INTERNATIONAL JOURNAL OF APPLIED AND EXPERIMENTAL BIOLOGY
(ISSN PRINT: 2790-6523; ISSN ONLINE: 2790-6531)
2024, Vol. 3, NO. 1, 31-36.
doi: 10.56612/ijaaeb.v1i1.49
https://eminentscientists.com/

An investigation on plant-soil interactions in some endemic *Centaurea* taxa from Hatay, Turkiye

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Abstract

The aim of the present investigation was to explore the ecological characteristics of some endemic *Centaurea* taxa (*C. arifolia*, *C. foliosa*, *C. antiochia* var. *antiochia*, *C. lycopifolia*, *C. haradjianii*, and *C. ptosimopappa*) distributed in the Hatay province of Turkiye. The genus *Centaurea* occurs widely in Turkiye with high endemism rate. Most of the species belonging to this genus are distributed in the Mediterranean as well as Near East, and a few are found in other continents such as Northern Eurasia, North and East Africa, North America, and Australia. This genus is represented by approximately 220 taxa in Turkiye, of which 133 are endemic. Moreover, it was also aimed to investigate the soil-plant interactions. Our results revealed that the taxa investigated prefer clayey-loamy, nonsaline, and slightly alkaline soils with high lime content and potassium. In all plant organs, the results for root, stem, and leaf parts showed that nitrogen and phosphorus were below the standard values, whereas sodium was over the standard level. In general, potassium values varied significantly among the endemic *Centaurea* taxa, which could have been due to variation in soils of the respective ecological habitats.

SECTION
Plant Biology (PB)

HANDLING EDITOR
İbadullayeva, S.J. (PB)

ARTICLE HISTORY
Received: 4 Aug, 2023
Accepted: 26 Oct, 2023
Published: 01 Jan, 2024

KEYWORDS
Conservation;
Eco-genetical;
Ecology;
Heritage;
Local endemics;
Plant-soil interactions

Introduction

Endemic plant species are potentially threatened as they are only distributed in limited areas. For this reason, information about the distribution of these species is very important both ecologically as well as in conservation biology and biogeography (Burgman et al., 2007; Murray-Smith et al., 2009; Huang et al., 2011; Memariani et al., 2016).

Globally, Turkiye holds an important position with regard to plant genetic resources and genetic diversity. The country serves as a meeting place for the Near East and Mediterranean diversity centers and gene centers (Demir, 2015). The wide variety of geomorphological, topographical and climatic features of Turkiye are mainly responsible for its wide habitat diversity and plant richness. This situation is also a major reason for the high rate of endemism in the country (Ozturk et al., 2011, 2016). The rich diversity of endemics is represented by 3035 endemic taxa making up nearly 31.12 percent of the total flora of Turkiye (Güner et al., 2012; Ozturk and Altay, 2017). Many studies have been undertaken on the floristic aspect during the last few decades, and a list of its endemic plant taxa of Turkiye has been published (Severoğlu et al., 2011; Ozturk et al., 2011, 2012). Some researchers have evaluated the ecological features of some endemic plants in the country (Ozturk et al., 2011; Eskin et al., 2013; Eroğlu et al., 2014; Altay et al., 2013, 2016a, 2016b, 2017).

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TO CITE THIS ARTICLE: Altay, V., Çelik, O., Ozturk, M. (2024). An investigation on plant-soil interactions in some endemic *Centaurea* taxa from Hatay, Turkiye. *International Journal of Applied and Experimental Biology* 3(1): 31-36.

Centaurea is a remarkable genus in Turkiye with high endemism rate including approximately 790 valid species worldwide (Uysal et al., 2022; WFO, 2022). Most of the species belonging to this genus are distributed in the Mediterranean region as well as Near East, and a few are found in Northern Eurasia, North and East Africa, North America, and Australia (Eskin et al., 2013; Eroğlu et al., 2014; Uysal et al., 2022). This genus is represented by 220 taxa in Turkiye, 133 of which are endemic (Uysal et al., 2022).

No detailed studies have been undertaken in the Hatay Province (Türkiye) on the plant-soil interactions of endemic taxa namely: *Centaurea arifolia* Boiss., *C. foliosa* Boiss. & Kotschy, *C. antiochia* Boiss. var. *antiochia*, *C. lycopifolia* Boiss. & Kotschy, *C. haradjianii* Wagenitz, and *C. ptosimopappa* Hayek. The present study was therefore conducted to fill the gap in knowledge on these taxa, and at the same time it provides insights into the plant-soil interactions of these endemic taxa.

Materials and Methods

Study area

It is located in the East Mediterranean, between 35°48’ and 37°00’N latitude and 35°46’ and 36°41’ E longitude. The area experiences a typical Mediterranean climate. The annual average temperature is 18.1 °C and average annual rainfall around 1,078 mm, mostly falling during the winter season. The annual precipitation is minimum during spring, but increases in winter. The mean minimum and maximum temperatures lie around 7 ^{o}C and 32 °C during January and July, respectively (Altay et al., 2016a).

The study material included six endemic *Centaurea* taxa, viz. *C. arifolia*, *C. foliosa*, *C. antiochia* var. *antiochia*, *C. lycopifolia*, *C. haradjianii*, and *C. Ptosimopappa,* all collected from different localities in the Hatay Province, Turkiye. The information on the collection sites is given below:

C. arifolia: from Hatay Mustafa Kemal University campus - near *Pinus* forest; around Kisecik village; Karaali municipality; between Tahtaköprü-Kömürçukuru villages.

C. foliosa: from Karaali municipality - near the creek; Kızıldağ- near the old mine quarry.

C. antiochia* var. *antiochia: around Hatay Mustafa Kemal University campus - near *Pinus* forest; Kırıkhan district - around Eşmişek village; around Ballıözü village; between Çevlik - Kale village; around Karaali municipality - near the creek; around Sinanlı village - near *Pinus* forest; between Tahtaköprü-Kömürçukuru villages; around Çerçikaya village; Arsuz - around Hoca Ahmetli village.

C. lycopifolia: Kırıkhan district - around Eşmişek and Atik villages; between Soğukoluk village - Karlıtepe; Dörtyol district - around Koz plateau.

C. haradjianii: Hassa district - from Akbez (near the olive groves).

***C. ptosimopappa*:** between Kömürçukuru - Çerçikaya villages; Arsuz - near Hoca Ahmetli village; around Soğukoluk village; and Karaali municipality - near the creek.

Plant and soil analyses

Plant parts (root, stem and leaf) samples of the endemic *Centaurea* taxa and soil samples from their habitats were collected; oven-dried at 80 °C for 48 h, milled in a micro-hammer cutter and passed through a 1.5-mm sieve. The samples (each 0.5 g) were weighed, transferred into each of Teflon vessels and 8 mL of 65% HNO_3 were added to each vessel. The samples were mineralized in a microwave oven at 145 ^{o}C for 5 min., at 165 ^{o}C for 5 min. and at 175 ^{o}C for 20 min. The samples were filtered using Whatman filters, and the volume was made up to 50 mL with ultrapure water. Standard solutions were prepared by using multi-element stock solutions-1000 mg/L (Merck) (Altay et al., 2017).

Potassium and sodium were measured by Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES); nitrogen and phosphorus were appraised by the methods outlined in detail in Ozturk et al. (2016a, 1997).

Soil samples (each 500 mg) were taken from a depth of 30 cm from all localities. pH was determined by the Hanna 211 pH meter; total soluble salts (TSS) and conductivity values were measured by the Hanna E.C. 211 conductivity meter; soil texture determined with the Bouyoucos Hydrometer; $CaCO_3$ by the Scheibler calcimeter; N analyzed by the modified Kjeldahl method, and phosphorus was determined by using the Olsen method. All measurements were taken according to the methods outlined in detail in Ozturk et al. (1997).

Results and Discussion

The data for physico-chemical analysis of the soils of endemic *Centaurea* taxa are presented in **Table 1**. All endemic *Centaurea* taxa grow in clayey loam soils.

The soil results of *Centaurea arifolia* reveal that it generally prefers clayey soils with a soil pH of 7.52-7.85 and EC 51 to 111 (µS/cm); values for calcium carbonate lie between 10.5 to 18 (%), TSS between 0.120 to 0.132 (%), nitrogen between 0.052 to 0.087 (%), phosphorus between 5.28 to 14.10 (mg kg^{-1}), sodium 32 to 36.50 (mg kg^{-1}) and potassium 32 to 152 (mg kg^{-1}) (**Table 1**).

The soils of *Centaurea antiochia* var*. antiochia* show that these plants generally prefer clayey soils with a soil pH of 7.50-8.00 and EC 32 to 155 (µS/cm). The values for calcium carbonate lie between 11 to 16 (%), TSS between 0.110 to 0.142 (%), nitrogen between 0.010 to 0.062 (%), phosphorus between 3.05 to 34 (mg kg^{-1}), sodium 18.5 to 73.5 (mg kg^{-1}) and potassium 20.5 to 203 (mg kg^{-1}) (**Table 1**).

Table 1. Physical and chemical analyses of the soils from the study sites

	N (%)		Na^+ (mg kg^{-1})		K^+ (mg kg^{-1})		P (mg kg^{-1})	
	min-max	**average**	**min-max**	**average**	**min-max**	**average**	**min-max**	**average**
C. arifolia	0.052-0.087	0,070	32.00-36.50	34.25	32-152	92.0	5.28-14.10	9.69
C. antiochia var. *antiochia*	0.010-0.062	0.036	18.50-73.50	46.00	20.5-203	112.0	3.05-34.00	18.52
C. foliosa	0.008-0.015	0.012	23.00-35.50	29.25	79-202	141.0	7.68-8.98	8.33
C. haradjianii	0.077	0.077	27.50	27.50	110.0	110.0	4.55	4.55
C. lycopifolia	0.008-0.087	0.048	22.50-37.50	30.00	24-103	63.5	6.83-27.10	16.96
C. ptosimopappa	0.002-0.007	0.004	29.50-64.00	46.75	101-460	280.0	7.27-12.05	9.66
	pH		**EC (µS/cm)**		**$CaCO_3$ (%)**		**TSS (%)**	
	min-max	**average**	**min-max**	**average**	**min-max**	**average**	**min-max**	**average**
C. arifolia	7.52-7.85	7.68	51-111	81.0	10.50-18.00	14.25	0.120-0.132	0.126
C. antiochia var. *antiochia*	7.50-8.00	7.75	32-155	93.5	11.00-16.00	13.50	0.110-0.142	0.126
C. foliosa	7.50-7.65	7.57	80-230	155.0	9.70-11.00	10.35	0.130-0.150	0.140
C. haradjianii	7.80	7.80	99	99.0	14.50	14.50	0.100	0.100
C. lycopifolia	7.55-7.85	7.70	53-199	126.0	11.00-16.00	13.50	0.095-0.143	0.119
C. ptosimopappa	7.35-7.85	7.60	46-104	75.0	9.50-14.00	11.75	0.124-0.134	0.129

Centaurea foliosa generally prefers clayey soils with a soil pH of 7.50-7.65 and EC 80 to 230 (µS/cm). The values for calcium carbonate, TSS, nitrogen, phosphorus, sodium and potassium lie between 9.7% to 11%, 0.130% to 0.150%, 0.008% to 0.015%, 7.68 to 8.98 (mg kg^{-1}), 23 to 35.5 (mg kg^{-1}) and 79 to 202 (mg kg^{-1}), respectively (**Table 1**).

The soil analysis of *Centaurea haradjianii* shows that it prefers clayey soils with a soil pH of 7.80 and EC 99 (µS/cm). The values for calcium carbonate are around 14.5 (%), TSS 0.100 (%), nitrogen 0.077 (%), phosphorus 4.55 (mg kg^{-1}), sodium 27.5 (mg kg^{-1}) and potassium 110 (mg kg^{-1}) (**Table 1**).

The soils of *Centaurea lycopifolia* reveal that it prefers clayey soils with a soil pH of 7.55-7.85 and EC 53 to 199 (µS/cm). The values for calcium carbonate lie between 11 to 16 (%), TSS between 0.095 to 0.143 (%), nitrogen between 0.008 to 0.087 (%), phosphorus between 6.83 to 27.10 (mg kg^{-1}), sodium 22.50 to 37.50 (mg kg^{-1}) and potassium 24 to 103 (mg kg^{-1}) (**Table 1**).

The results for soil analysis of *Centaurea ptosimopappa* show that it generally prefers clayey soils with a soil pH of 7.35-7.85 and EC 46 to 104 (µS/cm). The values for calcium carbonate lie between 9.5 to 14 (%), TSS between 0.124 to 0.134 (%), nitrogen between 0.002 to 0.007 (%), phosphorus between 7.27 to 12.05 (mg kg^{-1}), sodium 29.5 to 64.0 (mg kg^{-1}) and potassium 101 to 460 (mg kg^{-1}) (**Table 1**).

The data show that these endemic taxa prefer clayey-loamy, non-saline, slightly alkaline soils with high lime content. Potassium is at sufficient levels in the soils. Only *Centaurea ptosimopappa* grows in nitrogen-poor soils, while other endemic species grow in nitrogen-sufficient-level soils. All endemic species except *Centaurea haradjianii* prefer phosphorus rich soils (Tüzüner 1990; Ozturk et al. 1997; Altay et al., 2017).

The root, stem and leaves of *Centaurea arifolia* were collected during the flowering season (**Table 2**). On dry weight basis, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values ranged between 0.065-0.147, 118-376, 1960-5710 and 400-2220 in roots; 0.006-0.062, 0-133, 640-9500 and 50-1565 in stems; 0.146-0.543, 0-316.5, 6355-25250 and 395-1690 in leaves, respectively.

The analysis on dry weight basis of the plant parts shows that in *Centaurea antiochia* var. *antiochia*, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values varied between 0.031-0.065, 0-435.5, 1568.5-9475 and 900-5650, respectively, in roots; 0.010-0.079, 0-246, 975-10225 and 775-3545, respectively, in stems; 0.094-0.501, 0-407.5, 4770-12450 and 635-17205, respectively, in leaves (**Table 2**).

Table 2. Chemical analysis of the plants (leaf, stem and root) of endemic *Centaurea* taxa collected from different habitats

Taxa	Inorganic elements	Root		Stem		Leaf	
		min-max	average	min-max	average	min-max	average
C. arifolia	N (%)	0.065-0.147	0.106	0.006-0.062	0.034	0.146-0.543	0.345
	P (mg/kg)	118-376	247	0-133	66.50	0-316.5	158.25
	K (mg/kg)	1960-5710	3835	640-9500	5070	6355-25250	15803
	Na (mg/kg)	400-2220	1310	50-1565	807.5	395-1690	1042.5
C. antiochia var. *antiochia*	N (%)	0.031-0.065	0.048	0.010-0.079	0.045	0.094-0.501	0.298
	P (mg/kg)	0-435.5	217.75	0-246	123	0-407.5	203.75
	K (mg/kg)	1568.5-9475	5522	975-10225	5600	4770-12450	8610
	Na (mg/kg)	900-5650	3275	775-3545	2160	635-17205	8920
C. foliosa	N (%)	0.096-0.117	0.107	0.123	0.123	0.209-0.270	0.240
	P (mg/kg)	254.5-527.5	391	0	0	0-338	169
	K (mg/kg)	2195-5400	3798	4265	4265	4585-5145	4865
	Na (mg/kg)	2195-5355	3775	4265	4265	1120-2200	1660
C. haradjianii	N (%)	0.069	0.069	0.061	0.061	0.244	0.244
	P (mg/kg)	395	395	256	256	86.5	86.5
	K (mg/kg)	4910	4910	4950	4950	9700	9700
	Na (mg/kg)	450	450	295	295	405	405
C. lycopifolia	N (%)	0.065-0.152	0.109	0.029-0.084	0.057	0.128-0.365	0.247
	P (mg/kg)	157-1114	635.50	0-1242.5	621.25	0-141	70.50
	K (mg/kg)	2295-6600	4448	5100-9778.5	7439	5060-10405	7733
	Na (mg/kg)	2030-3210	2620	1945-6065	4005	2715-4310	3512.5
C. ptosimopappa	N (%)	0.050-0.113	0.082	0.036-0.054	0.045	0.059-0.230	0.145
	P (mg/kg)	0-322	161	0-171	85.50	0	0
	K (mg/kg)	615-965	790	155-520	337.5	4345-11267	7806
	Na (mg/kg)	640-6150	3395	119-520	319.5	505-2730	1617.5

The results for elemental analysis of plant part on dry weight basis show that in *Centaurea foliosa*, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values varied between 0.096-0.117, 254.5-527.5, 2195-5400 and 2195-5355, respectively, in roots; 0.123, 0, 4265 and 4265, respectively, in stems; 0.209-0.270, 0-338, 4585-5145 and 1120-2200, respectively, in leaves (**Table 2**).

In *Centaurea haradjianii*, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values in the root, stem and leaves were recorded as follows: 0.069, 395, 4910 and 450, respectively in the roots; 0.061, 256, 4950 and 295 in the stems; 0.244, 86.5, 9700 and 405 in the leaves (**Table 2**).

The root, stem and leaf analysis results on dry weight basis show that in *Centaurea lycopifolia*, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values varied between 0.065-0.152, 157-1114, 2295-6600 and 2030-3210, respectively, in roots; 0.029-0.084, 0-1242.5, 5100-9778.5 and 1945-6065, respectively, in stems; 0.128-0.365, 0-141, 5060-10405 and 2715-4310, respectively, in leaves (**Table 2**).

The elemental analysis of different plant parts on dry weight basis of root, stem and leaves shows that in *Centaurea ptosimopappa*, nitrogen (%), phosphorus (mg kg^{-1}), potassium (mg kg^{-1}) and sodium (mg kg^{-1}) values varied between 0.050-0.113, 0-322, 615-965 and 640-6150, respectively, in roots; 0.036-0.054, 0-171, 155-520 and 119-520, respectively, in stems; 0.059-0.230, 0, 4345-11267 and 505-2730, respectively, in leaves (**Table 2**).

According to Epstein (1999) and Altay et al. (2017), N, P, K and Na standard values are generally reported as 1.5%, 2,000 (mg kg^{-1}), 10,000 (mg kg^{-1}), and 10 (mg kg^{-1}), respectively in plants. In our results, nitrogen and phosphorus were below the standard values in all plant organs and sodium was over the normal value. However, the potassium values varied significantly with different endemic *Centaurea* taxa. In *Centaurea arifolia* and *C. antiochia* var. *antiochia*, potassium values were over the normal level in all plant parts. In *Centaurea lycopifolia* and *C. ptosimopappa*, potassium values were below the normal levels in roots and stems, and over normal in leaves. In *Centaurea haradjianii* and *C. foliosa*, potassium was below the normal values in all plant organs.

Endemic plants are an important part of plant diversity which need an immediate intervention in order to ascertain their long-term survival (Ozturk et al., 2011; Altay et al., 2017). The strategies for plant conservation include *in situ* approaches such as gene sanctuaries, national parks, biosphere reserves and establishment of protected areas. The *ex situ* approaches include *in vitro* conservation, field gene banks and seed conservation gene banks. Application of these conservation approaches will help save plant taxa facing multiple threats. These will pave a way for their sustainable use as beneficial resources for humans and at the same time widen our knowledge related to these species (Ozturk et al., 2011; Altay et al., 2017).

Conclusion

The endemic taxa *Centaurea arifolia*, *C. foliosa*, *C. antiochia* var. *antiochia*, *C. lycopifolia*, *C. haradjianii*, and *C. ptosimopappa* require a high priority. These should be monitored carefully and regularly in order to preserve this genetic diversity. These species are much more vulnerable to extinction than other species. In addition, ecological studies on such endangered endemic taxa should be supported with comprehensive physiological and molecular studies to promote the understanding of endangered endemic plants in general (Ozturk et al., 2011; Eroğlu et al., 2014; Altay et al., 2013; 2016a, b, 2017).

Author(s), Editor(s) and Publisher's declarations

Acknowledgement
This study was supported by the Scientific Research Commission of Mustafa Kemal University.

Conflict of interest
The authors declare no conflict of interest.

Source of funding
This study was supported by the Scientific Research Commission of Mustafa Kemal University (Project No: 12140).

Contribution of authors
Conceptualization and designing the study: VA and OÇ. Conduction of experiments: OÇ.
Data collection, visualization and interpretation: OÇ and VA. Proof reading and approval of the final version: VA and MO.

Ethical approval
This study does not involve human/animal subjects, and thus no ethical approval is needed.

Handling of bio-hazardous materials
The authors certify that all experimental materials were handled with care during collection and experimental procedures. After completion of experiment, all materials were properly discarded to minimize any types of bio-contamination(s).

Availability of primary data and materials
As per editorial policy, experimental materials, primary data, or software codes are not submitted to the publisher. These are available with the corresponding author and/or with other author(s) as declared by the corresponding author of this manuscript.

Authors' consent
All authors contributed in designing and writing the entire review article. All contributors have critically read this manuscript and agreed for publishing in IJAaEB.

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