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Determination of soil nutrient status in *Vuralia turcica* populations growing at different locations in the Central Anatolia Region of Turkey

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Abstract: This study is an overview of the importance of soil nutrients for the maintenance of *Vuralia turcica*, which is an endemic in Turkey due to its natural habitats. Electrical conductivity, pH, and mineral element content (macroelements: nitrogen, phosphorus, potassium, calcium, magnesium, and sodium, and microelements: boron, cadmium, copper, iron, manganese, nickel, lead, and zinc) were analyzed in 21 soil samples taken at 30–60 m depth at 21 points from 8 different locations where *V. turcica* was growing to determine nutrient content, which is important for soil fertility and controls the crop yield. According to pH analysis, all samples were strongly alkaline (pH 8.62 to 9.30). Only one sample taken from the Kırca region was saline/alkaline and other samples were saltless. All samples were not toxic in reference to Cd level and were rich in terms of Na, K, Mg, and Ca, whereas Ni and P content were lower than the recommended amount in all samples tested. B, Cd, Cu, and Fe contents were sufficient according to ideal soil nutrient content level in all samples. N level was sufficient in all except for 3 soil samples. All tested soil samples were considered poor in Zn content, which varied from 0.19 to 1.83.

Key words: Electrical conductivity, mineral element, pH, soil, *Thermopsis turcica*, Turkey, *Vuralia turcica*

1. Introduction

Vuralia turcica (Uysal et al., 2014) is a member of the subfamily Papilionoideae of the Fabaceae, and it was known by its previous name *Thermopsis turcica* Kit Tan, Vural & Küçüködük (Tan et al., 1983; Yıldız et al., 2017). This plant species is considered the only species belonging to the genus *Vuralia* and is a Turkish endemic species. *V. turcica* is a hermaphrodite plant. The flowering period of this plant is summertime (May to June). The main feature of *V. turcica* is to have a gynoecium with 2–4 fully developed carpels (Tan et al., 1983; Özdemir et al., 2008; Vural, 2009). An action plan for conservation of *T. turcica*, named 'The Queen of the family of Fabaceae: Eber's Yellow-Piyan (*Thermopsis turcica*)', was published by the General Directorate of Nature Conservation and National Parks under the Ministry of Forestry and Water Affairs of the Republic of Turkey in 2014. In this action plan, measures are determined for the conservation of this species in its natural habitat. *V. turcica* grows naturally in a very narrow range around lakes Eber and Akşehir in western Anatolia, Turkey (Tekdal and Cetiner, 2014). These lakes are tectonic lakes and are located in a region with a semiarid continental climate (Aşçı et al., 2015). The natural populations of *V. turcica* are in danger of extinction due to the careless usage of agricultural areas, destruction of natural habitats, and continuous removal of the rhizomes from nature, since local people think that this unusual species is a weed. It has a long rhizome (Figure 1) that grows horizontally underground, permitting the parent plant to propagate asexually.

The soil consists of organic debris and humus, water, air, mineral matter, and living organisms such as bacteria, protists, and algae (Moor et al., 2001). It is essential to determine the nutrient status of soils, in order to recommend appropriate nutrient supply from external sources for research into plant physiology and its application in agricultural experiments (Sahrawat, 2016), as well as for identification of levels of heavy metals toxic to plants (Falciani et al., 2000). The typical range of macro- and microelements in different soils is summarized in Table 1.

Crop production and plant growth can easily be affected by various parameters such as soil moisture; the presence of weeds, pests, or diseases in the habitat; and climatic change; furthermore, the results of a single soil nutrient analysis do not guarantee that the levels of

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Figure 1. Rhizomes of *V. turcica* with adventitious roots planted at Nezahat Gökyiğit Botanical Garden in 2016.

measured nutrients will be constant during the growth period (Dahnke and Olson, 1990; Marschner, 2012; Sahrawat, 2016). The analysis of soil status is especially useful in the assessment of nutrient uptake status, which is essential for in vivo conservation and soil mineral management on the application of fertilizer. Soil fertility is critical for crop growth and is assessed in terms of different parameters including soil nutrient availability (Stockdale et al., 2002).

There is currently no detailed literature available regarding mineral element content of the soil in the fields in which *V. turcica* grows. Thus, analyzing this soil is necessary in order to understand the growth parameters and mineral tolerance of *V. turcica*. Soil elemental analysis can be realized by inductively coupled plasma optical emission spectrometry (ICP-OES), which is a technique widely used to detect trace amounts of heavy metals and nutrients. In the present study, soils were collected from different points in the natural habitat of *V. turcica* for the first time and were evaluated for their mineral element content. Since *V. turcica* is seriously threatened with extinction, the most worrying situation concerning the conservation of this plant species is that its optimal developmental demand has not been elucidated. In this regard, determination of the mineral nutrient requirement of this unusual plant species, which is an important genetic resource, would be significant when developing a strategy for the protection of the plant. From this point of view, the main purpose of the present study was to determine the mineral content of the soils developed by *V. turcica.*

2. Materials and methods

2.1. Collection of soil samples from various habitats of V. turcica and plant parts of *V. turcica*

Soil samples were collected from different habitats (Figures 2 and 3) of *V. turcica*, during its flowering season, between April and June 2015 by the associates of Nezahat Gökyiğit Botanical Garden, and evaluated. Cenkci et al. (2007) reported that *V. turcica* has an extent of occurrence (EOO) of c. 40 km^2 as a result of intensive agricultural purposes such as the use of wetlands as agricultural land and groundwater abstraction for irrigation. Since *V. turcica* has a small EOO, this species has been categorized as Critically Endangered (CR) in the *Red Data Books* of Turkish plants (criterion B1ab (i, ii, iii)) (Ekim et al., 2000; Özhayat et al., 2005; IUCN, 2014; Kavak, 2014). The difference in the spread of the plant based on location was stated in the species protection action plan published by the General Directorate of Nature Conservation and National Parks under the Ministry of Forestry and Water Affairs of the Republic of Turkey. Due to lack of quality plant's habitat, small EOO, and limited numbers of individuals within rare populations, soil samples could not be collected in an equal number from each location. Soil samples in this study were collected from 8 different locations in Konya Province in Turkey with a soil stem auger at 30–60 cm depth, yielding a total of 21 samples. The coordinates of each sample collected were determined by a global positioning system (GPS; Magellan eXplorist 310). Each sample was labeled and stored in a sample container. Details of the locations from which soil samples were obtained are given in Table 2. Although the present study focused on analyzing the content of nutrients in soils more than that in plants, flowers and leaves of *V. turcica* were taken randomly from the 8 different locations (one sample from each location) with determined coordinates, so as not to harm the local population during the pollination period of *V. turcica*. The plant materials were dried at 80 °C for 2 days and preserved at Sabancı University, İstanbul, Turkey.

Table 1. Critical level of mineral elements (in mg kg^{-1} air dry soil) in the soil and evaluation of pH and EC (dS/m) level of the soils.

Soil content	Mean value/evaluation	References
Macronutrients (mg kg^{-1})		(Andersen, 2007)
Na	20–70	
Mg	60–480	
Ca	600–4000	
K	120–200	
N	1000–2000	
P	10.5–16	
Micronutrients (mg kg^{-1})		(Lindsay and Norvell, 1978; Ülgen and Yurtsever, 1995; Saraçoğlu et al., 2014)
Cd	0.1–1	
Cu	0.2–20	
Zn	0.5–50	
Fe	2.5–4.5	
Mn	4–170	
B	0.5–2.0	
Ni	2–50	
pH		(Ülgen and Yurtsever 1995; Özdemir and Kahraman 2015)
<4.5	Strongly acidic	
4.5–5.5	Moderately acidic	
5.5–6.5	Less acidic	
6.5–7.5	Neutral	
7.5–8.5	Less alkaline	
>8.5	Strongly alkaline	
EC (dS/m)		(Richards 1954; Özdemir and Kahraman 2015)
0–4	Saltless	
4–8	Less salty	
8–15	Moderately salty	
>15	Strongly salty	

2.2. Soil analysis

Collected soil samples were air dried for a couple of days and then were separated out through a 2-mm mesh for analysis. The analysis parameters used were hydrogen potential (pH), electrical conductivity (EC), and mineral element concentration of the soils.

2.3. Analysis of pH and electrical conductivity of collected soils

Soil pH was analyzed according to a procedure published by Jackson (1959) in the supernatant after extraction of moist soil samples using a water:soil ratio of 2.5:1. The pH of each sample was determined by a pH meter (Hanna instruments-HI 2211) with a glass electrode. The electrical conductivity (EC) of each soil sample was determined according to Richards (1954) using an electrical conductivity (EC) meter (WTW series-inoLab-Cond-720) in a 5:1 distilled water:soil dilution.

2.4. Mineral element analysis of the collected soils and plant parts

Microelement content (B, Cd, Cu, Fe, Mn, Ni, and Zn) of air-dried soil samples was analyzed according to a procedure published by Lindsay and Norvell (1978), whereas macroelements (Ca, K, Mg, and Na) of the samples were measured according to Olsen et al. (1954). Mineral concentrations of samples were measured by inductively coupled plasma optical emission spectrometry (ICP-OES) (Vista-Pro Axial, Varian Pty Ltd, Mulgrave, Australia) and were analyzed at ppm level. These measurements were checked with certified standard reference materials obtained from the National Institute of Standards and Technology (NIST; Gaithersburg, MD, USA). In addition, P was measured according to the method described in Tüzüner (1990), whereas N was analyzed according to TS 8337 ISO 11261 in the Research and Development

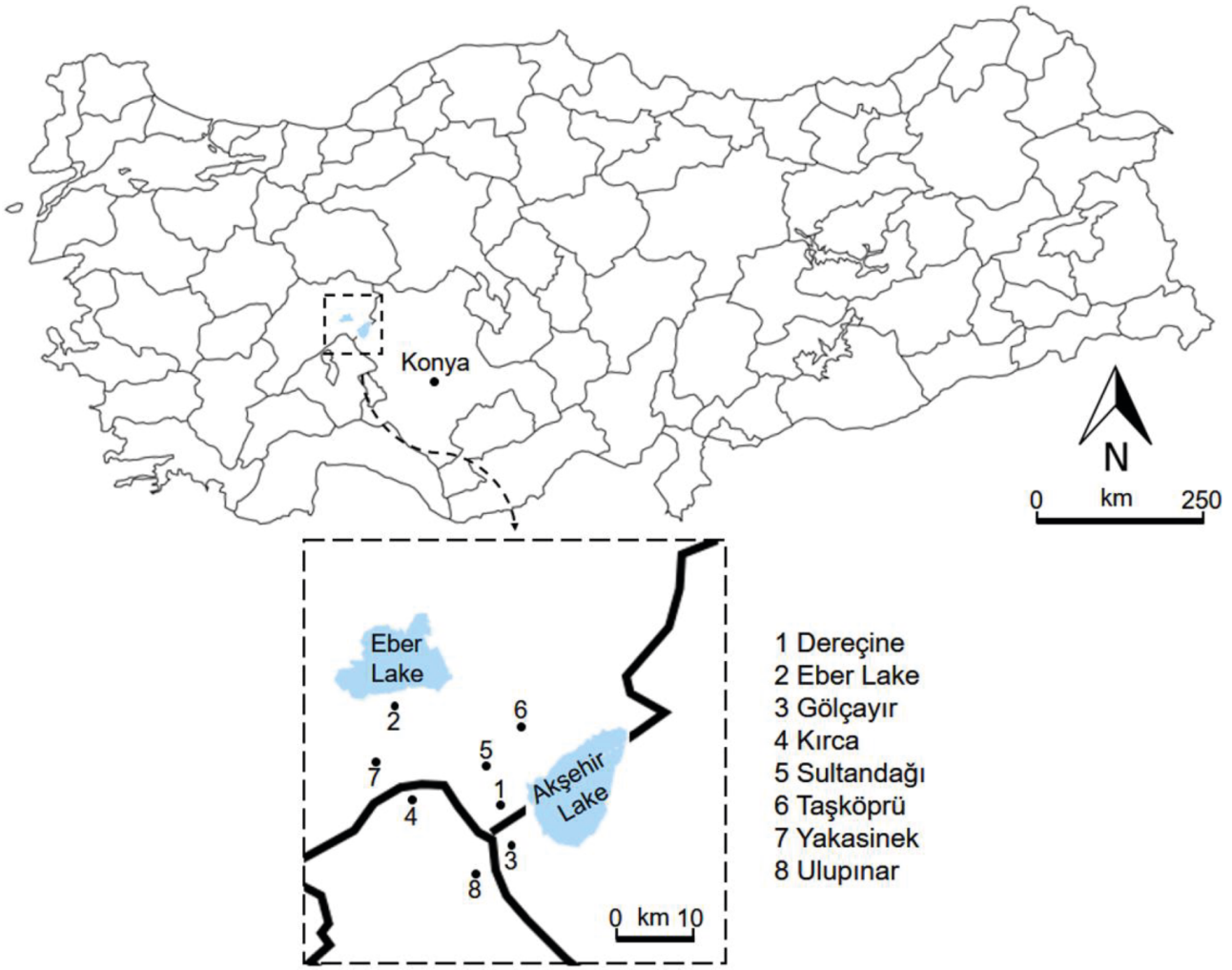

Figure 2. Map of Turkey showing sampling points.

Laboratory of İstanbul Tree Landscape, Education Services and Zoo Garden Management Industry and Trade Inc. (http://agac.istanbul/ar-ge/ar-ge-laboratuvari/toprak-analizi.aspx). Mineral content of the collected plant parts (flowers and leaves) was analyzed according to Mengutay et al. (2013) following drying.

2.5. Calculation of the mineral content

Concentrations of the elements were calculated by multiplying the values obtained from the ICP analysis by the dilution factor.

3. Results and discussion

Soil sampling is the first and most critical stage of soil analysis (Carter and Gregorich, 2008). In the present study, due to the limitation of individuals in a small-sized population, samples were collected separately under appropriate conditions and were air dried as soon as possible for further analysis. For many plants, soil for efficient growth and development requires a pH value of 5.5–6.5 and low salinity shown by 1.5–3.5 dS/m electrical conductivity (EC) (Table 1). In the present study, the pH and electrical conductivity of the soil samples were analyzed and are reported in Table 3. These results showed that all soil samples collected from different points were strongly alkaline as the pH range of tested samples was from 8.62 to 9.16 (Table 3). pH value is crucial for biological activity, nutrient uptake, and soil structure. The factors like removing bases by various causes such as root and microorganisms' organic acid secretion and leaching from solution make most of the world's soils highly substantial to acidic (Foth and Ellis, 1996). Two soil samples, sample 5 and sample 15, had high EC, 2.8 and 4.7 dS/m, respectively (Table 3). As stated in Özdemir and Kahraman (2015), if the pH of the soil is higher than 8.5 and the EC value is also greater than 4, this soil is classified as saline/alkaline, whereas if the pH is higher than 8.5 but the EC value is lower than 4, this soil is only alkaline. According to the results of pH and EC analysis in this study, sample 15 is

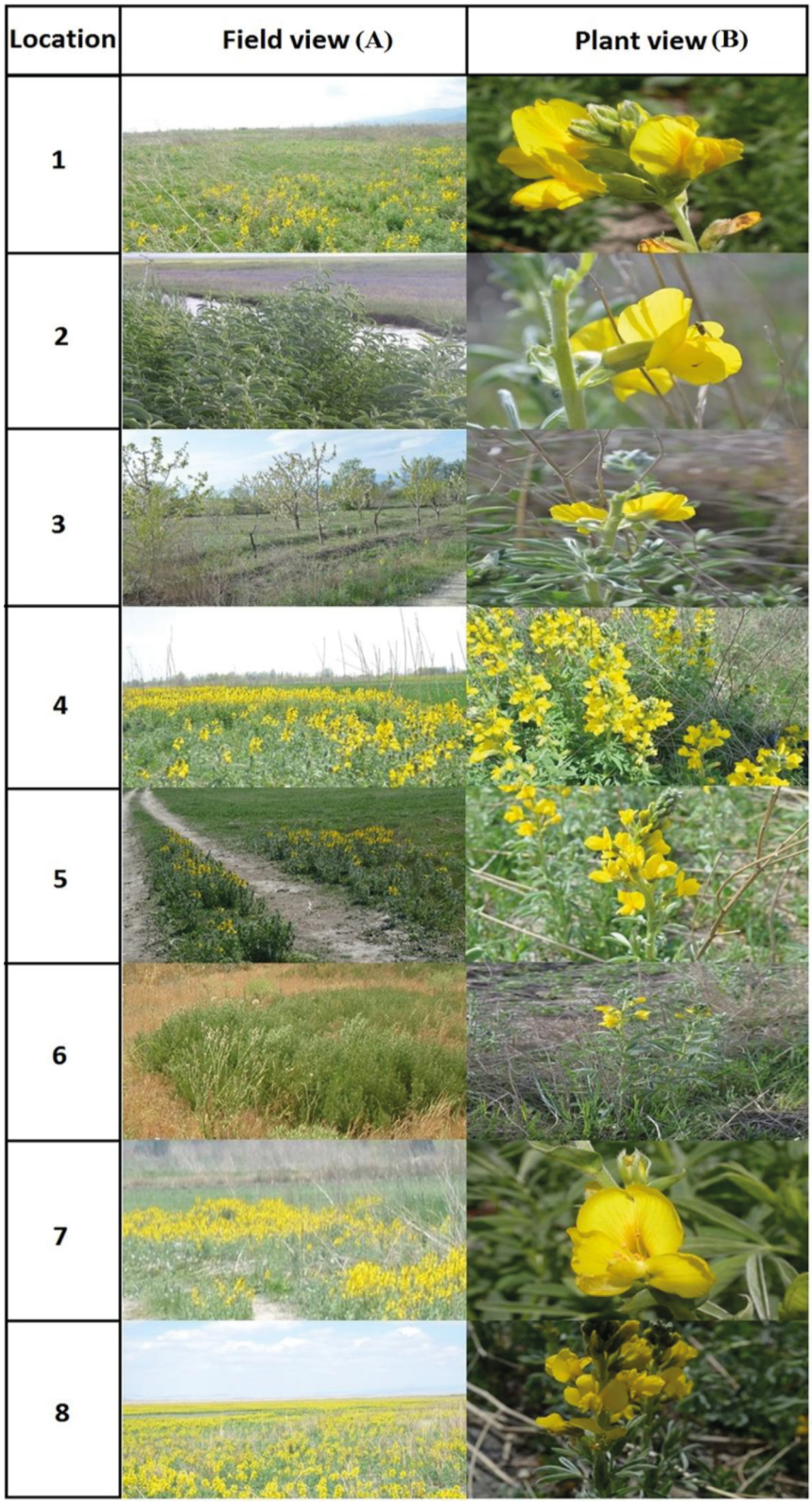

Figure 3. General views of each location where plants were collected (A) and close-up image of plants in each location during pollination period (B).

Table 2. Properties of areas where soils were collected.

Number	Location	X (North)	Y (East)	Height (m)	Field	Depth (cm)
1	1	35°28′24.46″	42°63′97.21″	687	Dereçine	30–60
2	1	35°28′27.3″	42°62′92.5″	1186	Dereçine	30–60
3	1	35°31′132.01″	42°62′607.54″	674	Dereçine	30–60
4	1	35°38′05.43″	42°62′349.22″	953	Dereçine	30–60
5	1	38°36′703″	31°09′0.72″	634	Dereçine	30–60
6	2	33°89′45.9″	42°75′39.2″	1011	Eber lake	30–60
7	2	38°31′47.3″	31°17′48″	955	Eber Lake	30–60
8	2	38°36′703″	31°07′11″	711	Eber Lake	30–60
9	3	38°27′20.5″	31°21′10.9″	692	Gölçayır	30–60
10	3	38°27′37.5″	31°21′15.6″	951	Gölçayır	30–60
11	3	38°28′04.1″	31°21′08″	946	Gölçayır	30–60
12	3	38°29′57.5″	31°19′13.3″	950	Gölçayır	30–60
13	4	35°18′40.603″	42°65′879.063″	953	Kırca	30–60
14	4	35°18′41.7″	42°65′32.8″	1083	Kırca	30–60
15	4	38°31′47.3″	31°17′48″	948	Kırca	30–60
16	5	35°14′46.17″	42°65′57.8″	1027	Sultandağı	30–60
17	6	35°10′42.581″	42°66′841.421″	981	Taşköprü	30–60
18	7	35°13′83.7″	42°67′92.3″	1057	Yakasinek	30–60
19	8	35°65′74.15″	42°55′684.08″	962	Ulupınar	30–60
20	8	35°65′97.31″	42°55′95.21″	953	Ulupınar	30–60
21	8	35°67′38.2″	42°55′77.9″	1109	Ulupınar	30–60

Table 3. Soil pH and salinity (EC) level.

Depth (cm)	Sample	Location	pH	EC (dS/m)
30–60	1	1	8.87	0.1
30–60	2	1	8.62	0.3
30–60	3	1	8.68	0.5
30–60	4	1	8.82	0.8
30–60	5	1	8.86	2.8*
30–60	6	2	9.16	0.4
30–60	7	2	8.97	0.1
30–60	8	2	8.77	0.4
30–60	9	3	8.87	0.5
30–60	10	3	8.72	0.5
30–60	11	3	8.75	0.4
30–60	12	3	9.08	0.2
30–60	13	4	8.80	0.2
30–60	14	4	8.74	0.2
30–60	15	4	9.03	4.7*
30–60	16	5	8.90	0.8
30–60	17	6	8.88	0.3
30–60	18	7	9.30	0.9
30–60	19	8	9.02	0.2
30–60	20	8	9.12	0.1
30–60	21	8	8.86	0.6

*The highest EC value

a saline/alkaline soil, whereas all the other soil samples including sample 5 were alkaline but not saline (Table 3).

The concentrations of the mineral macro- and micronutrients measured in the different soils are summarized in Table 4. ICP-OES is the most popular instrument to quantify macro- and micronutrients (Carter and Gregorich, 2008) and, in the present study, ICP-OES was used to measure nutrient content of collected soils.

Soil pH is critical for various events including iron formation in the soil. Iron (Fe) occurs in two forms in soils: (i) ferric-Fe (III) and (ii) ferrous-Fe (II). Soil pH, along with the aeration condition of the soil and availability of bicarbonate, plays a major role in determining which form of iron predominates in the soil (Black, 1993; Sahrawat, 2016). Iron deficiency is mostly observed in high pH soils (Thangasamy, 2015). If the soil pH is in the alkaline range (generally pH > 8.0), Fe, Zn, and Mn are available in the sufficiency ratio (Sahrawat, 2016). Zn concentration was very low in samples 1, 2, 3, 5, 6, 7, 8, 12, 14, 15, 16, 18, and 21, whereas samples 4, 9, 10, 11, 13, 17, 19, and 20 had sufficient Zn (Table 4) according to the ideal soil nutrient levels given in Table 1. Zn concentration of these soils varied from 0.19 to 1.83 mg kg^{-1}. Mn level was low in samples 5, 8, 17, and 18 compared to the ideal Mn level indicated in Table 1, but Mn concentration in others except these samples had an ideal level. Mn content in soils ranged between 1 and 15 mg kg^{-1}. The observed levels of Fe in all samples tested were within normal ranges for healthy plant growth according to Table 1, varying from 7 to 33 mg kg^{-1}. Cd is typically found in soil in a concentration range of 0.07–1.1 mg kg^{-1} (Ashraf et al., 2016). High levels of Pb and Cd can affect plant growth, photosynthesis rate, mineral nutrient uptake, and different types of biochemical and physiological processes (Khan et al., 2013; Ashraf et al., 2016). The concentration of Cd (Table 4) was very low in all soil samples tested. Hence, none of the samples were toxic with regard to their level of Cd. As reported in previous studies, application of heavy metals such as Cd and Pb to the plant growth medium tends to reduce the bio-absorption of Mg, Ca, and K (Ashraf et al., 2016). All the samples tested were very rich in terms of Ca, Mg, and Na, ranging from 2352 to 7090, 278 to 2565, and 25 to 4031

Table 4. The mineral analysis results for soil samples collected from various areas in the field of *V. turcica*.

Depth (cm)	Sample	B	Cd	Cu	Fe	Mn	Ni	Zn	Ca	K	Mg	Na	N	P
		(mg kg^{-1})												(kg ha^{-1})
30–60	1	0.58	0.02	2.17	11	4	0.33	0.63	4170	168	468	34	1260	0.38
30–60	2	0.09	0.01	3	12	7	0.31	0.29	3736	160	710	45	1040	0.10
30–60	3	0.46	0.01	3.02	7	7	0.31	0.45	4860	184	584	49	1850	0.35
30–60	4	0.40	0.01	3.45	11	6	1.01	1.37	4530	998	1278	70	2940	0.61
30–60	5	2.33	0.01	5.73	22	2	0.50	0.58	7090	466	1620	1083	1830	0.36
30–60	6	1.86	0.00*	3	10	4	0.48	0.24	2352	236	2158	73	1600	0.06
30–60	7	0.70	0.02	3.52	29	5	0.63	0.53	4700	325	747	98	2150	0.11
30–60	8	0.73	0.00*	4.08	7	3	0.64	0.33	4830	211	1115	46	1810	0.15
30–60	9	1.15	0.02	3.94	29	7	0.56	0.89	4990	204	928	213	2860	0.13
30–60	10	3.10	0.01	3.68	29	7	1.09	1.05	5980	476	2565	1437	2800	0.39
30–60	11	1.22	0.01	2.84	15	8	0.84	0.77	5460	149	857	186	2900	0.15
30–60	12	0.75	0.01	2.76	16	7	0.21	0.35	4310	211	450	28	1380	0.13
30–60	13	0.48	0.01	3.93	30	4	0.78	0.92	4900	324	840	43	2900	0.30
30–60	14	0.20	0.01	4	25	5	0.55	0.19	3782	169	936	40	1730	0.08
30–60	15	0.43	0.01	1.57	9	11	0.35	0.56	3610	175	278	25	900	0.07
30–60	16	0.92	0.01	3	33	6	0.48	0.41	2780	199	1318	3592	1150	0.09
30–60	17	0.90	0.01	3.06	11	1	0.43	1.83	4370	332	1083	48	2200	0.92
30–60	18	0.69	0.00*	2	17	3	0.15	0.29	2594	145	1034	4031	730	0.05
30–60	19	0.78	0.01	2.45	19	8	0.51	0.76	3500	267	734	29	1740	0.52
30–60	20	0.48	0.00*	2.08	12	5	0.39	0.87	3400	119	577	44	1170	0.24
30–60	21	1.47	0.02	2	27	15	0.29	0.50	2917	181	461	1644	700	0.13

*Very low value below detection limits

mg kg^{-1}, respectively. The highest Ca value was found in sample 5 (7090 mg kg^{-1}), whereas the highest Na value was found in sample 18 (4031 mg kg^{-1}). Although sample 15 had the highest EC value, the maximum Na concentration was found in sample 18 according to the ICP-OES measurement reported in Table 4. This could be due to increasing Cl^- ions more than Na^+ in the soil including a high concentration of NaCl as described in Tavakkoli et al. (2010). In the present study, data for Cl measurement are not available. The soil (sample 5) including the largest amount of Ca (7090 mg kg^{-1}) also contained the highest level of B (2.33 mg kg^{-1}). K level in all samples tested was ideal according to Table 1. In addition, B concentration was low in samples 2, 3, 4, 14, and 15, whereas B level was adequate in other samples indicated in Table 1. B content in these soils ranged from 0.09 to 3.10 mg kg^{-1}. On the other hand, Ni and Cu levels were very low in all samples tested. Ni and Cu levels in these soils ranged from 0.21 to 1.09 and 1.57 to 5.73 mg kg^{-1}, respectively. As seen in Figure 3, *V. turcica* spread in a narrow area in locations 3 and 5, which have soils with low Zn concentration. Nonetheless, it can be concluded that this unusual species is resistant to mineral changes in the soil due to growing in all soils having different mineral element content in the present study. Concentrations of P in all samples were far below the optimum level given in Table 1. P content in the soils varied from 0.05 to 0.92 kg ha^{-1}. The cause of low P value in the soil may be the result of uptake by growing crops and biological activity. It is known from earlier studies that phosphorus uptake increased during the growth stage in onion (Thangasamy, 2015). Soil samples analyzed in the present study were collected from natural habitats of *V. turcica* during the seed development period, and this may explain the low P state in the analyzed soils. In the case of N, three of the 21 samples (sample 15, 18, and 21) had deficient levels compared to reference levels (Table 1), but the concentration of N in the rest of the samples was adequate. N content in these soils ranged from 700 to 2940 mg kg^{-1}. Unlike P, the soil nitrogen cycle is very active and is connected with microbial biomass that participates in the conversion of an organic to an inorganic form of N. No data are available on microbial biomass in soils where *V. turcica* grows to date. A literature review has shown that the only information on mineral element content of soils where *V. turcica* grows was found in the species protection action plan published by the General Directorate of Nature Conservation and National Parks under the Ministry of Forestry and Water Affairs of the Republic of Turkey. In this book, mineral element contents of 4 soil samples collected from Sultandağı (n: 2) and Kırca (n: 2) were analyzed. Measured elements were Fe, Cu, Zn, Ca, Mg, P_2O_5, and K and the measured levels of these elements are in agreement with the outcomes of the present study. In addition, mineral element contents of plant tissue samples (flower and leaf) collected from 8 different locations were analyzed. The highest Ca, K, Na, N, and P were found in leaves of sample 1, whereas Mg content was highest in leaves of sample 18. On the other hand, Fe and Zn level were higher in flowers of sample 1 than in leaves. Cd, Cu, Ni, and Mn levels were similar in all analyzed plant tissue samples. Moreover, the present study revealed that the concentrations of Mg and N were higher in leaves of *V. turcica* than in flowers during pollination period. *V. turcica* grows on alkaline soils, and it is sufficient in essential elements (Tables S1 and S2, Supplementary Data).

Exogenous factors such as soil shaking time, digestion method, extraction temperature, and pH can affect the extraction efficiency of some micronutrients (Gaudino et al., 2007). In addition, sampling depth (30–60 cm depth) may have caused some variation in the range of mineral elements in the environmental analysis. As reported by Ferreiro et al. (2016), there is a correlation between soil depth and land use. In contrast, the present results showed not much variation in sampling distance because of the limited area of propagation of *V. turcica*. Soil pH and structure with different particle size can affect some water-soluble elements, as plants' one characteristic is to absorb water. Different samples tested had distinct soil structures. Thus, the above explanations show that there is a difference in mineral element content in the samples tested.

In conclusion, soil nutrient deficiency can significantly decrease plant growth and vigor, and reduce productivity. Soil tests, combined with plant tissue tests, are necessary in order to facilitate conservation of *V. turcica* in its natural habitat. Therefore, future studies should include plant tissue tests of *V. turcica* as nutrient uptake patterns and dry matter accumulation; hence nutrient supply can be optimized through fertilizers during the growing season. The outcomes obtained from this study will contribute to priority activity targets (3.1. Investigation of the effects of climate, hydrology and soil characteristics of the area on the spread of Piyan) specified in the species protection action plan designated by the General Directorate of Nature Conservation and National Parks under the Ministry of Forestry and Water Affairs of Republic of Turkey in 2014.

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References

Andersen A (2007). Carey reams' testing and evaluation methods. Acres U.S.A. 37: 1-3.

Republic of Turkey Ministry Forestry and Water Affairs (MFWA), General Directorate of Nature Conservation and National Parks (GDNCNP), (2014). Baklagillerin kraliçesi: Eber sarısı-Piyan (*Thermopsis turcica*) (Queen of the family of Fabaceae: Eber's Yellow-Piyan (*Thermopsis turcica*) [online]. Website: http://www.milliparklar.gov.tr/yabanhayati/turkorumasube/Piyan.pdf [accessed 18.09.2014].

Ashraf YM, Roohi M, Iqbal Z, Ashraf M, Ozturk M, Gucel S (2016). Cadmium (Cd) and lead (Pb) induced changes in growth, some biochemical attributes and mineral accumulation in two cultivars of mung bean [*Vigna radiata* (L.) Wilczek]. Commun Soil Sci Plan 47: 405-413.

Aşçı F, Bahadır M, Akkuş GU (2015). Study on the impact of elements in water on the diversity of water mites (*Acari*, *Hydrachnidia*) species. Advances in Bioscience and Biotechnology 6: 259-264.

Black CA (1993). Soil Fertility Evaluation and Control. Boca Raton, FL, USA: Lewis Publishers.

Carter MR, Gregorich EG (2006). Soil Sampling and Methods of Analysis. 2nd ed. Boca Raton, FL, USA: CRC Press.

Cenkci S, Kargıoğlu M, Dayan S, Konuk M (2007). Endangered status and propagation of an endemic plant species, *Thermopsis turcica* (Fabaceae). Asian J Plant Sci 6: 288-293.

Dahnke WC, Olson RA (1990). Soil test correlation, calibration, and recommendation. In: Westerman RL, editor. Soil Testing and Plant Analysis, 3rd ed., SSSA, Madison, WI, USA: Soil Science Society of America, pp. 45-71.

Ekim T, Koyuncu M, Vural M (2000). Türkiye Bitkileri Kırmızı Kitabı, Eğrelti ve Tohumlu Bitkiler (Red Data Book of Turkish plants, Pteridophyta and Spermatophyta). Ankara, Turkey: Barışcan Ofset.

Falciani R, Novaro E, Marchesini M, Gucciardi M (2000). Multi-element analysis of soil and sediment by ICP-MS after a microwave assisted digestion method. J Anal Atom Spectrom 15: 561-565.

Ferreiro PJ, Pereira De Almeida,V, Alves MC, Aparecida De Abreu C, Vieira SR, Vázquez EV (2016). Spatial variability of soil organic matter and cation exchange capacity in an oxisol under different land uses. Commun Soil Sci Plan 47: 75-89.

Foth HD, Ellis BG (1996). Soil Fertility. 2nd ed. Boca Raton, FL, USA: CRC Press.

Gaudino S, Galas C, Belli M, Barbizzi S, De Zorzi P, Jaćimović R, Jeran Z, Pati A, Sansone U (2007). The role of different soil sample digestion methods on trace elements analysis: a comparison of ICP-MS and INAA measurement results. Accred Qual Assur 12: 84-93.

IUCN 2014. The IUCN red list of threatened species. Version 2014.1 [online]. Website: www.iucnredlist.org [accessed 10.10.2017].

Jackson ML (1959). Soil Chemical Analysis. Englewood Cliffs, NJ, USA: Prentice Hall.

Kavak S (2014). *Thermopsis turcica*. The IUCN red list of threatened species 2014: e.T19619476A19620956 [online]. Website: http://dx.doi.org/10.2305/IUCN.UK.20141.RLTS.T19619476A19620956.en [accessed 09.10.2017].

Khan S, Naz A, Asim M, Ahmad SS, Yousaf S, Muhammad S (2013). Toxicity and bioaccumulation of heavy metals in spinach seedlings grown on freshly contaminated soil. Pak J Bot 45: 501-508.

Lindsay WL, Norvell WA (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal 42: 421-428.

Marschner P (2012). Mineral Nutrient in Higher Plants. 3rd ed. London, UK: Academic Press.

Mengütay M, Ceylan Y, Kutman UB, Cakmak I (2013). Adequate magnesium nutrition mitigates adverse effects of heat stress on maize and wheat. Plant Soil 368: 57-72.

Moor C, Lymberopoulou T, Dietrich VJ (2001). Determination of heavy metals in soils, sediments and geological materials by ICP-AES and ICP-MS. Microchim Acta 136: 123-128.

Olsen SR, Cole CV, Watanabe FS, Dean LA (1954). Estimation of Available Phosphorus in Soil by Extraction with Sodium Bicarbonate. USDA Circular. Washington, D.C.: United States Department of Agriculture.

Özdemir C, Dural H, Ertugrul K, Küçüködük M, Baran P, Sanda MA (2008). Morphology and anatomy of endemic *Thermopsis turcica* Kit Tan, Vural & Küçüködük. Bangladesh J Bot 37: 105-114.

Özdemir A, Kahraman S (2015). Toprak bilgisi ve bitki besleme. Website http://www.kitapark.com/pdf/toprak-bilgisi-ve-bitki-besleme.pdf. [accessed 29.06.2017].

Özhayat N, Byfield A, Atay S (2005). Türkiye'nin 122 Önemli Bitki Alanı (Important Plant Areas in Turkey: 122 Key Botanical Sites). İstanbul, Turkey: WWF-Türkiye (Doğal Hayatı Koruma Vakfı).

Richards LA (1954). Diagnosis and Improvement of Saline and Alkali Soils. California: U. S. Department of Agriculture, Agriculture handbook, no. 60.

Sahrawat KL (2016). Soil and plant testing for iron: an appraisal. Commun Soil Sci Plan 47: 280-283.

Saraçoğlu M, Sürücü A, Koşar İ, Taş Anlağan M, Aydoğdu M, Kara H (2014). Şanlıurfa ili Halfeti ilçesi topraklarının bazı özellikleri ve bitki besin elementi kapsamlarının belirlenmesi. Toprak Bilimi ve Bitki Besleme Dergisi 2: 38-45.

Stockdale E, Shepherd MA, Fortune S, Cuttle SP (2002). Soil fertility in organic farming systems – fundamentally different? Soil Use and Management 18: 301-308.

Tan K, Vural M, Küçüködük M (1983). An unusual new *Thermopsis* from Turkey. Notes Roy Bot Gard Edinburgh 40: 515-518.

Tavakkoli E, Rengasamy P, McDonald GK (2010). High concentrations of Na^+ and Cl^- ions in soil solution have simultaneous detrimental effects on growth of faba bean under salinity stress. J Exp Bot 61: 4449-4459.

Tekdal D, Cetiner S (2014). In-ovule embryo culture of *Thermopsis turcica*. J Anim Plant Sci 24: 1673-1679.

Thangasamy A (2015). Quantification of dry matter accumulation and nutrient uptake pattern of short day onion (*Allium cepa* L.). Commun Soil Sci Plan 47: 246-254.

Tüzüner A (1990). Toprak ve Su Analizi Laboratuvar El Kitabı. Ankara, Turkey: T.C. Tarım ve Köyişleri Bakanlığı.

Uysal T, Ertuğrul K, Bozkurt M (2014). A new genus segregated from *Thermopsis* (Fabaceae: Papilionoideae): *Vuralia*. Plant Syst Evol 300: 1627-1637.

Ülgen N, Yurtsever N (1995). Türkiye G*übre* ve Gübreleme Rehberi. Ankara, Turkey: Toprak ve Gübre Araştırma Enstitüsü.

Vural M (2009). Piyan (*Thermopsis turcica*). Bağbahçe 25: 14-16.

Yıldız M, Pehlivan E, Terzi H (2017). Proteomic analysis of flowers at two developmental stages in *Thermopsis turcica* (Fabaceae). Turk J Bot 41: 234-243.

Supplementary Data

Table S1. Mineral nutrient content of the flowers of *V. turcica* collected from various areas in the field.

Location	Sample*	B	Cd	Cu	Fe	Mn	Ni	Zn	Ca	K	Mg	Na	N	P
		mg kg^{-1}												
1-Dereçine	1	17	0.03	12	177	21	1	55	3196	14,971	1832	142	27,439	4135
2-Eber Lake	8	18	0.02	10	73	17	2	40	2612	14,930	1984	105	40,512	3988
3-Gölçayır	11	19	0.02	10	95	14	3	42	2642	15,155	1620	125	50,129	4487
4-Kırca	13	21	0.02	11	93	22	2	40	2675	15,233	2146	77	40,058	3611
5-Sultandağı	16	15	0.02	11	80	15	2	43	2156	16,683	1913	143	48,831	3944
6-Taşköprü	17	24	0.02	12	70	16	1	39	1158	15,171	2546	94	45,464	3937
7-Yakasinek	18	20	0.02	10	107	14	2	42	2794	15,713	1801	123	45,271	4393
8-Ulupınar	19	18	0.02	11	90	14	2	45	2010	14,331	1952	153	47,696	4119

*The coordinates of each sample were given in Table 2.

Table S2. Mineral nutrient content of the leaves of *V. turcica* collected from various areas in the field.

Location	Sample*	B	Cd	Cu	Fe	Mn	Ni	Zn	Ca	K	Mg	Na	N	P
		mg kg^{-1}												
1-Dereçine	1	34	0.04	16	165	17	2	36	16,133	16,340	4590	233	62,053	4789
2-Eber Lake	8	15	0.03	11	89	20	1	32	6576	9482	3918	165	51,208	2523
3-Gölçayır	11	23	0.02	14	75	21	1	54	3891	14,634	3506	99	52,854	3610
4-Kırca	13	18	0.02	11	97	18	1	47	3097	14,744	2005	130	43,239	3612
5-Sultandağı	16	18	0.01	11	112	20	1	41	4729	12,980	2828	105	44,762	2872
6-Taşköprü	17	18	0.02	9	89	14	2	47	2403	16,318	2831	100	45,092	4156
7-Yakasinek	18	18	0.01	11	75	28	1	32	5326	16,196	4916	76	43,400	2961
8-Ulupınar	19	15	0.03	17	93	36	1	51	7089	18,424	2695	103	49,787	3861

*The coordinates of each sample were given in Table 2.