. 7 bc	1062.2 d	3386.9 c	564.2 d	1255.5 a
	F5	133.3 d	310 bc	42 c	120 d	37.2 ghi	90 efg	213.72 bc	572.6 bcd	267.8 c	645. 7 d	322.9 fgh	1116.9 h	212.5 de	520 cde	804.4 ef	2335.2 h	458.9 e	766 f
	F6	61.1 i	187.5 fg	22.2fgh	80 fg	17.8 j	57.4 h	55.72 fg	297.7 efg	133.6 h	480. 7 f	166. 3 i	521.3 k	101.1 jk	324.9 f	355.7 l	1299.7 l	198.2 k	539.6 hi
	F1	100 f	321 bc	36.6 cd	120 d	83. 3 ab	160 b	95.8 e	505.5 d	229.6 d	674.5 d	1182.3 a	1612.2 d	219.9 d	601 b	1507.7 a	2792.2 f	789.7 a	1070.6 bc
	F2	172.2b	460 a	27.8 efg	190 a	50 ef	140 bc	217.7 b	925.6 a	162 ef	1079.1 a	949.4 b	1665.3 d	250 c	790 a	1329 b	3670 b	702.3 bc	1065.6 bc
I	F3	61.1 i	350 b	19.6 h	73.3 g	45.8 fg	70 gh	105.6 de	315.5 ef	114.3 h	489.1 f	491.2 d	936.5 i	126.5 i	493.3 de	711.1 fg	1741.1 i	345.2 gh	736.2 f
3	F4	88.9 g	220 defg	28.5 ef	116.7 d	86.3 a	220 a	98.4 e	642.2 bc	179.5 e	642.5 d	1176 a	2573.8 a	203.7 ef	556.7 bcd	1453.9 a	3858.5 a	753.4 ab	1315.4a
	F5	105.6 f	210 efg	31.3 de	146.7 c	45.6 fg	110 de	186.2 c	563.3 cd	173 e	779.5 c	379.7 ef	1197.6 g	182.5 g	466.7 e	738.8 f	2540.4 g	422.7 ef	972 d
	F6	116.7 e	170 fg	16.7 h	53.3 h	33 hi	80 fgh	207.5 bc	254.9 fgh	106.8 gh	326.8 g	308.3 fgh	857.5 i	166.3 h	303.3 f	622.7 gh	1439.2 k	375 fg	615.5 gh

F5(50%:F2+F3), F6(Control),Year:1=2016-2017, 2=2017-2018

Due to light texture and low organic matter of the soil at the test site, it seems that the application of cattle manure had a positive effect on plant growth through its nutritional role, improving the physical structure of the soil, and maintaining soil moisture. Based on the results of the present experiment in the two years under study, the lowest values of studied traits were obtained in the surface drip irrigation. Probably more water evaporation after irrigation and rainfall due to the increase in temperature caused by the black color of irrigation pipes, improper water distribution, reduced efficiency of nutrient use, etc. reduced the values of these traits. While the subsurface drip irrigation had the highest values of the traits under study due to proper distribution of irrigation in root and lack of surface evaporation. It seems that among the nutrient sources, cattle manure had the greatest role in increasing soil organic matter and water content retention in the first year. However, in the second year, due to increased yield and total biomass of saffron and the need for nutrients that were quickly and easily available to the plant, the combined (50%) use of cattle manure and chemical fertilizer (F4) was more preferable than other fertilizer levels, and as observed, this level of fertilizer was superior in most indicators. Production of the most number of large corms (greater than 8 g) in I3F4 treatment in both years may be attributed to better nutrition and moisture in this treatment compared to others. This means that due to the same volume of water consumption in all irrigation methods, probably because of the reduction of water loss caused by evaporation in the subsurface drip irrigation (I3), more irrigation water content was absorbed by saffron corms.

On the other hand, because of having a more complete set of nutrients required by the plant, the combined application of chemical and cattle fertilizers (F4) provided optimal conditions for the production of larger corms in the I3F4 treatment. While, I2F2 and I3F2, I1F2 treatments produced the largest number of small corms (less than 4 g) in thefirst and second year respectively, which may also be attributed to the role of chemical fertilizers in the production of corm; however, in the basin irrigation method (I1), because a large volume of water entered the ground in a short time (unlike method I3), leaching of nutrients and more evaporation of water caused the corms to have less growth, and due to the reduction of photosynthetic power of saffron plant, less photosynthetic material was transferred to the corms in I1F6 treatment. The weight changes trend of saffron replacement corms in the three weight classes studied in different treatments is largely consistent with the number of corms produced in the experimental treatments. This may be related to the high correlation between the number of replacement corms and the yield of corms (Table 4). The important point in the results of this study is that due to the greater numerical superiority of small corms compared to that of medium and large corms in both years.The total number of replacement corms per unit area in I1F2 treatment in the first year and I1F4 and I3F4 treatments in the second year had a significant advantage over other treatments (Table 4). Considering the significant superiority of total dry weight of corms in I1F1 and I3F1 treatments in the first year and I1F4, I2F4, and I3F4 treatments in the second year, it can be concluded that the use of rotten cattle manure (F1) at a rate of 25 tons per hectare in I1 and I3 irrigation levels in the first year alone was probably able to significantly increase the accumulation of photosynthetic material in saffron corms in mentioned treatments compared to other treatments, through increasing leaf area duration and plant photosynthetic power. However, in the second year, in all three irrigation levels, F4 fertilizer level had a significant advantage over other fertilizer levels, which may be because of a more balanced supply of all nutrients needed at F4 fertilizer level.

CONCLUSION

The results of the present study indicated that the yield of saffron was affected by irrigation and fertilizer treatments and their interaction. In general, among the three irrigation methods, modern subsurface drip irrigation system had priority over other methods. The highest value of important traits including the number of replacement corms above 8 g and the yield of replacement corms was obtained in the subsurface drip irrigation (I3). The effect of nutrition management on studied traits was significant during both years of the study.In general, the highest values of indices in the first and second years of the study were obtained in F1 and F4 fertilizer treatments, respectively. In most indices, I3F4 treatment had priority over other treatments. Saffron yield depends directly on environmental conditions, especially air and soil temperatures and soil water content. The superiority and efficiency of the subsurface drip irrigation is an encouraging issue, especially in areas with limited water. Increasing water and fertilizer use efficiency as a result of reducing losses caused by leaching, increasing yield's quantitative and qualitative parameters, reducing surface evaporation, uniform distribution of water and soil salts in root, and reducing and better control of weed are some advantages of this irrigation system.Therefore, considering the importance of water and nutrition management in agriculture and the current quantitative and qualitative limitations of these components and on the other hand, the comparative advantages of subsurface micro-irrigation, the development of this irrigation system will greatly contribute to production sustainability.

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