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Investigating the Effects of Summer Irrigation and Weed Management Methods on Phenological Characteristics and Yield of Saffron in Iran's Climate

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ABSTRACT

The present study aims at the investigation of the simultaneous effects of summer irrigation in two sessions, 15th of July and 15th of August, and applying weed management methods in three treatments, namely Sencor herbicide, Treflan herbicide and mechanical controls, over the phonological characteristics, growth and yield of a saffron farm, five years of age old, in Research-Training Station associated with agriculture department of the Isfahan Islamic Azad University(Khorasgan Branch), during the year of 2014-2015. The study was carried out in a complete randomized block design in the split-plots layout. Based on the obtained results regarding the phonological, morphological and physiological characteristics of the cases experimented within the format of the current research paper, it appears that Summer irrigation of saffron in August has been able to increase the saffron flowers yield via instigating the early and stronger flowering as well as through causing a greater number of flowers on a unit area. Quite contrarily, July irrigation has not been able to play a considerable role in augmenting the saffron yield. Also, the results indicated that making twice use of the two herbicides, namely Sencor and Treflan, for about 1kg/ha and 2.5lit/ha, respectively, at the first and second irrigation have effectively increased the shoot dry weight per every unit area in saffron and this would play an effective role in enhancing saffron yield during the upcoming years. Finally, as a general conclusion, it can be stated that one-time summer irrigation in August and two sessions of applying Sencor, for 1kg/ha, at the time of first and second irrigation of saffron can have a considerable effect on elevating the saffron yield in the same year as well as in the years to come. So, this procedure can be adopted anywhere with the same characteristics and conditions of the study area.

Keywords: *Saffron corm, Sencor herbicide, Treflan herbicide, Weeds on saffron farms, Summer irrigation*

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INTRODUCTION

Saffron as one of the most expensive agricultural and medicinal plants worldwide has a particular position among Iran's agricultural crops (Behda'ee and Fallahi, 2015; Naderi Darbaghshahi et al, 2012). With the annual production of over 200 tons' dry stigma, Iran is globally one of the most important producers of saffron in such a manner that 90% of the world's saffron is produced in Iran (Kuchaki, 2015). According to the fact that saffron plants usually develop distinguishable flower organs in the meristem of the ending shoot possibly in August (Mollafila'ee et al, 2015), thus many environmental factors can influence the saffron flower organs distinctive development. One such a factor is the soil moisture at the periphery of the corms that increases the saffron yield contributed by the flower organs distinctive emergence (Mollafila'ee et al, 2014; Naderi Darbaghshahi et al, 2008).

The results obtained in the studies performed by Geresta et al (2009) signify that soil moisture, besides its temperature, plays a determinative role in regulating the saffron's flowering behavior. The effect of complementary irrigation, particularly in summer has been reported by Behdani et al (2008) and Sadeghi (1996) to accelerate the flowering as well as performance enhancement in saffron. However, it is yet to be determined whether the irrigation exerts its influence via adjusting the temperature during warm summer seasons or it directly affects the saffron's flowering?

Summer irrigation is not so much customary due to the farmers' fear of corms getting rotted as a result of high heat but summer irrigation of recently cultivated farms showed an increase by 17% in flower weight performance which was about 40% in several years of age farms according to the experiments performed during two years of irrigation in summer. Therefore, one session of irrigation is recommended from 10th of August up to the end of August (Kuchaki et al, 2011).

In a two-year experiment on saffron farms from Khurasan, Sadeghi (1996) concluded that irrigation in August increases the flower performance in recently cultivated lands up to 17% and 40% in several years of age farms. In his study, he also showed that irrigation in July has a negative effect on the performance. Mosaferi (2001), as well, introduced mid-August irrigation as being the cause of a 40-percent increase in the performance of saffron plants and irrigation during the second half of July as detrimental featuring a 17-percent degradation of the flower performance.

In a study carried out by Behdani et al (2008), average yield was found higher (4.9kg/ha) for the farms with summer irrigation. They announced that reducing the irrigation intervals, especially summer irrigation, in flower differentiation stage, increases the saffron performance.

Based on the studies conducted by Kuchaki et al (2011), saffron growth can be divided to three stages:

1. Plant's complete resting period and ending shoot dormancy (about half a way to June when saffron leaves dry till 15th of July)

2. Intra-corm activation during which the flowers develop and become distinguishable (15th of July to 15th of October)
3. Regeneration period and leaf growth (15th of October till 15th of May)

According to the results obtained by Kuchaki et al (2011), summer irrigation causes a reduction in saffron yield. According to the fact that appropriate temperature for saffron activity in summer is about 23 °C to 27 °C and between 15 °C and 17 °C in fall, thus, they reported that seemingly irrigation in July adversely influences the plants' temperature requirements during the summer months which would be consequently followed by a reduction in saffron yield.

MATERIALS AND METHODS

Experiment Location

The present study aims at the survey of the simultaneous effects of summer irrigation and weed management methods on the phonological characteristics and saffron yield on a five-year old saffron farm located in research and training station associated with agriculture department of Isfahan Islamic Azad University, Khorasgan branch in Isfahan. The foresaid farm is situated within a 10-km distance on the eastern border of Isfahan in the northern latitude of 32° and 40′ and eastern longitude of 51° and 48′. The region's elevation from the sea level is 1555 meters and the climate is dry and very hot with dry summers based on Kopen's classification (Bwhs). Long-term precipitation mean and the annual temperature are 120 mm and 16℃ .

Soil Characteristics

To investigate the physical-chemical characteristics of the study area soil, samples were randomly collected from 0 to 40 cm depth the specifications .

Table of Soil Characteristics: Some of the study area soil physical and chemical characteristics

Soil depth (cm)	Electrical conductivity (desi siemens)	Acidity	Organic carbon (%)	Absorbable phosphor (ppm)	Absorbable potassium (ppm)	Total nitrogen (%)	Texture
0-40	3.5	7.7	0.9	16.5	300	0.07	Loamy silts

Type of the statistical design

The present study investigated two irrigation sessions in three levels, as the main factor, and weed management methods in three levels, as sub factors, in a split plot layout based on complete randomized block design for three replications

Cultivation Operation

Treatments in the present study were examined on a five-year-old saffron farm. After the plots were partitioned to main plats based on the experimental design, sufficient bordering activity was carried out so as to prevent water from percolating to the adjacent plots and every main plot, with normal bordering, was divided to three subplots. In 15th July, heavy irrigation was used for one plot in every replication. In 15th of August, heavy irrigation was used for one plot from the main plots in every replication. Then the farm was left on its own and in 15th of October after fertilization, all the plots received 50 tons of manure and 300 kg/ha chemical fertilizer, Ammonium Phosphate. From every three subplots, located in a main plot, one was treated with Sencor herbicide for 1kg/ha, one received Treflan herbicide for 2.5l/ha. After the fertilizers and the herbicides were evenly mixed with the surface soil, heavy irrigation was applied on all plots and, finally, they underwent crust-breaking operation. Flowers were picked from the plots with the onset of the flowering stage and after flowering termination in the first week of November the plots having been treated with herbicides again received the same amount of the same herbicide and the second irrigation session was initiated in 15th of November after crust-breaking of the entire plots upon examining the applied herbicides being mixed evenly with the soil which was followed with cultivation operations till the end of the season in all of the plots and in the next spring after the yellowing of the saffron leaves the specified samplings were undertaken.

Statistical Analyses

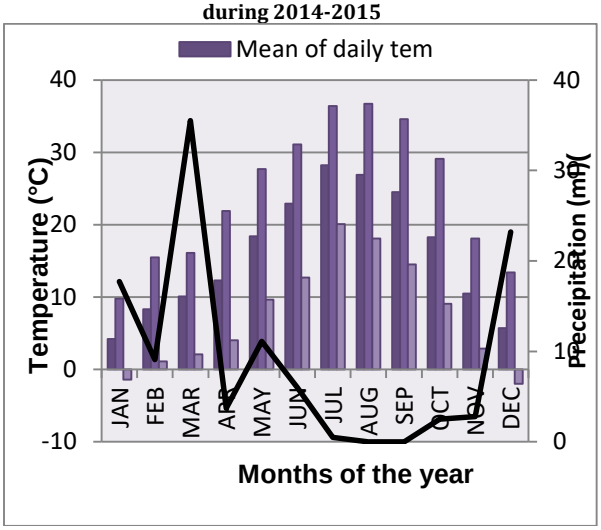
In the end, the obtained data were analyzed based on split plot statistical models within the paradigm of a complete randomized block design as well as by means of a software program named Mstat-C. The means were compared by the use of Duncan test in a 5% level and finally the diagrams were sketched by Excel program ver.2010.

RESULTS AND DISCUSSION

The region's climate during the test period:

Based on the region's climatic parameters mean, the maximum temperatures of the region were on average 37°C in July and August and the minimum means of the temperature in the region reached to an average of -3 °C in December. According to the region's precipitation statistics, the total precipitation rate was 118mm for a time span between November and May.

Figure (1): mean climatic conditions of the study region during 2014-2015



Phenological characteristics of Saffron

Number of days since the first irrigation to the emergence of the first flowers

The number of days since the first irrigation to the emergence of first flowers is significantly influenced by the irrigation treatments (Table 1) in such a manner that the first flowers appeared 23 days after the first irrigation in mid-August; whereas, the flowers appeared rather late, after about 35 days, in the normal irrigation which is performed in the mid-October. Also, in the mid-August irrigation in respect to the normal irrigation, flowering commenced 11 days earlier. This is indicative of a significant difference with the other two irrigation treatments (Table 2).

Based on the results obtained in the current research paper, weed management treatments did not have a significant effect on the flowering trait and the number of days till the flowering initiation in all three weed management treatments were placed in one statistical group with a 27-day period post normal irrigation (Table 2).
In the present study, the mutual effect between the experimental treatments and the number of days till the inflorescence was not found statistically significant (Table 1).

The number of harvestable Flowers in various reaping dates
Based on the results obtained, the irrigation treatments had a significant effect on the total number of harvestable flowers in the first reaping date, 15th of November, in a 5% significance level (Table 1) in such a manner that there was no flower harvestable in 15th of November in normal irrigation treatment. In irrigation treatment performed in mid-August a total of 38 flowers per every square meter were harvestable, additionally, the number of harvestable flowers was 12 per every square meter in mid-July irrigation. Statistically, the three treatments are indicative of different results so they are to be placed in different statistical groups (Table 2).

Table 1: Variance analysis results for the experimental treatments effect on the number of days to flowering and the total number of harvestable flowers in different reaping dates

Variation source	df	Ms					
		Days to inflorescence	8.15	8.20	8.22	8.28	9.7
Replication	2	0.33	387.21	11.44	188.24	249.24	7.34
Irrigation (A)	2	392.25**	3453.55**	92.44	2084.23*	1479.54**	6.25
Error (a)	4	0.11	375.45	18.34	217.25	79.54	11.45
Herbicide (B)	2	0.11	18.21	36.54*	75.69	244.12*	20.54
A*B	4	0.22	20.14	10.85	62.84	107.45	
Error (b)	12	1.07	243.84	7.05	455.20	42.14	8.55
Total	26						
(* and ** are indicative of the experimental treatments effect significance in 5% and 1% levels.)							

Table 2: Means comparison of simple effects the experimental treatments simple effects on the number of harvestable flowers in different reaping dates

Treatment	The number of harvestable flowers per square meter in various dates					
	Number of days to inflorescence	8.15	8.20	8.22	8.28	9.7
Irrigation						
July	23.12 c	12.17 b	4.43 ab	25.62 ab	5.66 b	0.67 b
August	24.78 b	38.33 a	2.66 b	39.33 a	1.00 b	0.1b
October	35.22 a	0.01 c	8.4 a	8.94 b	25.17 a	6.28 a
Herbicide						
Controls	27.67 a	15.33 a	7.37 a	21.72 a	16.62 a	2.66 a
Sencor	27.56 a	18.17 a	4.4 b	27.50 a	5.66 b	2.52 a
Treflan	27.78 a	17.00a	4.7 b	24.67 a	10.11 ab	1.67 a
Every columns' means with at least have one letter in common is devoid of significant difference in 5% level based on multi-domain Duncan Test						

The total number of the harvestable flowers is not subject to weed management treatments in the first reaping date (Table 1) in such a manner that all three treatments should be placed in one statistical group according to the total number of harvestable flowers (Table 2).
In the present study, the experimental treatments mutual effect on the number of flowers was not found significant in the first harvest (Table 1).
Based on the results obtained, the irrigation treatments exert significant effects, in 5% level, on the number of the harvestable flowers in the second saffron flower reaping date (20th of November) (Table 1) in such a manner that in 20th of November the total number of harvestable flowers in irrigation treatment applied in mid-July with a total of 4.43 flowers per square meter has been found significantly higher than the other two irrigation treatments, namely normal irrigation and mid-August irrigation (Table 2).
The number of harvestable flowers in the second reaping date has been subjected to the weed management treatments (Table 1) in such a manner that the number of the harvestable flowers in control group, lack of weed management, with a total of 7.37 flowers per square meter is found significantly higher than the other treatments (Table 2).
Experimental treatments' mutual effect on the number of the harvestable flowers in the second reaping date was not found statistically significant in the present study (Table 1).
Based on the results obtained, the irrigation treatments had a significant effect on the number of the harvestable flowers in the third reaping date in a 5% level (table 1) in such a manner that the number of harvestable flowers in 22nd of November in irrigation treatment performed in mid-August with an approximate number of 40 flowers per square meter was found significantly higher than the normal irrigation treatment with a total of 16 harvestable flowers per square meter (Table 2).
The number of harvestable flowers in the third reaping date was not subjected to the effect of weed management treatments (Table 1) in such a manner that the number of the harvestable flowers in all three treatments of weed control was to be placed in one statistical group (Table 2).
In the present study, the experimental treatments mutual effect on the number of harvestable flowers in the third reaping date was not found statistically significant (Table 1).
Based on the results obtained, the irrigation treatments had a significant effect on the number of harvestable flowers in the last reaping date (7th of December) in a 5% significance level (Table 1) in such a manner that in 7th of December, the number of harvestable flowers in normal irrigation treatment, with about 6.28 flowers per square meter, was significantly higher than the summer irrigation with 0.67 and 0.1 flowers per square meter, for July and August irrigations, respectively (Table 2).
The number of harvestable flowers in the last reaping date was not subjected to the weed management treatments (Table 1) in such a manner that the number of harvestable flowers in all three treatments of weed control was to be placed in a single group (Table 2).
Experimental treatments mutual effects on the number of harvestable flowers in the last reaping date were not found statistically significant (Table 1).

Total number of flowers in unit area
Based on the variance analyses results, the effect of irrigation treatment on the number of the produced flowers per unit area was found statistically significant in a 5% level (Table 3) in such a manner that based on simple effect means comparison results, saffron irrigation in August has been able to increase the number of flowers per every square meter to 29 in respect

to the lack of summer irrigation treatment which is statistically significant. Based on the results, summer irrigation in July has not been able to increase the number of the flowers produced per unit area (Table 4).

The effect of weed control treatments and the mutual effects of irrigation plus weed management treatments on the number of flowers per unit area were not found statistically significant (table 4).

Based on the results obtained from the summer irrigation effect on the onset of flowering, it seems that summer irrigation has a considerable effect on inflorescence initiation and it has been found causing early flowering and this effect is highly important and useful in terms of saffron's cultivation management and one advantage of early flowering can be the apportioning of the harvesting labor force as well as the reduction that is made in frosting risk of the saffron flowers in the final harvests in regions prone to early frostbite. Also, according to the likely adverse effects of the very low temperatures (T) on saffron flowers quality, the early gathering of the saffron flowers in summer-irrigated farms can be an advantage gained in saffron farm management.

Farm-experiment results obtained by Mosaferi et al (2007) indicated that summer irrigation treatment accelerate the flowering after the first irrigation. The results obtained in the studies performed by Geresta et al (2009) signify that besides temperature, soil moisture plays a determinative role in regulating saffron's flowering behavior. The effect of complementary irrigation, particularly in summer has been reported by Behdani et al (2008) and Sadeghi (1996) to accelerate the flowering as well as performance enhancement in saffron. However, it is yet to be determined whether the irrigation exerts its influence via adjusting the temperature during warm summer seasons or it directly affects the saffron's flowering?

Saffron's growth and development sequence in summer includes four stages. The first stage is a real dormancy period from late May to the mid- or late July; the second stage is the establishment and leaves differentiation period from late July to late August; the third stage is the period shape differentiation of the flower organs inside the shoot from late August to early September followed by the maturation of the flowering organs till the end of the September; and, finally, the fourth stage is the period of leaves and flower organs rapid growth inside the shoots from the end of September to the late October. In other words, saffron's dormancy period, from the late May till the 16th of July includes the real and apparent hibernation period. This goes on until mid-July during which the shoot tip meristem tissue exhibits very trivial activity. Then, it is followed by a period till August when the plants start growing and the organs differentiation is clearly observable. Next, the period of development and differentiation of the generative organs commences. Thus, saffron's induction of flowering takes place in high temperatures. The growth and differentiation of the generative and reproductive organs happens as a result of mitosis divisions in the head meristems of the corm's ending shoot in stagnancy period. Since such changes coincide with the general reduction of the corm humidity and an increase in summer temperatures, it is imagined that performing sessions of irrigation in summer can play an effective role in elevating the florescence of the saffron plants through reducing the soil temperature at the periphery of the corms and increasing the soil moisture reserve. Extreme temperatures in summer are among the factors degrading the saffron performance in summer that can adversely influence the flowering August. In the meantime, Kuchaki et al (2010) know the florescence and performance in saffron as being in direct relationship with environmental temperature. They have asserted that the occurrence of temperatures higher and lower than optimum can influence saffron's flowering induction.

The investigation of weed control method effect on saffron's flowering dates is reflective of the idea that the application or lack of using herbicides on saffron farms does not have any significant effect on the number of harvestable flowers in various dates as well as on the flowering cessation. The reason for such a lack of effectiveness is indicative of no adverse effects by the applied herbicides on the saffron farm before the emergence of flowers.

The results obtained show that summer irrigation in August has been able to considerably increase by twice as much the number of the produced flowers in saffron farms in comparison to no irrigation in summer as well as to July irrigation. It appears that summer irrigation in August causes the humidity to be increased in the corms and accelerates flowering primers production in saffron.

Sadeghi (2008) expresses that August irrigation in recently cultivated farms increases the number of flowers by 17% in comparison to a value of 40% for the several year-old farms; but, July irrigation leads to a reduction in performance. The reason for the reduction in the number of flowers post irrigation in July by these researchers has been reported to be the simultaneity of the July irrigation with the reproductive organs growth and differentiation; whereas, the simultaneity of the irrigation with generative organs' differentiation in August leads to an increase in flower performance. During the first year of irrigation, the positive role of the summer irrigation in improving the daughter corm's performance as well as a high percentage of daughter corms, 8 grams, might have been resulted from the improvement in generative growth mechanisms in saffron and, subsequently, root growth stimulation and the increase in the plants' reproductive growth. Kuchaki et al (2010) found florescence and performance in saffron in direct relationship with ambient temperatures. They stated that the occurrence of higher or lower than optimum temperatures can influence the florescence in saffron.

Table 3: The results of variance analyses for experimental treatments effect on some studied traits

Variations source	df	Ms		
		Total number of flowers per unit area	Shoot dry weight	Stigma yield
Replicates	2	1549.23	1472.54	1.96
Irrigation (A)	2	3070.54*	18604.23	17.06*
Error (a)	4	716.58	14629.54	1.97
Herbicide (B)	2	128.21	8325.36	0.53
A*B	4	1019.54	3948.58*	3.408
Error (b)	12	946.84	1388.24	3.206
Total	26	1549.23	1472.54	1.96
(*and**, respectively, indicate the significance of the experimental treatments effect in 5% and 1% likelihood levels.)				

Table 4: Means comparison of simple effects the experimental treatments on the number of the harvestable flowers in various reaping dates

Treatment	Number of flowers per square meter	shoot dry weight (g/m^2)	Stigma yield (kg/ha)
Irrigation			
July	42.78 b	272.54 a	2.32 b
August	77.22 a	205.56 ab	4.85 a

October	48.44 b	159.45 b	2.69 b
Herbicide			
Controls	58.33 a	202.45 b	3.53 a
Sencor	56.54 a	263.54 a	3.26 a
Treflan	51.87 a	223.85 b	3.04 a
The means for every column with at least one common letter is devoid of significant difference in 5% level based on multi-domain Duncan test			

Shoot Dry Weight

The effect of irrigation treatment and weed control method was found significant in 5% significance level on the aerial parts' dry weight produced in saffron plants (Table 3). Based on the results obtained from comparing the simple effects means of the applied treatments, summer irrigation in July has been able to increase the amount of dry matter for 112 g/m^2 and this increase is statistically significant. Also, the application of Sencor herbicide has been found to significantly increase the dry matter produced of the aerial parts of saffron plants in contrast to the use of Treflan herbicide and controls for which no herbicide was used (Table 4).

The interaction effects of summer irrigation and weed management methods on shoot dry matter in saffron were found statistically significant in 5% level (Table 3). Based on the results of the interaction effects of the experimental treatments on this trait, the use of Sencor and Treflan herbicides in July irrigation and no summer irrigation has not significantly influenced the amount of dry matter produced by saffron plants; whereas, the application of Sencor herbicide, during August irrigation, significantly increased the amount of dry matter produced per every unit area of the experimental plots in comparison to the two other treatments of applying Treflan herbicide and no herbicide use (Figure 2).

shoot dry weight of the saffron plants in summer irrigation treatment, in July, was increased for 113 g/m^2 higher than no summer irrigation treatment. It seems that summer irrigation in saffron brings about strengthening of the reproductive shoots which is subsequently followed by a greater number of leaf production upon the emergence of the shoots and this stimulatory effect was found lower in August irrigation because the aerial parts' dry weight was only increased by 35g/m^2 in this irrigation treatment in comparison to the no irrigation treatment.

Regarding the effect of the applied herbicides effect on the shoot parts' dry matter, the results indicated that the use of Sencor herbicide considerably increased aerial parts dry weight by 61g/m^2 in respect to no herbicide use treatment. It appears that Sencor herbicide has not only been able to adversely influence the aerial parts growth in saffron but it also has been found largely increasing the reproductive strength of the saffron plants due to appropriately controlling the weeds.

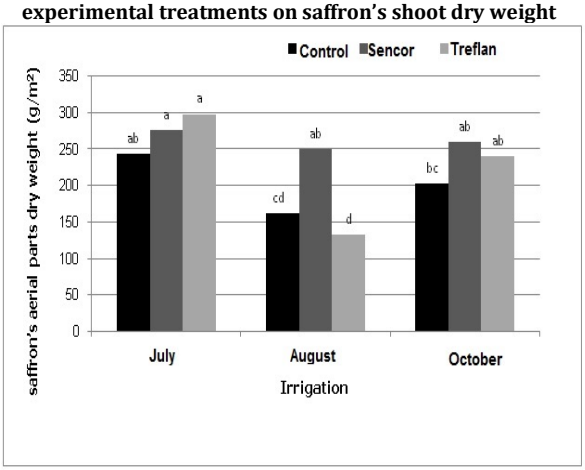
In the study performed by Kuchaki et al (2011), irrigation in June and August reduces the shoot dry weight of saffron's aerial parts. Mosaferi Zia'aldini et al (2007), as well, in a four-year experiment showed that irrigation in August increases by about 18% the flower performance in saffron and that the irrigation in July has no significant effect on performance.

Weeds cause interferences through competing with plants in taking in water, nutrients, light and infiltration into the corms and, consequently, cause the crop yield to decrease. Weeds damages have been very high in regard of the saffron plants being several years of age old and low growth rate of the chlorophyll in the saffron plants during the first years of the plants development and applying manures contaminated with weeds seeds. Therefore, weeding operations and fighting the weeds are deemed necessary. The absence of shadow-creating aerial stems in saffron plants makes them lack considerable competitive vigor in combating the weeds (Behdani and Fallahi, 2015).

Dry Stigma yield

Among the experimental treatments, only the irrigation treatment effect was found significant in 5% level on the dry stigma performance as the most important study parameter in the present study and the effect of weeds control treatment and the interaction effects of irrigation plus weed management method on this trait was not found statistically significant (Table 3). The results of irrigation's simple effects means comparison with the dry stigma performance are indicative of the idea that dry stigma performance in summer irrigation treatment, in August, is significantly higher than the stigma performance in two other summer irrigation treatments, namely in July and no summer irrigation treatments in such a manner that the performance in summer irrigation in August has been found approximately twice as much of the two other irrigation practices, namely July and no summer irrigation treatments (Table 4).

Figure (2): Means comparison of interaction effects the experimental treatments on saffron's shoot dry weight



Dry stigma yield is the main objective of the saffron farms and the entire traits investigation is in line with acquiring the ability to explain the effects of the studied treatments on this significant trait. The results obtained in the current research paper are suggestive of the idea that summer irrigation in saffron farms in Isfahan region has been able to considerably, for 2.16kg/ha, increase the dry stigma performance in respect to no summer irrigation treatment and such a production rate in summer irrigation, in August, is almost twice as much as the production rate belonging to no summer irrigation treatment and this is the finding featuring a huge potential in the economy of saffron farms. The important theme that has to be brought to the attention in the present study is that summer irrigation in July has not been able to exert useful effect on the increase in saffron farm's performance. According to the investigations conducted on the performance constituents, it can be stated that the most important reason for the double increase in saffron's stigmas performance in August irrigation has been the earlier and heavier flowering, a larger number of medium size and large size corms, higher dry weight of the corms and the higher number of the flowers per every unit area in contrast to the no summer irrigation treatment and July irrigation.

In a two-year experiment on saffron farms from Khurasan, Sadeghi (1996) concluded that irrigation in August increases the flower performance in recently cultivated lands up to 17% and 40% in several years of age farms. In his study, he also showed that irrigation in July has a negative effect on the

performance. Mosaferi (2001), as well, introduced mid-August irrigation as being the cause of a 40-percent increase in the performance of saffron plants and irrigation during the second half of July as detrimental featuring a 17-percent degradation of the flower performance.

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FINAL CONCLUSION

Based on the resultsobtained in the current research paper, irrigation in mid-August and application of 1 kilogram Sencor herbicide per hectare in two sessions during the first and second irrigation is recommended in saffron farms of the study region and the other regions featuring similar conditions.

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