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Research Article

Evaluation of the Effects of Priming and Cultivation Date on Quantity and Quality Performance of Cumin (*Cuminum cyminum* L.) Medical Plant

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ABSTRACT

A universal approach to using medicinal plants and natural compounds in cosmetics and pharmacological industries, and consequently by authorities, national industries, in addition to people's attention to use medicinal and aromatic plants especially *Cuminum cyminum* L., indicate the necessary need of wide basic science and applications research in this field. Our purpose is to evaluate cultivation date and priming effects on quantity and quality performance of cumin. This research has conducted in medicinal plant research field of Shahed University located at the beginning of Tehran-Qom Highway at the agricultural year of 2014-2015. The experiment performed as a two-treatment factorial in a randomized complete block design with three replications. The first treatment was priming at two level include without priming (control) and hydro priming for eight hours, and the second treatment was three cultivation date including 4 February, 19 February, and 5 March. Variance analysis of results showed that the effect of priming and cultivation date on seeds number per plant, harvest index and active ingredients like alpha pinene, beta pinene, o-cymene, limonene, p-cymene, linalool, alpha-terpineol, and cumin aldehyde, were significant at the statistical level of 5%. But it has not significant effect on the weight of 1000 seeds and biological performance. In addition, the highest number of the seeds per plant, seed performance, beta pinene, limonene, p-cymene, and linalool was for hydro priming at cultivation date of 4 February. However, it has not significant effect on the number of umbels per plant, the weight of 1000 seeds and biological performance. In addition, the highest number of seeds per plant, seed performance, beta pinene, limonene, p-cymene, and linalool observed for hydro priming treatment at cultivation date of 4 February. But, this treatment resulted in fewer amounts of active ingredients like o-cymene and alpha Terpineol. In this experiment, delay in cultivation date resulted in a decrease of biological performance and weight of 1000 seeds. Generally, results of the effect of the cultivation date and priming treatment interaction showed that using hydro priming results a non significant increasing in some of the active ingredients at cultivation date of 4 February in comparison with control.

Key words: Alpha pinene, Pretreatment, Seed performance, Active ingredients, Hydro priming

INTRODUCTION

Medicinal plants are one of the most important resources in extensive scope of natural resources of Iran, which with scientific insight, cultivation, adequate development and utilization can be of important role in public health, job creation and non-oil exports (Kashfi Banab, 2010). Cumin is one of the important native medicinal plant of Iran (Kafi *et al*., 2002) and one of the most important and oldest spicy seeds which had being used by humanity. Their fruit has medicinal properties and was used for gastrointestinal pains, indigestion, diarrhea, epilepsy and jaundice (Bettaieb *et al*., 2012), and have diuretic, stimulant and carminative activities. The favorable odor of its seeds correspond to its volatile essence which cuminol is its main compound, and several biological activities like antibacterial, antifungal, antidiabetic, antioxidant, antithrombotic, anticancer and antimicrobial activities have been reported for it (Sowbhagya, 2011; Zaman, 2009).

One of the fundamental problems in the wide cultivation of medicinal plants is the inadequate germination and consequently unsuccessful establishment in agricultural conditions. Germination and seedling

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establishment are critical stages in plant life cycle, and successful establishment depends on quick germination and uniformity of the seeds (Windauer, 2007). Seed priming is one of the best biological methods for seedling hardening in the germination stage and primary growth. Priming is related to specific treatments that are used for enhancing germination percent and uniformity, and improving seedling growth and seedling vigor indices against environmental stresses. In priming, the seeds are allowed to become partially hydrated, so that primary stages of germination, without radicle emergence, occurred (Bader *et al.*, 2006). Priming has beneficial effects include enhancing germination percent, faster and more uniform seedling emergence, preceded maturity, wider range of germination temperature, repair of injured cells, decreasing the embryo growth barriers, quality and quantity enhancement of protein synthesis, removing seed dormancy, higher resistance to environmental stresses at cultivation time, and higher development power of plant (Khan, 1992). According to one of the experiments, osmo priming and hydro priming of cumin seeds, affects significantly on performance parameters of this plant like the weight of 1000 seeds, the number of the umbels per plant and number of the seeds, and it increases the cumin essence and cumin seeds performance (Parry, 1969).

One of the other factors that have some effects on seed performance of crops is the cultivation date. In fact, medicinal plants performance and properties are affected by environmental factors like temperature and light which can differ based on the different time of germination (Ullaha *et al*., 2013). Kamkar et al (2007) have conducted a study in three different provinces (North Khorasan, Razavi Khorasan, South Khorasan) and they showed that cultivation date beginning with December with the circumstances that are provided for plant growth, showed that February is the best month for the cultivation of this plant. In the investigation of four dates (6 November, 21 December, 6 February, and 5 March) in Fars province, it was shown that late cultivation dates (6 February and 5 March) outrank the others due to the probability of untimely cold stresses (Nezami *et al.*, 2005).

Based on the above mentioned problems, the purpose of conducting this investigation is to study the effects of seed priming on performance and performance components and active ingredients of cumin at different cultivation dates.

MATERIALS AND METHODS

Properties of investigation field

In order to evaluate the effects of cultivation date and priming on quantity and quality performance of cumin medicinal plant, an experiment has been conducted in medicinal plant research field of Shahed University located at the beginning of Tehran-Qom Highway (latitude: 36’ 31’’, longitude: 53’ 48’’, height: 1050 m) at agricultural year of 2014-2015. In order to determine physical and chemical properties of the field, sampling was performed at 0-30 cm depth of the soil, and its properties are presented in table 1. Farm experiment performed as a two treatment factorial in a randomized complete block design with three replications. The first factor was priming at two levels of hydro priming for eight hours and control (without priming), and the second factor includes three cultivation dates including 4 February, 19 February, and 5 March. In this research, Sabzevar cumin landrace was used. These seeds were provided from Pakan Bazr Co., Esfahan. In order to perform this experiment, field preparation was done in appropriate climate condition before cultivation. After leveling the field, plots were defined in a 2.5 m × 2.5m, and each plot has five line of cultivation with the distance of 50 cm. Seed cultivation was done in defined dates. Watering was done based on the climate and soil properties, and water needs of the plants and hand-weeding were performed. From each plot, with ignoring the effect of border, six plants were selected randomly and transferred to the laboratory, in order to evaluate the number of the umbels per plant, the number of the seeds per plant, and the weight of 1000 seeds in the ripening time. To evaluate seed performance, biological performance, and harvesting index, the harvest process was done from each plot of 1.2m2. The samples were dried by air. Then the seeds were separated from straws. Harvest index obtained from dividing seed performance on biological performance. The amount of the components of the essence were determined by using Gas Chromatography (GC) tools.

Statistical analysis method

The resulted data were analyzed with SAS (v.6.12) statistic software, and the means were compared by Duncan multiple domains test. The diagrams were drawn by using Excel (2016) software.

RESULTS

Number of the umbels and seeds per plant

Based on the results of variance analysis data, the main effect of cultivation date and the interaction of priming and cultivation date on the number of seeds per plant were significant at the level of 1%. However, none of the treatments has a significant effect on the number of umbels per plants (Table 2). Results of comparing the means of the effect of priming and cultivation date interaction indicates that the highest number of the seeds per plants was corresponded to the hydro priming treatment and cultivation date of 4 February (611.6), so that the number of the seeds per plant for this treatment shows 89.52% increasing than hydro priming treatment at cultivation date of 5 March (Table 4).

The weight of 1000 seeds

Results indicate that the main effect of cultivation date on the weight of 1000 seeds was significant at the level of 5%. However, the main effect of priming and interaction of priming with cultivation date was not significant for this parameter (Table 2). Comparing the means showed that the higher weight of 1000 seeds obtained for cultivation date of 4 February (3.05 gr). There is no significant difference between the cultivation dates of 19 February and 5 March for the weight of 1000 seeds. The amount of this parameter increase 21.03% for cultivation date of 4 February than that of 19 February (Diagram 1).

Seed performance

The results of variance analysis showed that the main effect of cultivation date at the level of 1% and the effect of the interaction of priming with cultivation date at the level of 5% was significant (table 2). According to the results of comparing the means obtained for the effect of the interaction of priming and cultivation date, highest seed performance obtained for cultivation date 4 February in each treatment of control (232.11 Kg per hectare) and hydro priming (234.83 Kg per hectare). Delays in cultivation date from 4 February to 5 March resulted in the reduction of 56.56% in seed performance (table 4).

Harvest index

According to the results of variance analysis, the main effect of cultivation date, and the effect of the interaction of priming with cultivation date on harvest index was significant at 1% (table 2). Results from comparing the priming and cultivation date indicate that the highest harvest index was for cultivation date of 4 February in each treatment of control (24.85%) and hydro priming (23.49%). In this research, there is no significant difference was observed for 4 and 19 February with hydro priming for harvest index (table 4).

Biological performance

The experiment results indicate that the main effect of cultivation date on biological performance was significant on the level of 1%. However, the main effect of priming, and the effect of priming and cultivation date effect on this parameter was not significant (table 2). Comparing the means showed that the highest biological performance obtained for cultivation date of 4 February (968/86 Kg per hectare). There was no significant difference between two cultivation dates of 19 February and 5 March. The biological performance increased 25.6% for 4 February than cultivation date of 19 February (diagram 2).

Alpha-pinene

The results of variance analysis showed that the main effect of priming (at the level of 5%) and the main effect of cultivation date and that of the interaction of priming with cultivation date (at the level of 1%) was significant for alpha pinene content (table 3). According to the results of comparing the means of the interaction effect, the highest amount of alpha-pinene obtained for hydro priming and cultivation date of 4 February (1.4%) treatments, and control (without priming) and cultivation date of 19 February (1.3%). Lowest amount of it observed in the control (without priming) at cultivation date of 5 March (0.7%) (Table 5).

Beta-pinene

According to the results of variance analysis, the main effect of priming and cultivation date, and the effect of their interaction on one of the active ingredients (beta-pinene) were statistically significant at the level of 1% (table 3). Results of comparing the means showed that the highest content of beta-pinene belongs to the hydro priming treatment at cultivation date of 4 February (10.1%). The lowest content of this active ingredient obtained for control (without priming) at cultivation date of 4 February (6.9%) and 5 March (6%), (table 5). In this experiment, hydro priming increase this ingredient 46.38% than control (without priming), for cultivation date of 4 February.

O-cymene

In this experiment, the main effect of priming and the cultivation date, and their interaction on the active ingredient of o-cymene was statistically significant at the level of 1% (table 3). Comparing the means of their interaction showed that the cultivation dates of 19 February (8.3%) and 5 March (7.5%), both without priming, have the highest content of this active ingredient. The lowest content of it was obtained for hydro priming treatment at cultivation date of 4 February (4.4%) (Table 5).

Limonene

According to the results of variance analysis, the main effect of priming and cultivation date and their interaction, on the active ingredient of limonene, were statistically significant at the level of 1% (table 3). The results of the comparing the means indicates that highest content of limonene obtained for hydro priming at cultivation date of 4 February (16.1%). So that, it showed 23.84% increase than hydro priming at cultivation date of 5 March (table 5).

P-cymene

The results of variance analysis showed that the main effect of priming at the level of 5%, and the main effect of cultivation date, and cultivation date and cultivation date interaction at the level of 1% was significant (table 3). According to the results of comparing the means of the effect of the interaction, the highest p-cymene content obtained for hydro priming at cultivation date of 4 February (2%). However, there were no significant differences among other treatments (table 5).

Linalool

According to the results of variance analysis, the main effect of priming and cultivation date and their interaction on the active ingredient linalool was significant at the level of 1% (table 3). The result of comparing the means of the interaction effects showed that there was no significant difference for linalool active ingredient between hydro priming with the cultivation dates of 4 February (13.1%) and 19 February (11.9%), and these two have the highest content of it. However, for treatment without priming, there was a significant difference between cultivation dates of 4 February and 19 February (table 5).

Alpha-terpineol

In this experiment, the main effect of priming and cultivation date and their interaction with the content of alpha-terpineol were statistically significant at the level of 1% (table 3). Comparing the means of the interaction showed that the highest content of alpha-terpineol observed for cultivation dates of 19 February (10%) and 5 March (9.4%), both without priming. The lowest content of it observed for hydro priming at cultivation date of 4 February (5.1%) (Table 5).

Table 1: Physicochemical properties of the soil of research field (depth of 0-30 cm)

Soil texture	Gipsum (%)	Organiccarbon (%)	CEC (meq.100g soil^{-1})	SAR	ESP	pH	EC (ds/m)	Components of soil texture		
								Silt (%)	Sand (%)	Clay (%)
Sandy loam	7.5	0.10	10.3	7.41	8.8	8.13	6.2	15	75	10

Table 2: Variance analysis of the effect of priming and cultivation date on performance and its component in cumin

		Mean of squares					
Source of variation	Degree of freedom	Number of the umbels per plant	Number of the seeds per plant	Harvest index	Biological performance	Seed performance	Weight of 1000 seeds
Replication	2	1.17 *	14054.64 ^{ns}	1.69 ^{ns}	17210.04 ^{ns}	839.33 ^{ns}	0.17 ^{ns}
Priming (P)	1	0.5 ^{ns}	1541.23 ^{ns}	0.41 ^{ns}	574.38 ^{ns}	192.28 ^{ns}	0.006 ^{ns}
Cultivation date (D)	2	0.001 ^{ns}	53121.84**	74.17**	122201.31**	20377.75**	0.74*
(P×D)	2	0.67 ^{ns}	27904.68**	26.44**	8237^{ns}	2479.32*	0.1^{ns}
error	10	0.23	2524.66	2.53	5851.8	509.49	0.12
		7.43	12.12	7.69	9.44	13.19	13.21

ns, *, and ** are 0nonsignificant, significant at the level of 5%, significant at the level of 1 percent, respectively

Table 3: Variance analysis of the effect of priming and cultivation date on active ingredients of cumi

		Mean square							
Source of variation	Degree of freedom	Cumin aldehyde	α-Terpineol	Linalool	P-Cymene	Limonene	O-Cymene	ß-Pinene	α-Pinene
Replication	2	1.02 ^{ns}	0.58 *	0.06 ^{ns}	0.16 *	0.93 *	0.7 *	2.281 **	0.132**
Priming (P)	1	169.28 **	40.5 **	85.81 **	0.18 *	121.68 **	26.65 **	46.06 **	0.045 *
Cultivation date (D)	2	23.5**	5.04**	8.82**	0.74**	8.44**	2.77**	4.865**	0.32**
P×D	2	8.77**	2.37**	4.34**	0.59**	2.72**	1.06**	1.815**	0.24**
error	10	0.48	0.09	0.27	0.04	0.2	0.14	0.162	0.01
		4	3.75	5.46	15.59	3.75	6.13	5.38	9.67

ns, *, and ** are 0nonsignificant, significant at the level of 5%, significant at the level of 1 percent, respectively

Table 4: Comparing the means of the effect of priming and cultivation date interaction on performance and its component in cumin

Treatment levels		ß-Pinene (%/total)	α- Pinene (%/total)	Harvest index (%)	Seed performance (Kg/Hectare)	Number of the seeds per plants
Priming	Cultivation date					
Hydro priming	4 February	10.1 a	1.4a	23.49a	234.86a	611.6a
	19 February	9b	1b	23.42a	186.24ab	562.1ab
	5 March	8.1b	0.8bc	15.55b	102c	322.7c
Control (without priming)	4 February	6.9c	0.9bc	24.85a	232.11a	543.9ab
	19 February	4.7d	1.3a	18.34b	137.28bc	438.7bc
	5 March	6c	0.7c	18.36b	134.28bc	458.3abc

In each column, similar alphabets show insignificant difference among treatments.

Table 5: Comparing the means on priming and cultivation date effects on active ingredients (%/total) in cumi

Treatment levels		Cuminaldehyde	α-Terpineol	Linalool	P-Cymene	Limonene	O-Cymene
Priming	Cultivation date						
Hydro priming	4 February	13.3e	5.1d	13.1a	2a	16.1a	4.4d
	19 February	15.5d	6c	11.9a	0.7b	14.4b	4.9cd
	5 March	17.4c	7.8b	10.2b	1.2b	13c	5.6bc
Control	4 February	19.1c	8.5b	8.8c	1.1b	10.5d	6.4b
(without	19 February	24.2a	10a	5.8d	1b	8.1f	8.3a
priming)	5 March	21.3b	9.4a	7.5c	1.2b	9.3e	7.5a

In each column, similar alphabets show insignificant difference among treatments.

Cumin aldehyde

The results of variance analysis showed that the main effect of priming and cultivation date and their interaction on cumin aldehyde content was significant at the statistically level of 1% (table 3). Comparing the means of the interaction showed that the highest content of cumin aldehyde (24.2%) obtained for cultivation date of 19 February without priming, and the lowest content of it (13.3%) observed for hydro priming at cultivation date of 4 February (Table 5).

DISCUSSION

In this experiment, none of the treatments has a significant effect on the number of umbels per plant. In this regard, results of Qanbari & Khajavi Nejad (2014) showed that the number of the umbels per plant was not affected by cultivation date. In our investigation, hydro priming at cultivation date of 4 February results in 85.52% increase in the number of seeds per plant than hydro priming at cultivation date of 5 March. It also resulted in 12.45% increase of it than cultivation date of 4

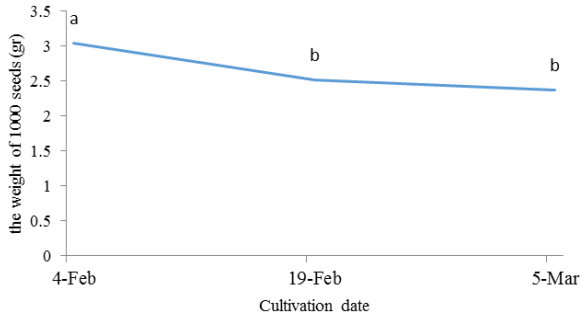

Diagram 1: The effect of cultivation date on the weight of 1000 seeds of cumin at the significant level of 5%

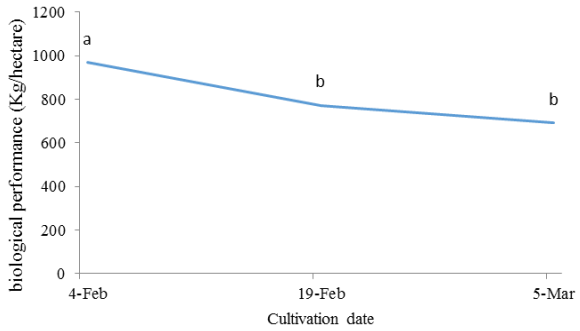

Diagram 1: The effect of cultivation date on the biological performance of cumin at the significant level of 5%

February without priming. In the same way, delays in cultivation dates resulted in significant reduction of a number of seeds per plant for cumin medicinal plant (Ghorbani *et al*, 2010).

According to the results of this experiment, delays in cultivation dates resulted in significant reduction of the weight of 1000 seeds. The weight of 1000 seeds of cultivation dates of 19 February and 5 March showed 17.38 and 21.97% reduction than cultivation date of 4 February, respectively. Many reports indicate the significant effect of cultivation date on the weight of 1000 seeds, and according to their results, with delays in cultivation date, there is a reduction in the weight of 1000 seeds (Arslan *et al*., 1987, Khorasani *et al*,. 2012). In fact, an increase of the weight of 1000 seeds for cultivation dates of 4 February is the result of the higher allocation of photosynthetic materials for each umbel and seed (Ghanbari *et al*., 2014). In our experiment, priming and the interaction of priming and cultivation date on this parameter are not statistically significant. In the same way, in another study, the weight of 1000 seed was not affected by priming (Rahimi, 2012).

In this experiment, delays in cultivation dates result in the reduction of biological performance. This parameter showed 20.39 and 28.61 percent reduction for cultivation dates of 19 February and 5 March, respectively, than 4 February. In the same way, the results of (Ghorbanifar *et al* 2010) indicate a significant reduction in biological performance of cumin, with delays in cultivation dates.

The results of our study indicate that delays in cultivation date resulted in the reduction in seed performance. The delay from 4 February to 5 March, with hydro primed conditions, results in the 56.56% reduction in seed performance. For explanation, it can be said that with longer growth period, the higher absorption rate of photosynthetically active light rays and consequently higher biomass production of plant resulted in the higher biological performance of them (Nezami *et al*., 2005). In fact, due to high sensitivity of cumin to photoperiod, delayed cultivation of this plant did not provide necessary time for plant development and umbel production for generative period, and plants enter the generative phase without completing their vegetative period, and it leads to reduction of number of the seeds, the weight of 1000 seeds and seeds performance for delayed cultivation (Rahimiyan, 1992). In addition, the highest seeds performance for cumin observed for osmo priming and hydro priming (Rahimi, 1992). It can be explained by faster and appropriate establishment of these plants, and higher use of minerals, soil moisture, and sun rays of them. Primed seeds germinate sooner and complete their life period faster which results in changes in the natural acclimation of phonologic properties of the plant with biological stresses. Altogether, they reduce the damages from encountering stress condition for germinating primed seeds and related plants (Bradford, 1990). Also, seeds pretreatment before cultivation results in the uniform growth of plants in the field, and produce vigor plantlets with higher quality and quantity. Observations showed that hydro priming is a critical and advantageous method which has beneficial effects on the performance parameters (Harris, 1996). As the same way, sunflower seeds hydro priming for 12 hours, resulted in an increase of the number of the plants per m2, the number of the capitula per plant, the number of seeds per capitula, seed performance and oil content in comparison with untreated seeds (Ashraf, 2003).

In this research, there was no significant difference between hydro priming and control treatment both at cultivation date of 4 February, and harvest index was highest for these two treatments. There was no significant difference between hydro priming for cultivation dates of 4 and 15, too. But it was significant for control treatment. Therefore, it can be concluded that hydro priming can compensate for this parameter. The results of variance analysis showed that the main effect of priming on the contents of alpha-pinene and p-cymene at the level of 5%, and beta pinene, o-cymene, limonene, linalool, alpha terpineol and cumin aldehyde at the level of 1% were significant. In addition, the main effect of cultivation date and the effect of cultivation date and priming interaction on alpha pinene, beta pinene, o-cymene, limonene, p-cymene, linalool, alpha terpineol and cumin aldehyde was significant at the level of 1%. Also, the highest amount of beta pinene, limonene, p-cymene, and linalool corresponded to hydro priming at cultivation date of 4 February, but this priming did not result in increasing the content of o-cymene and alpha terpineol. In the same way, the results of Rahimi (2012) showed that cumin osmo priming and hydro priming resulted in an increase of cumin essence and its quality. According to Palevitch (1987), although the production of secondary metabolites is under the control of gene expression, but their concentration is affected considerably by environmental factors. Therefore, changes in cultivation date by changing the environmental conditions during growth

season may be able to increase some of the active ingredients and decreasing some of them. One of these factors are light, and there is a close relationship between the light properties (quality, quantity, and continuation) and the production of secondary metabolite in medicinal plants (Davazdah *et al*., 2009).

REFERENCES

Ashraf M, R Zafar and MY Ashraf, 2003. Time-course changes in the inorganic and organic components of germinating sunflower achenes under salt (NaCl) Stress. Flora, 198: 26-36 .

Arslan N and A Bayrak, 1987. Effect of sowing date on fruit yield and some characters of cumin (*Cuminum cyminum* L.). Horticultural Abstracts, 58: 562.

Bader B, B Duijn and M Grzesik, 2006. Effect of water supply methods and seed moisture content on germination of China aster and tomato seeds. J Agron, 24: 45-51.

Bettaieb RI and I Jabri-Karoui, 2012. Effect of drought on the biochemical composition and antioxidant activities of cumin (*Cumin cyminum* L.) seeds. Indust Crops Prod, 36: 238-245.

Bradford KJ, JJ Steiner and SE Trawatha, 1990. Seed priming influence on germination and emergence of pepper seed lots. Crop Sci, 30: 718-721

Davazdah Emami S and MN Hosseini, 2009. Cultivation, and production of some medicinal and spice herbs. University of Tehran Publications.

Ehteramian K, MJ Bahrani and P Rezvani Moghaddam, 2007. Effects of different levels of nitrogen fertilizer and sowing dates on yield and yield components of cumin (*Cuminum cyminum* L.) in Kooshkak region of Fars province. Field Crops Res, 5: 1-8.

Ghanbari J and GR Khajavi nejhad, 2014. Evaluation of yield and crop characters on ecotypes of cumin (*Cuminum cyminum* L.) in different sowing dates in Kerman. J Agroecol, 6: 142-151.

Ghassemi G and B Esmaeilpour, 2008. The effect of salt priming on the performance of differentially matured cucumber (*Cucumis sativus*) seeds. J Notulae Botanicae Horti Agrobotanici Cluj- Napoca, 36: 67-70.

Ghorbani R, AR Koochaki, M Jahani, A Hosseini, AA Mahammad-Abadi and M Sabet Teimouri, 2010, Effect of planting date, weed control time and method on yield and yield components of cumin. Field Crops Res, 1: 151.

Harris DA, 1996. The effects of manure, genotype, seed priming, depth and date sowing on the emergence and early growth of *Sorghum bicolor* (L.) Moench in semi-arid Botswana. Soil Tillage Res, 40: 73-88.

Kafi M, MH Rashed Mohassel, A Koocheki and M Nassiri, 2002. Cumin (*Cuminum cyminum* L.) Production Technology and Processing. Ferdowsi University of Mashhad Publication. Mashhad, Iran.

Kamkar B, A Koocheki, M Nassiri mahallati and Rezvani moghaddam P, 2007. Yield gap analysis of cumin in nine regions of Khorasan provinces using modeling approach. Field Crops Res, 5: 333-341.

Kashfi Banab A, 2010. Economic comparative advantage of cultivation and trade of medicinal plants in Iran and their value in the world market. Business Studies, 44: 67-78.

Khan AA, 1992. Preplant Physiological seed conditioning. Horticulture Review, 13: 131-181.

Khorasani Z, Nezami A, Nassiri Mahallati M and Mohammad-Abadi AA, 2012. Evaluation of fall sowing ecotypes of cumin (*Cuminum cyminum* L.) in Mashhad climatic conditions. Field Crops Res, 10: 43-52.

Nezami A, S Khorramdel, M Nassiri-Mahallati and AA Mohammad-Abadi, 2009. Effect of planting date on cumin (*Cuminum cyminum*) landraces in Mashhad condition. Environm Stress Agric Sci (ESAS), 2: 1-13.

Nezami A and AR Bagheri, 2005. Responsiveness of cold tolerant chickpea characteristics in fall and spring planting: I- phenology and morphology. Field Crops Res, 1: 143-155

Parry JW. Spices. 1969, Volume I and II London. Food trade press LTD.

Rahimi A, 2012, Effect of osmo priming and irrigation regime on yield quantity and essential oil content of Cumin (*Cuminum ciminum* L.). Iranian Journal of Medicinal and Aromatic Plants, 28: 131-141.

Rahimiyan Mashhadi H, 1992. Effect of planting date and irrigation regime on growth and yield of cumin seeds. Journal of Agricultural Science, 3: 61-46.

Soheili R, A Nezami, H Khazaei and M Nassiri Mahallati, 2010. Effect of planting date on yield and yield components of four landraces of cumin (*Cuminum cyminum* L.). Field Crops Res, 8: 772-783.

Sowbhagya HB, P Srinivas, T Kaul, Purnima and N Krishnamurthy, 2011. Enzyme-assisted extraction of volatiles from cumin (*Cuminum cyminum L.*) seeds. Food Chem, 127: 1856–1861.

Palevitch D, 1987. Recent advances in the cultivation of medicinal plants. Acta Horticulture, No 208, 29-34.

Ullaha H and B Honermeier, 2013. Fruit yield, essential oil concentration and composition of three anise cultivars (*Pimpinella anisum L.*) in relation to sowing date, sowing rate, and locations. Indust Crops Prod, 42: 489–499.

Windauer L, A Altuna and R Benech-Arnold, 2007. Hydro time analysis of *Lesquerella fendleri* seed germination responses to priming treatments. Indust Crops Prod, 25: 70-74.

Zaman U and Abbasi A, 2009. Isolation, purification and characterization of a nonspecific lipid transfer protein from *Cuminum cyminum* L. Phytochem, 70: 979–987.