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EFFECTS OF SUPPLEMENTAL IRRIGATION AND PLANT CULTIVATION DENSITY ON YIELD AND YIELD COMPONENTS OF CARTHAMUS TINCTORIUS L. IN RAINFED AGRICULTURE IN KHORRAMABAD, LORESTAN

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ABSTRACT

Supplemental irrigation (SI) is regarded as an operation with high efficiency in order to increase the plant production and farmers income in rain-fed agriculture. An experiment has been conducted to evaluate the effects of supplemental irrigation and plant densities on*Carthamus tinctorius* L. in the research field of Agriculture and Natural Resources Research Center of Lorestan in 2012. The experiment has been implemented in the broken plots in a completely randomized blocks design with three replications. Supplemental irrigation involves 6 treatments of control (with no irrigation), after cultivation, start of stem extension, heading-bud , flowering (50%) and grain filling on main plots and cultivation densities include two treatments of 33.3 and 66.6 bushes/ m2 in secondary plots. Results of growth analysis showed that supplemental irrigation has had significant effects on the harvest index, yield, yield components, number of heads in a branch, number of seeds in a head, weight of 1000 grains, oil content, oil yield and grain yield. Research results demonstrated that supplemental irrigation in the grain filling stage was of the highest biologic yield given as 2826 kg ha-1 whereas the lowest biologic yield estimated as 2293 kg ha-1 was attributed to the control treatment. Also, supplemental irrigation in the grain filling stage increased the grain yield of *Carthamus tinctorius* L. by 41.7% as compared to the control treatment with no irrigation. Maximum harvest index and oil yield given as 0.348% and 319.5 kg ha-1 with the plant density of 66.6 bushes/ m2 were achieved for irrigation treatment in the grain filling stage.

Keywords: *Carthamus tinctorius* L., supplemental irrigation, plant density, Khorramabad

INTRODUCTION

Carthamus tinctorius L. is a yearling plant belonging to Cichorium family. Iran is considered as one of richest countries concerning genetic resources of *Carthamus tinctorius* L. world wide. This plant first grew in the areas between eastern Mediterranean and Persian Gulf (Zeynali, 1999; Naraki, 2001). Safflower oil has a variety of consumptions in addition to edible ones in the industries (Zeynali, 1999). High percentage of linoleic and oleic fatty acids may be regarded as the quality element of safflower oil (Aliari and Shekari, 2000). Safflower is adjustable to a vast range of densities while having a constant yield (Mundel et al., 1995). Of course, over increase of bush density in an area reduces the established bushes percent (Hang, 2002).

In general, as the number of bushes in an area increases more than the desired density, number of seeds will be decreased in the reproductive stage; it means that in order to obtain an appropriate yield, all the yield components should be in a suitable balance (Sarmadnia and Kochaki, 1989; Tomar, 1992). Ehsanzadeh et al. (2003) attributed the decrease of grain yield in high densities of safflower to the constraints of moisture, nutrients and light. High density results in narrower branches and lower number of secondary branches and the heads are concentrated in upper levels of plant so that mechanized harvesting is facilitated (Honey, 2002). Safflower is well-known to be tolerant against drought stress. Its roots are deep and able to grow in the area with sufficient soil moisture. In fall cultivation of safflower, rainfall can be more useful in the interval of rosette and flowering stages. In total, the rain-fed cultivation of safflower is not of considerable production in Iranian Plateau and it needs to be irrigated at least 3-6 times (Forozan, 1999; Naseri, 1991; Farashi et al., 1972).

The most important points in supplemental irrigation management are more likely to be time and amount of water. However, many farmers will tend to irrigate the plants more than the amount that they need if they have access to high water resources. Evidence of water overuse for irrigation can be seen in lots of dry regions and supplemental irrigation is not an exception. Farmers want to use more water in SI due to low costs of water and irrigation. All the SI management plans must try to provide sufficient water in the right time for the crops and farmers have to be avoided from water overuse. SI is able to be kept in the best form when soil moisture is below the critical level (Qajar Sepanlo et al., 2002). According to the study done by Kaey (1990), the effects of irrigation on the height of bush were significant and the highest bush height was related to the SI treatment in the stem extension stage. In an experiment in India, the highest bush height was attributed to the SI treatment in the grain filling stage. Also, maximum number of seeds in a head was achieved for the flowering stage (Chavan, 1991). In the research done by Honey (2002), number of seeds might be significantly affected by the irrigation treatment in the flowering stage. Oil yield based on the cultivar varies between 400-650 kg ha^{-1} (Zand, 1998). Number of seeds in a head and number of seeds in a bush affect the oil yield indirectly (Forozan, 1999). This study aims to evaluate the effects of supplemental irrigation and plant cultivation density on yield and yield components of safflower in rain-fed agriculture in Khorramabad.

MATERIALS AND METHODS

Experiment has been conducted in Research Station of Changaee, Agriculture and Natural Resources Center of Lorestan, 2011-2012. Research field is located in Northern longitude of 29° 33́ and western latitude of 21° 48́ with the elevation of 1171 m above sea level. It has been implemented in the broken plots in the form of completely randomized blocks design with three replications. Supplemental irrigation with 6 treatments involving control with no irrigation, after cultivation, start of stem extension, stem extension, flowering (50%) and grain filling and cultivation densities including two treatments of 33.3 and 66.6 bushes per m2 were allocated to main and secondary plots. Safflower (a local cultivar of Isfahan called shark) was cultivated in 13th March. Each plot involved 5 rows with the length of 8 m and the interval of cultivation lines was 30 cm. The intervals of bushes on the rows with respect to the densities given as 33.3 and 66.6 bushes were estimated as 5 and 10 cm, respectively.

Before cultivation, seeds were disinfected by the use of Vitavax- thiram fungicide by the ratio of one to one thousand. Seeds were planted in the furrows with the depth of 5 cm on the mounds and then, were covered by soft soil. In every stage, the water volume of irrigation was calculated by the following equation:

$$V = \frac{(Fc - pwp) \times Pa \times A \times ds}{Ea}$$

Where,

V= irrigation volume

Fc= moisture percent in the field capacity

pwp= moisture percent in permanent wilting point

Pa= apparent specific weight of soil

A= plot area

ds= maximum depth of root penetration (cm) in the desired stage

Ea= irrigation efficiency (85%)

Analysis of variance of experimental data was done by MSTATC software. In order to compare the means, Duncan test was used at 5% probability level.

RESULTS AND DISCUSSION

Biologic yield: SI has significant effects on biologic yield (Table 1). SI treatment had the highest yield given as 2826 kg ha-1 in the grain filling stage (Table 2). All the irrigation treatment led to the significant increase of biologic yield as compared to the control with no irrigation. At the end of growth season, drought stress might be regarded as one of the important factors influencing the SI treatments. Significant impact of density on biologic yield was seen (Table 1). Increase of cultivation density from 33.3 to 66.6 bushes per m2 resulted in the increased biologic yield from 2608.33 to 2647.33 kg ha-1 (Table 3). Interaction of SI and cultivation density on biologic yield was not significant (Table 4). However, the highest and lowest biologic yields given as 2834 and 2290 kg ha-1 were related to the irrigation and control treatments with the density of 66.6 bushes per m2, respectively (Table 4).

These results are in conformity with the findings of Zhou and Peter (1998), Sirait et al. (1994) and Diode et al. (1994).

Grain yield: Effects of supplemental irrigation on the grain yield were significant (Table 1). The highest grain yield estimated as 985 kg ha-1 belonged to the irrigation yield in the grain filling stage (Table 2). Supplemental irrigation led to the 41.7% increase of grain yield in the grain filling stage as compared to the control. All the supplemental irrigation treatments increased the grain yield significantly in comparison with the control. Irrigation treatments enhanced the grain yield by 10.5, 21.6, 28.5 and 30.9% in the stages of after cultivation, start of stem extension, heading-bud and flowering as compared to the control. Also, cultivation density had significant effects on the grain yield. Interactions of SI and cultivation density on the grain yield were insignificant (Table 1). Cultivation density of 66.6 bushes per m2 along with SI in the grain filling stage computed as 857.5 kg ha-1 had the highest grain yield (Table 3). It seems that as the intervals of rows were reduced, cultivation density was increased; as a result, the leaf area index was enhanced in order to receive sufficient light in the grain filling stage and the usage efficiency of solar energy was augmented. It caused the increased grain yield in the lower intervals of rows. Furthermore, the reduced intervals of rows to reach the square cultivation and less competition between the bushes to receive sufficient light, nutrients and moisture provided the necessary space for the plant growth. This finding was reported by Shiebles and Weber (1995) for the soybean.

Choice of appropriate density is of highly importance in order to maximize the exploitation efficiency of environmental factors and increased yield (Kochaki, 2000). Chegeni (2005) reported that supplemental irrigation in the grain filling stage had the highest grain yield but the results of other experiments indicated high grain yield by SI in the flowering stage.

Probably, suitable precipitation in the flowering stage is a varying element; in other words, suitable precipitation prevents from the appearance of SI effects in this stage whereas SI in the grain filling stage at early June coincides with the drought period (lack of rainfall) and consequently, the impact of supplemental irrigation has been observed in the mentioned stage.

Harvest index: Effects of SI on harvest index were significant (Table1). Regarding all the treatments, the highest harvest index was related to the supplemental irrigation in the grain filling stage (Table 2). Cultivation density had significant impacts on harvest index. Considering the interactions of SI and cultivation density, the highest and lowest harvest indices estimated as 0.352 and 0.303 were attributed to the supplemental irrigation and control treatments with the cultivation densities of 66.6 and 66.6-33.3 bushes per m2, respectively (Table 4). Number of heads in secondary branches: Effects of SI on number of heads in secondary branches were significant (Table 5). In start of stem extension stage, SI and control treatments had the highest and lowest number of heads in secondary branches (Table 6). Effects of density on number of heads in secondary branches were insignificant. Interactions of SI and cultivation density on number of heads in secondary branches were significant (table 5). SI in the start of stem extension stage with the density of 66.6 bushes per m2 was of the highest number of heads in secondary branches calculated as 8.17 (Table 7).

Number of seeds in a head: Effects of SI on number of seeds in a head were significant. Considering the irrigation treatments, the highest number of seeds in a head was attributed to SI in the 50% flowering stage (Table 6). The highest number of seeds in a head was achieved for SI treatment estimated as 48.30 in the 50% flowering stage with density of 33.3 bushes (Table 8).

Weight of 1000 grains: Effects of SI on weight of 1000 grains were insignificant (Table 6). Regarding the treatments, SI treatment in the grain filling stage has the highest weight of 1000 grains given as 33.42 g (Table 7). Density has significant effects on the weight of 1000 grains (Table 5). Weight of 1000 grains for the densities of 33.3 and 66.6 bushes was computed as 31.1 and 31.4 g, respectively (Table 7). Interactions of SI and cultivation density on weight of 1000grains were insignificant (Table 5). SI treatment in the grain filling stage with the density of 33.3 bushes was of the highest weight of 1000 grains given as 33.72 g (Table 8). Studies done by Nabavi Kalat *et al*. (2005) in Javin, Sabzevar indicated that the weight of safflower was not affected by the cultivation density.

Oil percent: Effects of SI on safflower oil percent were significant (Table 5). The highest oil percent was related to SI treatment at the grain filling stage (Table 6). Effects of cultivation density on oil percent were significant (Table 5). Mean oil percent for the densities of 33.3 and 66.6 bushes might be given as 30.37 and 30.47%, respectively (Table 7). Interactions of SI and density on oil percent were significant (Table 5). Supplemental irrigation treatment in the grain filling stage with the density of 33.3 bushes per m2 resulted in the highest oil percent estimated as 32.28% (Table 8).

Oil yield: Effects of SI on oil yield were significant (Table 5). The highest oil yield was achieved for the irrigation in the grain filling stage (Table 7). Effects of density on oil yield were significant (Table 6). Oil yield was computed as 30.37 and 30.47 kg ha-1 for the densities of 33.3 and 66.6 bushes, respectively. Significant interactions of supplemental irrigation and density on the yield were observed (Table 5). Supplemental irrigation treatment in the grain filling stage along with the density of 66.6 bushes gave the highest oil yield (Table 8).

Ramazani *et al.* (2006) reported that the increased density in a range of 14-20 bushes per m2 would lead to the increased biologic yield of safflower. Although in high densities, weight of one bush is reduced, more densities compensate the reduced weight. In the study, the increased of cultivation density caused the decreases of bush height, number of seeds in a boll, harvest index and number of bolls in a bus.

Majd Nasiri et al. (2002) showed that the densities of 40 and 13 bushes were attributed to the highest and lowest water use efficiencies, respectively. Ramazani et al. (2006) reported 20 bushes per m2 for the suitable density of safflower in Damavand region. Higher suitable density may be in relation to more precipitation in the weather conditions of Khorramabad as compared to the ecologic conditions of Damavand region.

Based upon the research results, the highest grain yield, biologic yield, harvest index, weight of 1000 grains, oil percent and oil yield are more likely to be attributed to supplemental irrigation treatment in the grain filling stage.

Table 1: Results of ANOVA of biologic yield, grain yield and harvest index of safflower

		Mean squares		
Variation sources	**Freedom degree**	**Biologic yield**	**Grain yield**	**Harvest index**
Replication	2	214.11 ns	1.18*	50.18*
SI	5	2187**	6.14**	69.28**
Main plot error	10	81.11	0.777	39.14
Cultivation density	1	2985.01**	16.17*	48.17*
Interaction	5	38.43 ns	0.117	5.37 ns
Secondary plot error	12	40.12	0.344	14.82
Variation of coefficient (%)		9.42	9.18	10.92

*Significant at 5% level, ** significant at 1% level, ns non-significant

Table 2: Effects of SI on biologic yield, grain yield and harvest index of safflower

Irrigation treatment	Biologic yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index
Control with no irrigation	2293 cd	695 d	0.303 bc
Irrigation after cultivation	2457 b	768 c	0.312 b
Irrigation in start of stem extension stage	2681 ab	845 b	0.314 b
Irrigation in heading-bud stage	2777 ab	893 b	0.310 b
Irrigation in flowering stage	2732 a	910 ab	0.332 ab
Irrigation in grain filling stage	2826 a	985 a	0.348 a

Treatments with similar letters in each column have no significant differences based on Duncan test at 5% level.

Table 3: Comparisons of safflower cultivars regarding biologic yield, grain yield and harvest index

Cultivation density (number of bushes/ m2)	Biologic yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index
33.3	2608.33	840.83 b	0.321
66.6	2647.33	857.5 a	0.323

Treatments with similar letters in each column have no significant differences at 5% level.

Table 4: Interactions of SI and cultivar on biologic yield, grain yield and harvest index of safflower

Irrigation	Cultivation density	Biologic yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Harvest index
Control with no irrigation	33.3	2297 cd	696 e	0.303 bc
	66.6	2290 cd	694 e	0.303 bc
Irrigation after cultivation	33.3	2412 b	754 d	0.312 b
	66.6	2502 b	782 d	0.312 b
Irrigation in stem extension stage	33.3	2660 ab	834 c	0.313 b
	66.6	2701 ab	855 bc	0.316 b
Irrigation in heading-bud stage	33.3	2753 ab	899 b	0.320 ab
	66.6	2802 ab	903 b	0.331 ab
Irrigation in flowering stage	33.3	2710 ab	903 b	0.331 ab
	66.6	2755 ab	917 b	0.333 ab
Irrigation in grain filling stage	33.3	2818 a	972 a	0.344 a
	66.6	2834 a	998 a	0.352 a

Treatments with similar letters in each column have no significant differences based on Duncan test at 5% level.

Table 5: Results of ANOVA of safflower yield indices

				Mean squares			
Variation sources	**Degree of freedom**	**Number of branches in a bush**	**Number of heads in a branch**	**Number of grains in a head**	**Weight of 1000 grains**	**Oil percent**	**Oil yield**
Replication	2	6.12 ns	0.92 ns	14.11 ns	3.08 ns	2.018*	182.56 ns
SI	5	11.33**	2.17**	173.22**	7.18 ns	1.17*	618.91**
Main plot error	10	2.30	1.01	4.82	1.62	0.591	499.21
Cultivation density	1	8.71*	1.38 ns	5.16 ns	91.58*	17.93*	9141.88*
Interaction	5	9.18*	1.53*	4.59 ns	1.41 ns	0.993*	1102.83**
Secondary plot error	12	3.8	0.99	6.18	1.13	0.611	200.17
Variation of coefficient (%)		10.84	7.14	6.39	8.92	8.25	7.97

***Significant at 5% level, ** significant at 1% level, ns non-significant**

Table 6: Effects of SI on some yield indices of safflower

Irrigation treatment	Number of branches in a bush	Number of heads in a branch	Number of grains in a head	Weight of 1000 grains	Oil percent	Oil yield
Control with no irrigation	6.50 c	7.12 b	43.50 bc	28.77 c	28.90 cd	200.80 ef
Irrigation after cultivation	8.16 a	7.92 ab	44.20 b	30.35 b	29.57 cd	227.10 d
Irrigation in stem extension stage	8.00 a	8.17 a	46.30 ab	30.88 b	30.15 c	254.60 c
Irrigation in heading-bud stage	7.75 b	7.26 b	45.70 b	30.77 b	30.59 c	274.50 bc
Irrigation in flowering stage	7.48 b	7.28 b	48.10 a	32.41 a	31.16 b	283.60 b
Irrigation in grain filling stage	7.15 b	7.57 b	47.20 a	33.42 a	32.15 a	316.60 a

Treatments with similar letters in each column have no significant differences based on Duncan test at 5% level.

Table 7: Effects of cultivation density on some yield indices of safflower

Cultivation density	Number of branches in a bush	Number of heads in a branch	Number of grains in a head	Weight of 1000 grains	Oil percent	Oil yield
33.3	7.58	7.54	45.9	31.1	30.37	256.4
66.6	7.43	7.59	45.8	31.4	30.47	262.7

Treatments with similar letters in each column have no significant differences based on Duncan test at 5% level.

Table 8: Interactions of SI and density on safflower yield indices

Irrigation treatment	Cultivation density	Number of branches in a bush	Number of heads in a branch	Number of grains in a head	Weight of 1000 grains	Oil percent	Oil yield
Control with no irrigation	33.3 66.6	6.44 c 6.55 c	7.11 b 7.14 b	43.60 bc 43.50 bc	28.42 c 29.12 c	28.92 28.88	201.20 ef 200.40 ef
Irrigation after cultivation	33.3 66.6	8.34 a 7.98 ab	7.92 ab 8.02 a	44.70 b 43.80 bc	30.24 b 30.46 b	29.41 cd 29.73 cd	221.70 d 232.40 cd
Irrigation in stem extension stage	33.3 66.6	8.07 a 7.93 ab	8.11 a 8.23 a	45.90 b 46.80 ab	30.93 b 31.29 b	29.92 cd 30.38 c	249.50 c 259.70 c
Irrigation in heading-bud stage	33.3 66.6	7.88 ab 7.63 b	7.24 b 7.29 b	45.70 b 45.70 b	30.91 b 30.83 b	30.65 c 30.53 c	271.60 bc 277.40 bc
Irrigation in flowering stage	33.3 66.6	7.54 b 7.42 b	7.24 b 7.33 b	48.30 a 47.80 a	32.42 b 33.42 a	31.05 b 31.28 b	280.30 b 286.80 b
Irrigation in grain filling stage	33.3 66.6	7.21 b 7.09 b	7.64 b 7.55 b	47.20 a 47.30 a	33.72 a 33.13 a	32.28 a 32.01 a	313.80 a 319.50 a

Treatments with similar letters in each column have no significant differences based on Duncan test at 5% level

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