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Original Article

Effect of Irrigation and Planting Date on the Selected Morphophenological and Quality Traits of Ajowan (*Carum copticum* BENTH. & HOOK.F.)

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Abstract

In order to study the effects of irrigation and planting date on selected traits of ajowan (*Carum copticum* BENTH. & HOOK.F.) an experiment was conducted in two successive conducive seasons of 2009/2010 and 2010/2011 in Birjand. The experimental design was a split plot based on randomized complete block with three replications. In the present study, two irrigation treatments (irrigation termination with flowering onset and complete irrigation) and six planting dates (Dec 6th, Dec 21st, Jan 5th, Feb 29th, Mar 30th and Apr 30th) were considered as main plot and subplot, respectively. As results indicated, the drought stress significantly reduced seed and essential oil yield, but had a non significant effect on the germination percent. Moreover, there was a nil effect on the morphological characteristics of the plants. It was interesting to note that the late planting date caused seed yield, number of umbels per plant, number of umbellules per inflorescence, plant height, number of branches per plant, essential oil percentage and the length of the vegetative growth period to decrease, but there was nil effect on the essential oil yield and the germination percent. In fine, the results indicated that water stress not only caused the essential oil percent and plant performance to decrease, but also influenced early plantings to have more seed yield and essential oil percent.

Key words: Seed yield, Plant height, Umbel number, Essential oil, Seed germination

Introduction

Medicinal plants have been spread throughout Mediterranean areas and utilized by native residents from ancient times. In the present scenario due to increased demand of raw materials, and the diverse researches upon the end products obtained via biological techniques vis-à-vis the side effects of chemically formulated medicines, the importance of these plants have substantiated. A limited research has been performed on increasing yield of medicinal plants, through adoption of appropriate cropping techniques to essentially improve the quality and quantum of medicinal plants [1].

Ajowan (*Carum copticum* BENTH. & HOOK.F.) is one of the most important medicinal plant that originates from the eastern Mediterranean areas [2]. Essential oil of ajowan has a high antioxidant activity [3] with diverse utilities as a natural anti-bacterial agent in drug and food industries [4].

Medicinal plants, unlike other agricultural crops, may have more chemical productions and higher efficiency in stressful conditions [5].

Water is one of the most important factors in agriculture [6]. In spite of the fact that extensive researches have been performed on the water stress in agricultural crops, the detailed studies on medicinal plant responses to the water shortage

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condition remains to be explored. Azhar *et al.* reported that the height of ajowan under water stress treatment of 80 and 100 percent of the field capacity didn't decrease significantly, but with an increase in the stress severity up to 60 percent of the field capacity, the plant height decreased significantly [2].

Similarly, Moussavi–Nik *et al.* suggested that an irrigation interval of 7 and 14 days had an insignificant effect on the number of umbels per ajowan plant and umbels per square meter, but, an irrigation interval of 21 days caused significant decrease. Furthermore, the seed yield was significantly affected by the drought stress treatment [7]. Contrastingly, Mohamed and Abdu reported that with reduced frequency of irrigation in ajowan from 6 to 3 times, number of branches per plant, seed yield, and essential oil yield decreased, but, with an increase in the stress severity the seed essential oil percent amplified significantly [8].

Choosing an appropriate planting date is one of the most important cropping techniques by which environmental factors such as moisture, temperature, and light can be optimally controlled. Early planting increases the probability of frost injury and late planting has negative effects on the biologic and seed yield due to shortened growth period. Late plantations of coriander caused reduced interval between its planting and flowering [9]. Susila and Rajkumar reported a significant decrease in the plant height, number of umbels and branches per plant and seed yield of ajowan with late planting due to the shortened growth period with an increase in the daily temperature [10].

Broomand Rezazadeh *et al*. reported that late planting was accompanied by non-germination of ajowan. In their experiment, planting date had no significant effect on the essential oil percent, but, it led to decrease in the essential oil yield [11].

The studies conducted by Meena *et al.* [12] and Sadeghi *et al.* [13] in cumin and coriander respectively, showed that late planting decreased plant height, besides a number of branches and umbels per plant. In another experiment, the highest fennel germination percent was obtained from the early planting date [14].

The present study was conducted to evaluate the effects of irrigation and planting dates on selected morphophenological and qualitative characteristics of ajowan.

Material and Methods

The present study was conducted in Agricultural Research Center of Islamic Azad University, Birjand branch in two successive conducive seasons of 2009/2010 and 2010/2011. The longitude, latitude and altitude of Birjand are 59° 13', 32° 53', and 1491 meters respectively. Its climate is dry and warm with mean annual rainfall of 172mm. Figures 1 and 2 show the daily temperature and monthly rainfall during the period of the experiment.

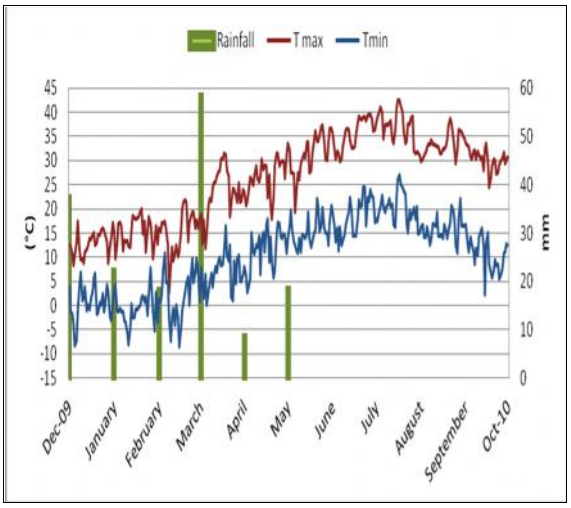

Fig. 1 Daily temperature and monthly rainfall during first year of experiment (2009/2010).

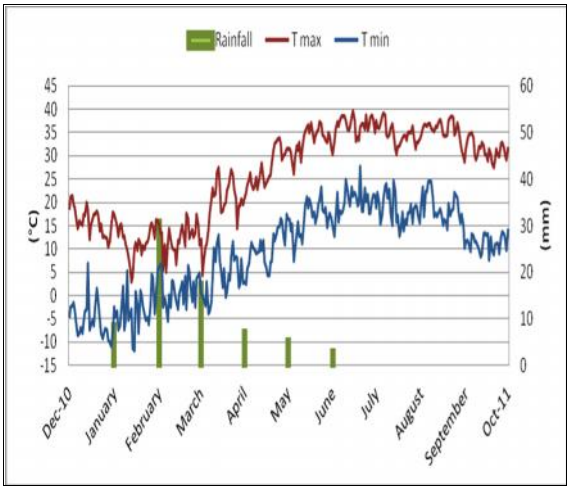

Fig. 2 Daily temperature and monthly rainfall during second year of experiment (2010/2011)

The experimental design was split plot based on randomized complete block with three replications. Two irrigation treatments (termination of the irrigation at flowering onset and complete irrigation) and 6 planting dates (Dec 6th, Dec 21^{st,} Jan 5th, Feb 29th, Mar 30th and Apr 30th) were considered as main plot and sub plot, respectively. Each sub plot had three ridges. The length of the ridges and distance between them were 4 and 0.7m, respectively. Sowing was carried out on the two sides of the ridges. Distance between plants after

thinning was 15cm. Prior to plantations and during land preparation, 120 kg.ha^{-1} triple superphosphate and 150 kg.ha^{-1} potassium sulphate were added to the soil. Eventually, urea (200 kg.ha^{-1}) was equally added to the soil at two varied stages: before planting and at the onset of flowering.

Irrigation was conducted every four days until seedling emergence and further weekly. However, in the water stress treatment, with flowering onset, the irrigation was completely halted. The number of irrigation from seedling emergence to maturing plant was 13 to 22 depending on the treatment type. Weed control was done by hand as and when required.

Phenological characteristics were determined by recording emergence, flowering, and maturating dates in 50% of the plants in each plot. Seed yield of mature plants was determined by harvesting one square meter of each plot with respect to the border effect. Morphological characteristics, including the number of umbels per plant, number of umbellules per inflorescence, plant height and number of branches per plant were determined by taking an average of over 5 plants from each plot. Seed essential oil percent was determined using Clevenger apparatus [3].

Data analysis was conducted by MSTATC software and the means were compared by Duncan's multiple range tests at the 5% probability level.

Results and Discussion

Effect of irrigation on yield and morphological characteristics

Seed yield was significantly affected by irrigation treatments and declined in both the years (Table 1, 2). The effect of irrigation on the number of umbels per plant and umbellules per inflorescence was not significant (Table 1). So, the effect of drought stress on the other seed yield components (especially seed number per plant) caused the seed yield to decrease (data are not shown). This effectually relates to the fact that flowers fertilization in the umbel was affected by the stress.

Sensitivity of ajowan in the seed filling stage towards severe water stress, change in assimilation allocation favoring the roots, photosynthesis reduction and inaccessibility to required nutrients as a result of drought stress, could be the possible reasons for yield loss in water stress conditions. Considering the varied drought stress stages and its nil effects on the number of umbels per plant and umbellules per inflorescence it can be determined that ajowan is a resistant plant and can optimally withstand medium drought stress in reproductive stage. However, Aliabadi Farahani *et al.*, reported that drought stress caused a reduction in the seed yield in the reproductive stage of coriander [1].

Plant height and number of branches per plant were not significantly affected by irrigation treatments in both the years (Table 3). Our results are in concurrence with Zehtab Salmasi who reported that non-irrigation in the seed filling stage had nil effect on the height of anise [15].

Effect of planting date on yield and morphological characteristics

Analysis of variance (Table 1) showed that the seed yield was not significantly affected by planting date in the first year but, in the second year it significantly reduced in too late planting dates (Table 3). The planting date of 29th February had the highest seed yield (59.2 g.m^{-2}), that was not significantly different with later planting dates viz. 6th December, 21st December and 5th January (Table 3). The winter plantings, because of exploitation of the appropriate environmental conditions such as rainfall, temperature, and non-existence of the stressful factors grew well with improved vegetative growth and seed yield. Decrease of seed yield in late plantings has been reported in ajowan [10, 11] and cumin [13].

The number of umbels per plant was not significantly affected by planting date in the first year but, in the second year it decreased in late planting. The highest number of umbels per plant in the second year was related to the winter plantings and the lowest recordings were from the fifth and sixth dates of planting (Table 3). Also, the number of umbellules per inflorescence decreased significantly in the last planting dates in both the years (Table 3). The confrontation of reproductive stage with unfavorable environmental conditions in summer was a reason for a decrease in the number of umbels per plant and umbellules per inflorescence. The plant height was significantly affected in the second year and the branch numbers per plant in both years due to planting dates (Table 1). These traits reduced with delayed plantings (Table 3) due to the shorter vegetative stage of the plant (Table 4 and 6). Meena and Malhotra obtained similar results in coriander [12]. As indicated in Table 1, the interaction of irrigation and planting date significantly affected the number of branches per plant in the first year, but the effects on other morphological characteristics of ajowan was insignificant.

Table 1 Mean squares for the effect of irrigation and planting date on seed yield and morphological characteristics of ajowan

Mean Square											
Branch number per plant		Plant height		Umbellules number per inflorescence		Umbel number per plant		Seed yield		Df	Source of variation
Year		Year		Year		Year		Year			
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010		
1.243	1.898	8.114	22.11	1.202	1.120	50.44	225.0	55.8	111.5	2	Replication
2.454^{ns}	8.41^{ns}	10.67^{ns}	120.20^{ns}	0.000^{ns}	3.738^{ns}	22361.9^{ns}	11396.2^{ns}	5980.5*	40019.3**	1	Irrigation (A)
3.774	1.693	24.36	91.64	0.064	1.938	450.9	919.7	206.9	568.8	2	Error A
10.327**	11.388**	5117**	59.90^{ns}	2.405*	5.803**	1724.8**	475.0^{ns}	442.7**	178.0^{ns}	5	Planting date (B)
1.497^{ns}	28.079**	23.03^{ns}	23.41^{ns}	0.340^{ns}	0.911^{ns}	103.9^{ns}	331.9^{ns}	210.7^{ns}	378.9^{ns}	5	A*B
2.297	1.250	12.34	23.99	0.882	1.137	201.3	419.5	112.5	325.1	20	Error B
14.55	12.06	7.34	10.42	9.43	9.93	22.94	27.47	21.92	25.28	CV%	

ns: no significant, * and **: significant at 5% and 1% probability level, respectively

Table 2 The effect of irrigation on seed yield and morphological characteristics of ajowan

Branch number per plant		Plant height (cm)		Umbellules number per inflorescence		Umbel number per plant		Seed yield ($g.m^{-2}$)		
Year		Year		Year		Year		Year		Irrigation Levels
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	
10.15 a	9.75 a	47.31 a	45.13 a	9.95 a	10.41 a	53.76 a	56.76 a	35.51b	37.99b	Drought stress
10.67 a	8.78 a	48.40 a	48.92 a	9.96 a	11.05 a	69.96 a	92.35 a	61.29 a	104.67a	Non stress

-Means at least with one similar letter in each column are not significantly different at 5% probability.

Table 3 The effect of planting date on seed yield and morphological characteristics of ajowan

Branch number per plant		Plant height (cm)		Umbellules number per inflorescence		Umbel number per plant		Seed yield ($g.m^{-2}$)		
Year		Year		Year		Year		Year		Planting dates
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	
10.10 abc	8.06 b	46.50 bcd	46.96 a	10.30 a	10.17 b	70.2 a	80.9 a	51.3 ab	72.7 a	Dec 6^{th}
11.40 ab	9.46 a	48.90 abc	48. 36 a	10.37 a	10.27 b	63.1 a	77.6 a	49.3 ab	72.6 a	Dec 21^{th}
12.03 a	10.33 a	51.40 a	45.40 a	10.70 a	10.30 b	79.6 a	81.4 a	54.0 a	69.3 a	Jan 5^{th}
10.73 ab	9.76 a	50.67 ab	52.20 a	9.65 ab	11.7 a	75.4 a	63.6 a	59.2 a	61.5 a	Feb 29^{th}
9.96 bc	10.80 a	45.53 cd	42.73 a	9.80 ab	12.03 a	45.1 b	80.8 a	37.5 b	77.3 a	Mar 30^{th}
8.26 c	7.20 b	44.13 d	46.50 a	8.93 b	9.86 b	37.6 b	62.7 a	38.8 b	74.4 a	Apr 30^{th}

-Means at least with one similar letter in each column are not significantly different at 5% probability.

Table 4 Mean squares for the effect of irrigation and planting date on phenological and qualitative traits of ajowan

Mean Square													
Germination percent		Essential oil yield		Essential oil percent		Days from flowering to ripening		Days from emergence to flowering		Days to emergence			
Year		Year		Year		Year		Year		Year		Df	Source of variation
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010		
3.11	9.333	0.067	0.603	0.117	0.365	17.58	0.111	31.02	0.25	9.528	2.333	2	Replication
28.44^{ns}	$2368.4^{ns.}$	9.376*	49.64**	2.341*	0.132^{ns}	8836.0**	3173.44**	18.77^{ns}	1.000^{ns}	0.694^{ns}	0.111^{ns}	1	Irrigation (A)
96.44	325.7	0.284	0.575	0.070	0.037	9.083	0.111	9.52	0.083	0.528	1.444	2	Error A
82.84^{ns}	248.2^{ns}	0.354^{ns}	0.983^{ns}	0.196^{ns}	1.082**	113.66**	153.178**	5759.7**	2597.0**	3115.8**	1557.4**	5	Planting date (B)
136.17*	206.31^{ns}	0.211^{ns}	0.314^{ns}	0.127^{ns}	0.083^{ns}	60.60**	81.378**	21.04^{ns}	0.267^{ns}	1.028^{ns}	0.444^{ns}	5	A*B
52.97	258.2	0.167	0.706	0.076	0.192	8.267	0.878	19.47	0.400	1.028	0.856	20	Error B
24.44	20.69	26.95	31.70	9.04	3.85	3.85	1.41	4.09	0.85	2.79	2.69	CV%	

ns: no significant, * and **: significant at 5% and 1% probability level, respectively

Table 5 The effect of irrigation on phenological and qualitative characteristics of ajowan

Germination percent		Essential oil yield ($g.m^{-2}$)		Essential oil percent		Days from flowering to ripening		Days from emergence to flowering		Days to emergence		Irrigation Levels
Year		Year		Year		Year		Year		Year		
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	
30.66 a	69.55 a	1.00b	1.47b	2.80b	3.78 a	59.00b	56.83b	107.16 a	74.50 a	36.16 a	34.38a	Drought stress
28.88 a	85.77 a	2.02 a	3.82 a	3.31 a	3.66 a	90.33 a	75.61 a	108.61 a	74.83 a	36.44 a	34.37 a	Non stress

-Means at least with one similar letter in each column are not significantly different at 5% probability.

Table 6 The effect of planting date on phenological and qualitative characteristics of ajowan

Germination percent		Essential oil yield ($g.m^{-2}$)		Essential oil percent		Days from flowering to ripening		Days from emergence to flowering		Days to emergence		Planting dates
Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	
33.33a	66.66 a	1.59 a	3.06 a	2.99 a	4.17 a	73.67 bc	69.59 b	129.2 b	101.2 a	67.33 a	45.33 b	Dec 6th
24.00a	82.00 a	1.48 a	3.01 a	2.97 a	4.19 a	70.83 cd	72.67 a	138.8 a	101.5 a	55.00 b	30.17 d	Dec 21st Dec 21th
30.00a	77.33 a	1.56 a	2.64 a	2.84 a	4.86 ab	68.67 d	67.00 c	138.3 a	66.50 b	44.50 c	59.67 a	Jan 5th
32.00a	85.33 a	1.90 a	1.97 a	3.18 a	3.24 c	79.17 a	62.17 d	79.50 d	62.17 c	24.67 d	32.33 c	Feb 29th
26.66a	79.33 a	1.19 a	2.43 a	3.00 a	3.26 c	76.67 ab	58.67 e	90.33 c	58.50 d	15.50 e	24.67 e	Mar 30th
32.66a	75.33 a	1.34 a	2.76 a	3.35 a	3.61 bc	79.00 a	67.33 c	71.17 e	59.17 d	10.83 f	13.83 f	Apr 30th

-Means at least with one similar letter in each column are not significantly different at 5% probability.

Table 7 Interaction effects of irrigation and planting dates on the selected traits of ajowan

Germination percent				Days from flowering to ripening				Branch number per plant				
Non stress		Drought stress		Non stress		Drought stress		Non stress		Drought stress		
Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	Year	Planting date Levels
2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	2010/2011	2009/2010	
36.00 a	82.66 a	30.67 ab	50.66 a	89.33 bc	81.67 a	58.00 b	57.33 c	10.60 a	6.66 cd	9.60 a	9.46 b	Dec 6th
26.67ab	90.66 a	21.33 b	73.33 a	85.00 cd	82.00 a	56.67 b	63.33 a	11.20 a	6.33 d	11.60 a	12.60 a	Dec 21st
29.33 a	80.00 a	30.67 ab	74.66 a	80.33 d	78.33 b	57.00 b	55.67 d	12.00 a	8.73 bc	12.06 a	11.93 a	Jan 5th
33.33 a	85.33 a	30.67 ab	85.33 a	100.3 a	75.67 c	58.00 b	48.67 e	11.86 a	13.00 a	9.60 a	6.53 c	Feb 29th
25.33ab	90.66 a	28.00 ab	68.00 a	93.33 b	63.00 e	60.00 ab	54.33 d	9.86 a	10.87 ab	10.06 a	10.73 ab	Mar 30th
25.67ab	85.33 a	42.67a	65.33 a	93.67 b	73.00 d	64.33 a	61.67 b	8.53 a	7.13 cd	8.00 a	7.26 c	Apr 30th

-Means at least with one similar letter in each column are not significantly different at 5% probability.

Table 8 The correlation coefficients for the selected traits of ajowan in 2009/2010

11- Germination percent	10- Essential oil yield	9- Essential oil percent	8- Days from flowering to ripening	7- Days from emergence to flowering	6- Days to emergence	5- Branch number per plant	4- Plant height	3- Umbellules number per inflorescence	2- Umbel number per plant	1- Seed Yield	Traits
-	-	-	-	-	-	-	-	-	-	1	1
-	-	-	-	-	-	-	-	-	1	0.898**	2
-	-	-	-	-	-	-	-	1	0.354	0.342	3
-	-	-	-	-	-	-	1	0.167	0.334	0.431	4
-	-	-	-	-	-	1	-0.106	0.447	0.107	-0.067	5
-	-	-	-	-	1	0.019	-0.011	-0.132	0.239	-0.047	6
-	-	-	-	1	0.266	-0.131	0.144	-0.385	0.180	0.026	7
-	-	-	1	0.333	0.085	-0.244	0.500	0.036	0.805**	0.814**	8
-	-	1	0.210	0.828**	0.400	-0.090	-0.131	-0.694**	0.005	-0.107	9
-	1	0.138	0.884**	0.225	0.034	-0.173	0.411	0.137	0.873**	0.936**	10
1	0.593*	-0.324	0.476	-0.197	-0.133	0.176	0.538	0.357	0.459	0.646*	11

Table 9 The correlation coefficients for the selected traits of ajowan in 2010/2011

11- Germination percent	10- Essential oil yield	9- Essential oil percent	8- Days from flowering to ripening	7- Days from emergence to flowering	6- Days to emergence	5- Branch number per plant	4- Plant height	3- Umbellules number per inflorescence	2- Umbel number per plant	1- Seed Yield	Traits
-	-	-	-	-	-	-	-	-	-	1	1
-	-	-	-	-	-	-	-	-	1	0.826**	2
-	-	-	-	-	-	-	-	1	0.582*	0.196	3
-	-	-	-	-	-	-	1	0.361	0.797**	0.613*	4
-	-	-	-	-	-	1	0.869**	0.675**	0.788**	0.558*	5
-	-	-	-	-	1	0.500	0.285	0.747**	0.555*	0.252	6
-	-	-	-	1	0.881**	0.692**	0.387	0.878**	0.527*	0.212	7
-	-	-	1	-0.205	-0.167	0.069	0.149	-0.234	0.356	0.784**	8
-	-	1	0.820**	-0.399	-0.309	-0.291	-0.149	-0.318	0.096	0.515	9
-	1	0.684**	0.881**	0.062	0.1244	0.391	0.474	0.064	0.713**	0.975**	10
1	-0.082	-0.231	-0.064	-0.255	-0.047	-0.245	0.042	-0.380	0.002	-0.034	11

Effect of irrigation on phenological and qualitative traits

Although the water stress treatment initiated in the flowering stage, its effect on the interval between planting and emergence as well as emergence and flowering were insignificant in both the years (Table 4). This is essentially because ajowan is an indeterminate plant, and a complete irrigation treatment increased plant growth period (Table 5), thus increasing plant photosynthesis and yield (Table 2).

Among the qualitative characteristics, essential oil percent in the second year and essential oil yield in both years were significantly affected by irrigation treatment but, germination percent was insignificantly affected.

In the second year, water stress caused essential oil percent of the seeds to decrease from 3.31 to 2.80 (Table 5). Water stress, increased the rate of seed ripening, and with a probability that essential oil accumulation period coincided with high temperature. Given the high correlation between seed yield and essential oil yield (Tables 8 and 9); significant decrease of the essential oil yield was as a result of a decrease in seed yield. Mohamed and Abdu showed that increasing the irrigation times decreased the essential oil percent but increased the essential oil yield [8].

Effect of planting date on phenological and qualitative traits

Effect of planting date on phenological traits was significant (Table 4 and 6). The reason for increasing interval between planting and emergence for the winter plantings was low air temperature (Fig. 1 and 2). The greatest number of days between germination and flowering (vegetative growth) was obtained from the first, second, and third dates of planting and the lowest was obtained from the fifth and sixth dates of planting (Table 6). Considering the sensitivity of ajowan, from the viewpoint of response to photoperiod, this plant, in long days, without considering the vegetative growth state, enters the reproductive growth, therefore its vegetative period is shortened and assimilates accumulation doesn't reach an optimal level. None of the quality traits, except the essential oil percent, were affected by the planting date treatment in the first year. With delayed planting the essential oil percent decreased significantly (Table 6), whereas Broomand Rezazadeh *et al.* [11] reported that the essential oil percent of ajowan, unlike the essential oil yield, was not affected by varying planting dates. Interaction effects of irrigation and planting date were significant on the number of days from flowering to ripening and in the germination percent in the second year. The greatest number of days from flowering to ripening was obtained in the first and second years from the planting dates of 21st December and 29th February, respectively in the complete irrigation treatment.

Conclusion

Delayed implantation in the second experiment year when the weather was warmer and seed filling period coincide with high temperature, reduced seed yield and morphological characteristics. This indicates that ajowan is a cool season plant. Although water stress reduced the grain yield, but had no significant effect on the morphological characteristics and essential oil percent.

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