SOIL AND PLANT RELATIONS OF SOME *ORNITHOGALUM* (ENDEMIC/NON ENDEMIC) SPECIES

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Abstract. The study was carried out to determine the soil properties of the Ornithogalum L. species in the West Mediterranean Region of Turkey and their effects on plant morphology. Plant and soil samples concerning species *Ornithogalum umbellatum* L., *O. oligophyllum* E.D. Clarke, *O. narbonense* L., *O. pyrenaicum* L., *O. lanceolatum* Labill., *O. pamphylicum* (endemic) O.D. Düşen & Sümbül, *O. montanum* Cirillo, *O. armeniacum* Baker, *O. neurostegium* Boiss. & Blanche, *O. orthophylum* Ten. and *O. chetikianum* (endemic) Uysal, Ertugrul & Dural were collected from 32 different populations between March and June in 2012. The soils of the plant taxa were textured with sandy loam, loam, silty loam, and sandy clay loam; their EC values were in the range 71-741 μmhos cm^{-1}; and their pH values varied between 6.9 and 8.3. The highest organic matter content was in *O. orthophylum*, whereas the lowest value was in *O. chetikianum* (endemic) and *O. pamphylicum* (endemic). According to the means, the highest values of phosphorus, potassium, calcium, and magnesium were determined in the soil samples belonging to *O. lanceolatum* (106.0 mg kg^{-1}), *O. lanceolatum* (657.5 mg kg^{-1}), *O. montanum* (6552 mg kg^{-1}) and *O. pyrenaicum* (746.8 mg kg- 1), respectively.
Keywords: *Ornithogalum, ecology, habitats, soil properties, morphological characters, Turkey*

Introduction

Asparagaceae is a family of flowering plants containing 143 plant genera and 3632 species. The genus *Ornithogalum* L. is in the family *Asparagaceae* in the major group Angiosperms. *Ornithogalum* L. is a perennial plant and is widely distributed in Europe, Asia, Africa and Madagascar. The genus *Ornithogalum* in tribe Ornithogaleae (Caurel) J.C. Manning & Goldblatt of subfamily Ornithogaloideae Speta (Hyacinthaceae *Batsch*) consists of about 200 species of bulbous herbs native to Southern Europe, the Mediterranean basin, and South Africa (Manning et al., 2009; Andric et al., 2015; Aykurt et al., 2016).

The West Mediterranean Region is one of the richest places of Turkey in terms of plant diversity. According to the latest research, there are 54 known *Ornithogalum* species in the world, with 17 of them being endemic to Turkey. The West Mediterranean Region possesses 18 *Ornithogalum* species and 5 of them are endemic to the region (Davis, 1988; Düşen and Deniz, 2005; Uysal et al., 2005; Mutlu and Karakuş, 2012).

Ornithogalum species is used for ornamental or medicinal plant and can also be consumed as vegetable (Kamanestsky and Okubo, 2012). There are a number of studies on the taxonomy, cytology, ecology, seed micromorphology (Goldblatt and Manning, 2011; Yılmaz, G., 2014; Rat et al., 2016; Corominas et al., 2017), and in vitro propagation of *Ornithogalum* (Yanagawa and Ito, 1988; Nayak and Sen, 1995; Ziv and Lilien-Kipnes, 2000; Kariuki and Kako, 2003; Malabadi and van Staden, 2004; Naik and Nayak, 2005; Ozel and Khawar, 2007).

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Ornithogalum species in Turkey have distribution from 0 to 2600 m and in the Mediterrenean, Euro Siberian and Iranian Turan phytogeographical region.

To the best of knowledge, there is no study on the natural populations of Ornithogalum with the physical and chemical characteristic concentrations of the soils convenient.

Soil is a key environmental factor for wild plant populations since plant development depends largely on the nutrients of soil. Therefore, soil analyses of wild plant populations may be the means for understanding soil and its possible correlations with plants (Li and Mazza, 1999; Roca-Perez et al., 2004). Several studies showed that microelement contents in plants were affected by not only soil microelement concentrations but also the differences in chemical properties (i.e. pH and carbonate content) of the soil (Brun et al., 1998; Rapp et al., 1999; Saatçi and Yağmur, 2000; Roca-Perez et al., 2004).

Soil is known to have a significant impact on plants. Knowledge of the physical and chemical properties of soil helps to keep and grow plants effectively, and the use of the type of soil required for a plant will be essential for its faster cultivation and development (Reed, 2011).

The main aim of our study was aimed to determine the interactions between soil and plant properties in different *Ornithogalum* species growing in the West Mediterranean Region of Turkey, in order to provide information to the future cultivation studies in Ornithogalum species.

Materials and methods

The study was conducted in 32 populations of 11 Ornithogalum species (*O. umbellatum* L., *O. oligophyllum* E.C. Clarke, *O. narbonense* L., *O. pyrenaicum* L., *O. lanceolatum* Labill., *O. pamphylicum* O.D. Düşen & Sümbül 'endemic', *O. montanum* Cyr., *O. armeniacum* Baker, *O. neurostegium* Boiss. & Blanche, *O. orthophylum* Ten., and *O. chetikianum* Uysal, Ertugrul & Dural 'endemic' located in the West Mediterranean Region of Turkey. Soil samples were collected by means of a garden spade in a depth of 30 cm after removing the surface litter between March and June in 2012. Details of original locations of collected samples are shown in *Figure 1*.

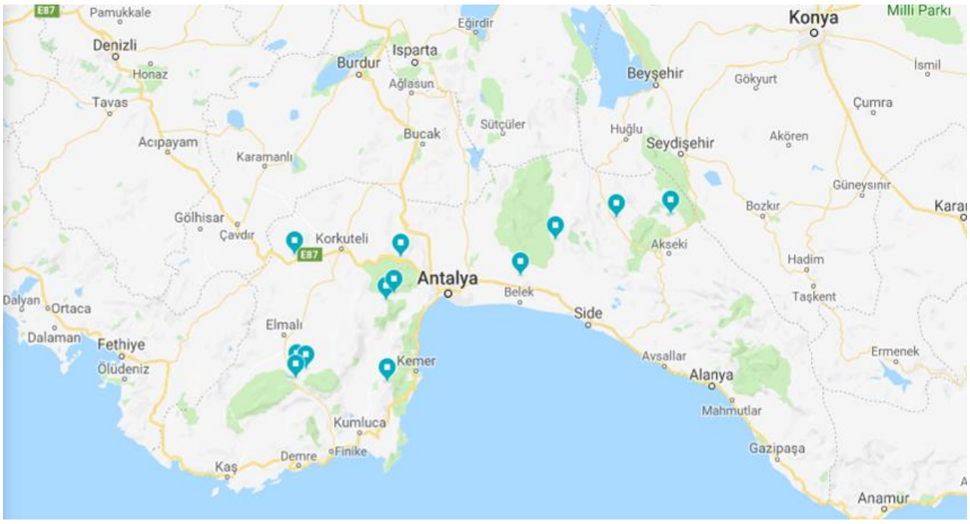

Figure 1. *The location of sampling site of Ornithogalum species*

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Their appearances of flowering stage of the Ornithogalum species are presented in *Figure 2*.

Figure 2. *Some different genotypes of Ornithogalum species plant sampling flowering period.* ***a*** *O. pamphyllicum (endemic),* ***b*** *O. lanceolatum,* ***c*** *O. orthophyllum,* ***d*** *O. pyrenaicum,* ***e*** *O. narborense,* ***f*** *O. montanum,* ***g*** *O. umbellatum,* ***h*** *O. oligophyllum,* ***i*** *O. armeniacum*

At every site, four 1000-g soil samples were collected at three randomly selected points from an area of 25 m^2, placed in clear plastic bags (35 × 25 cm), sealed with a rubber band, and brought to the laboratory. Then, the air-dried soil samples were prepared for the analyses by sifting them through a 2-mm mesh sieve. The analyses were conducted in the soil analysis laboratory of the Batı Akdeniz Agricultural Research Institute (BATEM). The pH (potential of hydrogen-soil reaction) and EC (The Electrical Conductivity) values of the soils were analyzed in a 1:2.5 soil and water mixture, as recommended by Jackson (1967). The organic matter was determined using

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the Walkley-Black method, as suggested by Black (1965). The available P was found with the Olsen method (Olsen and Sommers, 1982). $CaCO_3$ was determined with the Scheibler calcimeter method (Kacar, 2009). The texture of soil was tested with the hydrometer method by Bouyoucos (1951), and the available K, Ca and Mg were found by using 1 N ammonium acetate extraction suggested by Kacar (2009). All the collected data were subjected to the analysis of variance, and the mean values were compared using Duncan's multiple range tests at the 0.05 level (Gomez and Gomez, 1984).

In the study, morphological characters of the plants such as flowering time (day), length of flower stems (mm/plant), bulb diameter (number/plant) and the number of flowers (number) were determined according to Martinez-Azorin et al. (2007). Taxonomic description was made according to Davis (1988). Morphologic characters of the five plants belong to each species were measured in natural habitats when the soil samples were collected. All the measurements were done by a compass and analytical balance.

The number of the soil samples varied from 2 to 6, because the number of location was limited for some species. The number of the soil sample was collected according to the number of location.

Results

Thirty-two soil samples were collected from different geographical sites distributed throughout the West Mediterranean, Antalya between March and June in 2012. *Table 1* presents the soil numbers, localities, habitats, and altitudes, while *Table 2* provides some properties of the soils (texture, pH, EC, CaCO3, organic matter, potassium, phosphorus, calcium and magnesium).

Table 1. *Soil samples, localities, altitudes and habitats of the Ornithogalum species*

Species	Soil number	Date of collection	Locality	Coordinates	Altitude (m)	Habitat
O. pamphylicum	1	17.04.2012	The Feslikan Plateau Sakarpınarı	N 36.50492 E 30.24494	1787	Stony, rocky, and limestone slopes
	2	12.04.2012	Çığlıkara Forest, Elmalı	N 36.52530 E 29.82927	1782	Stony and rocky areas
O. lanceolatum	3	14.04.2012	Sedir Research Forest Road, Elmalı	N 36.35215 E 30.01264	1593	Ground water withdrawal, meadows
	4	10.04.2012	Sedir Research Forest, Elmalı	N 36.36023 E 29.57353	1350	Rocky slopes
O. orthophyllum	5	14.04.2012	Entrance of the Yenice Village, Old Korkuteli Road	N 37.00433 E 30.29021	402	Road side and the rocky and limestone area
	6	20.03.2012	Akdeniz University Health Sciences School	N 36.53497 E 30.39151	35	Road side and macquis groves
O. armeniacum	7	09.04.2012	The Çakıllı Passage, Cevizli, Akseki	N 37.10287 E 37.04368	1210	Macquis groves as well as Rocky and limestone areas

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	8	21.04.2012	The Ormana Village, İbradı	N 37.04368 E 31.35383	978	Rocky and limestone areas
	9	22.05.2012	Köprülü Canyon, Manavgat	N 37.14490 E 31.06435	1468	Rocky areas
	10	14.04.2012	Sedir Research Forest, Elmalı	N 36.36023 E 29.57353	1089	Macquis groves and stony area
	11	01.05.2012	The Serinyaka Village, Gündoğmuş	N 36.47351 E 31.49572	620	Stony and rocky slopes
	12	15.04.2012	Hisarönü, İbradı	N 37.05503 E 31.36025	1075	Rocky and humid area
O. neurostegium	13	14.04.2012	6 km from Korkuteli to Kızılcadağ	N 37.01023 E 29.58256	663	Limestone and stony slopes
	14	14.04.2012	Between Korkuteli and Elmalı Road	N 36.480172 E 30.007571	1231	Road side and open field
O. umbellatum	15	21.04.2012	The Burmahancı Village, Serik	N 36.56288 E 31.03501	15	Humid meadows
	16	09.04.2012	Akseki Ömer Duruk Facility	N 36.998694 E 31.759739	1100	Road side humid area
O. montanum	17	14.04.2012	Sedir Research Forest Road, Elmalı	N 36.35285 E 29.58350	1273	Macquis groves and limestone and stony area
	18	14.04.2012	Between Elmalı and Finike Road	N 40.46678 E 36.23239	849	Rocky and stony area as well as under the Juniperus
O. chetikianum	19	24.05.2012	The Feslikan Plateau	N 36.48588 E 30.22266	2016	Road side, slopes as well as sandy and open area
	20	15.05.2012	Above Feslikan Plateau, Sakarpınarı	N 36.49413 E 30.24328	1850	Open slopes
O. pyrenaicum	21	14.04.2012	The Göltarla Village, Elmalı	N 36.33197 E 29.58208	1172	Slope and macquis groves
	22	20.04.2012	Çıralı Kemer	N 40.21440 E 36.27147	10	Sandy and macquis groves
	23	17.04.2012	Mt. Tahtalı, Tekirova	N 36.32274 E 30.25091	649	Road side and under the pine forest
	24	14.04.2012	Yukarı Karaman, Korkuteli	N 37.06781 E 30.04358	1500	Field side
O. narbonense	25	17.04.2012	Entrance of the Altınbeşik Cave, Manavgat	N 37.02188 E 31.37312	645	Rocky and limestone slopes
	26	09.04.2012	The Çakıllı Passage, Cevizli, Akseki	N 37.10287 E 31.47583	1210	Roadside, humid, limestone area
	27	20.04.2012	The Ovacık Plateau, Kemer	N 36.38153 E 30.25331	1080	Open flat meadows

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	28	24.05.2012	Mountain Tahtalı, Tekirova	N 36.32274 E 30.25091	645	Road side and under the pine forest
	29	14.05.2012	Akdeniz University Health Sciences School	N 36.53528 E 30.39529	49	Road side and macquis groves
	30	15.05.2012	Yukarı Karaman, Korkuteli	N 37.06781 E 30.04358	1500	Field side
O. oligophyllum	31	15.04.2012	The Gembos Plateau (Karamuklu), İbradı	N 37.12381 E 31.29384	1478	Humid, open slopes
	32	27.04.2012	The Ormana Village, İbradı	N 37.04368 E 31.35383	978	Rocky slopes

Table 2. *Some physical and chemical properties of the soils where the Ornithogalum species were grown*

Species	Soil number	Texture	pH (1:2.5)	EC (µmhos/cm)	CaCO3 (%)	Organic matter (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mgkg^{-1})	Mg (mgkg^{-1})
O. pamphylicum	1	Sandy loam	8.1	210	47.0	4.2	19	85	1.870	689
	2	Sandy loam	8.0	214	52.0	4.5	22	75	1.780	695
O. lanceolatum	3	Loam	7.8	216	1.8	5.9	104	661	4.426	365
	4	Loam	7.8	225	1.9	5.2	108	654	4.342	380
O. orthophyllum	5	Sandy loam	7.8	363	13.8	11.6	89	481	5.089	430
	6	Sandy loam	7.9	380	11.2	10.8	84	456	5.123	445
O. armeniacum	7	Loam	7.9	108	2.6	3.9	5	152	4.032	327
	8	Loam	8.0	104	2.6	4.8	53	205	5.880	112
	9	Sandy loam	6.9	741	1.8	13.2	211	799	4.241	1.232
	10	Loam	7.6	196	5.4	5.1	21	515	9.030	226
	11	Sandy loam	8.3	96	2.0	2.1	3.2	62	2.320	93
	12	Loam	7.9	147	23.1	4.8	53	205	5.880	112
O. neurostegium	13	Sandy loam	8.2	187	4.1	4.1	24	436	5.698	542
	14	Loam	7.8	419	16.4	12.6	118	607	4.978	391
O. umbellatum	15	Sandy loam	8.2	256	33.3	1.8	16	178	2.899	265
	16	Loam	7.6	310	10.2	7.6	145	718	5.429	336
O. montanum	17	Loam	7.8	419	16.4	12.6	118	607	4.978	391
	18	Loam	7.8	142	10.0	1.6	28	275	8.127	210
O. chetikianum	19	Sandy	8.0	187	2.6	2.4	16	92	4.468	391

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		loam								
	20	Sandy loam	8.1	212	2.8	2.9	25	100	4.325	386
O. pyrenaicum	21	Silty loam	7.9	196	1.8	8.3	25	453	4.735	420
	22	Loam	7.1	143	1.7	10	7	178	3.381	1.690
	23	Silty loam	7.9	120	2.3	4.3	7	257	8.190	470
	24	Silty loam	7.9	108	2.9	1.4	40	723	7.878	407
O. narbonense	25	Sandy loam	7.3	685	5.2	13.1	111	276	4.736	381
	26	Loam	7.3	71	2.3	3.9	5	152	4.032	327
	27	Loam	7.3	78	2.4	3.6	8	165	4.535	342
	28	Sandy clay	7.9	120	2.3	4.3	7	257	8.195	470
	29	Sandy loam	8.1	160	22.2	3.6	13	183	4.970	427
	30	Silty loam	7.9	108	2.9	1.2	40	723	7.880	407
O. oligophyllum	31	Sandy loam	7.2	709	2.3	13.3	48	288	5.020	515
	32	Sandy clay	8.0	104	2.6	4.8	53	205	5.880	112

Ornithogalums are usually grown in open meadows, roadside or limestone rocky slopes. Their altitude ranges from 15 m to 2016 m. The flowers are generally starched, petals are green striped and there are 2-20 flowers. Flower stem lengths vary between 2-45 cm. Leaves are thin or long strip, linear or thick-fleshy, with bright dark green or matte gray-green colors, bulbs of different sizes (small to medium-large) are round or ovoid (*Table 3*).

***Table 3**. Morphological characters of natural Ornithogalum species*

Species	Bulb size-average bulb diameter (mm)	Leaf characteristics	Average number of flowers per inflorescence (number)	Stem length (mm/plant)	Flowering time
O. pamphylicum	Small, long-ovoid-6.5	Thin long strip	2-2.5	70-80	Mid May
O. lanceolatum	Big ovoid-26.7	Thick fleshy bright dark green	2	20-30	Mid April
O. orthophyllum	Small round-10.8	Quite thin	2.67-3.00	50-100	March
O. armeniacum	Medium round-17.0	Thin	4.5-6.00	100-250	April-early May
O. neurostegium	Medium long ovoid-18.7	Thin	5.63-6.63	200-250	Mid May
O. umbellatum	Numerous number of tooth shaped bulblet, Medium Round-18.3	Thin	12.00-18.00	100-200	Mid March

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O. montanum	Big round-24.3	Thick fleshy matte gray-green	9.79-13.00	100-250	End of April
O. chetikianum	Numerous bulblet, Medium, Round-18.8	Thick	7.17-9.13	200-300	Early May
O. pyrenaicum	Small ovoid-17.2	Thin long strip	17.93-21.75	300-450	Mid May-end of May
O. narbonense	Big round-22.8	Thin linear matte gray-green	52.00-57.33	250-350	End of April-end of May
O. oligophyllum	Small round-12.7	Thick	8.00-9.25	100-150	Mid March-end of March

Statistical analyses of the results for the soil analyses and the soil classes of the *Ornithogalum* species are shown in *Tables 4* and *5*, respectively.

The soil analyses results are also shown in graphs (*Fig. 3a-h*). Some evaluations and interpretations of the soil analysis results are provided in detail below.

Table 4. *Results of the statistical analyses (Mean ± SE and minimum–maximum) on the soils of Ornithogalum species*

Species	N	pH (1:2.5)	EC (µmhos/cm)	$CaCO_3$ (%)	Organic matter %	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg kg^{-1})	Mg (mg kg^{-1})
		Mean±SE (Min.-Max.)							
O. pamphylicum	2	8.1^{ns}±0.1 (8.0-8.1)	212.0^{ns}±2.0 (210.0-214.0)	49.5a**±2.5 (47.0-52.0)	4.4^{ns}±0.2 (4.2-4.5)	20.5^{ns}±1.5 (19.0-22.0)	80.0b**±5.0 (75.0-85.0)	1825.0b**±45.0 (1780.0-1870.0)	692.0^{ns}±3.0 (695.0-689.0)
O. lanceolatum	2	7.8±0.0 (7.7-7.8)	220.5±4.5 (216.0-225.0)	1.9c±0.1 (1.8-1.9)	5.6±0.4 (5.2-5.9)	106.0±2.0 (104.0-108.0)	657.5a±3.5 (654.0-661.0)	4384.0ab±42.0 (4342.0-4426.0)	372.5±7.5 (365.0-380.0)
O. ortophyllum	2	7.9±0.1 (7.8-7.9)	371.5±8.5 (363.0-380.0)	12.5bc±1.3 (11.2-13.8)	11.2±0.4 (10.8-11.6)	86.5±2.5 (84.0-89.0)	468.5ab±12.5 (456.0-481.0)	5106.0ab±17.0 (5089.0-5123.0)	437.5±7.5 (430.0-445.0)
O. armeniacum	6	7.8±0.2 (6.9-8.3)	232.0±102.9 (96.0-741.0)	6.3c±3.4 (1.8-23.1)	5.7±1.6 (2.1-13.2)	57.7±32.0 (3.2-211.0)	323.0ab±113.8 (62.0-799.0)	5230.5ab±933.7 (2320.0-9030.0)	350.3±180.1 (93.0-1232.0)
O. neurostegium	2	8.0±0.2 (7.8-8.2)	303.0±116.0 (187.0-419.0)	10.3bc±6.2 (4.1-16.4)	8.4±4.3 (4.1-12.6)	71.0±47.0 (24.0-118.0)	521.5ab±85.5 (436.0-607.0)	5338.0ab±360.0 (4978.0-5698.0)	466.5±75.5 (391.0-542.0)
O. umbellatum	2	7.9±0.3 (7.6-8.2)	283.0±27.0 (256.0-310.0)	21.8b±11.6 (10.2-33.3)	4.7±2.9 (1.8-7.6)	80.5±64.5 (16.0-145.0)	448.0ab±270.0 (178.0-718.0)	4164.0ab±1265.0 (2899.0-5429.0)	300.5±35.5 (265.0-336.0)
O. montanum	2	7.8±0.0 (7.7-7.8)	280.5±138.5 (142.0-419.0)	13.2bc±3.2 (10.0-16.4)	7.1±5.5 (1.6-12.6)	73.0±45.0 (28.0-118.0)	441.0ab±166.0 (275.0-607.0)	6552.5a±1574.5 (4978.0-8127.0)	300.5±90.5 (210.0-391.0)
O. chetikianum	2	8.1±0.1 (8.0-8.1)	199.5±12.5 (187.0-212.0)	2.7c±0.1 (2.6-2.8)	2.7b±0.3 (2.4-2.9)	20.5±4.5 (16.0-25.0)	96.0b±4.0 (92.0-100.0)	4396.5ab±71.5 (4325.0-4468.0)	388.5±2.5 (386.0-391.0)
O. pyrenaicum	4	7.7±0.2 (7.1-7.9)	141.8±19.5 (143.0-196.0)	2.2c±0.3 (1.7-2.9)	6.0±1.9 (8.3-10.0)	19.8±8.0 (7.0-40.0)	402.8ab±121.4 (178.0-723.0)	6046.0a±1182.3 (3381.0-8190.0)	746.8±314.7 (407.0-1690.0)
O. narbonense	6	7.6±0.2 (7.3-8.1)	203.7±97.1 (71.0-685.0)	6.2c±3.2 (2.3-22.2)	5.0±1.7 (1.2-13.1)	30.7±16.9 (5.0-111.0)	292.7ab±88.5 (152.0-723.0)	5723.5ab±742.4 (4032.0-8190.0)	392.3±21.9 (327.0-470.0)
O. oligophyllum	2	7.6±0.4 (7.2-8.0)	406.5±302.5 (104.0-709.0)	2.5c±0.2 (2.3-2.6)	9.1±4.3 (4.8-13.3)	50.5±2.5 (48.0-53.0)	246.5ab±41.5 (205.0-288.0)	5450.0ab±430.0 (5020.0-5880.0)	313.5±201.5 (112.0-515.0)
General	32	7.8±0.3 (6.9-8.3)	241.7±39.6 (71.0-741.0)	9.7±2.6 (1.7-52.0)	6.0±0.9 (1.2-13.3)	50.8±10.5 (3.2-211.0)	350.7±52.0 (62.0-799.0)	5135.6±484.9 (1780.0-9030.0)	437.1±68.5 (93.0-1690.0)

Mean seperation within columns by Duncan's multiple range test, at 0.05 level
N.S, *, **, ***: Non significiant or significiant at P < 0.05, 0.01 and 0.001 alpha level respectively
[a]Capitals show the comparison between the averages given vertically (along the column)

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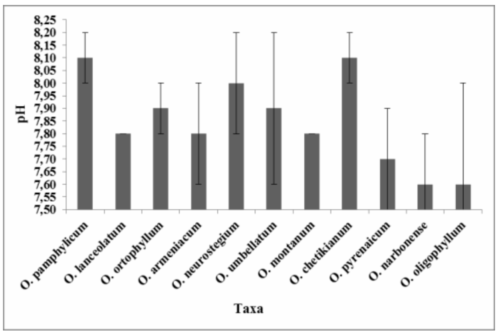
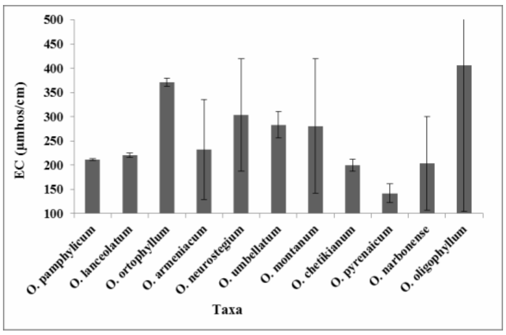
Table 5. *Soil classes of the Ornithogalum species*

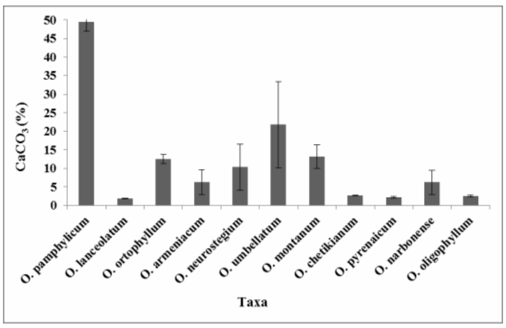
Species	pH (1:2.5)	EC (µmhos/cm)	CaCO3 (%)	Organic matter (%)	P (mg kg^{-1})	K (mg kg^{-1})	Ca (mg g^{-1})	Mg (mg kg^{-1})
O. pamphylicum	Alkaline	Non-saline	Excess	Medium	Medium-high	Medium	Medium	High
O. lanceolatum	Slightly alkaline	Non-saline	Low	High	High	Very high	High	High
O. ortophyllum	Slightly alkaline	Non-saline	Very high	High	High	Very high	High	High
O. armeniacum	Neutral-alkaline	Non-saline-very slightly saline	Low-excess	Medium-high	Low-high	Low-very high	Medium-high	High
O. neurostegium	Slightly alkaline-alkaline	Non-saline-very slightly saline	Medium-very high	Medium-high	High	Very high	High	High
O. umbellatum	Slightly alkaline-alkaline	Non-saline	Very high-excess	Low-high	Medium-high	Low-very high	High	High
O. montanum	Slightly alkaline	Non-saline-very slightly saline	Very high	Low-high	High	High-very high	High	High
O. chetikianum	Alkaline	Non-saline	Medium	Medium	Medium-high	Low	High	High
O. pyrenaicum	Slightly alkaline-alkaline	Non-saline	Medium	Low-High	Low-high	Low-very high	High	High
O. narbonense	Neutral-alkaline	Non-saline-very slightly saline	Low-excess	Low-high	Low-high	Low-very high	High	High
O. oligophyllum	Slightly alkaline-alkaline	Non-saline-very slightly saline	Low-medium	Medium-high	High	Medium-high	High	High
General (average)	Slightly alkaline	Non-saline	High	High	High	Very high	High	High



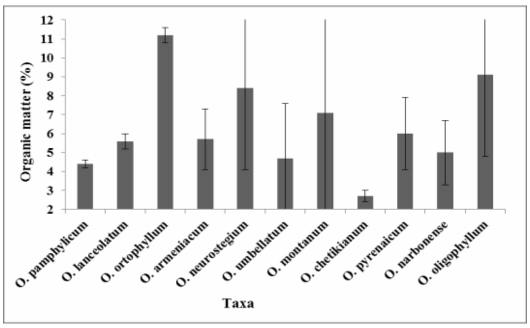
a



b



c



d

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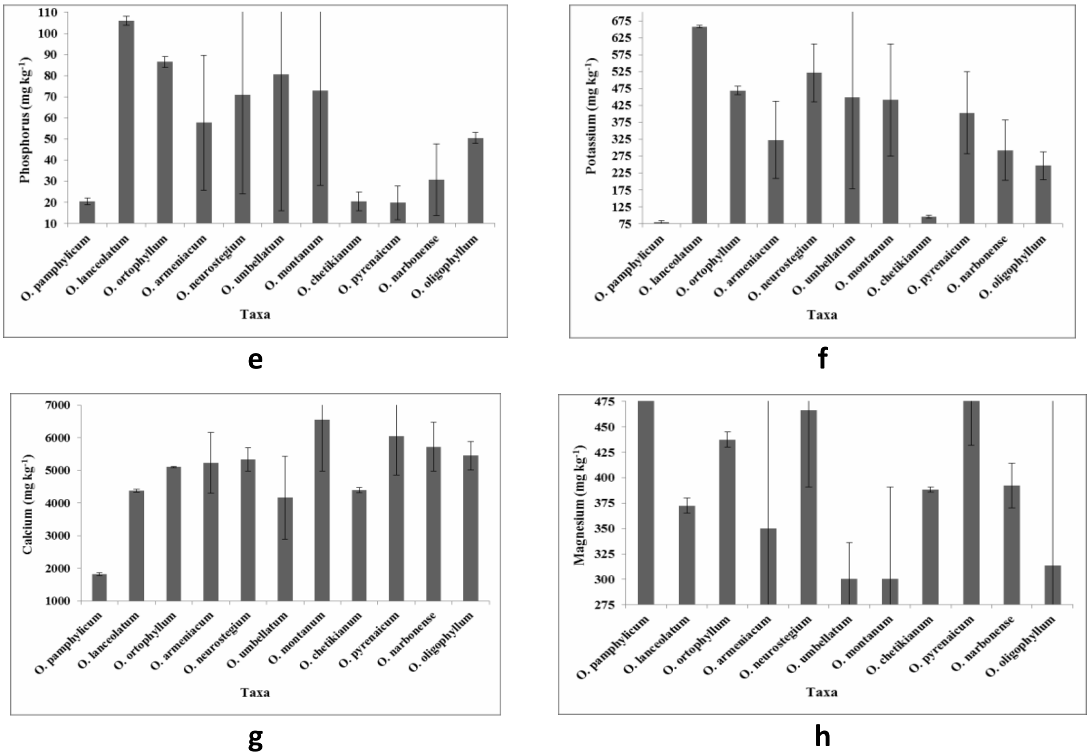

Figure 3. ***a*** *pH values,* ***b*** *EC values,* ***c*** *CaCO3 contents,* ***d*** *organic matter contents,* ***e*** *phosporus contents,* ***f*** *potassium contents,* ***g*** *calcium contents,* ***h*** *magnesium contents*

The results indicated that there were no significant differences in pH, EC (μmhos/cm), organic matter (%), phosphorus (mg kg^{-1}) or magnesium (mg kg^{-1}) values among the statistical averages of the soil samples ($P > 0.05$). Nevertheless, there were significant differences in the $CaCO_3$ (%), potassium (mg kg^{-1}), and calcium (mg kg^{-1}) values ($P < 0.001$) (*Table 4*). Regarding the soil texture, the species generally grew in the medium-textured types of soil. The soil samplesof the species were classified as 'loam', 'sandy loam', and 'silty loam' (*Table 2*). However, Soil Samples 28 (C3: Mt. Tahtalı, Tekirova, Antalya) and 32 (C3: The Ormana Village, İbradı, Antalya) were in the 'sandy clay' soil class. Furthermore, there were no differences in salinity among the values of the statistical test results. All soil samples were classified as 'non-saline' and 'very slightly saline'. An aggregation was present among the soils in terms of salinity. The EC values of the soil samples in the present study were low and varied between 71 and 741 μmhos cm^{-1}, while the highest EC value (741 μmhos cm^{-1}) was in *O. armeniacum* (C3: Mt. Termessos, Antalya) but the lowest EC value (71 μmhos cm^{-1}) in *O. narbonense* (C3: The Çakıllı Passage, Cevizli, Akseki, Antalya). Most *Ornithogalum* species grew in slightly alkaline soils. In the present study, the pH values were in the range 6.9-8.3, and both the highest pH values (C: Mt. Güllük, Termessos, Antalya) and the lowest (C3: The Serinyaka Village, Gündoğmuş, Antalya) pH values were determined in *O. armeniacum.* No significant difference in soil reaction (pH) existed among the species. The results demonstrated that the *Ornithogalum* species grew in soils with low to excess $CaCO_3$ levels. There was a significant difference among the species ($P < 0.05$). In terms of $CaCO_3$, the soils of *O. pamphylicum* (49.5%) were statistically quite different from the others ($P < 0.01$). The averages of the $CaCO_3$ contents of the species were very close to each other. *O. montanum* (13.2%), *O. neurostegium* (10.3%), *O. umbellatum* (21.8%) and

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O. o*rthophyllum* (12.5%) grew in soils with a very high CaCO3 content. The soils, where *O. lanceolatum* (1.9%)*, O. chetikianum* (2.7%)*, O. pyrenaicum* (2.2%) and *O. oligophyllum* (2.5%) are grown had low $CaCO_3$ values (*Table 4*). According to the average $CaCO_3$ values, the soils belonging to *O. pamphylicum* were regarded as excess but the soils belonging to *O. narbonense* as low. In addition, the averages of the other species were in the 'medium' and 'very high' soil classes (*Table 5*). The species grew in soils mostly with high organic matter. There was no significant difference in organic matter among the soils of the species ($P > 0.05$). However, the evaluation of the organic matter contents showed that the soils of *O. oligophllum* and *O. orthophyllum* contained high organic matter. Additionally, the soils of the other species had low to high organic matter contents (*Table 4*), and there were great variations among the organic matter contents (1.2 and 13.3%) of the soil samples studied (*Table 2*), with the highest and the lowest organic matter contents recorded in *O. oligophllum* (C3: The Gembos Plateau, İbradı, Antalya) and *O. narbonense* (C3: Yukarı Karaman, Korkuteli, Antalya), respectively. No differences in phosphorus were present among the averages of the statistical test results. The phosphorus values of the soil samples were in the range 3.2-211.0 mg kg^{-1} (*Table 2*) and high in most of the soil samples (*Table 4*). In addition, both the highest (C3: Mt. Termessos, Antalya) and the lowest (C3: The Serinyaka Village, Gündoğmuş, Antalya) phosphorus values were found in *O. armeniacum* and the phosphorus values showed great variations (*Tables 1* and *2*). The *Ornithogalum* species grew in soils with high concentrations of potassium. According to the statistical tests, there was a significant difference in potassium among the species ($P < 0.05$). According to the values, the species were included in various classes. For instance, potassium was medium and low in the soils of *O. pamphylicum* and *O. chetikianum*, whereas the soils of *O. lanceolatum* (657.5 mg kg^{-1}) had the highest potassium values (*Tables 3* and *4*). The *Ornithogalum* species grew in soils with high concentrations of calcium. As the statistical tests showed, a significant difference in calcium was present among the species ($P < 0.05$). In terms of calcium, the soils of *O. montanum* (6552 mg kg^{-1}) and *O. pyrenaicum* (6046 mg kg^{-1}) were statistically quite different from those of the others. The averages of the calcium contents of the species were very close to each other, and the soil of *O. pamphylicum* (1825 mg kg^{-1}) had a medium concentration of calcium (*Table 4*). The *Ornithogalum* species grew in soils with high concentrations of magnesium. There was no significant difference in magnesium among the species according to the statistical tests ($P > 0.05$). As a result of the evaluation of the averages, magnesium was found high in most of the species (*Table 5*). Moreover, the highest and the lowest averages of magnesium were determined in *O. pyrenaicum* (746.8 mg kg^{-1}) and *O. umbellatum* (300.5 mg kg^{-1}), respectively (*Table 4*).

Discussion

As a result, physical and chemical properties of the soil of natural Ornithogalum species have been determined, and the relationship between the plant and soil was evaluated in the present study. It is thought that the results will provide significant contributions to the cultivation studies regarding of Ornithogalum in its natural habitat.

The soil samples of the Ornithogalum species were mostly medium-textured (classified as 'loam' and 'sandy loam). Their salt contents were very low (non-saline); they were generally slightly alkaline; and their $CaCO_3$ values ranged from low to excess. The organic matter contents showed great variability in the types of locality and varied

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between the ‘low’ and ‘high’ classes. Additionally, the P, K, Ca and Mg concentrations of the soil samples were generally high.

Soil texture affects many physical properties of soil such as the water-holding capacity, and the water infiltration rates. Sandy soils generally have high infiltration rates but poor water-holding capacity. All soil samples in the study were medium-textured; therefore, they had poor water infiltration rates and poor water-holding capacity. Soil texture influences the inherent fertility of soil as well. More nutrients can be absorbed by a gram of clay particles than by a gram of sand or silt particles, for the clay particles provide a much greater surface area for adsorption. Soil Samples 23, 24, 28, 30 and 32 had high Ca concentrations (8190, 7878, 8195, 7880, and 5880). According to Havlin et al. (2013), the pH values of soil samples are slightly alkaline. The level of acidity or alkalinity in a soil affects the availability of soil nutrients and the activity of soil micro-organisms and can affect the level of exchangeable nutrients. Soil Sample 9 had a lower pH value. pH affects the availability of nutrients to plants and can therefore be used to determine the production potential of the soil. pH preferences by plants can vary, though for most plants the desirable pH range is 6.0-6.5. At this level, microbial growth was also at the maximum level.

According to Dellavalle (1992), the EC levels become non-saline in the soil samples. Soil Sample 9 with a lower pH value had the highest EC level. Soil salinity affects a plant’s uptake of water and nutrients and limits plant growth. The salt contents of all soil samples analyzed were low; thus, it was hard to evaluate the *Ornithogalum* species in terms of resistance to salt. The resistance of plants to calcium carbonate ($CaCO_3$) is one of the parameters which limit expansion and cultivation of natural plant species. Differences in the $CaCO_3$ contents of the soils where the *Ornithogalum* species were grown were found among the varieties. The $CaCO_3$ contents were high in the soils of the *O. pamphylicum, O. armeniacum, O. umbellatum* and *O. narbonense* varieties, low and medium in the soils of the *O. lanceolatum, O. chetikianum, O. pyrenaicum* and *O. oligophyllum* varieties, and very high in the soils of the *O. orthophylum*, *O. neurostegium* and *O. montanum* varieties.

Organic matter is a source of nutrients for plants besides being effective on the physical and chemical properties of soils. In general, organic matter content of soils that Ornithogalum species are grown was found to be high. The most interesting situation in organic matter content results is that the endemic species have the lowest organic matter content. *O. pamphylicum* (endemic) and *O. chetikianum* (endemic) were found to be grown in soils with low organic matter content, *O. orthophylum* in soils with high organic matter content, *O. umbellatum, O. montanum, O. pyrenaicum* and *O. narbonense* in soils with low to high organic matter content, *O. armeniacum, O. neurostegium* and *O. oligophyllum* in soils with medium to high organic matter content.

Phosphorus is essential in photosynthesis, and it is involved in energy transfer. It improves root development and rapid growth; encourages blooming; and increases resistance to diseases. An excess amount of phosphorus does not damage plants. Phosphorus also improves microbial activity in the soil. All soil samples had a high P value. Khan et al. (2016) showed that phosphorus significantly affected bulb volume and number of bulblets per plant, except the number of bulbs per plant in *Polianthes tuberosa*. Moreover, high phosphorus supply increased tuber biomass; however, it decreased the number of flowers per plant in Zantedeschia (Scagel and Schreiner, 2006). Furthermore, high phosphorus content reduced the number of flowers. This situation can be explained

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DOI: http://dx.doi.org/10.15666/aeer/1702_31073121

by the fact that phosphorus is extremely important as a structural element of many components, particularly nucleic acids and phospholipids.

Potassium plays a vital role in the physiological and biochemical functions of plants. It is absorbed in large amounts by plants. Moreover, it is used to build proteins; increases resistance to diseases by strengthening stalks and stems; increases the cuticle (waxy layer) to prevent water loss; helps prevent wilting; and enhances fruit size and development. According to Olsen and Sommers (1982), the potassium levels in the soil are adequate for the plant. According to Claassens (1990), the potassium requirements of Ornithogalum are low and the highest potassium levels do not significantly reduce the yield, but low potassium levels may reduce the probability of inconsistent yields. Bulbs of *O. lanceolatum* have a bigger size than the other species's bulbs. In our study, the highest phosphorus and potassium contents were obtained from the soils of the *O. lanceolatum.*

Calcium, which is an essential part of the plant cell wall structure, provides for normal transport and retention of other elements as well as strength in the plant. It is also considered to counteract the effect of alkali salts and organic acids within a plant. Ghoname et al. (2007) reported that calcium treatment to the plant from the soil significantly affected the plant length, fresh and dry weight however, in the vegetative stage, there was no significant effect on the diameter of the bulb. According to the results, *O. pyrenaicum*, *O. narborense*, *O. montanum*, species had the maximum flower stem lengths. Calcium contents of these species were also found to be high.

Magnesium is part of the chlorophyll in all green plants and essential for photosynthesis. It also helps activate many plant enzymes needed for growth. Gerandas and Fuhrs (2013) reported that the degradation of anthocyanins at high temperature decreased by Mg applications in ornamental plants. Anthocyanins are important constituents for specific colouration to flowers in ornamentals. Ornithogalum species are white in color. In this study, there was no significant difference between the Ornithogalum species and Mg contents.

Conclusions

The bulbs of *O. nutans* species are collected from the natural habitat and exported for ornamental and medicinal purposes in Turkey. In some cases, harvesting from nature is illegal for the species; nevertheless, the populations are in decline and are not cultivated. Therefore, cultivation and breeding studies are urgently needed. Natural distribution area should be taken into consideration when *Ornithogalum* sp. is cultivated. Understanding the relationship between certain soil properties and plant relation for Ornithogalum species, which have an economic value, can act as a guide for florists and botanists for a particular purpose.

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