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Evaluation of the Impacts of Fall Sowing Dates on Different Ecotypes of Cumin (*Cuminum cyminum*, *Apiaceae* L.) Productivity in Northeast of Iran

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Abstract

Locally adapted plants can be considered as an alternative to commercial crops for cultivation in harsh environments within semi-arid regions. Nowadays, exploring these plants industrial benefits has motivated many farmers around the world to extend their cultivation. However, agronomic characters of these forgotten plants are still unknown. The main aim of this study was to evaluate the influence of fall sowing dates on yield and yield components of different Cumin (*Cuminum cyminum* L., *Apiaceae*) ecotypes in the semi-arid region of Khorasan Iran. An experiment of two years duration was performed using a split-plot randomized complete block design, employing sowing dates as main-plot factor, and cumin ecotypes as sub-plot factor in three replicates. Three levels of sowing dates included the following: mid October, mid November and mid December. Additonally, sub-plot treatments consisted of four local ecotypes of cumin from different regions of the Khorasan province (Gayen, Torbat, Sabzevar and Khaf). The plants' survival percentage in field conditions, number of umbels m^{-2}, number of seeds per umbel, thousand seed weight, biological, and seed yield were measured in this experiment. The results showed that all study parameters were influenced by different sowing dates except thousand seed weight. The third sowing date resulted in the highest biological (110 g m^{-2} and 94 g m^{-2} in 2006 and 2007) and seed yield (50 g m^{-2} and 55 g m^{-2} in 2006 and 2007). There was a significant positive correlation between average minimum temperature and biological yield of cumin across all ecotypes and years. The results showed significant difference in productivity of different ecotypes of cumin from various parts of northeast of Iran. The Gayen and Khaf ecotypes showed the highest plant survival percentage, biological and seed yield across study ecotypes under the third sowing date. In conclusion, delayed fall sowing date and appropriate cumin ecotypes are able to increase yield of this plant in northeast of Iran.

Keywords: cumin, ecotype, sowing date, yield, yield components

Introduction

Cumin (*Cuminum cyminum* L.) is one of the most important domestic medicinal plants of Iran, which has been cultivated for centuries in different locations within the country (Kamkar *et al.,* 2007). The value of this plant is based on its aroma, as well as its medicinal and therapeutic properties (Sowbhagya *et al.,* 2008) such as reduction of blood glucose levels for the treatment of diabetes (Hashemi *et al.,* 2008). Reduction of plasma and tissue cholesterol, phospholipids, free fatty acids, and triglycerides by cumin (Gachkar *et al.,* 2007) as well as antimicrobial properties of cumin seed oil have been demonstrated (Zaman and Abbasi, 2009). This plant belongs to Umbellifereae (*Apiaceae*) family andhas a short growth period (120 days). This plant also possesses resistance to drought stress, which is especially importat, considering water deficits in many locations in semi-arid environments. It has been shown that even 250 mm precipitation is sufficient for suitable production of this plant (Alizadeh *et al.,* 2005).

Sowing date of crops have an important influence upon quantity (Singh *et al.,* 1998) and quality (Gul *et al.,* 2008) of agricultural products, since crops are then exposed to diverse environmental conditions through time. Sowing date also affects the grain protein percentage mainly through the pattern of the thermal conditions prevailing during the grain filling period. Usually, late sown seed material flowers late, thereby forcing the grain filling period to coincide with a high temperature regime. Extreme temperature and drought during grain filling have been identified as major sources of variation of seed quality characteristics (Singh *et al.,* 2010). He *et al.* (1998) showed that early planting decreased economic yield of potato by lower temperature than optimum levels during tuber filling period. Under limited soil moisture , planting too early to capture higher portion of the fall rainfall can cause excessive fall growth which usually results in the decline of available soil moisture for early spring growth (Winter and Musick, 1993). Felabi (1992) reported that fall sowing dates of cumin could significantly increase dry matter accumulation, and improve seed yield by increasing growth period length compared to spring sowing dates in central parts of Iran. Ehteramyan *et al.* (2007) reported that different fall sowing dates of cumin had significant influences on height

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of plants, seed weight, biological and economic yield. A few studies have indicated that spring sowing dates of cumin were not suitable for semi-arid regions such as the Khorasan province (Rahemyan, 1991). Cumin could be exposed to high temperatures and prolonged day length by spring sowing dates, while its growth duration is sensitive to long day lengths (Felabi, 1992). Therefore, spring sowing dates may disrupt cumin production in northeast of Iran (Felabi, 1992). Ehteramyan *et al.* (2007) showed 16% increase in cumin yield in fall sowing dates compared to spring sowing dates for one cumin ecotype in central Iran. This was due to a higher precipitation rate during the growth period, as well as a protracted growth period. Selection of cold resistance varieties of cumin is of the main goal for fall cultivation of this plant. Fall sowing of cumin requires certain factors which include: freezing stress resistance during the early growth period and high growth rate in spring to avoid growth coinciding with a rapid increase in air temperature. The main objective of this study was to investigate the survival and yield response of four local ecotypes of cumin (*Cuminum cyminum* L., *Apiaceae*) to different fall sowing dates.

Materials and methods

Study location

The field experiment was carried out during two growing seasons (2006 and 2007) at The College of Agriculture, Ferdowsi University of Mashhad experiment station (latitude: 36°15' N, longitude: 59°28' Elevation: 999 m), located in the central part of Khorasan province in Iran. The climatic conditions of Khorasan province varies between semi-dry and locally humid in the north to dry in the southern parts. Annual precipitation rate in Khorasan province is 269 mm for the northern parts, 250 mm for the central parts as well as 110 mm for the southern parts. Maximum and minimum temperatures and precipitation rate for all years of this experiment are shown in Fig. 1.

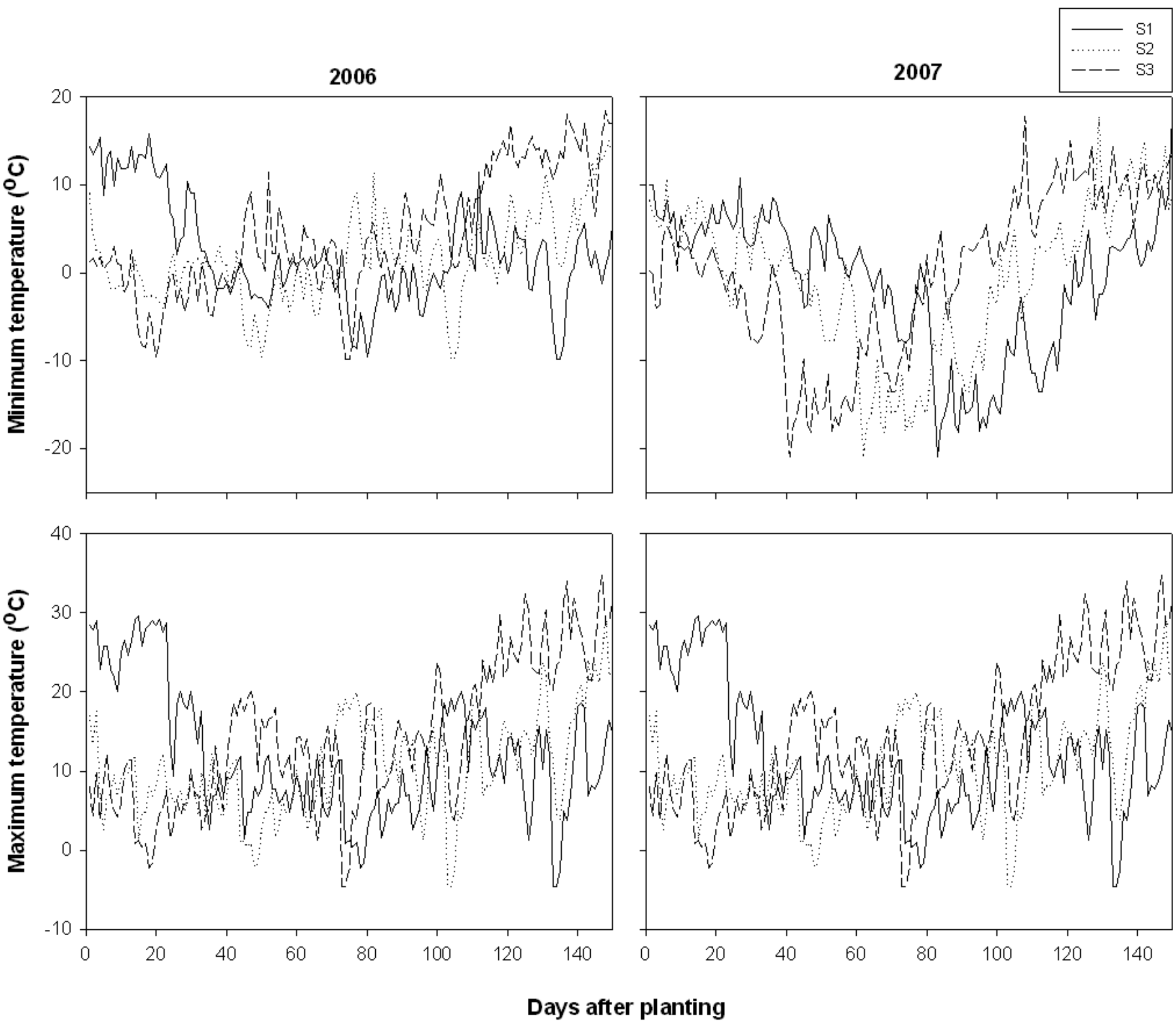

Fig. 1. Daily values of maximum and minimum air temperature (°C) in different sowing dates in 2006 and 2007

Tab. 1. Climatic features of origin regions of study ecotypes

Location	LA	LN	Altitude (meter)	Annual precipitation (mm)	Average maximum temperature (°C)	Average minimum temperature (°C)
Sabzevar	36.12	57.43	977.6	192.1	34.5	19.7
Torbat	35.16	59.13	1450	273.0	21.3	13.5
Gayen	33.43	59.10	1432	177.7	30.6	13.0
Khaf	34.21	58.41	1056	142.3	24.3	10.5

Rainfall during the growing period is shown in Fig. 2. The soil type of the experimental field was silty loam with a pH of 7.5, containingtotal N (200 ppm), total P (9.4 ppm), and total K (120 ppm) with an EC of 0.11 dsm^{-1}.

Experimental design

A two-factor experiment was set up in a split-plot randomized complete block design with sowing dates as the main-plot factor and cumin ecotypes as the sub-plot factor in three replicates for a duration of two years (2006-2007). Three levels of sowing dates included: mid October (S_1), mid November (S_2) and mid December (S_3) and sub-plot treatments consisted of four local ecotypes of cumin belonging to different regions; Gayen (E1), Torbat (E_2), Sabzevar (E_3) and Khaf (E_4), respectively, were used in this experiment. The size of each plot was 4 m×3 m. Each ecotype was selected based on its region of origin in northeastern Iran. Climatic features of each region are represented in Tab. 1.

Field conditions

All plots were fertilized uniformly with nitrogen (50 kg/ha) and phosphorus (30 kg/ha) prior to the experiment. Plants were irrigated 5 times during the growing season at different growth stages: 1- immediately after planting, 2- two to three leaf appearance, 3- branching, 4- flowering and 5- grain filling period according to plant water requirements (Alizadeh *et al.*, 2005). Irrigation brought the soil moisture back to field capacity. Cumin plants are extremely sensitive to *Fusarium* fungi (Ghorbany *et al.*, 2010). As the study location was severely infected by this harmful fungus (Mohammadi and Mofrad, 2009), the irrigation shedule was performed carefully, according to the plants' water requirement. Weeds were controlled by hand when needed. Suitable planting density was obtained after thinning (120 plants m^{-2}) 20 days after emergence. Plants were harvested manually by pulling the dry plant out of the soil and removing the roots on 15th June of 2006 and 23th June of 2007.

Plant measurements

The plants' survival percentage which showed resistance to cold stress in field conditions was evaluated based on the Singh *et al.* (1984) method. According to this method, plants' resistance classifications include: 1- 100% plant survival (fully cold tolerant); 2- 99% to 67% plant survival (cold tolerant); 3- 66% to 34% plant survival (semi cold tolerant); 4- 33% to 1% plant survival (cold sensitive) and 5- 0% plant survival (fully cold sensitive). This percentage was obtained by counting live plants number before and after the winter months. Yield components included: number of umbels m^{-2}, number of seeds per umbel and thousand seed weight measured by 0.5 m^{-2} sampling from each plot. Biological and seed yield measured by collecting plants materials from 2.4 m^{-2} of each plot. Collected materials were weighted after drying in a heater at 45°C for 72 h.

Statistical analysis

In order to compare the treatments' impacts on study parameters, an analysis of variance (ANOVA) was performed as a standard procedure for the split-plot randomized complete block design. The t-test was used to find significant differences among treatments. The significant differences between treatments were compared by Duncan's multiple range tests at 5% probability level.

Results

Sowing date

Plant survival percentage was statistically influenced ($P > 0.05$) by different sowing dates in both years of the experiment (Tab. 2). The highest and lowest values of plant survival percentage were obtained by the third sowing date (85% for 2006 and 100% for 2007) and for the first sow-

Tab. 2. Effects of different sowing dates on plant survival, number of umbels, seed number, thousand seed weight, biological and seed yield of cumin (*Cuminum cyminum* L.)

Sowing dates	Plantsurvival (%)		Umbels (m^{-2})		Seed number (m^{-2})		Thousand seed weight (g)		Biological yield (g m^{-2})		Seed yield (g m^{-2})	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
S_1	71^a	64^b	2340^a	1790^a	14^a	18^a	4.7^a	4.6^a	75^b	84^b	30^b	48^b
S_2	83^a	68^b	1164^c	1518^b	13^c	17^b	4.6^b	4.4^b	55^c	87^b	23^b	51^b
S_3	85^a	100^a	1428^b	1260^c	13^b	16^c	4.2^a	4.2^c	110^a	94^a	50^a	55^a

Letters indicated different sowing dates include mid October (S_1), mid November (S_2) and mid December (S_3)

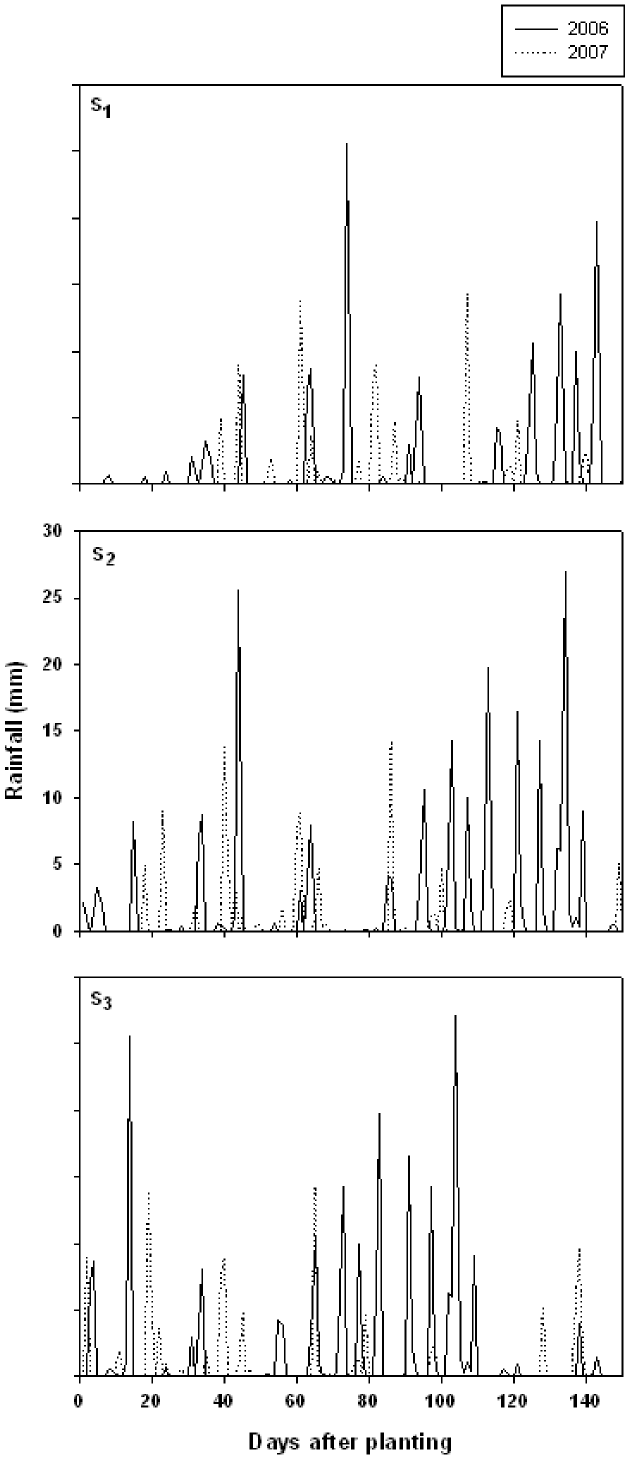

Fig. 2. Daily values of rainfall in different sowing dates in 2006 and 2007 (mid October (S_1), mid November (S_2) and mid December (S_3))

ing date (71% for 2006 and 64% for 2007) across all study years (Tab. 2). Different sowing dates highly impacted the umbels and seed numbers in both years of the experiment (Tab. 2). The highest number of umbels (2340 and 1790 m^{-2} for 2006 and 2007) and seed (14 and 18 m^{-2} for 2006 and 2007) numbers were obtained in the first sowing date (Tab. 2). Thousands seed weight was not significantly affected in both years of the experiment under various sowing dates (Tab. 2).

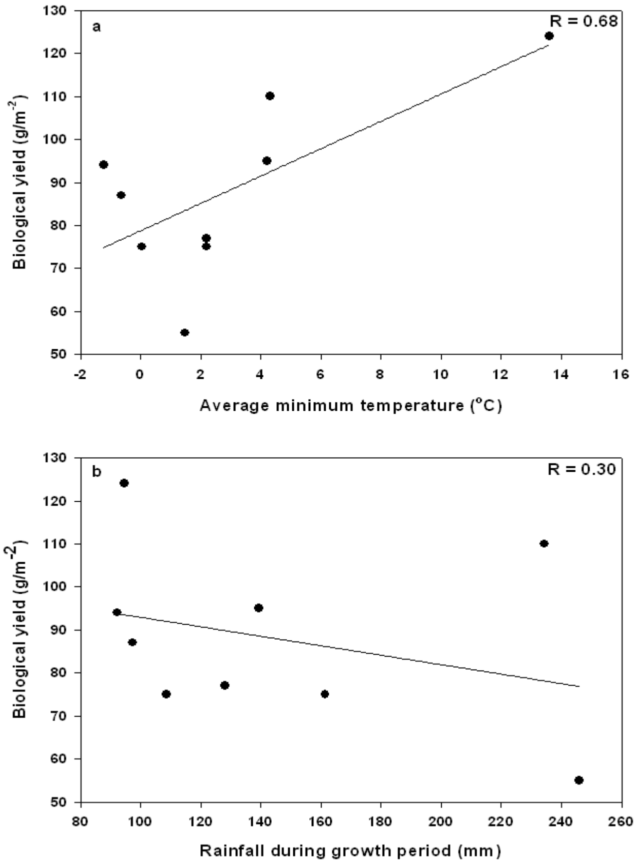

Fig. 3. Relationship between biological yield and average minimum temperature (a) and rainfall (b) during growth period

Biological (above ground biomass) and seed yields showed significant response to different sowing dates in both years of experiment (Tab. 2). Highest biological (110 g m^{-2} and 94 g m^{-2}) and seed (50 g m^{-2} and 54 g m^{-2}) yields obtained by third sowing date in 2006 and 2007 (Tab. 2). Additionally, the lowest biological (55 g m^{-2}) and seed yield (23 g m^{-2}) were achieved by second sowing date in 2006 and first sowing date in 2007 (Tab. 2). There was significant positive relationship between biological yield and average minimum temperature during growth period (Fig. 3a) and biological yield increased by increasing average minimum temperature. On the other hand, there was negative correlation between biological yield and rainfall in growth period (Fig. 3b).

Cumin ecotypes

Each ecotype of cumin evolved differently different regions of northeastern of Iran. Various ecotypes of cumin showed significant impact ($P > 0.05$) on plant survival percentage in both years of the experiment (Tab. 3). Gayen (71% for 2006 and 85% for 2007) and Khaf (84% for 2006 and 80% for 2007) ecotypes represented the highest plant survival percentage between study ecotypes in both years of the experiment (Tab. 3). Different ecotypes of cumin showed significant impact on umbels and seed numbers in both years of experiment ($P > 0.05$) (Tab. 3). The Gayen ecotype showed highest umbels (2316 and 2326 number m^{-2} in 2006 and 2007) and seed numbers (22 m^{-2}) in 2007 (Tab. 3). However, the Sabzevar ecotype illustrated high-

Tab. 3. Effects of different ecotypes of cumin (*Cuminum cyminum* L.) on plant survival, number of umbelest, seed number, thousand seed weight, biological and seed yield

Ecotypes	Plants survival (%)		Umbels (m^{-2})		Seed number (m^{-2})		Thousands seed weight (g)		Biological yield ($g\ m^{-2}$)		Seed yield ($g\ m^{-2}$)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
E_1	71^b	85^a	2316^a	2326^a	14^a	22^a	4.5^b	4.8^a	122^a	113^a	50^a	66^a
E_2	81^a	76^c	1404^b	1107^d	14^a	15^d	4.5^b	4.4^b	49^d	86^c	20^c	48^c
E_3	77^b	81^b	1404^b	1369^c	15^a	16^c	4.9^a	4.3^b	93^b	71^d	41^b	41^d
E_4	84^a	80^b	1500^b	1633^b	13^c	18^b	4.4^b	4.3^b	68^c	97^b	23^c	53^b

Letters indicate cumin's different ecotypes include Gayen (E_1), Torbat (E_2), Sabzevar (E_3) and Khaf (E_4)

Tab. 4. Interactive effects of sowing dates and different ecotypes of cumin (*Cuminum cyminum* L.) plant survival, biological, and seed yield in 2008 and 2009

Ecotypes	Sowing dates														
	Plant survival (%)			Ratio		Biological yield ($g\ m^{-2}$)			Ratio		Seed yield ($g\ m^{-2}$)			Ratio	
	S_1	S_2	S_3	S_2/S_1	S_3/S_1	S_1	S_2	S_3	S_2/S_1	S_3/S_1	S_1	S_2	S_3	S_2/S_1	S_3/S_1
2006															
E_1	52	76	79	1.46	1.51	126	104	136	0.82	1.07	47	38	62	0.80	1.31
E_2	85	86	84	1.01	0.98	37	37	75	1	2.02	12	13	40	1.08	3.33
E_3	48	86	83	1.79	1.72	112	62	104	0.55	0.92	48	23	51	0.47	1.06
E_4	85	91	90	1.07	1.05	46	24	134	0.52	2.91	15	12	60	0.80	4.06
2007															
E_1	75	81	100	1.08	1.33	122	114	102	0.93	0.83	68	66	63	0.97	0.92
E_2	65	64	100	0.98	1.53	97	87	75	0.89	0.77	43	41	39	0.95	0.90
E_3	69	74	100	1.07	1.44	78	71	65	0.91	0.83	53	49	45	0.92	0.84
E_4	69	73	100	1.05	1.44	106	102	84	0.96	0.79	56	53	51	0.94	0.91

Letters indicate different sowing dates include mid October (S_1), mid November (S_2) and mid December (S_3) and cumin's different ecotypes include Gayen (E_1), Torbat (E_2), Sabzevar (E_3) and Khaf (E_4)

est seed number in 2006 (Tab. 3), but there was no statistical difference between the Sabzevar and Gayen ecotypes. Furthermore, the Sabzevar (4.9 g) and Gayen (4.8 g) ecotypes showed the highest values of thousands seed weight in 2006 and 2007 respectively (Tab. 3).

There were sharp differences in biological and seed yields of various cumin ecotypes (Tab. 3). The Gayen ecotype showed highest biological (112, 113 g m^{-2} in 2006 and 2007) and seed (50, 66 g m^{-2} in 2006 and 2007) yields in both years of experiment (Tab. 3). The Torbat and Sabzevar ecotypes showed the lowest values of biological and seed yields in 2006 and 2007 respectively (Tab. 3).

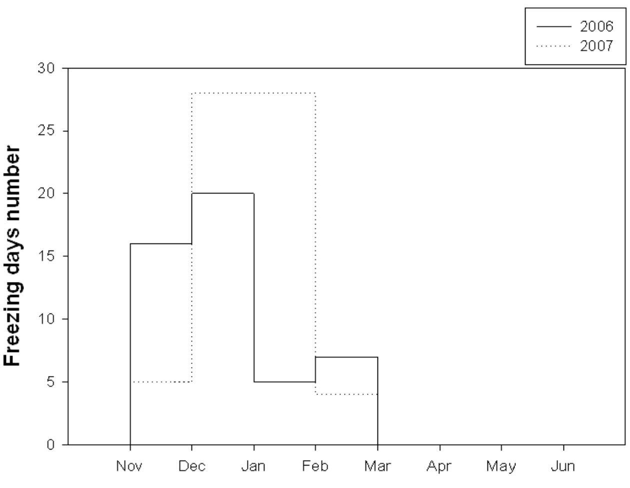

Fig. 4. Freezing days number during growth period of cumin in 2006 and 2007

Interactive effects of different sowing dates and cumin ecotypes

Plant survival percentage

Our results showed a 30 day interval between first sowing to second one induced highest interaction (79%) of the two treatments on plant survival percentage in the first year of experiment (Tab. 4). Additionally, the Khaf ecotype showed maximum plant survival percentage in all sowing dates in 2006. On the other hand, the Gayen ecotype showed the highest values for plant survival percentage in all sowing dates in the second year of experiment (Tab. 4). The highest increase in plant survival percentage (53%) was obtained by delaying the sowing date for 30 days, from second sowing to third sowing date in 2007 (Tab. 4).

Biological and seed yield

The highest biological (136 g m^{-2}) and seed (62 g m^{-2}) yields of cumin obtained in the third sowing date (mid December) by Gayen ecotype in 2006 (Tab. 4). However, the Gayen ecotype which was cultivated in first sowing date (mid October) showed the highest values for biological ($122\ g\ m^{-2}$) and seed ($68\ g\ m^{-2}$) yields in 2007 (Tab. 4). Minimum values of biological ($67\ g\ m^{-2}$) and seed yields ($12\ g\ m^{-2}$) yields were obtained by first sowing date using Torbat ecotype during both years of experiment (Tab. 4). Generally, the third sowing date and Gayen ecotype showed the highest biological and seed yields in both years of study (Tab. 4).

Discussion

This study results indicated that sowing date and different ecotypes of cumin have the potential to change and improve plant survival percentage, yield components, biological and seed yields. Delayed fall sowing resulted in higher plant survival percentage; yield components, biological and seed yields. The third sowing date indicated highest values of biological and seed yields. Mershekari (2004) reported a significant increase in plant survival percentage of cumin by delaying the sowing date for one month. It seems freezing days (below zero degrees Centigrade of air temperature) during growth period played a vital role in determination of plant survival factor (Fig. 4). The first sowing date showed sharp decrease in minimum temperature at the end of growth period during both years of experiment (Fig. 1). Additionally, there was a strong direct relation between minimum temperature and biological yield (Fig. 3a). Lower survival percentage (lower density) of cumin might result in more available water, nutrients and less competition for plants which were cultivated in first planting date. For this reason, this sowing date produced more umbels and seed numbers m^{-2} (Rahemyan, 1991). Some studies showed that various sowing dates had no appreciable effects on thousands seed weight of cumin (Ehteramyan *et al*., 2007; Mershekari, 2004) which could lead to the conclusion that this factor is under genomic control. Generally, the Gayen and Kafe ecotypes biological and seed yields showed better response compared to the Sabzevar and Torbat ecotypes in both years of the experiment, especially in third sowing date (Tab. 4). These ecotypes showed higher resistance to freezing conditions in winter; because these ecotypes have evolved within a harsh environment (Tab. 1). For instance, both Khaf and Gayen ecotypes originated in colder regions, compared to the other ecotypes. Additionally, annual rainfall is lower in these regions compared to other parts of northeastern Iran.

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