Journal of Medicinal Plants and By-products (2016) 1: 51-57

Original Article

Yield and Qualitative Traits of Sesame as Affected by Irrigation Interval, N Fertilizer and Superabsorbent

Zeinolabedin Jouyban[1*], Seyyed Gholamreza Moosavi[2], Mohammad Javad Seghatoleslami[3], Seyyed Hamidreza Ramezani[4] and Elahe Ansarinia[5]

[1]*Young Researchers and Elite Club, Borujerd Branch, Islamic Azad University, Borujerd, Iran*
[2,3]*Associate Professor of Crop Physiology, College of Agriculture, Birjand Branch, Islamic Azad University, Birjand, Iran*
[4]*Assistant Professor of Agronomy and Plant Breeding, University of Birjand*
[5]*Young Researchers and Elite Club, Kermanshah Branch, Islamic Azad University, Kermanshah, Iran*

Article History: Received: 18 April 2015/Accepted in revised form: 28 February 2016

Abstract

In order to study the effect of irrigation interval, N fertilizer and superabsorbent on yield and qualitative traits of sesame (*Sesamum indicum* L.), a split-split-plot experiment was coducted in a farm in Khusf of Birjand, Iran in 2009 on the basis of a Randomized Complete Block Design. The main plot was devoted to irrigation interval at three levels of 6, 12 and 18 days, the sub-plot was devoted to N fertilization rate at three levels of 0, 100 and 200 kg ha^{-1} and the sub-sub-plot was devoted to superabsorbent at two levels of 0 and 200 kg ha^{-1}. It was found that the effect of irrigation interval was significant on seed yield, oil percentage, protein percentage, seed N percentage, oil yield and protein yield, so that the increase in irrigation interval from 6 to 18 days resulted in significant loss of seed yield, oil yield and protein yield by 44.5, 44.5 and 39.7%, respectively. Different N fertilization rates significantly influenced seed yield, oil yield and protein yield, but its effect was not significant on seed oil percentage, protein percentage and N percentage, so that the increase in N level from 0 to 200 kg ha^{-1} significantly increased seed yield, oil yield and protein yield by 25.6, 28.3 and 25.1%, respectively. According to the results, it is recommended to use the irrigation interval of 6 days with the treatment of 200 kg N ha^{-1} in order to realize optimum yield of sesame in Birjand, Iran.

Keywords: Sesame, Irrigation, Nitrogen, Superabsorbent, Seed yield.

Introduction

Various applications of oilseeds in people's food regime and the application of their meal in feeding animals as well as their industrial applications such as in medicine, fuel and soup production have been growingly taking farmers and governments' attention [1]. Sesame seeds have more oil than most of the other oilseeds. The oil content of sesame seeds reportedly ranging from 37 to 63% varies with genetic traits and climatic conditions [2]. In addition to containing oil, sesame is regarded as a medicinal herb so that its seeds and leaves are used as herbal medicines in traditional medicine [3].

Tantawy *et al*. [4] stated that the increase in irrigation interval reduced sesame yield. Rezvani Moqaddam *et al*. [5] reported that increased irrigation interval resulted in significantly lower oil percentage and oil yield of sesame. In a study conducted by Bahrani & Babaei [6], the increase in N fertilization level brought about an increase in seed yield and the highest seed yield of sesame was obtained at 90 kg ha^{-1} N fertilization rate. Ahmadi & Bahrani [7] reported that the increase in N fertilization level resulted in the decrease in seed oil per-

* Corresponding author: Borujerd Branch, Islamic Azad University, Borujerd, Iran
Email Address: abed_jouyban88@yahoo.com

centage, but there was no significant difference between the means which is in agreement with Papari Moqaddam Fard & Bohrani [8], Ramakrishnan *et al*. [9] and Imayavaramban *et al*. [10]. Kadam [11] reported that higher N level resulted in higher oil content in sesame seeds. However, Award *et al*. [12] showed that the accumulation of oil in seeds was not influenced by fertilization treatments, especially N. Similar contradictory findings have been reported about some other oilseeds, too [13].

Some additive materials like superabsorbent polymers can store various amounts of water and can increase soil water retention. The water stored in these materials is released in soil during water deficit conditions and this water is used by roots [14]. Yazdani *et al*. [15] reported that seed yield, oil yield, seed protein percentage and seed protein yield of soybean were affected by different levels of superabsorbents so that as the rate of superabsorbent was increased, these traits were increased. Therefore, the present study was carried out to examine the effect of N fertilization and superabsorbent on yield and qualitative traits of sesame under different irrigation intervals.

Materials and Methods

The present study was carried out in a farm in Khusf (Long. 59°13' E., Lat. 32°53' N., Alt. 1480 m) located in Birjand, Iran in 2009 as a split-split-plot experiment based on a Randomized Complete Block Design with three replications. The main plot was devoted to irrigation interval at three levels of 6, 12 and 18 days, the sub-plot was devoted to N fertilization rate at three levels of 0, 100 and 200 kg ha^{-1} and the sub-sub-plot was devoted to superabsorbent at two levels of 0 and 200 kg ha^{-1}. The studied seeds were taken from a local landrace. The plots were 6 m long composed of 6 rows with inter-row spacing of 45 cm and on-row within-plant spacing of 5 cm.The soil texture was clay-sandy with 0.11% organic matter, EC of 8.42 dS m^{-1} and saturated mud pH of 8.09. The soil preparation operation including plowing, disking and leveling were done in March-April 2009. The seeds were sown manually at the depth of 1.5-2.5 cm on June 20, 2009. The seeds were disinfected with Benomyl 2:1000 before sowing and the weeds were controlled by hand during growing season. The plots were thinned at 6-leaf stage until reaching the intended plant density. Meanwhile, irrigation treatments were practiced. The N fertilization treatments as urea were applied at three stages including pre-thinning, early-flowering, and late-flowering. The superabsorbent polymer (Tarawat A200 manufactured in Iranian Polymer and Petrochemical Research Center) were applied as stripe at two rates of 0 and 200 kg ha^{-1} at the depth of 20-25 cm in the middle of wide ridges before sowing.

When the plants turned yellow but the capsules have not split yet, an area of 2 m^2 from the two middle rows was harvested on November 5, 2009. Then, the harvested plants were left in open air to dry. Afterwards, the seeds were separated from capsules and the seed yield (with 10% moisture) was measured. Seed oil and protein percentages were measured bySoxhlet and micro-Kjeldahl methods, respectively. Oil and protein yields, too, were calculated as the products of oil and protein percentages, respectively. When the data were gathered, they were statistically analyzed by MSTATC software and the means were compared by Duncan Test at 5% level.

Results and Discussion

Seed Yield

Analysis of variance revealed that the effect of irrigation interval, N fertilization rates and their interaction was significant on seed yield at 1% statistical level, but the application of superabsorbent and other interactions did not significantly influence this trait (Table 1). The highest seed yield (687.04 kg ha^{-1}, on average) was obtained from the irrigation interval of 6 days which was 32 and 80.2% higher than that under the irrigation intervals of 12 and 18 days (Table 2) which can be related to the decrease in the competition between plants and the increase in the number of auxiliary branches and the number of capsules per plant. These results are in agreement with Rezvani Moqaddam *et al*. [5] and Praksh & Thimmegoawd [16].

Means comparison for seed yield under different N fertilization rates showed 6.5 and 25.6% superiority of 200 kg N ha^{-1} as compared to 100 and 0 kg N ha^{-1}, respectively (Table 2). It is likely that the increase in N rate resulted in higher seed yield through reducing the shedding of flowers and the consequence increase in the number of capsules per unit area as well as through affecting the number of seeds per capsule. Higher N rate resulted in significantly higher seed yield in Papari Moqaddam Fard & Bohrani [8], too.

Although the increase in N rate positively influenced seed yield at all irrigation levels, this effect was the greatest under optimum irrigation. Means comparison for the interaction between irrigation interval and N fertilization showed that the highest seed yield (770.37 kg ha^{-1}, on average) was obtained from the irrigation interval of 6 days treated with 200 kg N ha^{-1} which was 31.2% higher than that obtained from the irrigation interval of 6 days with no N treatment. The lowest seed yield (347.22 kg ha^{-1}, on average) was observed in the irrigation interval of 18 days with no N fertilization (Fig. 1). The greater water and N availability provides optimum conditions for vegetative growth and increases plant photosynthesizing area, assimilation, number of capsules per plant, and number of seeds per capsule which altogether result in significantly higher seed yield.

Oil Percentage

According to the analysis of variance, the effect of irrigation interval and its interaction with N fertilization was significant on oil percentage at 5% statistical level and the interaction between irrigation interval and superabsorbent was significant on it at 1% statistical level, but the effect of N rate, superabsorbent and other interactions was not significant on oil percentage (Table 1).

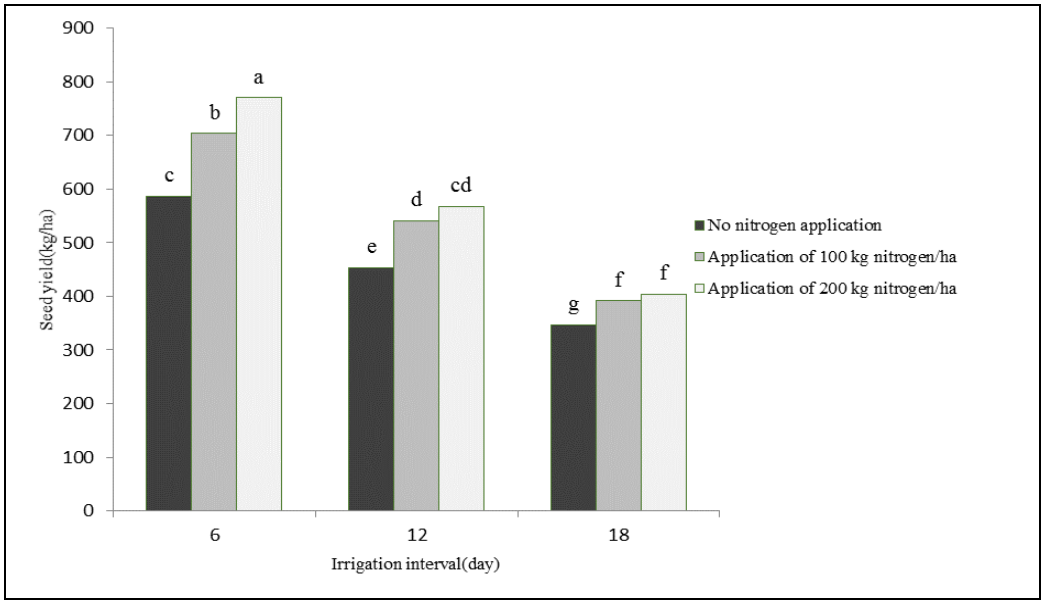

Fig. 1 Interaction between irrigation interval and N fertilization rate for the seed yield of sesame. Columns with similar letter(s) show non-significance at 5% level.

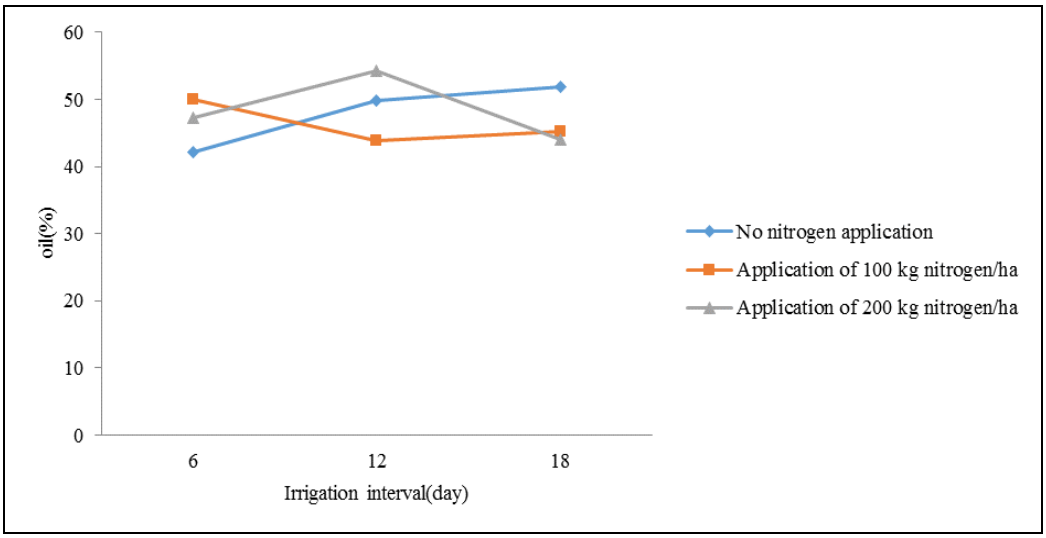

Fig. 2 Interaction between irrigation interval and N fertilization rate for the oil percentage of sesame

The highest oil percentage (49.36%, on average) was obtained under the irrigation interval of 12 days which was 6.2 and 5% higher than that under the intervals of 6 and 18 days, respectively (Table 2). However, Mozafari *et al.* [17] state that oil percentage of sunflower seeds does not much affected by drought stress and believe that oil is a qualitative trait that is controlled by a lot of genes and it is improbable that all controlling genes are damaged.

Means comparison indicated that the highest oil percentage (54.34%, on average) was obtained from the irrigation interval of 12 days treated with 200 kg N ha^{-1} which was 28.9% higher than that obtained under the irrigation interval of 6 days treated with no N fertilizer (Fig. 2). Irrigation interval of 12 days with no superabsorbent application had the highest oil percentage (51.63%, on average) (Table 4).

Oil Yield

Analysis of variance showed that the simple effects of irrigation interval and N fertilization and the interaction between irrigation interval and superabsorbent were significant on oil yield at 1% statistical level and the interaction between irrigation interval and N fertilization was significant at 5% level, but the application of superabsorbent and other interactions did not significantly impact this trait (Table 1).

The highest oil yield (321.40 kg ha^{-1}, on average) was obtained from the irrigation interval of 6 days which was 27 and 80.1% higher than that under the irrigation intervals of 12 and 18 days (Table 2). It can be associated with the increase in seed yield. This finding is consistent with the findings of Rezvani Moqaddam *et al.* [5] and Koutroubas *et al.* [18].

Means comparison revealed that the lowest oil yield (218.01 kg ha^{-1}, on average) was observed under no N fertilization and the application of 100 and 200 kg N ha^{-1} increased it by 17.1 and 28.3%, respectively (Table 2) which is in agreement with Moradi Talavat *et al.* [19]. It seems that N fertilization increased oil yield per unit area through increasing seed yield.

Means comparison for the interaction between irrigation interval and superabsorbent showed that the lowest oil yield (162.96 kg ha^{-1}, on average) was produced under the irrigation interval of 18 days with no superabsorbent application and the highest one (346.77 kg ha^{-1}, on average) under the irrigation interval of 6 days with no superabsorbent application (Table 4).

In addition, the irrigation interval of 6 days treated with 200 kg N ha^{-1} produced the highest oil yield (364.722 kg ha^{-1}, on average) and the irrigation interval of 18 days treated with 100 kg N ha^{-1} produced the lowest one (176.38 kg ha^{-1}, on average) (Table 3). Obviously, more water and N availability has significantly increased oil yield of sesame owing to greater photosynthesis capacity and higher seed yield. Also, high correlation of oil yield with seed yield ($r^2 = 0.876^{**}$) shows that oil yield was more affected by seed yield of sesame (Table 5).

Protein Percentage

The effect of irrigation interval and superabsorbent was significant on protein percentage at 5% statistical level, but the effect of N and the interactions were not significant on this trait (Table 1). The highest protein percentage (23.45%, on average) was associated with the irrigation interval of 18 days and the decrease in irrigation interval from 18 to 6 days resulted in 7.8% loss of protein content (Table 2). Overall, seed protein percentage of most seed crops increases with the increase in water deficiency. The findings reported by Baqeri [20] and Ozturk & Aydin [21] about wheat confirm the results of the present study. The highest protein percentage (22.73%, on average) was obtained under no superabsorbent application which was 1.7% higher than that under the application of 200 kg ha^{-1} superabsorbent which gave rise to the protein percentage of 22.36% (Table 2). It is likely that the application of superabsorbent has compensated the effect of water deficit stress owing to the water retention ability of superabsorbent. Therefore, in no superabsorbent application, water deficit stress emerged more seriously resulting in the loss of synthesis and percentage of protein in sesame seeds. Protein percentage had a negative, significant correlation ($r^2 = -0.674^{**}$) with seed yield mainly due to its increase with the decrease in irrigation on the one hand and the decrease in seed yield with the decrease in irrigation on the other hand (Table 5).

Protein Yield

Analysis of variance revealed that the effect of irrigation interval, N fertilization rate and their interaction was significant on protein yield at 1% statistical level, but the application of superabsorbent and other interactions did not significantly influence this trait (Table 1). The highest protein yield (148.38 kg ha^{-1}, on average) was obtained from the

irrigation interval of 6 days which was 26.2 and 65.9% higher than that under the irrigation intervals of 12 and 18 days (Table 2). This finding can be related to the decrease in inter-plant competition and the increase in the number of capsules per plant and seed yield.

Means comparison for protein yield at different rates of N fertilization showed that it was 5.6 and 25.1% higher under 200 kg N ha^{-1} rate than under 100 and 0 kg N ha^{-1} rates, respectively (Table 2). The main reason for this higher protein yield might be the higher leaf area and photosynthesis capacity of sesame and the resultant increase in seed yield under the application of N fertilizer.

Although at all irrigation levels the increase in N fertilization rate positively influenced protein yield, this effect was considerably greater and significant under optimum irrigation so that the increase in N fertilization rate from 0 to 200 kg ha^{-1} under irrigation interval of 6 days resulted in 27.5% higher protein yield while the same increase in N fertilization under irrigation interval of 18 days resulted in only 18% higher protein yield (Table 3). Means comparison revealed that the highest protein yield (164.89 kg ha^{-1}, on average) was produced under the irrigation interval of 6 days treated with 200 kg N ha^{-1} which was 105.7% higher than that under the irrigation interval of 18 days with no N fertilization in which the protein yield was 80.16 kg ha^{-1} (Table 3). The higher concurrent availability of water and N provides better conditions for the vegetative growth resulting in higher photosynthesizing area, assimilation and seed yield which finally, increases protein yield significantly. The high correlation of seed protein yield with seed yield ($r^2 = 0.991^{**}$) proves the high dependence of seed protein yield of sesame to its seed yield (Table 5).

Seed Nitrogen Percentage

Irrigation interval and superabsorbent significantly impacted seed N percentage at 5% statistical level, but the effect of N and the interactions was not significant on it (Table 1). The highest seed N percentage (3.64 and 3.78%, on average) was associated with the irrigation intervals of 12 and 18 days, respectively, while the decrease in irrigation interval from 18 to 6 days resulted in 7.7% loss of seed N content (Table 2). It is likely that the N absorbed by plants under the irrigation interval of 6 days was mostly for vegetative growth and was only partially stored in seeds as compared to the irrigation interval of 18 days. The highest seed N percentage (3.66%, on average) was observed under no superabsorbent application which 1.4% higher than that under the application of 200 kg ha^{-1} superabsorbent (Table 2).

Seed N percentage has negative, significant correlation with seed yield ($r^2 = -0.664^{**}$) which was due to the increase in seed n percentage with the decrease in irrigation interval on the one hand and the decrease in seed yield with the decrease in irrigation interval on the other hand (Table 5).

Table 1 Results of analysis of variance of the effect of different levels of irrigation interval, N rate and superabsorbent on seed yield and qualitative traits of sesame

S.O.V.	df	Seed yield (kg ha^{-1})	Oil percentage	Oil yield (kg ha^{-1})	Protein Percentage	Protein yield (kg ha^{-1})	Seed N percentage
Replication	2	1627.230^{ns}	11.033^{ns}	375.066^{ns}	0.060^{ns}	65.648^{ns}	0.061^{ns}
Irrigation	2	422069.600^{**}	42.028^{*}	92033.128^{**}	14.917^{*}	15633.830^{**}	0.386^{*}
Error a	4	1580.076	5.018	1068.448	0.946	126.225	0.025
N	2	66687.245^{**}	23.805^{ns}	17352.796^{**}	0.325^{ns}	3253.969^{**}	0.008^{ns}
Irrigation × N	4	6087.107^{**}	171.109^{*}	7958.073^{*}	0.919^{ns}	182.181^{**}	0.023^{ns}
Error b	12	320.073	44.759	1515.975	0.545	28.156	0.013
Superabsorbent	1	825.331^{ns}	48.659^{ns}	1296.540^{ns}	1.797^{*}	0.020^{ns}	0.046^{*}
Irrigation × superabsorbent	2	415.523^{ns}	231.024^{**}	7506.693^{**}	0.419^{ns}	31.349^{ns}	0.010^{ns}
N × superabsorbent	2	29.721^{ns}	29.749^{ns}	378.264^{ns}	0.130^{ns}	3.342^{ns}	0.003^{ns}
Irrigation × N × Superabsorbent	4	180.613^{ns}	47.310^{ns}	1142.987^{ns}	0.365^{ns}	35.585^{ns}	0.009^{ns}
Error c	18	301.783	28.159	901.71	0.365	23.396	0.009
Coefficient of variations		3.28	11.14	11.96	2.68	4.08	2.67

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

Journal of Medicinal Plants and By-products (2016) 1: 51-57

Table 2 Means comparison for the effects of irrigation interval, N fertilization rate and superabsorbent on seed yield and qualitative traits of sesame

Treatment	Seed yield (kg ha^{-1})	Oil percentage	Oil yield (kg ha^{-1})	Protein percentage	Protein yield (kg ha^{-1})	Seed N percentage
Irrigation interval (day)						
6	687.04a	46.49b	321.40a	21.63b	148.38a	3.49b
12	520.68b	49.36a	253.17b	22.56a	117.53b	3.64a
18	381.17c	47.00b	178.44c	23.45a	89.46c	3.78a
N (kg ha^{-1})						
0	462.35c	47.94a	218.01b	22.45a	103.44c	3.62a
100	545.68b	46.34a	255.36a	22.70a	122.55b	3.66a
200	580.86a	48.57a	279.65a	22.48a	129.38a	3.63a
Superabsorbent (kg ha^{-1})						
0	525.72a	48.57a	255.91a	22.73a	118.44a	3.66a
200	533.54a	46.67a	246.11a	22.36b	118.48a	3.61b

Means of traits with similar letter(s) in each column had no significant differences at 5% level.

Table 3 Means comparison for the interaction between irrigation interval and N fertilization rate

Irrigation interval (day)	N rate (kg ha^{-1})	Seed yield (kg ha^{-1})	Oil yield (kg ha^{-1})	Protein yield (kg ha^{-1})
6	0	587.04c	247.73bc	129.37c
	100	703.70b	351.76a	150.88b
	200	770.37a	364.72a	164.89a
12	0	452.78e	225.38cd	100.79d
	100	541.67d	237.95c	123.14c
	200	567.59cd	296.19b	128.68c
18	0	347.22g	180.91d	80.16e
	100	391.67f	176.38d	93.64d
	200	404.63f	178.03d	94.58d

Means with similar letter(s) did not exhibit significant differences at 5% probability level according to Duncan Test.

Table 4. Means comparison for the interaction between irrigation interval and superabsorbent

Irrigation interval (day)	Superabsorbent level (kg ha^{-1})	Oil percentage	Oil yield (kg ha^{-1})
6	0	50.17ab	346.77a
	200	42.81c	296.04b
12	0	51.63a	257.99c
	200	47.08bc	248.36c
18	0	43.89c	162.96d
	200	50.11ab	193.92d

Means with similar letter(s) did not exhibit significant differences at 5% probability level according to Duncan Test.

Table 5 Correlation coefficients between different traits of sesame

Trait	Seed yield	Oil percentage	Oil yield	Protein percentage	Protein yield	Seed N percentage
Seed yield (kg ha^{-1})	1					
Oil percentage	0.018	1				
Oil yield (kg ha^{-1})	0.876**	0.464**	1			
Protein percentage	-0.674**	-0.070	0.0636**	1		
Protein yield (kg ha^{-1})	0.991**	0.004	0.857**	-0.572**	1	
Seed N percentage	-0.664**	-0.065	-0.620**	0.971**	-0.566**	1

** shows significance at 1% level.

Conclusion

In total, it can be concluded that supplying enough water and nitrogen in sesame fields can increase oil

and protein yield through significant increase in seed yield. Therefore, it is recommended to use irrigation interval of 6 days with the application of 200 kg N ha^{-1} under the conditions of the present study in order to realize high economical yield. It should be noted that the application of superabsorbent exactly under the planting rows may positively affect the vegetative and reproductive growth of the plants and the yield which needs further study in future.

References

1. Weiss EA. Castor, sesame and safflower. London, UK: Leonard Hill Books. 1971.
2. Weiss EA. Oilseeds. (Naseri F. Trans.) Mashad, Iran: Astan-e Qods-e Razavi Press. 1991. (In Persian with English Summary).
3. Khajepour MR. Industrial crops. Isfahan, Iran: Jahad-e Daneshghahi Press. 2006. (In Persian with English Summary).
4. Tantawy MM, Ouda SA, Khalil FA. Irrigation optimization for different sesame varieties grown under water stress conditions. J Applied Sci Res. 2007;3:7-12.
5. Rezvani Moqaddam P, Norouzpour G, Nabati J, Mohammadabadi AA. Study on morphological traits, seed yield and oil yield of sesame at different plant densities and irrigation intervals. Iran J Agric Res. 2005;3:64. (In Persian)
6. Bahrani MJ, Babaei GH. Effect of different levels of plant density and N fertilization on seed yield, yield components and some qualitative traits of two sesame (*Sesamum indicum* L.) cultivars. Iran J Agric Sci. 2007;9:237-245. (In Persian)
7. Ahmadi M, Bahrani MJ. Effect of different rates of N on yield, yield components and seed oil content of sesame cultivars in Bushehr, Iran. J Agric and Natural Resources Sci and Tech. 2009;13:123-131. (In Persian)
8. Papari Moqaddam Fard A, Bohrani MJ. Effect of N fertilization and plant density on some agronomic traits of sesame. Iran J Agric Sci. 2005;36:132. (In Persian)
9. Ramakrishnan AN, Sundaram A, Appavoo K. Influence of fertilization on yield and components of sesame. Field Crop Abst. 1996;49:452.
10. Imayavaramban V, Singaravel R, Thanunathan K, Manickam G. Studies on the effect of different plant densities and the levels of nitorgen on the productivity and economic returns of sesame. Crop Res. 2002;24:314-316.
11. Kadam WG. Effect of row spacing and nitrogen on yield of sesame. J Maharastra Agric Univ. 1989;14:222-225.
12. Award G, Sliman GZ, Shalaby SA, Osman AO. Response of sesame plant (*Sesamum indicum* L.) to N, P, K fertilizers on new reclaimed sandy soils. Field Crop Abst. 1998;51:10.
13. Salehi F, Bahrani MJ. Sunflower summer-planting yield as affected by plant population and nitrogen application rates. Iran J Agric Res. 2000;18:63-72.
14. Chatzopoulos F, Fugit JF, Ouillous L. Etu deocation function do different parameters dolabsption et alla desorption do sodium retitule. European Polymer J. 2000;36:51-60.
15. Yazdani F, Alahverdi A, Akbari GA, Behbahani MR. Effect of superabsorbent polymer (Tarawat A200) and drought stress levels on yield and yield components of soybean (*Glycine max* L.). J Res and Dev in Agric and Hortiagric. 2007;75:170. (In Persian)
16. Praksh ND, Thimmegoawd S. Effect of irrigation and fertilizer levels on nutrients concentration and protein yield of sesame (*Sesamum indicum* L.). Indian J Agron. 1991;36:421-426.
17. Mozafari K, Arshi Y, Zeinali Khaneqah H. Study on effect of drought on some morphophysiological traits and seed yield components of sunflower. J Seed and Plant. 1996;12:24-33. (In Persian)
18. Koutroubas SD, Papakosta DK, Doitsinis A. Water requirements for castor oil crop (*Ricinnus communis* L.) in a Mediterranean climate. J Agron and Crop Sci. 2000;14:33-41.
19. Moradi Talavat MR, Siadat AA, Nadian HA, Fathi GA. Response of seed yield, oil and protein of safflower to different levels of nitogen and boron in Ahvaz region, Iran. Iran J Agric Sci. 2007;9:213-224. (In Persian)
20. Baqeri AR. Effect of drought stress on yield and ion content in four wheat cultivars. J Plant Ecophysiology. 2009;1:15-29. (In Persian)
21. Ozturk A, Aydin F. Effect of water stress at various growth stages on some quality characteristics of winter wheat. J Agron Crop Sci. 2004;190:93-99.