Journal of Medicinal Plants Research Vol. 6(12), pp. 2493-2503, 30 March, 2012
Available online at http://www.academicjournals.org/JMPR
DOI: 10.5897/JMPR12.004
ISSN 1996-0875 ©2012 Academic Journals

Full Length Research Paper

Effect of plant density on phenology and oil yield of safflower herb under irrigated and rainfed planting systems

Roghayeh Shakeri Amoghein[1], Ahmad Tobeh[1] and Shahzad Jamaati-e-Somarin[2]*

[1]Department of Agronomy and plant breeding, Faculty of Agriculture, University of Mohaghegh Ardabili. Ardabil. Iran.
[2]Young Researchers Club, Ardabil Branch, Islamic Azad University, Ardabil, Iran.

Accepted 24 January, 2012

In order to study the effect of plant density on phenology and oil yield of safflower herb under irrigated and rainfed planting systems, an experiment was conducted in Agriculture Research Station of Islamic Azad University, Ardabil Branch, Ardabil, Iran in 2010 as a factorial experiment based on a randomized complete block design with four replications. The factors included planting system (irrigation and rainfed) and plant density (60, 50, 40 and 30 plants.m^{-2}). The results showed that the density of 30 plants.m^{-2} under both planting systems and the density of 40 plants.m^{-2} under rainfed system had the highest number of days to 50% emergence. The densities of 60 and 50 plants.m^{-2} under rainfed system had the highest number of days to 50% branch-bearing. The density of 60 plants.m^{-2} under irrigated system had the lowest number of days to 50% bud-bearing. The plants at the densities of 60 and 50 plants.m^{-2} under rainfed system initiated flowering earlier than other treatments. The density of 50 platns.m^{-2} was ranked in the same group with the densities of 40 and 60 plants.m^{-2} and irrigated system. under irrigated system, the highest oil percentage was obtained from the lowest density and the lowest one from the density of 40 plants.m^{-2} and the densities of 50 and 60 plants.m^{-2} were ranked in the same group, while under rainfed system, the highest oil yield was obtained from the highest density under irrigated system and the lowest one from the densities of 40 and 60 plants.m^{-2} under rainfed system. As shown, oil percentage was increased with the decrease in density. The significantly highest seed yield was produced at the density of 60 plants.m^{-2} under rainfed system which was ranked in the same group with the density of 50 plants.m^{-2} under irrigated system.

Key words: Flowering time, emergence, oil percentage, safflower, yield, yield components.

INTRODUCTION

Out of the prevalent oilseeds, safflower is the only one native to Iran. Indeed, Iran has a high diversity of safflower. Safflower (*Carthamus tinctorius* L.) belongs to the family of Asteraceae. It has been established in various climates and its wild species are widespread throughout Iran (Poordad, 2006). Safflower (Honghua in China) is a member of the family Compositae or Asteraceae and an annual herb. It is soft with mild odor and slightly bitter in taste (Zheng, 1999).

Safflower is both edible and medicinal and is issued by the Ministry of Health in China and consumed safely (Guan et al., 1999). The main ingredients of safflower are safflower glucoside, safflower yellow and safflower quinone. In addition, it also contains a small amount of oleic acid, linoleic acid, linolenic acid, flavonoids, amino acids and polysaccharides (Zheng, 1999). Safflower grows widely in many areas of China and it is one of the traditional Chinese medicinal herb in common use with its flowers to treat coronary heart disease and thrombosis, remove blood stasis, cure pain and swelling (Zheng, 1999; Zhang et al., 2005).

Moreover, it was reported that safflower had the functions of anti-thrombosis and hypoxia tolerance, and

*Corresponding author. E-Mail: jamaati_1361@yahoo.com. Tel: +989141594490. Fax: +984517714126.

can increase coronary flow and improve microcirculation (Ling, 2002). In recent years, the use of safflower as a coloring and flavoring agent has been increased as a food additive in some Asian countries (Nobakht et al., 2000). Modern pharmacological studies have shown that the safflower polysaccharide has the activity of anti-tumor and antioxidative effect (Jin et al., 2004; Shi et al., 2010). Safflower yellow A has the functions to relieve myocardial ischemia, protect neuron against hypoxia injury and attenuate acute lung injury induced by lipopolysaccharide administration in mice (Jin et al., 2005; Ye and Guo, 2008). Exercise-induced fatigue, due to over-exercise, refers to the body that cannot maintain its specific level physiologically or cannot maintain the predetermined exercise intensity, manifested as mental and physical fatigue (Wu et al., 2003; Chen et al., 2004; Gao and Chen, 2003). Exercise-induced fatigue can be recovered by supplemented energetic substance, releasing metabolic production and administrated tonics, but these bring harms to the body even though retarding the fatigue (Li and Wei, 2005). In addition, some of the drugs are forbidden by the International Olympic Committee. During the process of seeking for safe and effective anti-athletic fatigue methods, the specialty of Chinese herbal medicine has drawn the attentions of scholars in the world (Shenhua et al., 2009) and some research results have been reported in recent years.

Nowadays, given its tolerance to heat and survival at minimum moisture, its cultivation is agronomically and economically feasible for local consumption as oilseed and edible dynes (Aliari et al., 2000). Since it is a native crop, it has marked characteristics such as adaptability to arid and semi-arid climates, high-quality oil, and resistance to abiotic stresses particularly drought stress (Weiss, 2000). Mundel et al. (1994) classified different developmental stages of safflower as emergence, rosette, stem elongation, formation of auxiliary branches, flowering and maturing. Bagheri (1995) categorized them as emergence, branching, flowering and maturing, whereas Mohammadi (1995) and Nejad (1996) named them as emergence, branching, emergence of reproductive buds, bud-bearing, head termination and maturing and Zand (1995) named them as emergence, stem-bearing, branch-bearing, flowering and maturing.

Seed development proceeds through a set of important stages such as nutrient storage, drying and dormancy. Each stage brings about some changes in seed which affect their yield. The stage at which the seeds reach to their maximum dry weight on their parental plants is known as the physiological maturity (Shaw and Loomis, 1950). Yazdi (1996) stated that harvest at complete maturity, when seed moisture content was 100 $g.kg^{-1}$, was preferable because of ease of threshing and high storage capability owing to the optimum moisture content in both pods and seeds. Also, the results of other studies (Tavakoli, 2002) have shown that irrigation withdrawal before and during flowering of safflower resulted in fewer numbers of seeds per head and that the closer the time of stress application was to flowering, the more effective it was on the number of seeds.

Rostami (2004) reported that the application of drought stress after flowering and pollination slightly decreased the number of seeds and mainly reduced 1000-seed weight. In a study on three high, moderate and poor-yielding genotypic groups of safflower in Mashad, Iran, Zand (1995) showed that they exhibited significantly different developmental stages. Yasari et al. (2005) revealed that branch-bearing period was the most effective period of completion of yield and yield components. The results of Hashemi and Marashi (1995) showed that the interaction of genotype and moisture regime was significant on all traits unless days to flowering initiation and 50% flowering, number of seeds per head and seed yield per plant.

Istanbulluoglu (2009) evaluated the effect of irrigation and water deficit at different developmental stages on seed yield per ha and 1000-seed weight and showed that safflower was significantly impacted by water stress at late-vegetative stage. The highest yield was obtained at early and late-vegetative growth and seed yield formation. There were significant differences among varieties at 1% probability level with respect to flowering initiation and termination, days to maturity, 1000-seed weight, oil percentage and yield. Under rainfed farming, cultivars with short maturity period have the highest seed yield. Means comparison of seed and oil yield of different cultivars showed significant differences. Also, as means comparison revealed, high-yielding cultivars had lower number of days to maturity than other traits. Means of varieties with shorter maturing period can tie higher seed yield with higher seed production (Hatamzadeh et al., 2003).

In the study of Omidi (2009), irrigation withdrawal at the end of flowering stage or at the initiation of grain-filling period not only did not greatly decrease seed yield, but also saved water. Zareian and Ehsanzadeh (2001) showed that plant density only significantly affected the bud-bearing initiation of safflower. In total, days after sowing and the heat demand for each developmental stage started to decrease with the increase in the density. The effect of cultivar was significant on such stages as emergence, bud-bearing, head production and 50% flowering, but it did not significantly affect other developmental stages. The results of the studies on the effect of plant density per unit area on crops indicate that the yield of the crops per unit area is change with the change in plant density (Koocheki, 1997). The effect of plant density on seed yield was significant too, so that the number of heads per m^2 was increased as the density was increased (Fazeli et al., 2007). Planting row spacing was shown to significantly affect the number of heads per plant, the number of seeds per head, seed yield and oil yield (Ghasemi et al., 2006).

The effect of on-row plant spacing was not statistically

Table 1. Results of the analysis of the soil of study field.

Depth	Saturation percentage	EC ($ds.m^{-1}$)	pH	Neutralizable material (%)	Organic C (%)	Total N (%)	Absorbable P (ppm)	Absorbable K (ppm)	Soil texture			Soil type
									Clay	Silt	Sand	
0-30	48	2.66	7.8	4.8	0.97	0.103	4.8	4601	28	41	31	Loam-clay
30-60	45	2.4	8.2	7	0.48	0.056	2	290	24	36	40	Clay

significant on the number of heads per plant, the number of seeds per head, 1000-seed weight, harvest index, and seed and oil yield. In the study of Ranjbar et al. (2004), optimum seeding rate (row spacing and on-row plant spacing) influenced yield and yield components through changing density and environmental resources. Majd et al. (2003) stated that seed yield per unit area and per plant, yield components, the number of seeds per plant and kernel percentage were influenced by plant density. Means comparison for different studied traits at different plant densities showed that as plant density was decreased, the number of heads per plant, 1000-seed weight, the number of seeds per plant, kernel percentage and seed yield per plant were increased, but the number of seeds per head and yield per unit area were significantly decreased.

In this study, safflower is considered as one of the resistant drought plants and it has excessive drug use and spice. Also, the Ardabil region in Iran has the highest talent to cultivate various medicinal plants. So, the objective of the current study was to examine the effect of plant density on phenology and oil yield of safflower herb under irrigated and rainfed systems in Ardabil, Iran.

MATERIALS AND METHODS

The current study was carried out in Agriculture Research Station of Islamic Azad University, Ardabil Branch, Ardabil, Iran (Alt. 1350 m., Long. 48°20´ E, Lat. 38°05´ N) in 2010. All the executive and laboratory operations were conducted in Department of Agronomy, University of Mohagheghe Ardabili, Ardabil, Iran. In order to determine physical and chemical characteristics of the soil of the study field, it was sampled before field preparation from the depths of 0 to 30 and 30 to 60 cm. Then, the samples were analyzed in Water and Soil Laboratory of Islamic Azad University, Ardabil Branch, whose results are given in Table 1.

Sina was the cultivar of autumn safflower which was used in this study. It was procured from Agriculture Research Center of Zanjan, Iran. Imported from ICARDA in 1997, Cv. Sina (line PI-537598) was first examined in Rainfed Agriculture Research Institute of Iran. It was one of the superior genotypes and was studied in terms of its local adaptability. Its evaluation in the fields of Kermanshah, Lorestan, Northern Khorasan and Ilam, all in Iran, showed that it performed considerably better than control cultivar (Namely, Zaraghan 279). Safflower cv. Sina is early-maturing with intermediate growth type, resistant to drought stress, thorny with yellow/orange flowers with mean height of 103.5 cm and 1000-seed weight of 34.7 g.

The study was a factorial experiment based on a randomized complete block design with four replications. The factors included plant density and planting system (irrigated and rainfed). Each block consisted of 8 treatments or plots with the dimensions of 4×2.1 m^2 with 7 rows with row spacing of 30 cm and inter-plant spacing of 8, 6, 5 and 4 cm used for making the densities of 60, 50, 40 and 30 $plants.m^{-2}$. The planting system was created with and without irrigation.

The study field had been under the cultivation of potato in the previous year. For the field preparation, the field was first plowed in autumn and was added with 100 kg ammonium phosphate per hectare. Then, it was leveled. After testing the germination percentage of the seeds, they were planted with the on-row spacing of 8, 6, 5 and 4 cm at the depth of 4 cm on April 9, 2010. At the same day, the first irrigation was carried out.

The measured traits included days to 50% emergence, 50% rosette, 50% branch-bearing, 50% boll-bearing, flowering initiation, 50% flowering and flowering termination in order to make phenological studies possible. To measure seed and oil yield, the upper and lower 0.5 m of the harvested plants were removed and the rest was used for this measurement. After harvesting, the plants were dried in open air. Then, their seeds were separated and weighed. Next, seed weight per unit area and per hectare was measured. Afterwards, the oil percentage of the seed samples (32 samples) was determined by Soxhlet method, and finally, oil yield was measured by the following formula:

Oil yield = oil percentage × weight of dried seed sample

Statistical analysis

To analyze the variance of the data, software MS-TATC and SAS were used and the means were compared by Duncan Test. Regression analysis was used to study the relations between different harvest stages and studied traits as well as to interpret the observed variation during seeds maturing, and the graphs were drawn by software MS-Excel. At the end, the coefficient of the correlations between the studied traits was measured.

RESULTS AND DISCUSSION

Days to 50% emergence

The results of analysis of variance of phenological traits are shown in Table 2. As shown, the simple effect of plant density was significant at 5% probability level with respect to 50% germination. The means comparison for this trait (Table 3) at the lowest density (30 $plants.m^{-2}$) showed the highest number of days to 50% emergence, while the simple effect of the density of 60 $plants.m^{-2}$ had the lowest number of days after emergence. In the study of Rahman et al. (2005), the plant density did not affect germination. In addition, drought stress had no effect on

Table 2. Summary of analysis of variance for some studied traits at final harvest.

Sources of variation	df	Mean of squares			
		50% emergence	50% rosette	50% branch-bearing	50% boll-bearing
Replication	3	6.00^{ns}	8.28^{ns}	6.36*	0.75^{ns}
Planting system (S)	1	2.00^{ns}	5.28^{ns}	30.03**	18.00*
Plant density (D)	3	8.66*	3.28^{ns}	26.94**	4.50^{ns}
Interaction S × D	3	3.33^{ns}	4.28^{ns}	6.86*	4.50^{ns}
Error	21	2.57	11.85	2.38	2.89
Coefficient of variations (%)		8.11	9.20	2.45	2.31

ns, * and ** show non-significance and significance at 5 and 1% probability level, respectively.

Table 3. Means comparison for the main studied effects on some traits at final harvest based on Duncan Test at 5% probability level.

Treatment	50% emergence (days after planting)	50% rosette (days after planting)	50% branch-bearing (days after planting)	50% boll-bearing (days after planting)
Planting system				
Irrigated	19.51^{a}	37.00^{a}	61.93^{b}	74.25^{a}
Rainfed	20.00^{a}	37.81^{a}	63.87^{a}	72.75^{b}
Plant density				
30 plants.m^{-2}	21.00^{a}	37.62^{a}	60.50^{c}	73.12^{a}
40 plants.m^{-2}	20.00^{ab}	38.00^{a}	62.50^{b}	73.12^{a}
50 plants.m^{-2}	19.50^{ab}	36.50^{a}	64.62^{a}	73.12^{a}
60 plants.m^{-2}	18.50^{a}	37.50^{a}	64.00^{ab}	74.62^{a}

Means with the same letter(s) showed no significant differences.

seed germination or vigor of corn and sorghum (Ghassemi-Golezani et al., 1997). Francaneto (1993) showed that drought stress can reduce the germination of soybean seeds and that irrigation can be used to counteract this effect.

Days to 50% rosette

The results of analysis of variance (Table 2) showed no statistically significant differences in the number of days to 50% rosette between planting system and plant density per m^2 as well as the interactions between them. Means comparison for this trait (Table 3) confirmed this result. Among the interactions between planting system and plant density (Figure 1), no statistically significant differences were observed in this trait. Nonetheless, rainfed system had lower number of days to 50% rosette than irrigated system. So, it can be concluded that as the density was increased from 30 to 60 plants.m^{-2}, the number of days to 50% emergence and 50% rosette decreased.

Days to 50% branch-bearing

According to the results of analysis of variance (Table 2), the simple effect of planting system and plant density resulted in statistically significant differences in the number of days to 50% branch-bearing at 1% probability level. Moreover, the interaction between planting system and plant density was significant at 5% probability level. Means comparison (Table 3) indicated that 50% branch-bearing was realized earlier under irrigated system than under rainfed system and that the densities of 50 and 60 plants.m^{-2} had the highest number of days to 50% branch-bearing and the density of 30 plants.m^{-2} had the lowest one.

The density of 40 plants.m^{-2} had the highest number of days to 50% branch-bearing and was ranked in the same group with the density of 60 plants.m^{-2}. Among the interactions (Figure 2), the densities of 60 and 50 plants.m^{-2} under rainfed system had the highest number of days to 50% branch-bearing and were ranked in the most superior group. The density 30 plants.m^{-2} under both planting systems and the density of 40 plants.m^{-2} under irrigated system had the lowest number of days to 50% branch-bearing; and the density of 50 plants.m^{-2} under irrigated system had the highest number of days to 50% branch-bearing and was ranked in the same group with the density of 40 plants.m^{-2} under rainfed system.

Yasari et al. (2005) revealed that the duration of

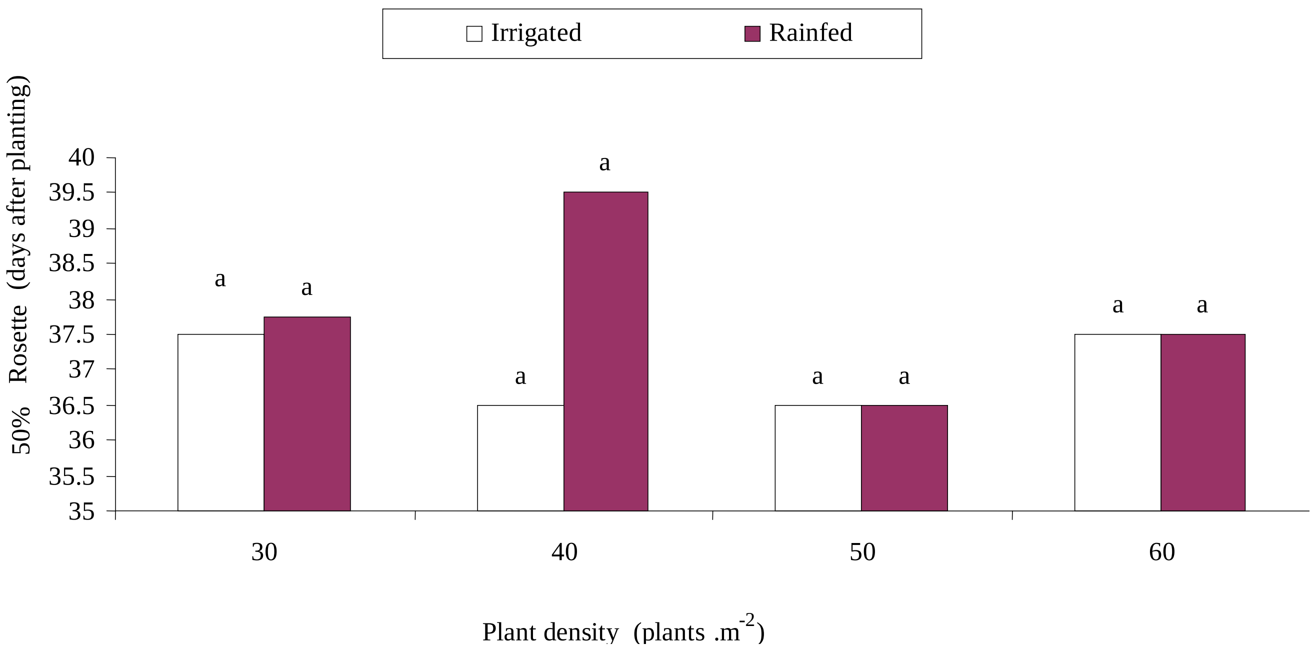

Figure 1. Diagram of 50% rosette (days after planting) as affected by plant density and planting system.

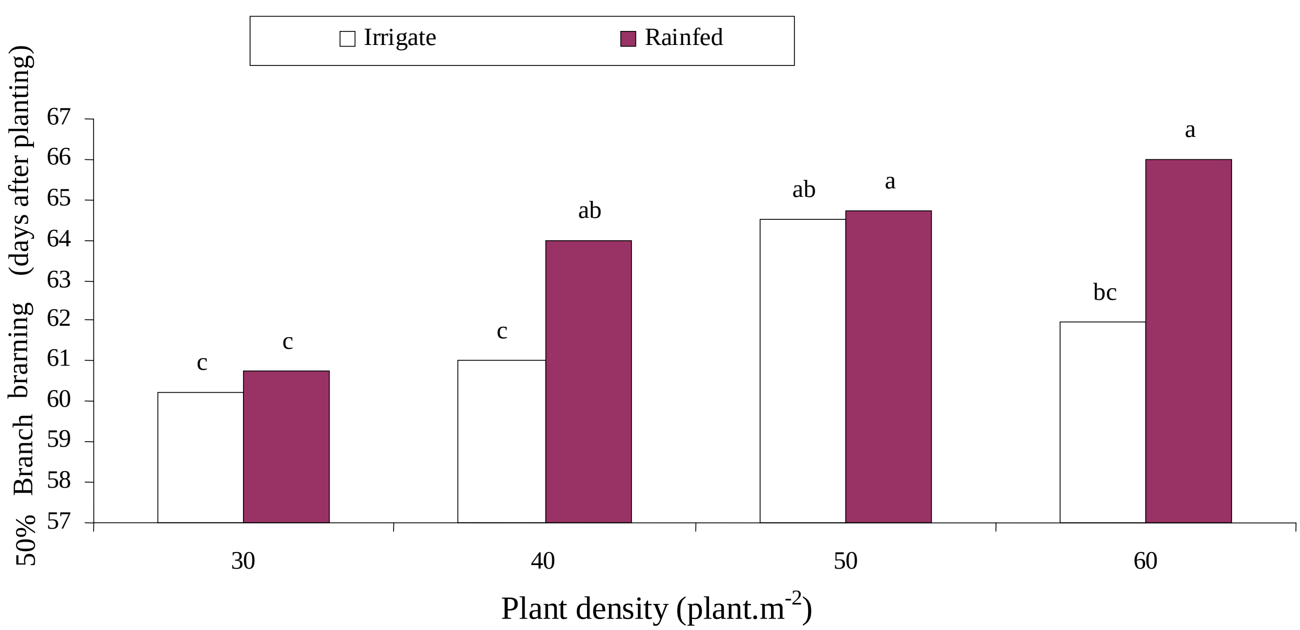

Figure 2. Diagram of 50% branch-bearing (days after planting) as affected by plant density and planting system.

branch-bearing period was the most effective period in completing yield and yield components. Therefore, supplying the needs of a plant during this period played an essential role in improving the yield of the plant and the duration of this period was recommended as a good criterion for selecting genotypes with higher potential yields.

Days to 50% boll-bearing

The results of the analysis of variance (Table 2) revealed that the planting system (irrigated and rainfed) showed statistically significant differences in the number of days to 50% boll-bearing or bud-bearing at 5% probability level, while means comparison (Table 3) indicated that

Table 4. Summary of analysis of variance for some studied traits at final harvest.

Sources of variation	df	Means of squares					
		Flowering initiation	50% flowering	Flowering termination	Oil percentage	Oil yield	Yield
Replication	3	1.20[ns]	0.83[ns]	1.50[ns]	2.51[ns]	0.01[ns]	112807.65[ns]
Planting system (S)	1	32.00[**]	32.00[**]	18.00[*]	4.67[ns]	0.35[**]	8258550.52[**]
Plant density (D)	3	4.70[ns]	0.83[ns]	3.16[ns]	12.03[*]	0.01[ns]	603124.29[ns]
C × D	3	1.08[ns]	0.33[ns]	7.33[*]	2.97[ns]	0.01[ns]	700845.92[ns]
Error	21	2.08	1.21	2.92	4.24	0.02	369363.87
Coefficient of variations (%)		1.59	1.14	1.70	10.56	5.51	25.86

ns, * and ** show non-significance and significance at 5 and 1% probability level, respectively.

Table 5. Means comparison for the main studied effects on some traits at final harvest based on Duncan Test at 5% probability level.

Treatment	Flowering initiation (days after planting)	50% flowering (days after planting)	Flowering termination (days after planting)	Oil percentage (%)	Oil yield ($kg.ha^{-1}$)	Seed yield ($kg.ha^{-1}$)
Planting system						
Irrigated rainfed	91.68[a] 89.68[b]	97.12[a] 95.12[b]	101.37[a] 99.87[b]	19.87[a] 19.11[a]	564.38[a] 359.99[b]	2857.5[a] 1841.5[b]
Plant density						
30 $plants.m^{-2}$	90.12[a]	96.25[a]	101.50[a]	21.16[a]	442.67[a]	2058.9[a]
40 $plants.m^{-2}$	91.75[a]	96.50[a]	100.50[a]	18.21[b]	413.81[a]	2221.0[a]
50 $plants.m^{-2}$	90.12[a]	96.00[a]	100.50[a]	19.24[ab]	463.38[a]	2422.3[a]
60 $plants.m^{-2}$	90.75[a]	95.75[a]	100.00[a]	19.34[ab]	528.88[a]	2695.7[a]

Means with the same letter(s) showed no significant differences.

irrigated system had the highest number of days to 50% boll-bearing and was ranked in the most superior group, but rainfed system had the lowest number of days to 50% boll-bearing.

Zareian and Ehsanzadeh (2001) showed that among different phenological stages, plant density significantly affected only the boll-bearing initiation in safflower. In total, the number of days after planting and the required heat demand to reach each developmental stage showed descending trend with the increase in density.

In the table of correlations (Table 6), 50% boll-bearing had positive, significant correlation with the number of initial branches per unit area, the number of seeds per unit area, biological yield and harvest index.

Days to flowering initiation

The results of analysis of variance (Table 4) showed that there was significant difference in the number of days to flowering initiation between different planting systems at 1% probability level. Means comparison (Table 5) for this trait revealed that the plant started flowering earlier under irrigated system, while plant density had no impact on the initiation of flowering. Istanbulluoglu (2009) showed that safflower plants were significantly influenced by the late-vegetative stage moisture deficiency. The highest yield was obtained at early and late-vegetative growth and seed yield formation. In a study on the effect of drought stress on safflower cv. Arak 2811, Hashemi Dezfuli (1994) showed that stress had no effect on flowering initiation.

Days to 50% flowering

The results of analysis of variance (Table 4) showed significant differences between the simple effects of planting system and plant density at 1% probability level. As shown, there was no significant difference in the number of days to 50% rosette between planting systems and plant densities, whereas this difference was observed after the termination of rosette stage at 50%

Table 6. Simple correlation between final studied traits at final harvest.

Trait	50% branch-bearing	50% flowering	Yield	Oil percentage	Oil yield
50% flowering	0.27^{ns}	1.00			
Yield	0.16^{ns}	-0.03^{ns}	1.00		
Oil percentage	0.29^{*}	-0.20^{ns}	0.46^{**}	1.00	
Oil yield	-0.23^{ns}	-0.26^{ns}	0.09^{ns}	0.24^{ns}	1.00

ns, * and ** show non-significance and significance at 5 and 1% probability level, respectively.

branch-bearing, flowering initiation and 50% flowering stages. Means comparison for the number of days to 50% flowering (Table 5) showed that plants reached to 50% flowering earlier under rainfed system than under irrigated system and plant density did not impact this trait. As the table of correlations (Table 6) showed, 50% flowering had positive, significant correlation with the distance of the first head-bearing branch from ground, seed weight per head and harvest index.

Days to flowering termination

The results of analysis of variance (Table 4) indicated statistically significant difference between the simple effect of planting system and the interactions of the density and planting system at 5% probability level. Similar results can be seen in the table of means comparison (Table 5), so that the plants cultivated under rainfed system reached to the end of flowering stage earlier than those planted under irrigated system.

Also, the interaction of planting system and plant density on this trait showed that the plants cultivated at the density of 30 plants.m^{-2} under irrigated system had the lower density of this treatment was the main reason for higher number of days to flowering termination of the plants cultivated at the density of 30 plants.m^{-2} under irrigated system; that is, lower density intensified inter-plant competition and so, the plants utilized nutrients, light and water as good as possible and increased their vegetative growth which led to the increase in the number of days to flowering termination.

Oil percentage

The results of analysis of variance for oil percentage (Table 4) showed significant differences between the simple effects of different plant densities at 5% probability level. Nonetheless, according to means comparison (Table 5), the simple effect of planting system was not significant on oil percentage but among the densities, the lowest one (30 plants.m^{-2}) had the highest oil percentage and the density of 40 plants.m^{-2} gave rise to the lowest oil percentage in their seeds. The oil percentage of the densities of 50 and 60 plants.m^{-2} was between these two extremes.

Denser population of the plants increases oil percentage but decreases iodine content (Abddollahi and Zarrinjoob, 2001). Patel and Patel (1996) concluded that oil percentage was influenced by irrigation regimes and that with the increase in irrigation, oil percentage was increased too. Singh et al. (1990) studied the effect of different irrigation regimes on yield and oil of safflower and reported that the highest oil percentage was produced by irrigating the plant at branch-bearing and seed formation stages. The results of other studies (Heidari and Asad, 1998; Patel, 1993) also show that irrigation withdrawal and drought stress reduces oil percentage of the seeds with the variations being slight but significant. By increasing the density, Sharikian and Babayian (2000) observed the decrease in oil percentage and increase in protein percentage of the seeds which are in agreement with the results of the current study (Figure 3).

As the table of correlations (Table 6) shows, oil percentage had positive, significant relation with the traits of 50% branch-bearing, the distance of the first head-bearing branch from ground, seed weight per head and seed weight per m^2 and had positive, very significant relation with the traits of the number of seeds per m^2, harvest index and yield.

Oil yield

Table 4 shows the analysis of variance for oil yield. It can be drawn from this table that there was statistically significant difference between the simple effects of planting systems (rainfed and irrigated) at 1% probability level, while according to the means comparison for this trait (Table 5), the highest oil yield was produced under irrigated system. But, the simple effect of density did not affect oil yield. Figure 4 shows the interactions between plant density and planting systems on this trait, according which the highest oil yield was obtained from the highest density under the irrigated system and the lowest one was obtained from the densities of 40 and 60 plants.m^{-2} under rainfed system.

As mentioned earlier, oil percentage was increased

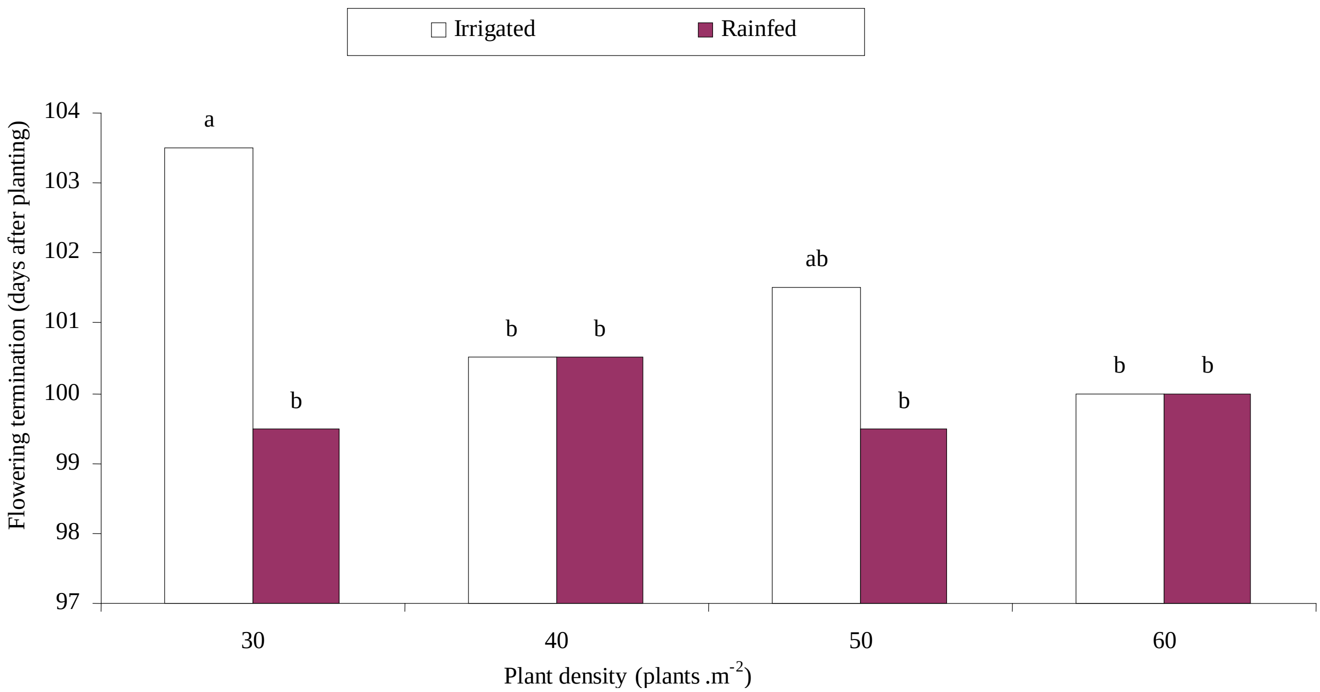

Figure 3. Diagram of flowering termination (days after planting) as affected by plant density and planting system.

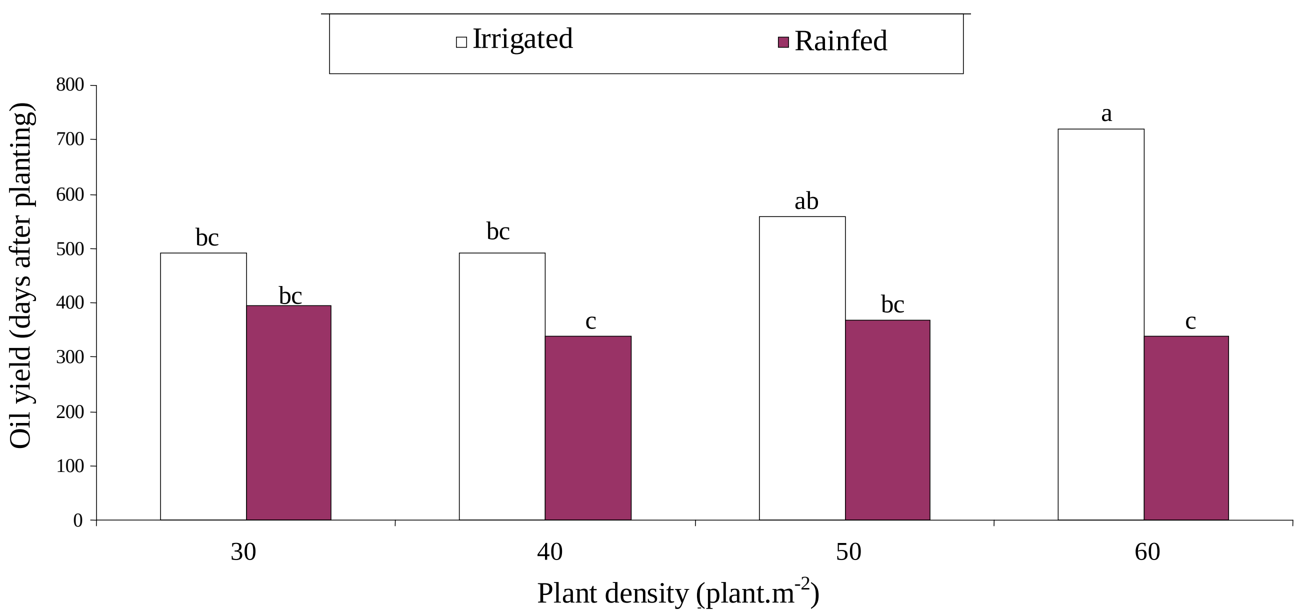

Figure 4. Diagram of oil yield (days after planting) as affected by plant density and planting system.

with the decrease in the density while oil yield was increased with the decrease in the density which was contrary to the results obtained for the oil. Since the highest seed yield was obtained from the density of 60 plants.m^{-}, it seems that seed yield per hectare was the reason for the increase in oil yield per hectare at this density. In a study on the stepwise regression for seed and oil yield including four traits of biological yield, the number of bolls, the number of auxiliary branches and the number of seeds per boll, the results of path analysis for seed and oil yield showed that in order to increase the yield, firstly seed yield must be increased which is in turn

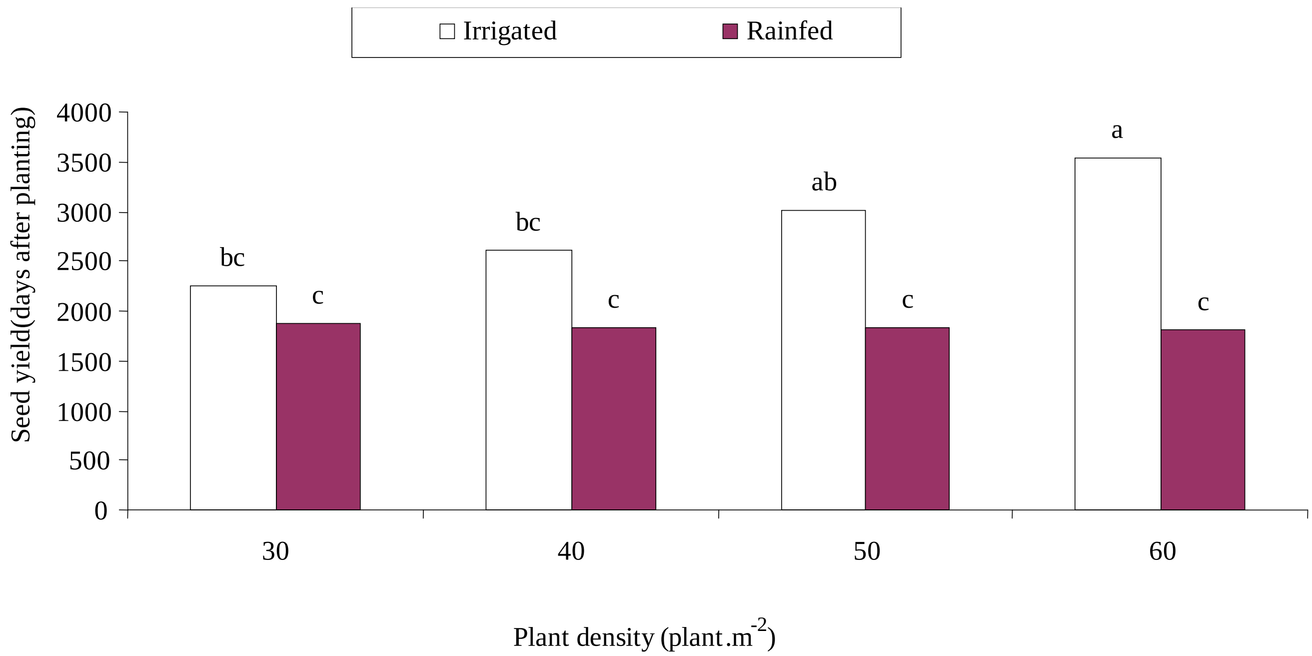

Figure 5. Diagram of seed yield (days after planting) as affected by plant density and planting system.

a function of plant biomass and the number of bolls per plant (Omidi, 2009). Drought stress significantly decreased oil yield and percentage (Kafi and Rostami, 2007).

The table of correlation for oil yield (Table 6) showed that this trait had positive, significant correlation with the number of seeds per m^2 and harvest index.

Seed yield (kg.ha^{-1})

As the results of analysis of variance showed (Table 4), there was significant difference in seed yield between planting systems at 1% probability level. Means comparison for this trait (Table 5) showed that seed yield was higher under irrigated system than under rainfed system and the density had no effect on increasing or decreasing seed yield under both planting systems. Figure 5 shows the interactions of planting systems and plant density on this trait which indicates that the highest seed yield was obtained from the density of 60 plants.m^{-2} under rainfed system which was ranked in the same group with the density of 50 plants.m^{-2} under irrigated system. The lowest seed yield was obtained from different planting densities (30, 40, 50 and 60 plants.m^{-2}) under rainfed system which was ranked in the same group with the densities of 40 and 30 plants.m^{-2} under irrigated system. Ranjbar et al. (2004) found that the decrease in seed yield per plant did not make significant differences in seed yield vs. different seeding rates, mainly because of the increase in the number of plants per m^2. Therefore, 30 seeds.m^{-2} with the row spacing of 30 cm produced the highest yield and 50 seeds.m^{-2} with the row spacing of 40 cm produced the lowest one which is not in agreement with the results of the current study, while Azari and Khajehpour (2003) reported that as the plant density was increased, the plant size and yield components was decreased, but the increase in the number of plants per unit area usually compensated the decrease in total yield.

Istanbulluoglu (2009) reported that the highest safflower seed yield was obtained from control treatment (full irrigation) which was 40.5 and 3.74 t.ha^{-1} for summer and winter treatments, respectively. Hayashi and Hanada (1985) concluded that the decrease in seed yield was brought about by the decrease in the number of bolls per plant which was in turn caused by the decrease in the number of branches per plant. Tavakoli (2002) showed that irrigation withdrawal at flowering stage reduced the yield which was the result of the decrease in the number of heads per plant and the number of seeds per head. Also, Bouchereau et al. (1996) revealed that plants exposed to moderate moisture stress during their vegetative growth produced higher seed yield. This yield was significantly decreased under severe stress applied during both vegetative and reproductive stages. Stern and Beech (1965) showed that the highest safflower seed yield was produced at the density of 610000 plants.ha^{-1} and it was decreased at densities of less than 288000 plants.ha^{-1}.

According to the table of final traits correlation (Table 6), yield had very significant, negative relation with harvest index and very significant, positive relation with oil percentage and yield.

Conclusion

According to the results of the current study, it can be concluded about oil percentage and yield that the former was increased with the decrease in density, but the latter was a function of seed yield.ha^{-1}, so that the highest oil yield was produced at the highest density (60 plants.m^{-2}). Also, it can be said that drought stress (rainfed system) impacted oil yield and percentage, so that both were decreased under rainfed system.

In the case of oil percentage, it can be drawn that despite being very slight, but the differences of planting systems were statistically significant. Therefore, it can be recommended to cultivate safflower in Ardabil, Iran under rainfed system with the density of 50 plants.m^{-2}. Also, safflower is harvested earlier under rainfed system than under irrigated system owing to well-ripening and the opening of the heads and the resulting fall of the seeds as well as late-season precipitations.

REFERENCES

Abddollahi A, Zarrinjoob H (2001). Safflower cultivation. Department of Extension and Public Contributions, Organization of Jahad-e Agriculture, Province of Ilam, Ilam, Iran.

Aliari H, Shekari F, Shekari F (2000). Oilseeds: cultivation and physiology. Tabriz University Press, Tabriz, Iran.

Azari A, Khajehpour MR (2003). Effects of planting pattern on growth, development, yield components and seed yield of safflower, local variety of Isfahan, Koseh, in spring planting. J. Agric. Nat. Resour. Sci. Technol., 7(1): 155-167.

Bagheri M (1995). Effect of sowing date on yield and yield components of safflower cultivars. M.Sc. Thesis on Agriculture, Department of Agronomy, Isfahan University of Technology, Isfahan, Iran.

Bouchereau A, Clossais-Besnard N, Bensaoud A, Leport RM (1996). Water stress effects on rape seed quality. Eur. J. Agro, 5(1-2): 19-30.

Chen Z, Yang ZY, Yao HE (2004). Effects of Chinese herhal for invigorating kidney on metaholism of free radical in testes of rat's with exercise induced fatigue. J. Clin. Rehabil. Tissue Eng. Res., 8: 5898-5900.

Fazeli F, Sadrabadi R, Zare FA, Ezat AM (2007). The effect of sowing date and plant density on yield and yield components of safflower (*Carthamus tinctorious* L.) in Rokh plateau. Iran. J. Agric. Sci., 5(2): 327-332.

Francaneto JB (1993). Soybean seed quality as affected by shriveling due to heat and drought stresses during seed filling. Seed Sci. Technol., 21: 107-111.

Gao BL, Chen HW (2003). The outlook research of anti-sport fatigue with Chinese drugs, J. Clin. Rehabil. Tissue Eng. Res., 7: 3018-3019.

Ghasemi S, Bahrani MJ, Kheradnam M, Matlabipoor S (2006). Effect of row and plant spacing on yield and yield components of two spring safflower cultivars. Iranian. J. Agric. Sci., 1-37(3): 585-591.

Ghassemi-Golezani K, Soltani A, Atlashi A (1997). The effect of water limitation in the field on seed quality of maize and sorghum. Iran. J. Agric. Sci., 25(2): 321-323.

Guan ZX, Zhang HZ, Wang JL (1999). Production technology of functional food. Light industry press, Beijing, Pp. 50-52.

Hashemi DA, Marashi A (1995). Variations of assimilates level during flowering and their effect on growth of seed, yield and yield components of wheat. J. Agric. Sci. Indust., 9: 16-32.

Hatamzadeh H, Eskandary M, Beyg A (2003). Comparision of seed, oil yield and Agronomic Traits of winter Rapaseed varietieties under Rainfeed conditions, Dryland Agric. Res. Institute, Khorasan.

Hayashi H, Hanada K (1985). Effects of soil water deficit on seed yield and yield components of safflower. Jpn. J. Crop Sci., 54: 346-352.

Heidari SH, Asad MT (1998). Effect of irrigation regimes, N fertilization and plant density on yield of safflower cv. Zargan in Arsanjan, Province of Fars, Iran. Proceedings of Conference on Agronomy and Plant Breeding, Karaj, Iran.

Istanbulluoglu A (2009). Effects of irrigation regimes on yield and water productivity of safflower under Mediterranean climatic conditions, Agric. Water Manag., 96: 1792-1798.

Jin M, Li JR, Wu W (2004). Study on the antioxidative effect of Safflor Yellow. China. J. Chin. Mater. Med., 29(5): 447-449.

Jin M, Piao YZ, Wu W (2005). The study of safflower yellow pigment on the functinsto relieve myocardial ischemia of mice. J. Beijing Univ. Chin. Med., 2: 65-69.

Kafi M, Rostami M (2007). Yield characteristics and oil content of three safflower (*Cathamus tinctorius*) cultivars under drought in reproductive stage and irrigation with saline water. Iran. J. Agric. Res., 5(6): 121-130.

Koocheki A (1997). Agriculture and breeding in dry-farming. Jahade Daneshghahi Press of Mashad, Iran, P. 302.

Li RW, Wei CL (2005). Experiment of Chinese herbal jian li fang on antikinetic fatigue. Chin. J. Clin. Rehabil., 9: 236-238.

Ling G (2002). Handbook of Health Food Ingredients. Chemical Industry Press, Beijing. Pp. 608-609.

Majd NB, Karimi M, Noormohammadi G, Ahmadi MR (2003). Evaluation of yield, yield components and physiological traits of five safflower genotypes sown in spring and summer. Sci-Res. J. Agric. Sci., 3-18.

Mohammadi NAR (1995). Study of effects of sowing date and plant density on yield and yield components of safflower in Mashad, Iran. M.Sc. Thesis on Agriculture, Department of Agronomy, Ferdowsi University, Mashad, Iran.

Mundel HRJ, Morrison RE, Blackshaw TE, Roth BT, Giudie R, Kiehn F (1994). Seeding-data effects on yield, quality and maturity of safflower. Can. J. Plant. Sci., 74: 561-266.

Nejad SAR (1996). Study of morphological and physiological traits and yield of spring safflower cultivars in Isfahan, Iran. M.Sc. Thesis on Agriculture, Department of Agronomy, Islamic Azad University, Khorasgan Branch, Isfahan, Iran.

Nobakht M, Fattahi M, Hoormand M, Milanian I, Rahbar N, Mahmoudian M (2000). A study on the teratogenic and cytotoxic effects of safflower extract. J. Ethnopharmacol., 73(3): 453-459.

Omidi AH (2009). Effect of drought stress at different growth stages on seed yield and some agro- physiological traits of three spring safflower cultivars. Seed Plant Prod. J., 25(1): 15-31.

Patel N (1993). Performance of safflower under different irrigation scheduling in sought Gujarat. Ann. Agric. Res., 14: 109-110.

Patel PG, Patel ZG (1996). Effect of irrigation methods and levels on seed yield and quality of safflower. J. Oilseed Res., 13: 53-55.

Poordad S (2006). Safflower. Sepehr Pub., Tehran, Iran.

Rahman MM, Mwakangwale MO, Hampton JG, Hill MJ (2005). Plant density affects soybean seed quality, Seed. Sci. Technol., 33(2): 521-525.

Ranjbar F, Hatamzadeh H, Beig A (2004). Determination of optimum seed rate (Row space and plant space on rows) for safflower. Dryland Agricultural Research Institute, Kermanshah (Iran).

Rostami M (2004). Effect of late-season drought stress on yield and physiological traits of wheat cultivars and determination of optimum drought resistance index. M.Sc. Thesis, Department of Agronomy, Ferdowsi University, Mashad, Iran.

Sharikian MA, Babayian JN (2000). Effect of plant population on yield, yield components and seed quality of soybean cultivars. J. Agric. Sci. Nat. Resour., 7(3): 3-12.

Shaw RW, loomis WE (1950). Bases for the prediction of corn yields. Plant. Physiol., 25: 225-244.

Shenhua C, Huanping S, Weibing W, Jingrong D, Ramesh P (2009). Evaluation of anti-athletic fatigue activity of Schizandra chinensis aqueous extracts in mice. Afr. J. Pharm. Pharmacol., 3(11): 593-597.

Shi X, Ruan D, Wang Y, Ma L, Li M (2010). Anti-tumor activity of polysaccharide (SPS) and effect on cytotoxicity of CTL cells, NK cells of T739 lung cancer in mice. China. J. Chin. Mater. Med., 35(2): 215-218.
Singh VD, Verma SK, Singh BL (1990). Effect of irrigation and phosphorus on safflower (*Carthamus tinctorious*) yield in Rajasthan. Indian J. Agric. Sci., 40: 644-647.
Stern WR, Beech DF (1965). The growth of safflower in low latitude environment. Auster. J. Agric. Res., 16: 801.
Tavakoli A (2002). Study of effect of irrigation withdrawal at different growth stages on yield, yield component and oil yield of safflower. M.Sc. Thesis, Department of Agronomy, Univ. Tehran, Tehran, Iran.
Weiss EA (2000). Oil Seed Crop. Blackwell Sci. Ltd., P. 364.
Wu QF, Wei CL, Lou XH (2003). The Experimental Research on Anti-Fatigue Effect of Jian Li Fang, China Sport Sci. Technol., 39: 40-42.
Yasari T, Shahsavari MR, Barzgar AB, Omidi AH (2005). Study of developmental stages and relationship between of them and seed yield in ten advanced safflower genotypes. Pajou. Saza, 68: 75-83.
Yazdi SB (1996). Study of drought resistance of Iranian and foreign cultivars of safflower. Iranian J. Sci. Agric., 2: 6-11.
Ye SY, Gao WY (2008). Hydroxysafflor yellow A protects neuron against hypoxia injury and suppresses inflammatory responses following focal ischemia reperfusion in rats. Arch. Pharm. Res., 31(8): 1010-1015.
Zand A (1995). Morphological and physiological ground for the difference in yield of safflower. M.Sc. Thesis on Agriculture, Department of Agronomy, Ferdowsi University, Mashad, Iran.
Zareian A, Ehsanzadeh P (2001). Study of effects of cultivar and plant density on yield, yield components and attributes of safflower. M.Sc. Thesis, Dept. Agronomy, Isfahan Univ. Technol., Isfahan, Iran.
Zhang Q, Peng JH, Zhang XN (2005). A clinical study of Safflower Yellow injection in treating coronary heart disease angina pectoris with Xin-blood stagnation syndrome. Chin. J. Integr. Med., 11(3): 222-225.
Zheng J (1999). Functional food. Chemical Industry Press, Beijing. Pp. 730-733.