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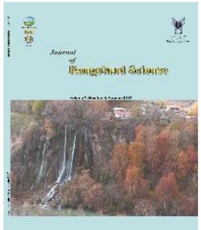

Research and Full Length Article:

Studying Drought Tolerance in *Thymus kotschyanus* Accessions for Cultivation in Dryland Farming and Low Efficient Grassland

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Abstract. This study was carried out to evaluate drought stress tolerance in *Thymus kotschyanus* accessions using a factorial experiment based on a Completely Randomized Design (CRD) with 5 replications during 2013-2014 in Qom, Iran. The first factor was the accession with 17 levels and the second factor was drought stress with three levels of irrigation including 80% (control), 60% and 40% Field Capacity (FC). Data were collected for shoot length, root length, root to shoot length ratio (R/S), shoot fresh yield, oil percent, oil production and Relative Water Content (RWC). Result of analysis of variance showed significant differences between accessions, irrigation and accessions by irrigation interaction for all of traits ($p<0.01$). Results of means comparison showed that by increasing drought stress, the shoot length, shoot weight and RWC were decreased. For root length, R/S, oil content and oil yield, higher mean values were obtained in drought stress. Higher shoot weight, oil yield and oil content were obtained in moderate stress (60% FC). Results showed that accessions 29 and 50 (Abhar) for shoot length, accessions 29 and 10 (Uremia) for root length, accessions 29 and 47 (Lorestan) for shoot weight, accessions 29 and 5 (Alamoot) for oil yield and accessions 29 and 10 (Uremia) for oil content had significantly higher values in moderate irrigation (60%FC) than others and ranked in class a. For root length, and shoot weight, the accession 23 (Divandare) and for R/S, the accessions 22 (Abyek) and 10 had higher mean values in severe irrigation (40% FC) than others. *Thymus kotschyanus* accessions showed a high variation for drought tolerance in greenhouse conditions and this species is semi-tolerant to drought stress. Accessions Qazvin 2, Abyek, Uremia and unknown had higher oil productions than others. Therefore, these accessions can be used for cultivation in irrigation deficit and Low-yielding pastures.

Key words: *Thymus kotschyanus*, Drought tolerance, Essential oil, Field capacity

Introduction

Thymus genus belongs to Lamiaceae family containing almost 215 species of perennial forbs and small shrubs native to the Mediterranean region and also grows in some parts of southern Europe, Africa and some parts of Asia (Stahl-Biskup and Saez, 2002). Thyme (*Thymus kotschyanus*) is one of the most important species that distribute in semi-arid and cold areas. This plant distributed in a wide range of mountainous rangelands in large areas of the western, northwestern, central and southern parts of the Iran (Richinger, 1982). Thymes have abundant stems relatively short and woody which gives a pulvinate crown to this species along with robust and dense roots playing a key role in soil stabilization and also preventing from water erosion in mountainous and sharp slope regions (Moghimi, 2005). Thyme oil is one of ten famous oils in the world that has anti-bacterial, and anti-fungal anti-oxidants and natural food preservatives and Thyme essential oils are used as anti-flatulence, strong antiseptic and anti-parasitic. This plant was used in a combination of 288 different medications. So far, 26 of antioxidants in the extract of this plant have been found (Golmakani and Rezaei, 2008).

Different climatic conditions make medicinal plants different in Iran. The need for comprehensive research and proper utilization of these plants for pharmaceutical and cosmetic industries, health and accelerating food is essential. A wide range of agricultural lands in dry lands has had a low efficiency and their production is low. The low efficiency pastures in large parts of Iran are lacking production capacity. At present, Iran with average annul precipitation of 240 mm is considered as arid regions among the countries worldwide. However, some regions go toward the dryness. Crops and cropping pattern in such areas should be revised. Most of plants with low water requirements have great economic benefits for entering the cropping pattern.

Regardless of the economic value of medicinal plants, most of these plants can interact well to endure unfavorable conditions. Secondary metabolites cause to stand up against environmental stresses (Pedneault and Léonhart, 2002). Therefore, medicinal plants unlike other crops that are in the stress conditions may produce more active components in such conditions and thereby increase their economic efficiency. In medicinal and aromatic plants, oil production and growth are influenced by environmental factors such as drought stress (Sabih *et al.*, 1999). Lebaschy and Sharifi (2010) reported that the secondary metabolite production in plants fluctuated with changing environmental conditions and water stress is a major factor for synthesis of natural products.

Water deficit is one of the limiting factors of plant production around the world. Low rainfall and its irregular distribution during the growing season of plants cause the drought stress (Saez, 1999). Drought stress on yield and active substances of medicinal plants have different effects. Lack of moisture causes different morphological reactions such as loss of leaf area, the early fall, reduced shoot length, and increased root growth and physiological and metabolic ones such as stomatal closure, reduction in the growth rate, and the concentration of antioxidants (Lebaschy & Sharifi, 2010). Amini Dehaghi and Babaee (2010) reported the increased drought stress at Thyme causing the reduced traits such as plant height, number of lateral shoots, dry and fresh weight of biomass and thymol and in contrast leading to increase the root volume, root dry weight and root length. Moradi *et al.* (2015) reported the highest values of fresh and dry weight, plant height and oil% in *Thymus daenensis* in irrigation at 60% of Field Capacity (FC) and the lowest values were related to irrigation in 40%FC. In another study, stress had a significant impact on the oil and essential components of *Thymus lancifolius* ecotypes. The compounds were obtained in different ecotypes of thymol, carvacrol and p-cymene (Dehghani *et al.*, 2014).

Behzadi *et al.* (2015) in a study of the irrigation effect on growth characteristics and essential oil yield of different accessions of *Thymus migricus* found the highest oil yield in irrigation at 60% FC. Accessions of Freidan and Qazvin had the highest tolerance to drought stress. Ranjbar *et al.* (2015) studying the effects of drought stress on yield and essential oil of *Thymus transcaucasicus* found the accession of Nodoushan Yazd superior than the others so that the highest oil yield as 2.03 kg/ha was obtained in the irrigation of 60%FC. The lowest essential oil was obtained in the same accession in the irrigation of 40%FC. Safikhani (2006) studied the effect of 100%, 60% and 40% FC drought stresses on *Dracocephalum moldavica* and concluded that the irrigation at 40% FC (severe drought stress) decreased plant height, leaf area, internodes length, shoot yield and essential oil yield as compared to two other treatments. Similarly, Stephanie *et al.* (2005) reported that drought stress reduced stem length and root length of *Salvia splendens*.

Given the importance of this species in rangeland improvement and cultivation in low rainfed lands, determining the effects of different amounts of irrigation on different accessions for selection and introducing desirable species and accessions are necessary. For the cultivation of medicinal plants, varieties with high quality and quantity of effective compounds and biomass, uniform germination and resistance to environmental stress are necessary (Sartip *et al.*, 2015). Keeping this in mind, the present study was carried out to assess the response of 17 accessions of *Thymus kotschyanus* to drought stress.

Materials and Methods

The research was conducted using a factorial experiment based on a Completely Randomized Design (CRD) with 5 replications (pot) in 2013-14 in Qom, Iran. Factor A was consisted of 17 accessions of *T. kotschyanus* that were originated from different parts of Iran and factor B was irrigation level including 80% Field Capacity (FC) as control, 60% FC and 40% FC. Seeds were sown in pots in January 2012, and irrigated immediately. Irrigation treatments were continued for three months.

In this experiment, the sandy loam soil was used. To determine the amount of water needed per pot at each irrigation, at the beginning of the experiment, the soil field capacity was determined by pot weighing method. To this end, water was gradually added to the dry soil in a pot. After saturation and the withdrawal of excess water, the pots were weighed again. The weight of pot (soil+ water) at 100% FC was 4050g. So, the weight of water at 100% FC was 1050 g. With regard to irrigation, each treatment after the reduction of 20% (210 g) of weight was irrigated. With 80%, 60% and 40% field capacities after achieving weight pots in each treatment as 3840, 3630 and 3420 g, irrigation was done. For this purpose, the pots were weighed daily based on the specified weight for each treatment, the amount of needed water was added to each pot.Pots were placed in a greenhouse with temperature of 24±2°C in days and 15±2°C at night. In this experiment, the following traits were measured: Shoot length and Root length (cm), Root/Shoot length ratio (R/S), Shoot fresh weight (g/pot), Relative Water Content (RWC) and essential oil yield (mg/pot).

The essential oil content of each accessions (mix of aerial biomass of five pots) in each treatment was estimated using water distillation method. For this purpose, 80 g of flowering branches were dried and ground using the British

Pharmacopoeia Clevenger for 4 hours at 100°C. Essential oil content was estimated as the dry weight percent (British pharmacopoeia, 1988). Analysis of variance and means comparison (Duncan method) were made using MSTAT-C software.

Results

Analysis of variance showed significant differences between accessions, irrigation and accessions by irrigation interaction ($p<0.01$) for all of traits (Table 1). This reflects the diversity in accessions and their different responses in levels of irrigation. In other words, behavior of different accessions at different levels of irrigation had a significant difference. The Coefficient of Variation (CV%) was ranged from 4.7 to 25.3% indicating good accuracy of experiment (Table 1).

Table 1. Analysis of variance and the level of MS significant for 17 accessions of *Thymus kotschyanus* in three irrigations levels and their interactions in greenhouse condition

SOV	DF	MS					
		Shoot length (cm)	Root length (cm)	Shoot fresh weight (g)	R/S	Oil yield (mg/pot)	RWC
Accessions (A)	16	54.3**	96.9**	15.73**	0.37**	0.52**	383**
Irrigation (I)	2	206.9**	207.1**	92.7**	2.81**	1.4**	1041**
A × I	32	14.33**	33.9**	19.8**	0.12**	0.88**	545**
Error	204	7.1	15.5	8.4	0.06	0.045	12.2
%CV		14	15.8	20.6	18.2	25.3	4.7

** significant at 0.01 probability level

Result of means comparison for shoot length showed that the accessions 29 (unknown) and 50 (Abhar) had the highest shoot length in irrigation of 60% FC (Table 2). By reducing the amount of irrigation and increasing levels of drought stress in many accessions, shoot length was decreased. The total means of shoot length in 80%FC, 60%FC and 40%FC were 20.13, 19.59 and 17.20 cm, respectively indicating the significant effect of drought stress on the decreasing of shoot length in 40%FC. In all of treatments, the accession 29 (unknown) was ranked in class a (Table 2). In other words, this accession in all of irrigation levels was superior than the others and with the rising stress, its ranking was not reduced between accessions.

Result of means comparison for root length showed that the accessions 10 (Uremia) and 29 (Unknown) with average values of 30.8 and 30.4 cm had the longest root length in 60% FC. For severe drought stress (40% FC), the accession 23 (Divandare) with average value of 31.5 cm had the longest root length than the other accessions (Table 2). By increasing drought stress, the root lengths in many accessions were increased. But there were no significant differences between total means of root length in 60%FC and 40%FC treatments indicating that although drought stress reduced *T. kotschyanus* shoot length, it significantly increased its root length (Table 2).

Table 2. Means comparison of shoot and root length (cm) in 17 accessions of *Thymus kotschyanus* in three irrigation levels in greenhouse conditions

No.	Code	Origin	Shoot length (cm)			Root length (cm)		
			80%FC	60%FC	40%FC	80%FC	60%FC	40%FC
3	12948	Ghazvin1	18.9 bc	18.3 cd	16.3cd	19.6 e	24.3 bc	25.5cde
5	12953	Alamoot	21.6 ab	17.1 d	15.4 d	25.4 ab	27.4 ab	21.5 de
7	19307	Zanjan	16.5 c	18.5 cd	17.4abc	18.8 e	20.2 d	20.6 e
8	19357	Taroom	21.8 ab	20.0 cd	17.0bc	23.4 bc	21.5 cd	24.9cde
10	19587	Uromia	20.0 bc	18.3 cd	15.8 d	22.3bcd	30.8 a	28.7 ab
17	17969	Azarbaijan	16.2 c	18.2 cd	17.1bc	18.9 e	20.3 cd	20.8 e
22	17091	Abyek	17.6 abc	16.5 d	15.2 d	19.3 e	24.7 bc	30.6 ab
23	17010	Divandare	16.1 c	16.9 d	18.8abc	22.4 cd	26.8 ab	31.5 a
27	23763	Ghazvin2	22.0 ab	20.4 cd	18.3abc	25.6 ab	28.9 ab	30.2 ab
29	-	Unknown	22.8 a	27.7 a	19.2 ab	29.1 a	30.4 a	23.7 de
47	8916	Lorestan	21.2 ab	20.3 cd	20.2 a	19.0 e	20.5 cd	24.5cde
50	19266	Abhar	23.1 a	24.0 a	20.3 a	24.6 bc	24.5 bc	26.4 bc
51	18803	Tehran	18.6 bc	18.2 cd	16.0cd	19.8 d	25.2 bc	25.5cde
54	18063	Nagade	22.1 ab	22.0 bc	16.5cd	22.7 bcd	24.1 bc	25.6cde
58	14297	Sanandaj	21.5 ab	16.9 d	15.1 d	25.5 ab	28.3 ab	21.9 de
67	14212	Piranshahr	20.1 bc	20.0 cd	17.2bc	25.7 ab	27.9 ab	28.3 ab
70	14216	Sardasht	22.1 ab	19.7 cd	16.6cd	23.3 bcd	21.7bcd	25.3cde
	Mean		20.13 A	19.59 A	17.20 B	22.67 B	25.15 A	25.62 A

In each column, numbers with the same letters are not significantly different at the error level of 1%

Result of means comparison for shoot fresh weight showed that the accessions 29 (Unknown) and 47 (Lorestan) with average values of 18.5 and 18.8 g/pot had the highest shoot weight in irrigation of 60% FC. For severe drought stress (40%FC), the accession 23 (Divandare) with average value of 16.2 g/pot had the highest shoot weight as compared to the other accessions (Table 3). Result showed that by increasing of drought stress from 80%FC to 60%FC, the shoot weights were increased from 13.69 to 14.79 g/pot. In contrast, the lowest total mean of shoot weight with average value of 12.65 g/pot was obtained in 40%FC. This finding indicated that moderate drought had a positive impact on *T. kotschyanus* production as compared to both 80% FC and 40% FC treatments (Table 3).

Higher root shoot length ratio (R/S) with average values of 1.43 was obtained in the accession 23 (Divandare) in 80% FC. Similarly, the accessions 10 (Uremia) and 58 (Sanandaj) with average values of 1.71 and 1.67, respectively had higher R/S and were ranked in class a in 60% FC. The accessions 22 (Abyek) and 10 (Uremia) in irrigation of 40% FC had the highest R/S values as compared to the others. The latter accession in all of three irrigation levels was ranked in class a. Result also showed that by the increasing of drought stress, the R/S values were increased and higher mean values with 1.52 was obtained in 40% FC. More R/S in the accessions allows more water to be absorbed (Table 3).

Table 3. Means comparison of shoot fresh weight and Root/Shoot length ratio (R/S) in 17 accessions of *Thymus kotschyanus* in three irrigation levels in greenhouse conditions

No.	Code	Origin	Shoot fresh weight (g/pot)			Root/Shoot length ratio (R/S)		
			80%FC	60%FC	40%FC	80%FC	60%FC	40%FC
3	12948	Ghazvin1	13.2 b	16.2 ab	13.5 abc	1.04 b	1.34 ab	1.58 cd
5	12953	Alamoot	15.4 ab	16.8 ab	11.1cd	1.17 ab	1.58 a	1.40 de
7	19307	Zanjan	14.8 ab	13.7 bcd	14.6 ab	1.15 ab	1.10 b	1.19 e
8	19357	Taroom	16.9 a	13.5 cd	12.7bcd	1.07 ab	1.10 b	1.49cde
10	19587	Uromia	10.6 b	12.5 cd	13.7 abc	1.12 ab	1.71 a	1.82ab
17	17969	Azarbaijan	14.7 ab	13.6 cd	14.2 ab	1.18 ab	1.13 b	1.23de
22	17091	Abyek	14.7 ab	13.2 cd	12.5 bcd	1.15 ab	1.52 a	2.04 a
23	17010	Divandare	14.5 ab	12.0 d	16.2 a	1.43 a	1.57 a	1.69 bc
27	23763	Ghazvin2	11.6 b	14.6 bc	10.6 d	1.17 ab	1.43 ab	1.68 bc
29	-	Unknown	13.5 ab	18.5 a	13.2 abc	1.30 ab	1.11 b	1.24de
47	8916	Lorestan	11.3 b	18.8 a	12.8 bcd	0.99 b	1.03 b	1.24de
50	19266	Abhar	14.4 ab	13.5 cd	9.7 d	1.07 ab	1.04 b	1.32de
51	18803	Tehran	12.9 b	15.9abc	13.3 abc	1.09 ab	1.43 ab	1.60 bc
54	18063	Nagade	10.9 b	12.3 cd	11.3 cd	1.03 b	1.10 b	1.56bcd
58	14297	Sanandaj	15.2 ab	16.8ab	11.2 cd	1.21 ab	1.67 a	1.44cde
67	14212	Piranshahr	11.2 b	15.0abc	11.9 cd	1.30 ab	1.40 ab	1.66bc
70	14216	Sardasht	16.9 a	13.4 cd	12.6 bcd	1.07ab	1.13 b	1.54bcd
	Mean		13.69 B	14.72 A	12.65 C	1.15 C	1.32 B	1.51 A

column, numbers with the same letters are not significantly different at the error level of 1%

For the oil yield, accessions showed a large variation in different irrigation levels. The highest oil yield with average values of 1.39 and 1.32 mg/pot was obtained in the accessions 3 (Ghazvin1) and 51 (Tehran), respectively in normal irrigation (80% FC). For moderate stress (60% FC), the accessions 29 (Unknown) and 5 (Alamoot) with average values of 1.79 and 1.54 mg/pot had higher oil productions. The total mean values of oil yield for 80% FC, 60% FC and 40% FC were 0.68, 0.92 and 0.88 mg/pot, respectively indicating the essential oil in moderate irrigation (60% FC) that was higher than normal and severe stresses (Table 4).

The highest values of RWC was observed in the accession 47 (Lorestan) in normal irrigation and similarly, the highest RWC was obtained in the accessions 8 (Taroom) and 70 (Sardasht) in moderate irrigation (60% FC). By increasing levels of drought stress in many accessions, RWC values were decreased. Higher and lower RWC with average values of 77.72 and 70.72% was obtained in 80% FC and 40% FC, respectively indicating that drought stress significantly decreased RWC% (Table 4).

Table 4. Means comparison of oil yield and Root/Shoot length ratio (RS) in 17 accessions of *Thymus kotschyanus* in three irrigation levels in greenhouse conditions

No.	Code	Origin	Oil yield (mg/pot)			Relative Water Content (RWC)		
			80%FC	60%FC	40%FC	80%FC	60%FC	40%FC
3	12948	Ghazvin1	1.39 a	0.78 cd	1.25 bc	82.4 cd	62.4 e	72.4b
5	12953	Alamoot	0.40 de	1.54 ab	0.99cde	84.4 bc	71.2 d	69.8cd
7	19307	Zanjan	0.47 cd	0.86 cd	1.66 a	84.4 bc	64.6 e	66.0 de
8	19357	Taroom	0.83 bc	0.56 e	0.64efg	78.4 de	92.0 a	75.0 b
10	19587	Uromia	0.72 cd	1.49 ab	0.35 g	71.2 e	85.8 b	61.6 e
17	17969	Azarbaijan	0.36 de	0.74cde	1.66 a	85.8 bc	66.6 de	68.0 cd
22	17091	Abyek	0.96 b	0.83cd	0.47fg	76.8 de	66.2 de	67.8 cd
23	17010	Divandare	0.55 cd	0.54 e	1.49ab	83.4 cd	83.2 b	54.0 f
27	23763	Ghazvin2	0.53 cd	0.50 e	0.65efg	76.6 de	90.4 a	71.6 bc
29	-	Unknown	0.50 cd	1.79 a	0.45 fg	60.6 f	70.4 d	88.0 a
47	8916	Lorestan	0.60 cd	0.60 de	0.73efg	96.0 a	73.2 d	67.0 cd
50	19266	Abhar	0.29 e	0.66 de	0.66efg	68.2 de	60.4 e	74.8 b
51	18803	Tehran	1.32 a	0.68 de	1.12cd	80.2 cd	65.0 de	73.2 bc
54	18063	Nagade	0.60cd	0.94cd	0.61efg	51.2 g	77.2 c	77.0 b
58	14297	Sanandaj	0.30 e	1.33 b	0.89 def	88.2 b	73.6 d	71.2 bc
67	14212	Piranshahr	1.01 b	1.32 b	0.82d-g	66.4 de	66.0 de	67.8 cd
70	14216	Sardasht	0.73 cd	0.47 e	0.54efg	87.0 bc	92.6 a	77.0 b
	Mean		0.68 B	0.92 A	0.88 A	77.72 A	74.16 B	70.72 C

column, numbers with the same letters are not significantly different at the error level of 5%

The highest essential oil content was obtained in the accessions 29 (Unknown) and 10 (Uremia) with average values of 2.7% and 2.5%, respectively in moderate irrigation of 60% FC (Fig. 1). In contrast, the lowest oil % was obtained in the accessions 58 and 50 with average values of 0.39 and 0.43%, respectively in normal irrigation (80% FC). In many accessions, essential oil content was less than unit, especially in normal conditions (Fig. 1). By increasing levels of drought stress in many accessions, oil content was increased. The total average values of oil% for 80%, 60% and 40% FC were 1.01, 1.15 and 1.14%, respectively (data not shown) indicating that drought stress increased *T. kotschyanus* oil content.

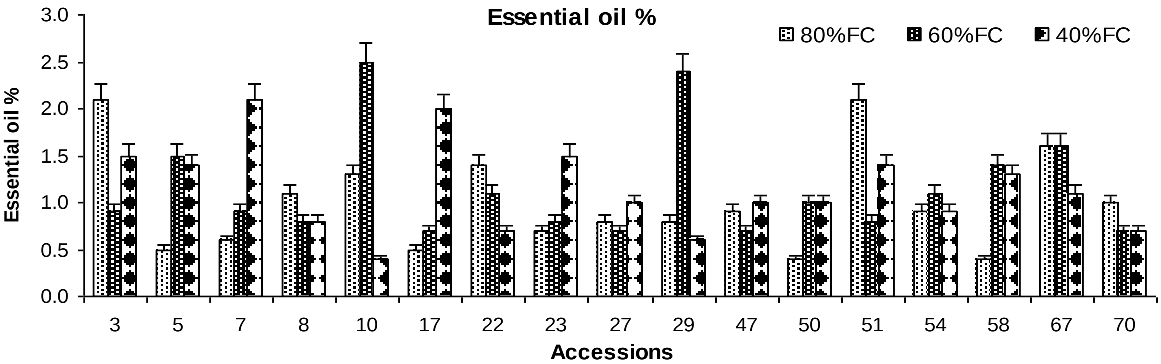

Fig. 1. The essential oil content in different accessions and different irrigation levels

Discussion

The purpose of this study was to evaluate the effects of water stress on morphological traits and essential oil yield in 17 accessions of *Thymus kotschyanus*. Results showed that means of all of accessions were reduced for most of traits in drought stress. But for some traits such as root length, shoot weight, essential oil yield and essential oil content, their mean values were increased in moderate irrigation (60% FC). These results were similar with the reports of Moradi *et al.* (2015) and Dehghani *et al.* (2014). From this result, it can be concluded that root growth was less sensitive than shoot growth to drought stress. In accessions with drought tolerance, R/S was high. This increases the plant ability to absorb water and nutrients. Ranjbar *et al.* (2015) also reported the root length increase in drought tolerance of accessions in *Thymus transcaucasicus*.

High oil yield in most accessions in irrigation at 60% FC showed that moderate stress can increase oil production. But severe stress by altering the metabolic pathways and reducing plant growth reduces oil yield. Similar to our result, Nouraei *et al.* (2013) studying the impact of drought stress on three accessions of *Thymus kotschyanus* of Qazvin, Isfahan and Kurdistan found that Kurdistan accession had the highest oil content in irrigation at 60% FC. They found that the reduced water from normal to mild stresses increases both yield and essential oil content, but severe stress reduces the morphological and yield traits in the accessions.

Rahimi *et al.* (2013) evaluated the changes in essential oil content and yield components of three accessions of Anise (*Pimpinella anisum*) under different irrigation regimes. In their experiment, essential oil content was the highest and lowest in 14 and 5 day irrigation regime. Bagheri *et al.* (2011) reported that the drought stress reduced the germination percent, root and shoot length in *Thymus kotschyanus*. Hosseini and Rezvani Moghadam (2006) studying the effect of drought stress on *Plantago psyllium* found the highest and lowest essential oil in 55% FC and the 100% FC treatments, respectively. Hasani (2006) studying the effect of water stress on the basil found that in drought stress, the essential oil yield decreased, but essential oil content was increased. Heidari *et al.* (2012) reported the highest and lowest essential oil content and essential oil yield of *Pimpinella anisum* related to stress and normal irrigation.

Conclusion

Thymus kotschyanus accessions have high variations in drought tolerance in greenhouse conditions and this species is semi-tolerant to drought stress. The superior accessions can be used for range and rainfed area improvement. The result indicated that the accessions 5 (Qazvin 2), 22 (Abyek), 10 (Uremia) and 29 (unknown) for more important traits such as oil yield on different irrigation levels were better than others. These accessions can be used for cultivation in irrigation deficit and dry farming.

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بررسی تحمل به خشکی در جمعیت‌های آویشن کوهی *Thymus kotschyanus* به منظور کشت در زراعت دیم و مراتع کم بازده

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چکیده. این تحقیق بمنظور بررسی تحمل به تنش خشکی در جمعیت‌های مختلف آویشن کوهی *Thymus kotschyanus* بصورت آزمایش فاکتوریل در قالب طرح کاملا تصادفی (CRD) با ۵ تکرار در سالهای ۹۳-۱۳۹۲ در منطقه قم-ایران انجام شد. فاکتور اول شامل ۱۷ جمعیت و فاکتور دوم شامل ۳ سطح آبیاری در ۸۰٪ (شاهد)، ۶۰٪ و ۴۰٪ ظرفیت زراعی (FC) بود. صفات شامل طول اندام هوائی، طول ریشه، نسبت طول ریشه به اندام هوائی، وزن تر اندام هوایی، درصد اسانس، عملکرد اسانس و محتوای نسبی آب بودند. نتایج تجزیه واریانس نشان داد، اثر اکسشن، سطوح مختلف آبیاری و اثر متقابل اکسشن × سطوح آبیاری در کلیه صفات معنی‌دار بود $(P<0.01)$. نتایج مقایسه میانگین نشان داد با افزایش تنش خشکی طول و وزن تر اندام هوایی و محتوای نسبی آب کاهش یافت. در مقابل میانگین طول ریشه، نسبت طول ریشه به اندام هوایی، درصد و عملکرد اسانس در شرایط تنش خشکی بیشتر بود. بیشترین وزن اندام هوایی، درصد و عملکرد اسانس در تیمار آبیاری در ۶۰٪ ظرفیت زراعی مشاهده شد. نتایج نشان داد جمعیت‌های ۲۹ و ۵۰ (ابهر) برای طول اندام هوایی، جمعیت‌های ۲۹ و ۱۰ (ارومیه) برای طول ریشه، جمعیت‌های ۲۹ و ۴۷ (لرستان) برای وزن اندام هوایی، جمعیت‌های ۲۹ و ۵ (الموت) برای عملکرد اسانس و جمعیت‌های ۲۹ و ۱۰ برای میزان اسانس بطور معنی‌داری در آبیاری در ۶۰٪ ظرفیت زراعی بالاتر از سایرین و در گروه a قرار گرفتند. برای طول ریشه و وزن اندام هوایی جمعیت ۲۳ (دیواندره) و برای نسبت طول اندام هوایی به ریشه جمعیت‌های ۲۲ (آبیک) و ۱۰ (ارومیه) در آبیاری در ۴۰٪ ظرفیت زراعی بالاتر از سایرین بودند. جمعیت‌های آویشن کوهی تنوع زیادی از نظر تحمل به تنش خشکی در شرایط گلخانه نشان دادند و این گونه نسبت به تنش خشکی نیمه متحمل محسوب می‌شود. جمعیت‌های مطلوب را می‌توان برای اصلاح مراتع و اراضی دیم بکار برد. جمعیت‌های قزوین ۲، آبیک، ارومیه و نامعلوم در بیشتر صفات مهم نظیر عملکرد اسانس در سطوح مختلف آبیاری بهتر از دیگر جمعیت‌ها بودند. بنابراین می‌توان از آنها در جهت گسترش کشت در شرایط کم آبیاری و نیز مراتع کم بازده استفاده نمود.

کلمات کلیدی: آویشن کوهی، تحمل خشکی، اسانس، ظرفیت زراعی