



RESEARCH PAPER

OPEN ACCESS

Fennel morphological traits and yield as affected by sowing date and plant density

S.G. Moosavi*, M. Seghatoleslami, E. Ansarinia

Departement of Agricultural, Birjand Branch, Islamic Azad University, Birjand, Iran

Key words: Fennel, sowing date, density, morphological, single plant.

<http://dx.doi.org/10.12692/ijb/5.4.222-229>

Article published on August 30, 2014

Abstract

In order to study the effect of sowing date and plant density on morphological traits and yield of fennel, an experiment was conducted in research field of Islamic Azad University, Birjand branch, Iran in 2009 as a split-plot experiment based on a randomized complete block design with nine treatments and three replications. The main plot was sowing date at three levels of March 19, April 9 and April 30. The sub-plot was plant density at three levels of 6.7, 10 and 20 plants/m². The results showed that sowing date and plant density significantly affected fennel morphological traits at 1% level. Plant height decreased by 48.2% at third sowing dates as compared with that at the first sowing date. 21-day delay in sowing decreased auxiliary branch number per plant by 59.2% and stem diameter from 5 to 1.8 mm. In addition, the increase in plant density from 6.7 to 20 plants/m² decreased auxiliary branch number per plant and stem diameter by 26.4 and 26%, respectively. According the results, single-plant seed and biomass yield and seed yield per hectare were significantly affected by sowing date, plant density and their interaction at 1% level and harvest index was only affected by plant density. As means comparison showed, the delay in sowing from March 19 to April 30 led to 86.7, 86.8 and 85.6 % loss of seed yield per plant, single-plant biomass, seed yield, respectively. Also, the increase in density from 6.7 to 20 plants/m² led to the decrease in single-plant biomass and seed yield by 42.5 and 45.8%, respectively. In total, according to the results, it is recommended to use sowing date of March 10 with the density of 20 plants/m² for the cultivation of fennel in Birjand, Iran.

*Corresponding Author: S.G. Moosavi ✉ s_reza1350@yahoo.com

Introduction

The diversity of climates and ecological conditions of Iran has made it a rich country with invaluable resources of medicinal herbs and prone to cultivation of them. Fennel (*Foeniculum vulgare* Mill.) belongs to the family of Apiaceae. Its total cultivated area was 706 hectares in Iran in 2006. Its commercial value was 138000 US\$ in Iran in 2005 with 0.6% share in its global trade. As the two main fennel importers from Iran, Pakistan and the United Arab Emirates import 50 and 30% of Iran's fennel produce, respectively (Sayyari, 2010).

Sowing date and plant density are very important parameters in crop production. There are various suggestions about fennel sowing date. Some researchers recommend autumn (October-November) as the suitable sowing date for fennel given the optimum temperature for its germination (6-8°C), although in the case of the occurrence of long chilling, the roots might be struck by hypothermia which may lead to desiccation of the plants (Thomas, 1994; Ayub *et al.*, 2008). Foldesi *et al.* (1968) studied the effect of sowing date on fennel production in Hungary and reported that late-autumn sowing date led to earlier maturity than spring sowing. As well, they showed that autumn sowing produced higher yield than spring sowing. However, Landi (1996) indicated that late-autumn sowing of fennel in Northern and Central Italy led to the failure of harvest because of frost. A study on fennel cv. Shorke Shadi at eight sowing dates showed that the sowing date of May 20 was the best (Omidbeigi *et al.*, 2005).

Bahreininejad *et al.* (2006) reported that the fennel density of 3.5 plants/m² produced 2669.3 kg seed/ha and was significantly superior over other studied densities, i.e. 5 and 10 plants/m². In a study on the effect of sowing date and plant density on seed yield of fennel, Darzi *et al.* (2002) showed that they significantly affected seed yield and that the best sowing date was March 25 and the best density was 10 plants/m². In a study on the effect of sowing date and plant density on seed yield and morphological traits of *Pimpinella anisum*, Rassam *et al.* (2007)

concluded that the influence of sowing date, densities and their interaction was significant on most studied traits.

The current study was intended to investigate the effect of sowing date and plant density on yield and morphological traits of fennel.

Materials and methods

Study side

The study was carried out in Hajiabad Research Station of Islamic Azad University, Birjand Branch, Iran (Long. 59°13' E., Lat. 32°52' N., Alt. 1400 m) in 2009. The soil was loam-sandy with pH of 8.6, EC of 4.57 µmho.cm⁻¹ and organic carbon content of 0.25% at the depth of 0-30 cm. The average long-time minimum and maximum temperature is 4.6 and 27.5°C with average annual precipitation of 169 mm and average minimum and maximum relative humidity of 23.5 and 59.6%, respectively. The regional climate is hot and arid.

Experimental design and treatments

It was a split-plot experiment based on a randomized complete block design with nine treatments and three replications. In this study, the effects of sowing date at three levels (March 19, April 9 and April 30) as the main plot and plant densities at three levels (6.7, 10 and 20 plants/m²) as the sub-plot were examined. Each plot was 2×6 m with four 50-cm-long planting rows. The space between plots and replications was 1 and 2 m, respectively. The field had been left fallow in the previous year.

Cultivation

The field preparation operation including tillage was carried out in early-March. According to the results of soil test, 200 kg/ha ammonium phosphate was applied to the soil before final disking. Having disinfected by fungicide carboxin thiram with the ratio of 2:1000, the seeds were dry-sown at the depth of 2 cm. The desired plant densities were created by changing the spacing between plants at the emergence of the second filiform leaf. Given the local climate and soil type, the irrigation was carried out once every 6-10 days and the weeds were removed 3-4

times at each sowing date.

To specify morphological traits including plant height, main branch number per plant and stem diameter, eight plants were selected from the middle of the plots and then, they were measured. To determine the yield, an area of 2 m² was harvested from the middle of each plot. Then, after counting the number of plants, their seeds were winnowed in order to specify seed yield per hectare, single-plant seed yield and single-plant biomass. In addition, seed yield was divided by biological yield and multiplied by 100 to have seed harvest index in terms of percent.

Statistical analysis

At the end, the data were analyzed by statistical software MSTAT-C and the means were compared by Duncan Multiple Range Test at 5% level. The graphs were drawn by MS-Excel.

Results

Morphological traits

The results of analysis of variance for morphological traits showed that plant height, main branch number per plant and stem diameter of fennel were significantly affected by sowing date and plant density at 1% level (Table 1).

Table 1. Results of analysis of variance for the effect of sowing date and plant density on morphological and yield traits of fennel.

Source of variation	df	Plant height	Main branch number per plant	Stem diameter	Seed yield/ha	Seed yield/plant	Single-plant biomass	Harvest index
Replication	2	7.918 ^{ns}	0.114 ^{ns}	0.622 ^{ns}	18622.366 ^{ns}	1.678 ^{ns}	34.487 ^{ns}	4.91
Sowing date (A)	2	2019.509 ^{**}	18.858 ^{**}	22.976 ^{**}	1723439.6 ^{**}	156.16 ^{**}	2423.684 ^{**}	2.287 ^{ns}
Error a	4	9.458	0.076	0.265	7309.883	0.881	17.118	0.568
Plant density (B)	2	170.88 ^{**}	2.563 ^{**}	2.629 ^{**}	178710.6 ^{**}	24.724 ^{**}	301.485 ^{**}	19.63 ^{**}
A × B	4	6.598 [*]	0.139 ^{ns}	0.197 ^{**}	19296.69 ^{**}	7.834 ^{**}	115.183 ^{**}	0.878 ^{ns}
Error b	12	1.733	0.067	0.025	542.258	0.141	5.193	0.31
C.V. (%)	-	2.44	7.35	4.52	3.88	6.80	10.69	2.12

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

Means comparison indicated significant difference in them with the delay in sowing, so that plant height was decreased by 19.3 and 43.7% at the sowing dates of April 9 and April 30 as compared with the sowing date of March 19, respectively, and 41-day delay in sowing led to the 59.2% loss of main branch number per plant and decreased stem diameter from 5 to 1.8 mm (Table 2). The increase in plant density from 6.7 to 20 plants/m² increased plant height from 38.49 to 68.38 cm, but it decreased main branch number per plant and stem diameter by 26.4 and 26%, respectively (Table 3). The interaction of sowing date and plant density significantly affected plant height and stem diameter, too (Table 1). The treatment of sowing date of March 19 with the density of 20 plants/m² produced the highest plant height (73.23 cm on average) and the treatment of sowing date of April 30 with the density of 6.7 plants/m² produced the lowest one (35.30 cm on average). Also, the

highest stem diameter (5.78 mm on average) was obtained under the treatment of sowing date of March 19 with the density of 6.7 plants/m² and the lowest one (1.46 mm on average) was obtained under the treatment of sowing date of April 30 with the density of 20 plants/m² (Table 4).

Seed yield

The results showed that sowing date, plant density and their interaction significantly affected seed yield and biological yield of fennel at 1% probability level (Table 1).

As shown in Table 2 with the delay in sowing from March 19 to April 30, fennel seed yield decreased from 1019.77 to 146.62 kg/ha (85.6%).

The increase in plant density significantly increased seed yield, so that the highest mean seed yield

(726.90 kg/ha) was obtained at the density of 20 plants/m² which was 16 and 62% greater than that at the densities of 10 and 6.7 plants/m², respectively (Table 3).

The highest seed yield (1161.30 kg/ha) was obtained at sowing date of March 19 with the density of 20 plants/m² and the lowest one (97.93 kg/ha) was

obtained at sowing date of April 30 with the density of 6.7 plants/m² (Table 4). The highest biological yield (4798.34 kg/ha) was obtained at sowing date of March 19 with the density of 20 plants/m² and the lowest one (355.70 kg/ha) was obtained at sowing date of April 30 with the density of 6.7 plants/m² (Table 4).

Table 2. Means comparison morphological and yield traits of fennel as affected by sowing date.

Sowing date	Plant height (cm)	Main branch number per plant	Stem Diameter (mm)	Seed yield (kg/ha)	Seed yield per plant (gr)	Single-plant Biomass (gr)	Harvest Index (%)
March 19	68.38 a	4.80 a	5.00 a	1019.77 a	9.61 a	37.79 a	26.13 a
April 9	55.21 b	3.84 b	3.76 b	635.63 b	5.70 b	21.21 b	26.74 a
April 30	38.49 c	1.96 c	1.83 c	146.62 c	1.28 c	4.97 c	25.74 a

Means with the same letter(s) in each column had no significant difference at 5% level.

Seed and biomass yield of single-plant

According to the results of analysis of variance, seed yield per plant and single-plant biomass were significantly affected by sowing date, plant density and their interaction at 1% statistical level (Table 1).

Their means comparison showed their significant drop with the delay in sowing, so that with the delay in sowing from March 19 to April 30, seed yield per

plant decreased from 9.61 to 1.28 g (86.7%) and single-plant biomass decreased from 37.79 to 4.97 g (86.8%) (Table 2).

As means comparison showed, the increase in plant density from 6.7 to 20 plants/m² led to 45.8 and 42.5% decrease in seed yield per plant and single-plant biomass (Table 3).

Table 3. Means comparison morphological and yield traits of fennel as affected by plant density.

Density (plants/m ²)	Plant height (cm)	Main branch number per plant	Stem diameter (mm)	Seed yield (kg/ha)	Seed yield per plant (gr)	Single-plant Biomass (gr)	Harvest index (%)
6.7	49.46 b	4.06 a	4.11 a	448.63 c	6.70 a	25.62 a	27.61 a
10	54.49 b	3.56 b	3.44 b	626.44 b	6.27 a	23.61 a	26.34 b
20	58.13 a	2.99 c	3.04 c	726.90 a	3.63 b	14.74 b	24.67 c

Means with the same letter(s) in each column had no significant difference at 5% level.

Means comparison of the interaction between sowing date and plant density indicated that the treatment of sowing date of March 19 with the density of 6.7 plants/m² had the highest potential seed yield per plant and single-plant biomass (12.24 and 48.31 g, respectively) and the treatment of sowing date of April 30 with the density of 20 plants/m² had the lowest ones (1.03 and 4.27 g, respectively) (Table 4).

Harvest index

As the results showed, harvest index was only affected by plant density and sowing date and its interaction with the density had no significant effect on it (Table

1). Means comparison showed that the densities of 6.7 and 20 plants/m² had the highest and lowest harvest index (27.61 and 24.67%, respectively) (Table 3).

Discussion

The significant decrease in morphological trait following the delay in sowing can be associated with higher temperatures that the plants at the second and third sowing dates experienced which limited their growing period and assimilate-building because of the early maturity of plants. Thus, the plants did not have adequate opportunity for photosynthesis and their height, stem diameter and branch-bearing capacity

increased. It seems that the decrease in height at the last sowing date was brought about not only by shorter growing period, but also by shorter day length which accelerated flowering and thus, stunted the growth of main stem. These results are in agreement with the results of Kazerani *et al.* (2005) on fennel,

Zahtab Salmasi *et al.* (2003) on *Pimpinella anisum* and Rassam *et al.* (2006) on dill. El-Hag (1996) stated the delay in sowing of black cumin stunted the growth of plants. Also, Gowada *et al.* (2006) reported the decrease in fenugreek branch number per plant with the delay in sowing.

Table 4. Means comparison morphological and yield traits of fennel as affected by sowing date and plant density interaction.

Sowing date	Density (plant/m ²)	Plant height (cm)	Main branch number per plant	Stem Diameter (mm)	Seedyield (kg/ha)	Seed yield per plant (gr)	Single-plant Biomass (gr)	Harvest Index (%)
March 19	6.7	63.77 c	5.47 a	5.91 a	820.10 b	12.24 a	48.31 a	25.47 cd
	10	68.13 b	4.93 b	4.81 b	1077.77 a	10.78 a	41.08 b	27.80 a
	20	73.23 a	4.00 cd	4.27 bc	1161.30 a	5.81 bc	23.99 c	26.33 bc
April 9	6.7	49.30 e	4.33 c	4.19 bc	127.87 d	6.39 b	23.24 c	24.27 d
	10	56.07 d	3.70 d	3.71 cd	666.10 c	6.66 b	24.42 c	27.50 ab
	20	60.27 c	3.50 d	3.39 d	812.93 b	4.06 c	15.97 d	27.27 ab
April 30	6.7	35.30 g	2.37 e	1.23 e	97.93 f	1.46 d	5.31 e	24.27 d
	10	39.27 f	2.03 e	1.79 ef	135.47 ef	1.36 d	5.34 e	27.53 ab
	20	40.90 f	1.47 f	1.46 f	206.47 e	1.03 d	4.27 e	25.43 cd

Means with the same letter(s) in each column had no significant difference at 5% level.

It appears that the increase in plant height following the increase in plant density was brought about by the increase in the inter-plant competition over light and the disruption of the balance of growth regulators. Under these conditions, plant height increases if other environmental parameters – e.g. moisture and soil fertility – do not limit the growth of plants (Imam and Ranjbar, 2000). In other words, the decrease in light penetration into middle and lower layers of canopy decreases auxin decomposition and thus, plant height increases. However, some researchers found that under excessively high densities, plant height do not increase and even tends to decrease because the plants compete over other growth-affecting parameters than light, too (Mukhopadhy and Sen, 1997). Also, Kumar *et al.* (2007) on coriander and Mohammadi Nikpoor (1995) on safflower reported the increase in plant height with the increase in plant density. They stated that the increase in internode length was the main reason for the increase in plant height. Nonetheless, Rezvani Moghaddam *et al.* (2005) stated that the increase in plant density had no significant effect of sesame plant height.

On contrary to plant height, main branch number per

plant and stem diameter decreased with the increase in plant density (Table 2). The reason for the increase in branch number under lower densities is that the thinner the plants are, the higher number of branches they produce and the more space they occupy, because there is not severe competition between adjacent plants at the beginning of the growth season. In addition, higher number of auxiliary branches at lower densities can be due to the balance between plants growth rate and the accumulation of all produced dry matter by plant (Khodashenas, 1995). In other words, it can be said that plants intercept less light at higher densities and thus, there is not enough assimilates for the growth of auxiliary branches. Indeed, it should be noted that although plants produced less auxiliary branches at higher densities, the increase in densities increases the number of flowering branches per unit area (Khajehpoor, 2004). The results of Toncer and Kizil (2004) confirm it.

The decrease in stem diameter at higher densities can be related to the decrease in assimilates allocated to the stem. The lower the density is, the more active the plants are to intake nutrients to increase its vegetative growth as well as stem diameter given that the competition is mitigated too, while the conditions are

different at higher densities. Ahmad and Haque (1986) and El-Deen and Ahmad (1997) confirmed this finding.

The decrease in seed yield per plant with the delay in sowing can be related to the shortening of growth period and the decrease in assimilate production which in turn, decreases plant branching potential. It can be said that earlier sowing increased seed yield per hectare and seed and biomass yield per single plant through lengthening growth period, increasing leaf area and producing a plenty of auxiliary branches. It appears that favorable environmental conditions especially light and temperature at the first and second sowing dates allowed the plants to better use these conditions, to produce more assimilates and finally, to increase their seed yield. Soleimani *et al.* (2010) reported 29.9% decrease in fennel yield due to the delay in sowing date from March 25 to May 5. Also, Bahreininejad *et al.* (2006), Sharma and Prasad (1990) and Hornak (1992) in their study on the effect of sowing date on fennel yield, Sadeghi *et al.* (2009) on black cumin, Kumar *et al.* (2007) on coriander and Maletic and Jevdjovic (2007) on fenugreek reported the decrease in seed yield with the delay in sowing which is in agreement with the results of the current study.

The increase in plant density had positive effect on fennel seed yield (Table 3). Under the conditions of the current study, it can be said that although single-plant yield increased at lower densities, the increase could not compensate the decrease in plant number; thus, yield per unit area decreased. At very low densities, environmental resources, especially radiation, is not usually well used because of low leaf area index and the delay in full plant coverage of land and then, total yield decreases.

Some researchers stated that the increase in density increased competition capability of fennel against weeds and so, in addition to the increase in radiation use efficiency with the increase in umbel number per unit area, seed yield increased (Damato *et al.*, 1994). The studies of Bahreininejad *et al.* (2006) and

Koocheki *et al.* (2006) on fennel and Tabatabayi *et al.* (2010) on *Trachyspermum copticum* L. showed the increase in seed yield with the increase in plant density, too. Also, Gowda *et al.* (2006) and Singh *et al.* (2005) stated that yield decreased under low densities because of less assimilates production.

Due to an increasing in inter plants competition, fruit and biological yield of single plant decreased in high densities (Table 3) because intensification of competition for water, light and space. In other words, with increasing plant density reduced the fruit and biomass production potential in single plant because reduction of leaf area duration and also moreshading and respiration in canopy and finally net photosynthesis and assimilates production reduction. This result is in agreement with findings of Zareie *et al.* (2012). These researchers reported that fruit and biomass yield of single plant of coriander decreased significantly with increasing plant density so that fruit and biomass yield of single plant in density of 20 plants per m² was 60.1 and 53.6 % more than density of 60 plants per m², respectively.

As plant density was increased, harvest index significantly decreased (Table 4). Seemingly, under higher densities, less assimilates are allocated to economical parts due to fiercer inter-plant competition and therefore, harvest index loss at higher densities seems reasonable. Rassam *et al.* (2007) in their study on *Pimpinella anisum* reported same results, too.

Conclusion

In total, according to the results, it is recommended to use sowing date of March 10 with the density of 20 plants/m² for the cultivation of fennel in Birjand, Iran since it produced 1163.30 kg seed per ha.

Reference

Ahmed NU, Haque KR. 1986. Effect of row spacing and time of sowing on the yield of black cumin (*Nigella sativa* L.). Bangladesh. J. Agric. **11**, 21-24.

- Ayub M, Nadeem MA, Tanveer A, Tahir M, Saqib MTY, Nawaz R.** 2008. Effect of different sowing methods and times on the growth and yield of fennel (*Foeniculum vulgare* Mill.). Pakistan J. Bot. **40**, 259-264.
- Bahreininejad B, Bagherzadeh K, Asfa M.** 2006. Study of effects of plant density and sowing date on yield of fennel in Isfahan, Iran. Proceedings of 9th Iranian Conference of Agriculture and Plant Breeding.
- Damato G, Bianco VA, Laterza M.** 1994. First results of plant density and nitrogen rate on yield and quality of Florence fennel (*Foeniculum vulgare* Mill. Var. *azoricum*) seeds. Acta Horticulturae **362**, 67-73.
- Darzi MT, Khodabandeh N, Hajseyedhadi M, Yasa N.** 2002. Study of effects of sowing date and plant density on fennel seed yield and active substance quantity and quality. Proceedings of 7th Iranian Conference of Agriculture and Plant Breeding.
- El-Deen E, Ahmad T.** 1997. Influence of plant distance and some phosphorus fertilization sources on black cumin (*Nigella sativa* L.) plant. Journal of Agricultural Science **28**, 39-56.
- El-Hag ZM.** 1996. Effect of planting date, seed rate and method of planting on growth, yield and quality of black cumin (*Nigella sativa* L.) in Khartoum state. Khartoum. 97p.
- Foldesi D, Svab J, Doby S.** 1968. Azedekomeny nagyuzemi termeszesenek korszerusitesere iranyuleo hazai kiserle tek eredmenyei, Novenytermeles **1**, 59-68.
- Gowda MC, Halesh DP, Farooqi AA.** 2006. Effect of dates of sowing and spacing on growth of fenugreek (*Trigonella foenum gracum* L.). Biomedicine **1(2)**, 141-146.
[http://dx.doi.org/10.1016/0169-2607\(90\)90094-P](http://dx.doi.org/10.1016/0169-2607(90)90094-P)
- Hornak L.** 1992. Cultivation and processing of medicinal plants. Akademia Kiado. Budapest.
- Imam Y, Ranjbar G.** 2000. Effect of plant density and drought stress at vegetative growth stage on yield, yield components and water use efficiency in grain corn. Iranian Journal of Agricultural Researches **2(3)**, 118-129.
- Kazerani N, Sa'dabadi L, Saeedi Naeeni F, Dashti P.** 2005. Effect of sowing date and method on yield and yield components of fennel in Boushehr, Iran. Proceedings of National Conference of Medicinal Herbs Sustainable Development, 353 P.
- Khajehpoor MR.** 2004. Industrial crops. Jahad-e Daneshgahi Press, Isfahan University of Technology, Isfahan, Iran, 564 P.
- Khodashenas A.** 1995. Effects of sowing date, row spacing and density on yield and active matter of borage (*Brago officinalis*) in Isfahan conditions, Iran. M.Sc. Thesis, University of Isfahan, Isfahan, Iran.
- Koocheki A, Nassiri Mahallati M, Azizi G.** 2006. The effect of different irrigation intervals and plant densities on yield and yield components of two fennel (*Foeniculum vulgare*) landraces. Iranian Journal of Agricultural Researches **4(1)**, 131-140.
- Kumar K, Singh GP, Singh N, Bhatla AK, Nehra BK.** 2007. Performance of seed crop of coriander under different levels of row spacing, nitrogen and cycocel. Haryana J. Hort. Sci, **36(1&2)**, 127-128.
- Landi R.** 1996. Cultural problems with seed fennel (*Foeniculum vulgare* Mill.) in Italy and possibilities for cultural diffusion. Problemi colturali del finocchio da seme (*Foeniculum vulgare* Mill.) in Italia e possibilita di diffonderne la coltivazione. Atti convegno internazionale: Coltivazione e miglioramento di piante officinali, Trento, Italy, 2-3 giugno 1994. Istituto Sperimentale per l'Assessment Forestale e per l'Alpicoltura; Trento;

Italy. 165-188.

Mahammadi Nikpoor A. 1995. Study of effect of sowing date and plant density on yield and yield components of safflower in Mashad Region, Iran. M.Sc. Thesis on Agriculture, Ferdowsi University of Mashad, Mashad, Iran.

Maletic R, Jevdjovic R. 2007. Sowing date- the factor of yield and quality of fenugreek seed (*Trigonella foenum gracum L.*). Journal of Agricultural Sciences Belgrade **52(1)**, 1-8.

Mukhopadhy D, Sen SP. 1997. Augmentation of growth variables and yield components of plants yielding speices by foliar application of diazotrophic bacteria. Indian J. Agric. Res. **31**, 1-9.

Omidbeigi R. 2005. Medicinal herbs production and processing approaches. Astan-e Ghods-e Razavi Pub. House, Mashad, Iran.

Rassam GA, Naddaf M, Sefidkan F. 2007. Effects of sowing date and plant density on seed yield and yield components of *Pimpinella anisum*. Research and Scientific Journal of Iranian Ministry of Agriculture **20(75)**, 127-133.

Rezvani Moghaddam P, Norozpoor Gh, Nabati J, Mohammad Abadi AA. 2005. Effects of different irrigation intervals and plant density on morphological characteristics, grain and oil yields of sesame (*Sesamum indicum*). Iranian Journal of Agricultural Researches **3(1)**, 57-68.

Sadeghi S, Rahnavard A, Ashraf ZY. 2009. Study importance of sowing date and plant density affect on black cumin (*Cuminum carvi*) yield. Botany Research International **2(2)**, 94-98.

Sayyari M. 2010. Effect of plant density and N on marigold flower and seed yield in Mashad, Iran. M.Sc. Thesis on Agriculture, Islamic Azad University, Birjand Branch, Iran, 174 P.

Sharma PK, Koul AK. 1986. Mucilage in seeds *plantago ovata* and its wild allies. Journal of Ethnopharmacology **17**, 289-295.

Singh S, Buttar GS, Singh SP, Brar DS. 2005. Effect of different dates of sowing and row spacings on yield of fenugreek (*Trigonella foenumgracum*). Journal of Medicinal and Aromatic Plant Sci. **27(4)**, 629-630.

Soleimani A, Shahrajabian MH, Emami Abarghooyi P, Narenjani L. 2010. Effect of sowing date and cultivar on fennel yield and yield components. Proceedings of 11th Iranian Conference of Agriculture and Plant Breeding, University of Shahid Beheshti, Tehran, Iran, July 24-26.

Tabatabayi SA, Soltanzadeh A, Morovati A. 2010. Effect of N fertilization and plant density on essential oil of *Trachyspermum copticum L.* under Yazd climate, Iran. Proceedings of National Conference of Medicinal Herbs and their Economical Potentials, 44 P.

Thomas TH. 1994. Responses of florence fennel (*Foeniculum vulgare*) seeds to light, temperature and gibberellin. Plant Growth Reg. **14**, 139-143.

Toncer O, Kizil S. 2004. Effect of seed rate on agronomic and technologic characters of *Nigella sativa*. International Journal of Agriculture and Biology **6(3)**, 529-532.

Zahtab Salmasi S, Javanshir A, Omidbeigi R, Aliari H, Ghasemi Golezani K. 2003. Ecophysiological effects of irrigation and sowing date on growth, yield and yield components of *Pimpinella anisum*. Journal of Agriculture Knowledge **13(4)**, 37-49.

Zareie MH, Moosavi SG, Seghatoleslami MJ. 2012. Effects of sowing date and planting density on yield and yield components of coriander. International Journal of Agriculture: Research and Review **2(5)**, 555-563.