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The autecological characteristics of *Thymus transcaspicus* Klokov medicinal plant in North East Rangelands of Iran

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Abstract
Thymus transcaspicus Klokov. (Lamiaceae) is one of the most important medicinal plants had been used in traditional medicine in natural sites of mountainous areas of Iran. This study is subjected to determine the main autecological properties of plant in North East Iran. In this site, different parameters such as climate characters, vegetation studies, physical and chemical analysis of the soil were determined. The results showed that *Thymus transcaspicus* could be adapted in regions with arid cold climate, annual rainfall average of 295 mm and annual average temperature of 11.28 °C. *Thymus transcaspicus* have dispersed in northern, south and north east slope and altitude 1200- 1900 m of sea level in area. It was observed that this plant generally prefers sandy loam texture, lime, alkaline pH and non-saline soils. The content of organic matter is rich in its habitat. Individual plants height varies from 7 to 25 cm with canopy diameter of 20 to 60 cm. Mean canopy cover was 23.51% in the habitat. Distribution pattern of plant is clumped. According to the results of the vegetation studies, average of the current yield was 851.96 kg/ha and 43000 species per hectare was estimated as average of the density of *Thymus transcaspicus.*

Keywords: Autecology, *Thymus transcaspicus*, rangeland, Iran

1. Introduction
Iran with about 1.65 million square kilometer area is a large country and after Turkey is the richest country of plant diversity in the Middle East (Jafari and Akhani, 2008) [16]. Iran is one of the main centers of endemism in the world. This country is rich in plant diversity; topographic factors have created a very diverse microclimate and edaphic conditions that caused growth around 8000 plant species (Haghighi and Mozafariyan, 2011) [12].
Study the relationship between different plants with abiotic and biotic factors which are in an ecosystem is usually a part of ecological researches. The results of investigates help to progress our knowledge of each plant species (Jafari *et al.,* 2013) [15]. The distribution, pattern and abundance of plant species have been related to three groups of factors: soil chemistry, physical environmental variables and anthropogenic disturbance (Enright *et al.,* 2005) [8].
The principle problem in plant investigation is advice of plant ecological situation in order to available desired condition for planting. There are many medicinal plants in Iran but there is lack of enough knowledge about plants condition and their utilization. Medicinal aromatic herbs have been used traditionally as a stout source of vegetables, spices and natural drugs for many centuries (Salehi *et al.,* 2005; Aliakbarlu and Farnaz Shameli, 2013) [33, 2].
The Labiatae family (Lamiaceae) is one of the largest and most distinctive families of flowering plants, with about 220 genera and almost 4000 species worldwide. This family has an almost cosmopolitan distribution. Some genera like *Thymus*, *Nepeta*, *Phlomis*, *Eremostachys, Salvia* and *Lagochilus* have a great diversity in the Mediterranean and C/SW Asia (Naghibi *et al.,* 2005) [29]. The genus Thymus L., an aromatic and medicinal plant, includes numerous species with quite different botanical properties. This genus contains of about 215 species of herbaceous perennials and sub shrubs that grow naturally in the Mediterranean region, which is stated in the Iranian flora by 14 species (Javadi *et al.,* 2009) [17], and four of them are endemic [Mozaffarian, 1998] [27]. Leaves and flowers of Thymus species are commonly used as herbal tea, spice, flavoring agents and medicinal plants. Furthermore, Thymus oils and extracts are widely used in pharmaceutical, perfume and cosmetic industries and are also used for savoring and protecting food products.

It has been accounted that Thymus species have stout antibacterial, antifungal, antiviral, anti-parasitic, spasmolytic and antioxidant activities (Imelouane *et al.,* 2009) [13]. *Thymus transcaspicus* Klokov is a member of genus Thymus. It is native in Iran (Mozaffarian, 1998) [27] with limited distribution in the Northeast and Turkmenistan and also this species is a restricted distribution in the Northeast of Iran, in addition grows in high altitudes almost from 1700 to 2800 m (Rechinger, 1982).

Kaya and Aksaka (2007) [19] investigated Autecological characteristics of *Salvia rosifolia* and found that there is a relation between the quantities of nitrogen, potassium and phosphorus and plant abundance and distribution. The properties of *Nepeta oxyodonta* habitat have been studied in central Zagros Mountains (Mirinejad *et al.,* 2014) [24]. The results indicated that *Nepeta oxyodonta* usually grows in the mountain regions with the elevation of 2150 to 2800 meters (above sea level) and the slopes of 10% to 75%. This plant can tolerate the EC from 0.37 to 0.85 µ mho/cm. Asaadi and Khoshnod Yazdi (2010) found that *Dracocephalum kotschyi* have dispersed in northern and north- west slope and altitude 1600-1800 m of sea level in rocky area. They also reported that this plant generally prefers the soil of very shallow with loomy texture, pH 7.6 and EC 0.55 ds/m. Nadjafi *et al*. (2009) [28] studied *Nepeta binaludensis* Autecology. The results showed that this plant grows in north-facing slopes with more than 50% and 2300-2700 m elevations. They also found that it prefers the average annual rainfall ranging from 350 to 370 mm and temperature of 6 to 7 °C and grows in light soils with a neutral pH and low mineral content. Autecological investigates are essential to obtain main information required for the species management. Identifying ecological factors such as climate, topography, soil, and disturbance that influence plant species distribution is necessary to conserve and manage rangeland ecosystems (Ajeer & Shahmoradi, 2007; Nautiyal *et al.,* 2009) [1, 30]. The present study was done to introduce ecological characteristic and dense cultivation on farm land and then using this plant in medicinal industries.

2. Materials and Methods

2.1 Study area

The studied area was located in arid rangelands of Bojnourd city in North East of Iran (North Khorasan Provinces). This region is situated between 37° 23' to 37° 36' North latitude and 57° 7' to 57° 15' East longitudes. The area is approximately 5300 hectares with elevation ranging from 1200 m to 1900 meter. The means of precipitation is 295mm/year that maximum and minimum of precipitation occur in April and July respectively. The mean of annual temperature is 11.28 ˚C. The average maximum temperature is 2 6 ˚C in July and minimum temperature is -6.8 ˚C in January. The climate of this region with using of Emberger method is cold arid. The Embrothermic diagram show that drought period is for five months of year and wet season start in November and continues until May (Fig.1).

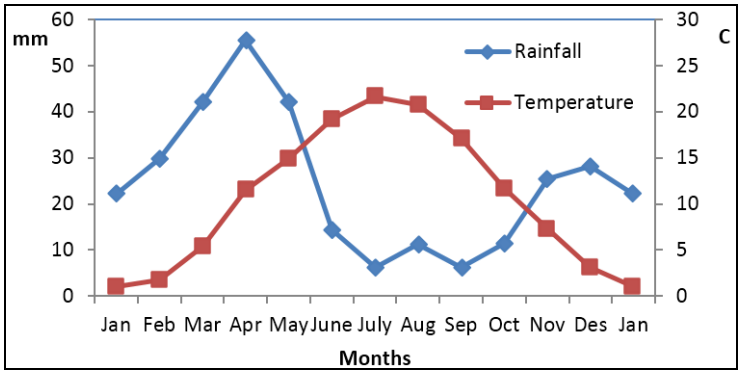

Fig 1: Embrothermic curve in the study area.

2.2 Measurement of habitat characteristics

The data of vegetation cover and environmental factors were collected after primary visiting and indicating the study area. The climatic (temperature, rainfall), topographic (slope, altitude), and edaphic (physical and chemical) properties of the habitat were determined. Meteorological data including rainfall and temperature were obtained from Bojnourd meteorological station. Plant height, density, abundance, canopy cover, the largest and smallest diameter, and yield of *Thymus transcaspicus* were directly measured in the field using transect and quadrate method (Mannetje, 1978) [22]. Plot size and sample size were determined by minimum area and vegetation procedure using 80 plots along ten 50 m transects. To determine phenology and growth duration, from the beginning of growing season, the plant growth area was visited biweekly and vegetative stages of plant growth were recorded in related forms. Rooting depth was also measured in each soil profile. Plant distributions pattern was determined by the Hopkins index (Moghaddam, 2001) [25]:

$$I_h = \frac{\sum(x_i)^2}{\sum(x_i)^2 + \sum(r_i)^2}$$

Where I_h is Hopkins index, x_i is distance of nearest plant and r_i is distance of nearest neighbor plant

Five soil profiles were randomly dug at area. Soil samples were analyzed for organic carbon percentage, EC, pH, CEC, N, Na, K, P, Ca, HCO3, Cl, Mg, SO4, gravel percentage, lime percentage, gypsum percentage and texture. After collecting all data from the sites, analysis was done using SPSS software (one-way analysis of variance). Mean comparisons were performed using Duncan's Multiple Test.

3. Results and Discussion

The habitat of a species is the most important part of its life cycle. Therefore there is a need to understand the habitat for an evaluation of the biological features of a species which is also critical for the wildlife management. Habitat of a species is informative about bioclimatic, edaphic, topographic, biotic characteristics of a specific area, it describes sum of the biotic

and abiotic factors required by an organism (Thomas 1979) [34].

Climate is one of the most important factors in the plant development (Vallejo *et al.,* 1998) [35]. In Irano-Turanian zone, fall and winters are cold, rainy and snowy, and summers are dry and hot, are covered by sclerophyllous species that need quite little water and high temperatures (Dogan, 2003) [6]. The results showed that *Thymus transcaspicus* grows at altitudes of 1200-1900 m above sea level. They can be seen in the north, northeast, west and east slopes. The mean annual precipitation is 295 mm, the average of the maximum and minimum rainfall occurs in April (55.6 mm) and July (6.14 mm) for the habitat, respectively. The mean annual temperature is 11.28 °C. The average of the maximum and minimum temperatures is 26 °C in July and -6.8 ˚C in January in these regions, respectively. Using the Emberger climate classification (Alizadeh *et al.,* 1995) [3], the habitat of *Thymus transcaspicus* was categorized as cold arid. According to Embrothermic curve June, July, August, September and October are the driest months of the year (Fig. 2). Altitude has a vital role in the growth and production of plants in a variety of natural ecosystems and areas (Habibi *et al.,* 2006; Haider *et al.,* 2009; Mahdavi *et al.,* 2013) [10, 11, 20]. It is one of the indirect environmental gradients which may have direct effects on environmental gradients such as climate and soil and directly affect the other factors including temperature through which plant species distribution will be also changed and the rangeland ecosystem structure will be revolutionized (Ebrahimi *et al.,* 2015) [7]. So, increasing and decreasing the altitude level can change the temperature, relative humidity, wind speed, available water to the plant root and sunlight rates; hence, regarding the altitude level changes, ecophysiological reactions of plant will also change (Mahzooni–Kachapi *et al.,* 2014).

Dispersion or distribution patterns show the spatial relationship between members of a population within a habitat. The distribution of species into clumped, uniform, or random depends on different abiotic and biotic factors (Moghaddam, 2001) [25]. The results showed that distribution pattern of *Thymus transcaspicus* species are clumped. Clumped distribution is the most common type of dispersion found in nature. In clumped distribution, the distance between neighboring individuals is minimized. This type of distribution is found in environments that are characterized by patchy resources (Moghaddam, 2001) [25].

The Flora of study area is rich composed of annual and perennial plants. Vegetation survey showed that *Thymus transcaspicus* is the dominant species and *Poa bulbosa* and *Ziziphora clinopodioides* are associated species in this habitat. This plant grows with several different types of species. Some of these species are listed in Table 1.

Table1: Some of the Companion species that growing along with *Thymus transcaspicus* in the study areas.

Scientific name	Scientific name
Acer monspessulanum L.	*Hordeum bulbosum* L.
Achillea micrantha Willd	*Hordeum glaucum* Stand.
Adonis flammea Jacq.	*Hulthemia persica* Mich.
Aegilops crassa Boiss.	*Hypericum perforatum* L.
Aegilops cylindrica Host.	*Inula oculus- Christi* L.
Aegilops ovata L.	*Iris songarica* Schrenk.
Agropyron intermedium (Host) P. Beauv	*Iris kopetdaghensis* (Vved) Mathew & Wendelbo
Agropyron trichophorum (Link) Richter.	*Lappula microcarpa* (Ledeb.) Gurke
Allium caspium (Pall.) M.B.	*Lepidium draba* L.
Allium monophyllum Vved.	*Medicago sativa* L.
Alyssum linifolium Steph et Willd.	*Medicago radiata* L.
Arum orientale M.B	*Medicago polymorpha* L.
Asperula arvensis L.	*Melica persica* Kunth subsp. *persica*
Asperula setosa Jaub. et Spah	*Melilotus officinalis* (L.) Lam.
Astragalus brachycalyx Syn.	*Nonea lutea* (Desri) Reichenb.
Astragalus grammocalyx Boiss. et Hoh.	*Onobrychis transcaspica* V. Nikitn
Astragalus microcephalus Maass & Mozaff.	*Onosma bulbotrichum* DC.
Astragalus mollis M.B.	*Onosma koschyi* Boiss.
Astragalus vanilla Boiss.	*Orobanche alba* Stephan
Berberis integerrima Bunge.	*Perovskia abrotanoides* Karel.
Berberis khorasanica Browicz & Zielinski	*Phlomis persica* Boiss.
Boissiera squarrosa (Banks et soland) Nevski	*Plantago lagopus* L.
Bongardia chrysogonum (L.) Boiss.	*Plantago lanceolata* L.
Bromus briziformis Fisch. et C.A.Mey.	*Poa bulbosa* L.
Bromus danthoniae Trin.	*Polygonum aviculare* L.
Bromus tectorum L.	*Potentilla recta* L.
Bromus tomentellus Boiss.	*Phuopsis styloso* (Trin) Hook. F.
Capsella bursa-pastoris (L.) Medicus	*Pyrus boissieriana* Buhse
Carex stenophylla Wahlenb.	*Ranunculus arvensis* L.
Centaurea aucheri (DC.) Wagenitz.	*Rosa beggeriana* Schrenk
Centaurea depressa M.B.	*Rosa canina* L.
Centaurea virgata Lam.	*Rosa lutea* Mill.
Cerasus incana (Pall.) Spachr	*Rubia florida* Boiss.
Cerasus microcarpa (C.A. mey) Boiss	*Rubia tinctorum* L.
Ceratocephallus falcatus (L.) Pers	*Rumex acetosella* L
Consolida regalis S.F.Gray	*Salvia chloroleuca* Rech. F. et. Aell.
Coronila varia L.	*Salvia nemorosa* L.
Cotoneaster multiflora Bge	*Salvia reuterana* Boiss.
Dactylis glomerata L.	*Salvia sclarea* L.
Dianthus orietalis Adams	*Sanguisorba minor* Boiss. et Hausskn.
Dracocephalum kotschyi Boiss.	*Scutellaria orientalis* L.

Echinops ritrodes Bunge.	*Stachys turcomanica* Trautv.
Eminium alberti (Rgl.) Engl	*Stipa barbata* Desf.
Ephedra procera Fisch. & Mey.	*Thalictrum minus* L.
Eremostachys laevigata Bge.	*Thymus kotschyanus* Boiss. et Hohen.
Thalictrum foetidum L.	*Thymus transcaucasicus* Ronniger
Eremurus olgae Regel.	*Trigonella monantha* C.A.Mey.
Euphorbia humilis C.A. Mey. et Ledeb	*Vicia monantha* Retz.
Festuca ovina L.	*Vaillantia hispida* L.
Galium humifusum Bieb.	*Verbascum songaricum* Schrenk ex Fisch.
Galium verum L.	*Veronica biloba* Schreb.
Geum kokanicum Regel et Schmalh.	*Zataria multiflora* Boiss.
Glycyrrhiza glabra L.	*Ziziphora clinopodioides* Lam.
Hedysarum kopetdaghi Boriss.	*Ziziphora tenuior* L.
Heteranthelium piliferum (Banks et Soland.) Hochst.	

3.1 Plant characteristics

In table 2, vegetative characteristics of *Thymus transcaspicus* were shown in the study area. Based on these accomplished studies, this plant is distributed on the northern slopes, calcareous places and altitude of 1200-1900 m. The average canopy cover of *Thymus transcaspicus* was 23.51% across the habitat. Height of individual plants varies from 7 to 25 cm with a crown diameter of 20 to 60 cm. The density of plants in habitat was counted as 43000 per hectare. Product of this plant in areas is 851.96 Kilograms per hectare. Germinating capacity of seeds was 95% in laboratory conditions. Like any other plants, growth and survival of *Thymus transcaspicus*, during the different stages of growth need different amounts of moisture. The root system was in surface soils. *Thymus transcaspicus* have horizontal and vertical roots. The main roots penetrate to a depth of 20 to 30 cm depending on the soil texture and moisture and then spread horizontally.). Distribution of the roots of plants occurs at different soil levels and the form of distribution depends on the type of plant, environmental conditions and type of soil (Moghadam, 2008) [26].

Table 2: The vegetative characteristics of *Thymus transcaspicus* in the study area

Abundance %	Germination %	product per hectare (kg)	Density (per hectare)	canopy average diameter (cm)	Canopy cover (%)	Rooting depth (cm)	Minimum Height (cm)	Maximum Height (cm)	Mean Height (cm)
90.9	95	851.96	43000	35.02	23.51	30	7	25	11.13

3.2 Phenology

The obtained results of phenological observations in the plant habitat shows that *Thymus transcaspicus* depended on the rain condition of the area in that year from late March starts the plant growth and continues until late July. Flowers of this plant appear at the beginning of early May to late June. Seed formation occurs in mid- May and July is seed maturity time. From the beginning of August seeds start to fall and to the late September the plant begins to wilt and the stems are dried and crushed. Due to weather conditions, plant winter dormancy period begins in September and will continue until late March (Table 3).

Table 3: Phenological stages of *Thymus transcaspicus*

Vegetative stages	March		April		May		June		July		August		September		October		November		December		January		February	
Vegetative growth		*	*	*																				
Flowering					*	*	*	*	*	*														
Seed production						*	*	*	*	*	*	*												
Winter dormancy	*												*	*	*	*	*	*	*	*	*	*	*	*

3.3 The physical and chemical results of the soil analysis

The results of physical and chemical analysis of the soil samples collected from the distribution area of *Thymus transcaspicus* have been presented in Table 1. The analysis of the properties of lime, gypsum, clay, silt, sand, organic carbon, pH, EC, N, K, Na, Ca, Mg, Cl, HCO3, SO4 and P were applied. The results indicated that among the soil variables in the studied sites, only measured in 0-30 cm depth of potassium was significantly different ($P<0.05$). From the physical analysis of the soils, it was found in this study that *Thymus transcaspicus* grows on sandy loam soils. Soil texture has a large influence on controlling soil moisture and nutrients available to plants (Jafari *et al.,* 2006) [14]. The minimum and maximum electrical conductivity are 0.97 and 1.03ds/m, respectively, indicating that this plant grows in the non-saline soils. The soil pH values range from 7.79 to 7.85, which are related to alkaline class. Soil pH is a major factor influencing the availability of elements in the soil for plant uptake (Marschner 1995) [23]. Among the effects of pH, the most important is mainly on the solubility of nutrients and their ionic forms (Ronen 2007) [32]. Some nutrients might become unavailable while others might reach high concentrations leading to deficiency or toxicity, respectively, at different levels of pH (Ronen 2007) [32]. In our study, pH range is optimum. Saturation moisture ranges were between 35 and 36(%) in the habitats. The Cation exchange capacity of these soils varies from 11.5-12.5cmol/km. Concentration of CaSO4 varies from 34.5-39.25meq/100gr. The calcium carbonate content of the soils of *Thymus transcaspicus* varies from 25.52- 29.81%. It can be seen that this plant generally prefers calcareous soils.

The nitrogen contents of the soils of *Thymus transcaspicus* varies from 0.082- 0.105% (table1). In general, percentage N contents of mineral soils varies are between 0.02 and 0.5, while the average value is 0.15 (Kacar and Katkat 2010; Bruce and Rayment 1982) [18, 5]. Our results indicated that values are within normal range, but lower than average. The organic carbon of these soils varies from 1.99-2.05%. These soils contain rich in organic carbon. Average P values in the soils were 0.8 (ppm) for area. The average value for soil P is between 0.0006 and 0.0009% (Eskin *et al.* 2013) [9]. The results showed that soil P for locations is low. Average K values were 123-145 ppm in area. Normal values of K in soil lie between 130 and 580 ppm and the average value is 355 ppm (Eskin *et al.* 2013) [9]. Therefore, it can be concluded that K levels in the soils of *Thymus transcaspicus* are lower than the average. The average of soil Na in mmol/lit were measured as 4.75-4.86 (mmol/lit) in the habitats of *Thymus transcaspicus*. These values are lower than normal limits lying around 46 mmol/lit (Eskin *et al.* 2013) [9]. The calcium, magnesium, bicarbonate, chlorine and sulfate contents have been found to be 2.2-2.7, 1.1-1.5, 2.8-3, 1.1-1.3 and 1.15-2 mmol/lit in the soil, respectively. Between morphological parameters, soil and vegetation are closely related. Therefore, any suggestion for reform in the habitat should take into account the soil characteristics. Having the knowledge of soil properties of each species has effective role in suggesting suitable species to the soil conditions in the same areas (Xia *et al.,* 2015; Jafari *et al.,* 2006) [36, 14].

Table 4: The analysis results of soil in the habitats of *thymus transcaspicus*.

Parameters	Key area			
	1	2	3	F
Sand (%)	64.8	67.3	64.3	2.966^{ns}
Silt (%)	23.5	24.5	27.5	2.444^{ns}
Clay (%)	11.7	8.2	8.2	2.516^{ns}
Gravel%	26.41	29.99	28.79	0.059^{ns}
Texture	Sandy loam	Sandy loam	Sandy loam	-
EC (ds/m)	1.03	0.97	1.01	2.949^{ns}
pH	7.83	7.79	7.85	0.627^{ns}
CEC(CMol/kg)	11.8	12.5	11.5	0.699^{NS}
Organic Carbon (%)	2.034	2.05	1.99	1.155^{ns}
Bulk density(gr/cm^3)	1.46	1.45	1.44	0.662^{NS}
Particle density(gr/cm^3)	2.65	2.65	2.65	1.372^{NS}
CaCO3 (%)	26.56	25.52	29.81	0.813^{ns}
CaSO4 (meq/100gr)	39.25	36.08	34.5	1.09^{NS}
N (%)	0.105	0.089	0.082	3.187^{NS}
Saturation moisture (%)	36	35	35	0.963^{NS}
P (ppm)	0.8	0.8	0.8	0.306^{NS}
K (ppm)	145	129	123	4.446^{*}
Na (mmol/lit)	4.82	4.86	4.75	0.663^{ns}
Ca(mmol/lit)	2.5	2.2	2.7	0.520^{NS}
$HCO3^-$(mmol/lit)	3	2.8	2.95	0.978^{NS}
CL(mmol/lit)	1.2	1.1	1.3	1.871^{NS}
Mg(mmol/lit)	1.5	1.1	1.3	0.076^{NS}
SO4(mmol/lit)	1.2	1.15	1.2	0.405^{NS}

4. Conclusion

Thymus transcaspicus is one of the most important medicinal plants had been used in traditional medicine in natural sites of mountainous areas of Iran. Thymus species have stout antibacterial, antifungal, antiviral, anti-parasitic, spasmolytic and antioxidant activities. Results indicated that *T. transcaspicus* generally prefers the climate conditions with low temperature and high rainfall. Soil texture of the region is sandy loam. *T. transcaspicus* grows in the non- saline soils and prefers the calcareous soils. The result showed that distribution pattern of *T. transcaspicus* species is clumped. Hence, we can conclude that at higher altitudes, there are more optimal conditions for this plant domestication and harvest.

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