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EFFECT OF DROUGHT AND HUMIC ACID ON MORPHOLOGICAL TRAITS AND ESSENTIAL OIL CONTENT OF THYMUS KOTSCHYANUS

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ABSTRACT

The study was conducted to investigate the effect of Humic Acid organic fertilizer on the performance of *Thymus Kotschyanus* populations under the influence of drought stress. This experiment was performed as a three-factor factorial in the form of a completely randomized design (CRD) for 5 replications (pots) in the greenhouse of Pardisan Research Station belonging to Qom Agricultural and Natural Resources Research and Training Center. Three factors include 5 top accessions of *T. Kotschyanus* (factor A), irrigation levels at 80% crop capacity (control), irrigation at 60% crop and irrigation capacity at 40% crop capacity (FC) (factor B); and different levels of Humic acid including 3 Levels of 0, 1500 and 3000 mg/l were dissolved in irrigation water twice after full establishment of the plants and twenty days after the first iteration (factor C). The results of trait variance analysis showed that there was a significant difference at the level of possible error of 1% or 5% between the top accessions of *T. Kotschyanus* and between different irrigation levels in terms of all traits under study. Effectiveness of accession × irrigation levels were also significant in most traits at the level of 1% or 5% probability of error. In other words, the behavior of different Thymus accessions at different irrigation levels was significantly different and the effect of irrigation levels on different irrigations was not similar. These results are consistent with the reports of many researchers on the effect of drought stress on morphological traits as well as increasing essential oil content in drought stress conditions in medicinal plants. Hassani *et al.* (2006) reported on the effect of different levels of water stress on growth, performance, and essential oil content of *Dracocephalum moldavica*. Many traits, such as aerial organ length, wet and dry weight of aerial organ were reduced in dry stress conditions, and the highest percentage of essential oil was obtained for 70% crop capacity in moisture conditions. Hosseini and Rezvani Moghadam (2006), in examining the effect of drought stress on *Plantago ovata* germination, concluded that the highest and lowest amounts of essential oil were obtained in 55%, 70%, and 100% irrigation treatments, respectively. Dry stress reduced dry performance.
Keywords: *Thymus Kotschyanus*, Dry Stress, Humic Acid, Function.

Introduction

Today, with the improvement of economic conditions, the creation of diversity in the culture of consumption and the harmful effects of chemical drugs, the general tendency of society to use herbal medicines has increased. Increasing confidence in the use of medicinal plants in advanced societies has led to increased attention to treatment through extracting, making herbal medicines in the old way, and widely using the essential oils of medicinal plants in a wide range of food products and so the use of traditional medicines and medicinal plants is known as a norm for maintaining good health (Lucy, 1999).

The human need to find new medicinal compounds and the increasing use of medicinal plants in the pharmaceutical industry in recent years has led to an increase in the harvest of these plants from nature. This unprecedented conception has created many problems for these resources and has put the generation of medicinal species at risk of extinction or loss of desirable genotypes (Lucy, 1999). Therefore, it is very important to pay attention to localization and import of these plants into agricultural cultivation. The process of introducing a plant to cultivation includes careful ecophysiological, genetic studies, chemical aspects, as well as the potential for the production of selected accessions (Nemethe, 2000).

When a plant first encounters specific environmental changes, changes in its physiological behavior are created to sustain the new environment, which are usually unstable. If this environmental situation persists in the growing area, the next generations will be selected for sustainability in the new environment, this sustainability will gradually increase the number of compatible people and reduce incompatibility in accession, and finally a consistent accession will be established (Bernath, 2002).

The diversity of climates and different ecological conditions has led to the diversity and richness of medicinal plants throughout Iran. The need for comprehensive research and proper use of these plants, especially for use in the pharmaceutical, cosmetic and food industries, is essential. At present, Iran is among the driest regions in the world with an average annual rainfall of 240 mm. On the other hand, some areas of Iran are moving towards drought and should be reconsidered in the type of crops and cultivation pattern in these areas. Some plants that need a lot of water should be replaced with plants that require low water. The selection and cultivation of compatible plants is of particular importance in these conditions.

Regardless of the economic value of medicinal plants, most of these plants can tolerate adverse environmental conditions well and secondary metabolites support the plant against environmental stresses (Pedneault *et al*., 2002). Therefore, medicinal plants, unlike other crops that are damaged in terms of production, may produce more effective compounds in these conditions, and as a result, their economic efficiency will increase. In medicinal plants, the growth and production of essential oils are affected by various environmental factors such as drought stress (Sabih *et al*., 1999). Solinaz & Diana (1996) reported that the production of secondary metabolites of plants fluctuated with changes in environmental factors, and water stress is one of the main factors in the synthesis of this natural product.

Due to the climatic conditions of most regions of the country and the possibility of drought and salinity stress in the cultivation stages of this species and lack of information about agricultural needs and its response to environmental stresses, it is necessary to study the response of this plant to the conditions of salinity and drought stress well and optimal conditions for its cultivation should be determined. Plants resistant to salinity and drought stress can grow in saline and dehydrated conditions and produce minimal economic performance.

So far, little research has been done on the evaluation of morphological, molecular, and phytochemical traits of *T. Kotschyanus* (*Thymus Kotschyanus*) accessions, and it is still harvested from natural habitats. This could lead to the loss of much of the germplasm of this valuable plant, as well as deprive our country of the benefits of using cultivars with higher quantity and quality.

Thymus is one of the most important genera of the Lamiaceae family, which has a wide range of applications in health, medicine and food industry. Its active ingredient is essential oil, of which Thymol and Carvacrol are essential components. Thymus essential oil is one of the ten most famous essential oils in the world, which has antibacterial, antifungal, antioxidant and natural food preserving properties and has a special place in world trade (James *et al*., 1992).

Water scarcity is one of the limiting factors in crop production worldwide. Low rainfall and its irregular distribution cause drought stress during the growing period of crops (Sadras, 1996). Scientists have come up with a limited range of words for large-scale droughts, indicating the complexity of the interactions between water-deficient accession and dehydration. In general, drought is a climatic term and has different indicators, and means a period in which rainfall is less than evaporation and transpiration, because lack of rain causes water shortage. Therefore, in some cases, the term drought stress, stress is used due to the lack of effective and useful rainfall.

Edmids (1989) introduced the most common definition of drought in agriculture. Deficiency or moisture stress increases when the demand for atmospheric evaporation above the leaf (potential evaporation and transpiration) exceeds the capacity of the roots to extract water from the soil (actual evaporation and transpiration). According to a plant physiologist, drought is more than just a lack of rainfall.

Drought stress has severe effects on three important stages of growth, including flower formation, pollination, fertilization, and seed formation. During the reproductive stage, the plant is particularly sensitive to water stress. There are many reasons why stress limitation prevents the emergence of stem cell of flower. However, it has been proven that by relieving stress, stem cells are formed at a higher rate than irrigated plants (Sarmadnia, 1993).

Materials and Methods

In this study, 5 seed samples (accession) from *Thymus Kotschyanus* were used. Accession seeds from natural areas in different regions were collected by the Natural Resources Bank of Iran (Table 1). Table 1 shows the specifications and methods of each experiment separately.

Table 1 : Specifications of the main habitat of *T. Kotschyanus* accessions under review

Percentage of nominal power	Weight of one thousand seeds	Longitude	Latitude	Height	Province	Source	No.	Code
100	0.36	49 55 00	36 34 00	2000	Qazvin	Qazvin 1	12953	5
100	0.43	44 57 07	36 12 09		Western Azerbaijan	Western Azerbaijan	19587	10
100	0.31	50 07 00	36 26 00	1500	Qazvin	Qazvin 2	17091	22
100	0.53	46 40 00	35 55 00	2400	Kurdistan	Divandere	17010	23
100	0.34	45 22 45	36 55 12	1389	Western Azerbaijan	Naqadeh	18063	54

Study of the effect of drought stress on the characteristics of the 5 top accession of T. Kotschyanus in greenhouse conditions

This experiment was performed as a three-factor factorial in the form of a completely randomized design (CRD) for 5 replications (pots) in the greenhouse of Pardisan Research Station belonging to Qom Agricultural and Natural Resources Research and Training Center. Three factors include 5 top accessions of *T. Kotschyanus* (factor A), irrigation levels at 80% crop capacity (control), irrigation at 60% crop and irrigation capacity at 40% crop capacity (FC) (factor B); and different levels of Humic acid including 3 Levels of 0, 1500 and 3000 mg/l were dissolved in irrigation water twice after full establishment of the plants and twenty days after the first iteration (factor C).

After preparing the required pots, the soil used in the pots was first sampled and its physical and chemical properties were examined (Table 2). To determine the amount of water required for each pot each time of irrigation, at the beginning of the experiment, the agricultural capacity of the soil used in the pots was determined. To do this, the manual method was used. So that the soil sample was dried in an oven at 105 °C for 24 h and then, by pouring 3 kg of completely dry soil in the pot, water was gradually added to it. After complete saturation and the beginning of the outflow of water from the end of the pot, the addition of water was stopped and the pot was weighed again after 8 hours. This weight is equal to the weight of the soil in 100% agricultural capacity, which was equal to 4050 g. In other words, the agronomic capacity of the experimental soil was 25.9%. This number was obtained from the ratio of 1050 (water weight in 100% crop capacity) to 4050 (pot weight in 100% crop capacity).

In order to achieve optimal and uniform germination, the seeds were first planted in coco peat and perlite trays and then transferred to pots. In this experiment, large 4 kg pots containing sandy loam soil were used. The pots were placed in a greenhouse at 24 ± 2 °C during the day and 15 ± 2 °C at night. Until the initial establishment, all pots were watered to the extent of crop capacity. According to the definition of irrigation treatments, the pots of each treatment were irrigated after reducing the weight of each pot by 20% (210 g). In irrigation treatments of 80%, 60% and 40% of crop capacity, irrigation was done after reaching the weight of each pot to 3840, 3630 and 3420 g, respectively. For this purpose, the pots were weighed daily and if the weight of the pots was less than the above limit for each treatment, the amount of water needed to provide the desired potential be added to each pot. In this experiment, the traits and characteristics of aerial organ length, root length, root length to aerial organ ratio, wet and dry weight of aerial organ, wet performance per hectare, dry weight to wet weight ratio of aerial organ, wet and dry weight of root, dry weight to wet weight ratio of root, root weight ratio to aerial organ, dry root weight to aerial organ ratio, dry matter performance, percentage and essential oil performance were measured and calculated.

Table 2 : Results of physical and chemical analysis of experimental potting soil

OP bar	Organic matter	Organic carbon	CEC	E.S.P	SAR	mil.eq/100			Sum Cation	mil.eq/100		% Sand	% Silt	% Clay	% S.P	Acidity	103×EC
						+Na	+k	Ca+Mg		SO4	Cl						
−0.94	1	0.51	23	12	8	15	0.1	7	22.1	9	13	69	12	19	20	8.1	2.6

Result and Discussion

The results obtained from the variance analysis of trait showed that there was a significant difference between the different traits of *T. Kotschyanus* in terms of most traits under study at the level of error probability of 1% or 5% (Table 3). In other words, the different traits differed from the 5 top accessions of *T. Kotschyanus*. In addition, the effect of different irrigation levels in most studied traits at probable levels of 1% or 5% showed a significant difference, which shows the effect of different irrigation levels on the occurrence of traits in the studied accessions. On the other hand, between different levels of Humic acid, there was a significant difference in the probability of error of 1% or 5% in terms of most of the traits under study, which indicates the effect of its application on the occurrence of different traits.

The interaction effect of accession × irrigation levels was not significant in morphological traits at the level of 5% probability of error. This interaction was significant in the occurrence of functional traits of essential oil percentage and performance at the level of 1% error probability. In other words, the performance of different accessions of *Thymus* at different irrigation levels was significantly different and the effect of irrigation levels on the performance of different accessions was not similar. The interaction effect of × Humic acid levels was not significant in morphological traits at the level of 5% error probability. This interaction was significant in the occurrence of functional traits of essential oil percentage and performance at the level of 1% probability of error and in the occurrence of dry root weight traits and aerial organ length at 5% probability level. In other words, the performance of different accessions of *Thymus* at different levels of Humic acid was significantly different and the effect of the application levels of this acid on the performance of different accessions was not similar. The interaction of Humic acid × irrigation levels was significant in most morphological and functional traits at the level of 5% or 1% probability of error. In other words, the use of Humic acid at different irrigation levels has a significant difference in the occurrence of traits and the effect of Humic acid levels at different irrigation levels has not been similar. Of course, the ineffectiveness of the simple or interaction effect on some traits was due to the large coefficient of variation and trial error. The rate of change was relatively high, ranging from 15.9% to 41.2% along the aerial organ length and the dry weight of root to the aerial organ ratio, respectively.

Comparison of average traits (interaction of accession × irrigation levels)

The results of comparing the mean traits due to the interaction of top accessions × irrigation levels of *T. Kotschyanus* are given in Table 4. As expected from the analysis of variance results, the longitudinal growth trend of different accessions at different irrigation levels was not the same. The highest aerial organ length was observed in Qazvin 2 and West Azarbaijan accessions and irrigation treatment in 60% of crop capacity with 24.5 and 22.4 cm, respectively. By reducing irrigation and increasing the level of drought stress, aerial organ length was reduced in many accessions. Qazvin 2 accession was higher in all three irrigation levels than other accessions. In other words, this accession was superior to the others in all irrigation levels and its ranking among accessions did not decrease with increasing stress. In terms of root length, Qazvin 2 accession in irrigation treatments of 40% crop capacity and irrigation and 60% of crop capacity and about 22.5 cm was superior to others. By reducing irrigation and increasing the level of drought stress, root length has increased in many accessions. It seems that the plant has increased its volume and root length to increase the water absorption capacity to withstand drought stress.

In terms of root : aerial organ ratio, Naqadeh's accession of irrigation treatments in 40% of crop capacity higher than 1.14 time compared to others. In this trait, the accessions of West Azerbaijan and Qazvin 1 or the ratio of 1.11 in the normal irrigation level were placed group a. In terms of wet aerial organ weight, all accessions except Naqadeh in irrigation were 80% higher than other crops. Under normal circumstances, there was not much variation between accessions, and most were placed to group a. It seems that wet weight of aerial organ decreased with a sharp increase in drought stress. The lowest weight of wet aerial organ was observed in Qazvin 2 and West Azerbaijan accession and irrigation at 40% of crop capacity.

In terms of dry weight of aerial organ, Divandereh accession in irrigation treatment of 60% crop capacity was higher than other treatments. The same accession was superior to others in other irrigation treatments. It seems that the dry weight of the aerial organ did not decrease much with increasing drought stress. The lowest dry weight of aerial organ was observed in Naqadeh accession and irrigation at 40% crop capacity.

The studied accessions at different irrigation levels showed a great variety in terms of essential oil percentage. Each treatment was divided into several groups. The highest percentage of essential oil was observed in Qazvin 1 and West Azarbaijan accessions in irrigation at 60% of crop capacity. It seems that the percentage of essential oil in irrigation at 60% of crop capacity in many accessions was higher than normal and severe stress. The lowest percentage of essential oil was recorded in Qazvin 2, Naqadeh and Divandere accessions and in irrigation at 80% and 40% of crop capacity.

The studied accessions at different irrigation levels showed great diversity in terms of essential oil performance. Each treatment was divided into several groups. The highest essential oil performance was observed in Divandarreh and Qazvin 1 accessions in irrigation at 60% of crop capacity. It seems that the performance of essential oil in irrigation at 60% of crop capacity in many accessions was higher than normal and severe stress. The lowest essential oil performance was recorded in Naqadeh and Divandere accessions in irrigation at 40% of crop capacity and West Azerbaijan and in irrigation at 80% of crop capacity.

Comparison of average traits (interaction of Humic acid × irrigation levels)

The results of comparing the mean traits due to the interaction of Humic acid × irrigation levels of *T. Kotschyanus* are given in Table 5. As expected from the results of analysis of variance, the longitudinal growth process of aerial organs at different irrigation levels and different amounts of humic acid was not the same. The highest length of aerial organ was observed at irrigation level at 60% of crop capacity and level 3 of Humic acid application at 24.12 cm. At each irrigation level, the highest length of aerial organ was observed at level 3 of Humic acid. In other words, the use of higher levels of Humic acid at all irrigation levels has had a positive effect on aerial organ growth. The lowest length of aerial organ was observed in normal irrigation and simultaneous application of a level of humic acid. Longitudinal root growth was not the same at different irrigation levels and different amounts of humic acid. The highest root length at irrigation level was observed in 60% of crop capacity and level 3 of Humic acid application at 22.76 cm. At each irrigation level, the maximum root length was observed at level 3 of Humic acid application. In other words, the use of more Humic acid at all irrigation levels has had a positive effect on root growth. The lowest root length was observed in normal irrigation as well as irrigation at 40% of crop capacity at the same time as the application of a level of humic acid. Overall, there was no significant difference between different irrigation levels and different amounts of Humic acid in terms of aerial organ length and root length.

In terms of wet weight of aerial organ, average accessions in irrigation were higher than 80% of crop capacity and higher use of humic acid than others. Under normal conditions, there was not much difference between the use of different amounts of humic acid and most of them were grouped a together. It seems that wet weight of aerial organ decreased with a sharp increase in drought stress. The lowest wet weight of aerial organ was observed in application of levels 2 and 3 of humic acid and irrigation in 40% of crop capacity. In terms of dry performance, irrigation in 80% of crop capacity and higher application of humic acid was higher than others. Under normal conditions, there was not much difference between the use of different amounts of humic acid and most of them were grouped a together. Different levels of irrigation and Humic acid did not show much diversity in terms of essential oil percentage. Dry performance appears to decrease with a sharp increase in drought stress. The lowest dry performance was observed in the application of different levels of humic acid and irrigation in 40% of crop capacity.

Different levels of irrigation at different levels of Humic acid did not show much diversity in terms of essential oil percentage. Each treatment was divided into several groups. The highest percentage of essential oil in irrigation was observed in 60% of crop capacity and different levels of humic acid. It seems that the percentage of essential oil in irrigation in 60% of crop capacity was higher was higher than normal conditions and severe stress conditions, and the use of different levels of humic acid did not have much effect on the movement between irrigation levels. The lowest percentage of essential oil in irrigation was observed in 80% and 40% of crop capacity and all levels of application of humic acid. Different levels of irrigation at different levels of Humic acid did not show much diversity in terms of essential oil performance. Each treatment was divided into several groups. The highest performance of essential oil in irrigation was observed in 60% of crop capacity and different levels of humic acid. It seems that the essential oil performance in irrigation in 60% of crop capacity was higher than normal conditions and severe stress conditions, and the use of different levels of humic acid did not have much effect on the movement between irrigation levels. The lowest performance of essential oil in irrigation was observed in 80% and 40% of crop capacity and all levels of application of humic acid.

Comparison of average traits (interaction of different levels of Humic acid × accession)

The results of comparing the mean traits due to the interaction of top accession of *T. Kotschyanus* × different levels of Humic acid are given in Table 6. As expected from the results of variance analysis, the longitudinal growth process of different accessions at different levels of humic acid was not the same. The highest length of aerial organ in Qazvin 2 accession was 25.5, 24.9 and 24.5 cm in treatments 3, 2 and 1 of Humic acid, respectively. By reducing the amount of humic acid, the length of the aerial organ in many accessions was reduced. Qazvin 2 accession was higher than all other accessions in all three levels of Humic acid. In other words, this accession was superior to others at all levels of humic acid. In terms of root length, Qazvin 2 accession was superior to others in treatment 3 of Humic acid. By reducing the amount of humic acid, root length was reduced in many accessions. The roots of the plant seem to have grown more with the use of Humic acid. More volume and root length have a positive effect on increasing water absorption capacity.

In terms of wet weight of aerial organ, Divandere accession was higher than others in levels 3 and 1 of Humic acid. Under normal conditions, there was not much difference between the accessions and most of them were grouped a together. It seems that wet weight of aerial organ did not change much with increasing use of humic acid. In terms of wet weight of aerial organ, Qazvin 2 accession was superior to other accessions in most applications of Humic acid levels after Divandere accession.

In terms of dry weight of aerial organ, accessions of Naqadeh and Divandereh in the treatment of Humic level 2 application with values of 88.3 and 85.2 $g.m^{-2}$ were higher than other treatments. The same accession was superior to others in other Humic acid treatments. It seems that the dry weight of the aerial organ did not change much with increasing use of humic acid. The lowest dry weight of aerial organ was observed in Qazvin 2 accession and level 3 of Humic acid.

The available accessions at different irrigation levels showed great diversity in terms of essential oil percentage. Each treatment was divided into several groups. The highest percentage of essential oil was observed in Qazvin 1 accession at levels 2 and 3 of Humic acid and with 0.93 and 0.89%, respectively. West Azerbaijan's accession without the use of Humic acid was next. It seems that Qazvin 1 accession had the desired percentage of essential oil in all 3 levels of Humic acid. Qazvin 2 and Naqadeh accessions at different levels of Humic acid had a lower percentage of essential oil than other accessions. It seems that the percentage of essential oil was more affected by accession and less affected by the use of humic acid.

The accessions studied at different levels of Humic acid application showed great diversity in terms of essential oil performance. The highest essential oil performance was observed in Qazvin 1 and Naqadeh accessions and in levels 2 and 3 of Humic acid. It seems that the performance of essential oil in the treatment of level 2 Humic acid in many accessions was higher than other levels. The lowest essential oil performance was recorded in Qazvin 2 and Divandere accessions.

Table 3 : Results of analysis of variance of traits in top accessions of *T. Kotschyanus* at different levels of irrigation and Humic acid.

Change coefficient (%)	Average squares (Ms)							Traits
	Error df=196	accession× Humic acid df=8	Irrigation levels × accession df=8	Irrigation levels × Humic acid df=4	Accession df=4	Humic acid df=2	Irrigation levels df=2	
15.6	10.22	*20.8	^{ns}14.92	*31.6	**148.1	**209.3	**66	Aerial organ length
20.3	17.03	^{ns} 8.15	^{ns} 9.03	*43.7	^{ns} 38.7	**197.7	^{ns} 16.32	Root length
20.8	0.044	^{ns} 0.033	**0.12	^{ns} 0.06	*0.15	^{ns} 0.047	^{ns} 0.054	Root length to aerial organ ratio
22	7.19	^{ns} 8.8	^{ns} 9.07	*21.9	*21.6	^{ns} 7.5	**319.8	Wet weight of the aerial organ
25	0.89	^{ns} 1.5	^{ns} 0.95	^{ns} 1.95	**3.36	^{ns} 1.04	**27.3	Dry weight of the aerial organ
22	2875	^{ns} 3516	^{ns} 3627	*8768	*8644	^{ns} 2995	**127959	Wet performance per hectare aerial organ
20	0.004	^{ns} 0.003	^{ns} 0.002	*0.02	^{ns} 0.003	**0.026	**0.053	Dry to wet weight ratio
28	0.55	^{ns} 0.91	^{ns} 0.37	**1.99	**1.94	**1.73	**2.75	Wet root weight
32	0.082	*0.2	^{ns} 0.1	**0.32	**0.76	**0.61	^{ns} 0.15	Dry root weight
24.6	0.005	^{ns} 0.004	^{ns} 0.003	**0.017	**0.03	**0.05	^{ns} 0.006	The ratio of dry weight to wet root
33.1	0.007	^{ns} 0.003	^{ns} 0.011	^{ns} 0.006	^{ns} 0.004	**0.04	**0.16	The ratio of wet root weight to wet aerial organ weight
41.2	0.011	^{ns} 0.007	*0.023	^{ns} 0.018	^{ns} 0.02	^{ns} ^{ns} 0.024	**0.056	The ratio of root weight to aerial organ
25.7	356.7	^{ns} 598	^{ns} 380.4	*780.7	**1344	^{ns} 417	**10919	Dry performance
17.8	0.017	**0.08	**0.35	**0.89	**0.44	**0.22	**3.55	Percentage of essential oil
28.6	278.4	**911	**1571	**4901	**1614	**2721	**27634	Essential oil performance

* and ** are significant at the 5% and 1% probability of error, respectively.

Table 4 : Results of the comparison of the mean traits due to the interaction of accession × irrigation levels

Essential oil performance	Percentage of essential oil	Dry performance	Wet performance per hectare aerial organ	Wet weight of the aerial organ	Root length to aerial organ ratio	Root length	Aerial organ length	accession	Irrigation levels
68.46cd	0.80cd	83.24bc	294.40a	14.72a	1.11abc	20.53cde	18.73ef	**Qazvin 1**	**1**
28.24h	0.33g	85.35bc	292.67a	14.63a	1.11abc	20.77cde	19.07efg	**Western Azerbaijan**	**1**
38.56g	0.45f	81.76cd	286.67ab	14.33ab	0.98d	21.33bcd	22.00bc	**Qazvin 2**	**1**
48.19def	0.56ef	86.85b	292.00a	14.60a	0.94def	18.53e	20.33def	**Divandere**	**1**
44.23ef	0.54ef	80.44cd	275.07bc	13.75b	1.08bc	19.33de	18.00efg	**Naqadeh**	**1**
81.72ab	1.05a	79.20cde	223.60cd	11.18cd	0.94def	20.20cde	21.67cde	**Qazvin 1**	**2**
75.59b	1.01ab	76.33de	221.20cd	11.06d	0.92efg	20.47cde	22.40bc	**Western Azerbaijan**	**2**
68.22cd	0.92bcd	74.04de	225.33cd	11.27cd	0.91efg	22.47a	24.53a	**Qazvin 2**	**2**
82.58a	0.90cde	91.29a	267.87bcd	13.39b	1.12ab	21.53bcd	19.80def	**Divandere**	**2**
74.43bc	0.94bc	79.44cde	234.53cd	11.73c	1.07c	19.73de	18.93ef	**Naqadeh**	**2**
41.82f	0.82cd	52.61f	178.13f	8.91ef	0.92ef	19.17de	20.93de	**Qazvin 1**	**3**
53.62de	0.95bc	55.25f	195.47ef	9.77f	0.93def	19.80de	21.40cde	**Western Azerbaijan**	**3**
41.12f	0.75d	55.13f	195.87ef	9.79e	0.97de	22.00ab	22.73bc	**Qazvin 2**	**3**
38.41fg	0.52ef	73.24de	239.60cd	11.98c	1.07c	19.47de	18.40efg	**Divandere**	**3**
31.91g	0.45f	69.32e	225.60cd	11.28cd	1.14a	19.80de	17.67fg	**Naqadeh**	**3**

In each column, numbers with similar letters do not differ significantly from each other in the 5% probability error level.

Table 5 : Results of the comparison of the mean traits due to the interaction of Humic acid × irrigation levels

Essential oil performance	Percentage of essential oil	Dry performance	Dry weight of root	Wet weight of root	Wet weight of the aerial organ	Root length	Aerial organ length	Humic acid levels	**Irrigation levels**
32.63f	0.42d	78.09bc	0.65cd	2.27e	13.96b	17.80d	17.20d	**1**	**1**
65.53cde	0.74bcd	88.74a	0.90a	2.77bc	14.61a	21.24bc	20.32bc	**2**	**1**
38.46ef	0.45d	83.76ab	0.63cd	2.53cde	14.65a	21.26bc	21.36b	**3**	**1**
75.42ab	0.92ab	81.70abc	0.66cd	2.53cde	11.63c	20.28c	20.16bc	**1**	**2**
82.74a	1.09a	77.99bc	0.86a	2.80b	11.28c	19.60c	20.12bc	**2**	**2**
71.36abc	0.89abc	80.50abc	0.82abc	3.26a	12.26bc	22.76a	24.12a	**3**	**2**
55.90de	0.90abc	65.30cd	0.78bcd	2.60cd	11.83c	17.56d	19.16c	**1**	**3**
32.96f	0.51cd	64.85cd	0.75bcd	2.68bc	9.64d	21.48bc	20.48bc	**2**	**3**
35.27ef	0.69bcd	53.18d	0.54d	2.34de	9.56d	21.10bc	21.04b	**3**	**3**

In each column, numbers with similar letters do not differ significantly from each other in the 5% probability error level.

Table 6 : Results of the comparison of the mean traits due to the interaction of accession × Humic acid application levels

Essential oil performance	**Percentage of essential oil**	**Dry performance**	**Wet weight of root**	**Wet weight of the aerial organ**	**Root length**	**Aerial organ length**	**accession**	**Humic acid levels**
58.6cd	0.85b	70.1cd	2.20c	11.5bcd	18.6cd	20.0bc	Qazvin 1	1
60.5bc	0.87ab	72.4cd	2.29c	12.1bc	19.1cd	20.4bc	Western Azerbaijan	1
58.0d	0.78c	75.9c	2.41c	12.4ab	19.9bcd	21.5b	Qazvin 2	1
52.8e	0.64de	82.7b	2.62bc	13.5a	17.6d	16.7c	Divandere	1
43.4f	0.59e	74.1c	2.82b	12.8ab	17.6d	15.7c	Naqadeh	1
67.3a	0.93a	70.1cd	2.40c	10.8d	20.5bc	20.4bc	Qazvin 1	2
53.0e	0.83bc	69.6d	2.48c	11.0cd	20.9bc	20.8bc	Western Azerbaijan	2
53.8e	0.74cd	72.7c	2.61bc	12.0bc	21.5b	21.9b	Qazvin 2	2
62.9b	0.71d	85.2ab	2.96b	12.8ab	20.2bc	19.9bc	Divandere	2
65.1ab	0.70d	88.3a	3.29a	12.7ab	20.7bc	18.5bc	Naqadeh	2
66.1a	0.89ab	74.9c	2.59bc	12.5ab	20.8bc	20.9bc	Qazvin 1	3
44.0f	0.60e	74.9c	2.63bc	12.4ab	21.1b	21.7b	Western Azerbaijan	3
36.0g	0.61e	62.4e	2.93b	11.0cd	24.4a	25.9a	Qazvin 2	3
53.5e	0.63e	83.5b	2.96b	13.7a	21.7b	21.9b	Divandere	3
42.1f	0.64de	66.7d	2.43c	11.2cd	20.5bc	20.4bc	Naqadeh	3

In each column, numbers with similar letters do not differ significantly from each other in the 5% probability error level.

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