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Morphological and taxonomic investigations on a local endemic species: *Allium ilgazense* N. Özhatay

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Abstract

The genus Allium is represented by a high number of taxa and a high endemism ratio in Turkey. Moreover, the genus has medicinal and economic importance because some of its species can be regarded as among mankind's the most important and the most ancient cultivated crops (onion, garlic, and leek). In this study, the morphological features and taxonomic status of a local endemic species (*Allium ilgazense*) were determined and the recommendations dealing with its conservation status were presented. For this purpose, a total of 30 individuals collected from 3 different populations (10 individuals per population) of the species that grow in different locations and ecologies were investigated. The morphological results clearly indicated that *A. ilgazense* is a polymorphic species and shows distinct variation in almost all of the quantitative characters (21 out of 36), although the qualitative characters (15 out of 36) are more stable. The diagnostic characteristics of *A. ilgazense* were specified as 'colour of flowers', 'indumentum and shape of inner and outer perianth segments', 'shape of spathe valves', 'colour of anthers' and 'slightly exserted stamens'. The UPGMA analysis, based on morphological similarities and dissimilarities (21 selected morphological characters) among 30 individuals from 3 populations of *A. ilgazense* and 10 individuals of *A. jubatum*, presented that *A. ilgazense* is a clearly distinct species and there is no significant specialization among its populations distributed in different ecologies. Moreover, in order to protect the natural populations of *A. ilgazense*, the threat factors were determined. According to the IUCN criteria, a new threat category (EN, Endangered) was recommended for the species.

Keywords: *A. ilgazense*; conservation status; endemic; morphology; taxonomy; Turkey.
Abbreviations: ANK-Ankara University, Faculty of Sciences, Department of Biology Herbarium; ANKE-Ankara University, Faculty of Pharmacy Herbarium; AOO-area of occupancy; BDm-bulb diameter; CAn-colour of anther; CPr-colour of perianth; EN-endangered; EOO-extent of occurrence; GAZI-Gazi University, Faculty of Sciences, Department of Biology Herbarium IIPr-indumentum of inner perianth segment; IoF-indumentum of filament; IOPr-indumentum of outer perianth segment; ISTE-İstanbul University, Faculty of Pharmacy Herbarium; IUCN-the International Union for Conservation of Nature; LIPr-length of inner perianth segment; LLC-length of lateral cusp; LMC-length of median cusp; LoC-length of capsule; LOFl-length of outer filament; LOPr-length of outer perianth segment; LOv-length of ovary; LPd-length of pedicel; LS-length of scape; LSt-length of style; LSV-length of spathe valves; MVSP-multivariate statistical package; NT-near threatened; NL-number of leaves; NSV-number of spathe valves; OMB-outer membrane of bulb; SIPr-shape of inner perianth segment; SoB-shape of bulb; SoC-shape of capsule; SoL-shape of leaves; SoO-shape of ovary; SOPr-shape of outer perianth segment; SoU-shape of umbel; SPr-shape of perianth; SSV-shape of spathe valve; UPGMA-unweighted paired group with arithmetic average; UD-umbel diameter; WIFl-width of inner filament; WIPr-width of inner perianth segment; WL-width of leaves; WOFl-width of outer filament; WOPr-width of outer perianth segment; WOv-width of ovary.

Introduction

According to the *Angiosperm* Phylogeny Grouping System III, genus *Allium* is a member of the family *Amaryllidaceae* (APG III, 2009). The genus is represented by 194 taxa within 14 sections in Turkey. The endemism ratio is nearly 36% (Kollmann et al., 1983; Kollmann, 1984; Davis et al., 1988; Özhatay and Tzanoudakis, 2000; Özhatay and Kültür, 2006; Özhatay et al., 2009; Özhatay et al., 2011). The importance of the genus in Turkey is not found in its high number of taxa and high endemism ratio, but also its medicinal and economic properties. Some members of the genus *Allium* can be regarded as among mankind's most important and the most ancient cultivated crops such as *A. cepa* L., *A. sativum* L., and *A. porrum* L. (Brewster, 2008). The genus *Allium* is widely accepted as taxonomically difficult genus. Even some recent studies emphasize the complexity of the genus. The general argument the members of the genus have many misleading morphological characters, no available precise monorgraph and necessity of comprehensive and detailed analysis, including morphology and other aspects (Fritsch and Abbasi 2009, Son et al. 2012). *A. ilgazense* is recognised in Section

Allium (Özhatay, 1986), and this section comprises 120 species worldwide. The general distribution of the members of the section is in the Northern Hemisphere. Turkey is the richest country in terms of the number of the species, following Russia (Şiraneci, 1991). There are 70 taxa of the section occuring in Turkey (Kollmann et al., 1983; Kollmann, 1984; Davis et al., 1988; Özhatay and Tzanoudakis, 2000; Özhatay and Kültür, 2006; Özhatay et al., 2009; Özhatay et al., 2011). *A. ilgazense* is a local endemic geophyte species that was collected for the first time from Ilgaz Mountain in the Kastamonu Province of Turkey by Özhatay in 1983 (Fig 1). Later, it was described and published as a new species in 1986 (Özhatay, 1986; Davis et al., 1988). The aim of this study can be summarised as follows: First, determine all of the morphological properties of *A. ilgazense*. Identify its taxonomical status and diagnostic characters. Detect the threat factors against the species and its habitat, and finally, assess its threat category. At the end of the study, the description of the species was expanded and a more appropriate diagnosis of *A. ilgazense* against closely related species was defined. The taxonomic status of *A. ilgazense* as a distinct species was supported by the UPGMA analysis. Moreover, it was determined that there is no morphological differentiation among the populations that grow under different ecological conditions.

Results

Allium ilgazense N. Özhatay

Bulb ovoid, 3–18 mm diam.; tunic membranous, outer ones black, inner white. Scape 22.5–73.2 cm long, 1–3 mm broad, erect, purplish at base or towards upper side. Leaves 1–4, 2–3 mm wide, semiterete and hollow, shorter than the scape. Spathe, 2–3-valved, valves 10 mm, ovate, acute, persistent. Umbel 10–35 mm diam., ovoid-spherical, 11–185-flowered; pedicels 3–25 mm, verrucose above, subequal, with white membranous bracts at base. Perianth campanulate, pink, pale pink or white at base; outer segments 3–8 × 1–2.7 mm, shorter than inner, ovate-oblong, cymbiform, acute, verrucose-scabrid keel; inner segments 3.5–9.5 × 0.7–3 mm, lanceolate, truncate or retuse at apex. Filaments slightly longer than the flowers, ciliate at base; outer filaments 4–9.5 × 0.5–1.5; inner ones 4–10 × 0.7–1.5 mm; median cusp 4–8.5 mm, subequal to lateral cusps (5–10 mm) and entire lamina; anthers purplish. Ovary ovoid, 1.5–5 × 0.7–3 mm, retuse at apex; style 1.5–7.5 mm, exserted. Capsule ovoid, 4–5 mm, valves ovate, bifid at apex and included in perianth.

The following characters were first measured and added to the description in this study: Scape thickness, number of flowers, broadness of outer and inner perianth segments, size of outer and inner filaments and their parts, and size of ovary and style. Moreover, the variation limits of following characters were expanded: bulb diameter, scape length, number of leaves, umbel diameter, pedicel length, length of outer and inner perianth segments (Table 1). According to Flora of Turkey, *A. ilgazense* is close to *A. jubatum* and *A. heldreichii*, but differs from *A. jubatum* by its length, scabridity and colour of the perianth segments, and differs from *A. heldreichii* by its longer filaments, and purple anthers (Davis et al., 1988; Özhatay, 1986). Hence, the most important diagnostic characters of *A. ilgazense* are perianth and filament features.

For the proper discrimination of these 3 taxa, herbarium vouchers of *A. jubatum* were investigated, in addition to the specimens of *A. ilgazense*. We only use the relevant literatures for *A. heldreichii* because of its absence of a natural distribution in Turkey. Moreover, there are no specimens of it in any herbarium in Turkey (Davis et al., 1988; Tutin et al., 1980). With these recent findings, the detailed morphological features and taxonomic status of *A. ilgazense* were fully determined. Furthermore, all of the measured characters that were gathered from the specimens per population, were compared with the description of *A. ilgazense* in Flora of Turkey (Table 1) (Davis et al., 1988).

Statistical analysis

The UPGMA statistical analysis was done for determining the relationship between *A. ilgazense* and *A. jubatum*. *A. heldreichii* was omitted for this analysis due to the absence of specimens. This statistical analysis, showing the relationships among the 3 populations of *A. ilgazense* and *A. jubatum*, were investigated in terms of 21 morphological characters (Fig 2). According to the UPGMA analysis 2 major clusters were observed. The first one consisted of 10 randomly selected individuals of *A. jubatum*. The second cluster contained 30 randomly selected individuals from different populations (10 individuals per population) of *A. ilgazense*. In accordance with the phenogram, *A. ilgazense* and *A. jubatum* were clearly distinguishable. A totally 40 individuals of 2 species were located in two different clades, separately, with the similarity coefficient of 0.544. The second major cluster completely belonged to the individuals of *A. ilgazense*. This cluster was composed of 2 main clades, one of which comprised 6 out of 10 individuals collected from Hacet Hill. The other clade was composed of 2 clusters. In the first clade, 7 individuals from Yaralıgöz Hill were observed. The second clade was divided into 2 clusters. The first clade was composed of the remaining 4 individuals from Hacet Hill and 4 individuals from the Campus area, while the other clade was split into 2 different clades again. Respectively, the remaining 3 individuals from Yaralıgöz Hill and the last 6 individuals from the Campus area were shown within these clusters.

Conservation status

A. ilgazense is affected by various threat factors. In the population of the Küçük Hacet district, which includes the border of the Ilgaz National Park, the grazing pressure and touristic and recreational activities harmfully affect its natural habitat. Moreover, it was observed that beetle larva damaged the bulbs of the species. Another distribution area of the species is the campus of Kastamonu University, where the on-going construction and landscape design activities in this area have, damaged the natural habitat of *A. ilgazense.* Another population has been degraded by grazing pressure in the Yaralıgöz district. Moreover the Ministry of Forestry and Water Affairs would like to establish a facility dealing with education, application, and recreational activities in the Yaralıgöz district. Unfortunately, this is a potential threat for natural populations and habitats within the near future. The IUCN threat category of *A. ilgazense* was recognised as NT in the Red Data Book of Turkish Plants (Ekim et al., 2000). This species is distributed in a limited area in Kastamonu Province and additionally, there are various threat factors against the natural populations and habitats. Hence, the category of NT is inadequate for *A. ilgazense*.

Table 1. Comparison of the description of *A. ilgazense* in Flora of Turkey and the samples collected from the different populations, in terms of morphological characters.

	Characters	Flora of Turkey	Campus area	Yaralıgöz Hill	Hacet Hil
A1	BDm (mm)	5–10	4–12	5–14	3–18
A2	NL	2–4	1–3	2–4	2–4
A3	LS (cm)	25–50	22.5–47.3	25–57.9	24–73.2
A4	LPd (mm)	5–15	4–18	4–21	3–25
A5	Spr	Campanulate	Campanulate	Campanulate	Campanulate
A6	CPr	Pink	Pink	Pink	Pink
A7	LOPr (mm)	6.5–8	5–7	4.5–7	3–6
A8	WOPr (mm)	2–2.5*	1–2.5	1–2.7	1–2.3
A9	SOPr	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong
A10	LIPr (mm)	8–9.5	5.5–7.5	6–9	3.5–7
A11	WIPr (mm)	2–3*	1–3	1–3	0.7–2
A12	SIPr	Lanceolate	Lanceolate	Lanceolate	Lanceolate
A13	LOFl (mm)	7–9.5*	5.5–6.5	5–8	4–7
A14	WOFl (mm)	0.7–1*	0.5–1.2	0.5–1.5	0.5–1
A15	LMC (mm)	8.5*	4–7.5	5–8	4–8
A16	LLC (mm)	9–9.5*	6.5–9	6–10	5–10
A17	WIFl (mm)	1–1.5*	0.7–1.5	0.7–1.5	0.7–1.5
A18	CAn	Mor	Mor	Mor	Mor
A19	LOv (mm)	3–4*	2–4	2–5	1.5–4
A20	WOv (mm)	1.3–2*	0.7–2.5	0.7–3	0.7–2
A21	LSt (mm)	4–5.5*	3–7	2.5–7.5	1.5–6

A1-21: number of each character used for the cluster analysis. Definitions of the abbreviations in the characters column are given in the Abbreviations section, Tables 4 and 5. *These characters were not found in the description of the species in Flora of Turkey. We measured them from the type specimen for a more proper comparison.

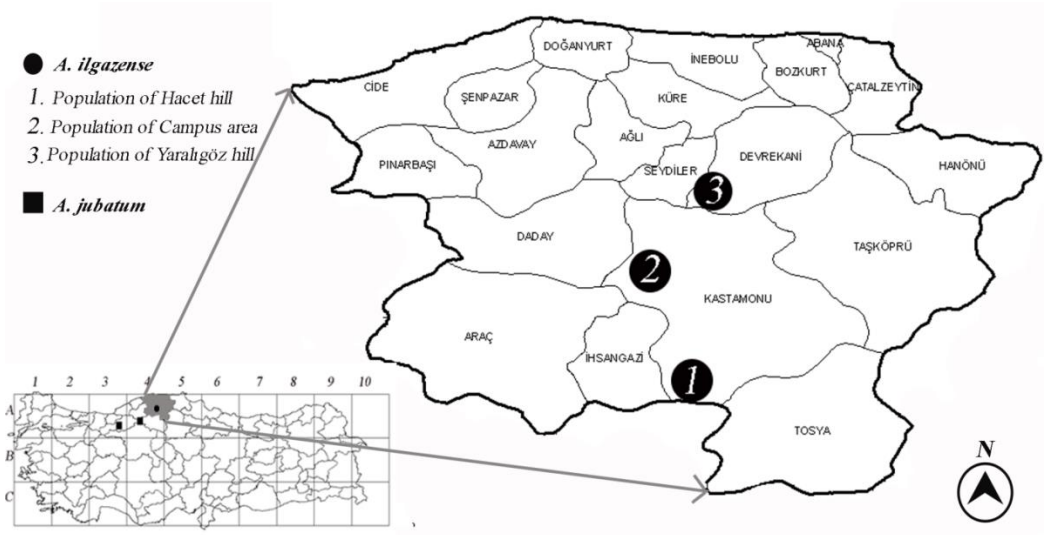

Fig 1. The map of Kastamonu Province and distributions of studied the samples of *A. ilgazense* and *A. jubatum* in Turkey: Kastamonu province is marked as grey in the small map of Turkey, and the bigger map of it shows the details. Three different populations of *A. ilgazense* are numbered as 1–3 in the black circles. The location of the investigated individuals of *A. jubatum* are marked as the black squares in the map.

For a more realistic evaluation of the conservation status of the species, threat category of *A. ilgazense* was reassessed according to the IUCN Red List criteria (IUCN, 2001; IUCN, 2003). The EOO and the AOO of the species were calculated as, respectively, 952 km^2 and 36 km^2. These 2 values meet the thresholds of EN (EOO < 5000 km²; AOO < 500 km²) (EN B1+2). The location number of the species is 3 (EN B1a+2a). It was observed that the continuing decline in the quality of the habitat was because of grazing pressure, touristic and recreational activities, and landscape designing and building construction. Remedial actions should be performed to ensure the survival of the species [EN B1ab(iii, v)+2ab(iii,v)]. The new threat category for *A. ilgazense* should be EN, because of the results of the assessment.

Discussion

At the end of the study, the morphological status and variation limits of *A. ilgazense* were expanded (Table 1). The former discrimination of *A. ilgazense* according to Flora of Turkey is as follows: *A. ilgazense* differs from *A. jubatum* by its longer (6.5–9.5 mm, not up to 6 mm), scabrid and pink (not purple) coloured perianth segments. It differs from *A. heldreichii* by its longer filaments (not less than 10 mm) and purplish anthers (not yellow). If the species is compared with *A. jubatum* and *A. heldreichii* in terms of the new findings of this study (Table 2), the length of the perianth segments and scabridity of the outer segments was not differentiated between in *A. jubatum* and *A. ilgazense*, as opposed to the

Table 2. Comparison of *A. ilgazense*, *A. jubatum* and *A. heldreichii* in terms of their morphological characters.

	Species		
Characters	*A. ilgazense*	*A. jubatum*	*A. heldreichii*
SoB	Ovoid	Ovoid	Ovoid
BDm (mm)	0.3–1.8	0.8–1.5	1
OMB	Membranous, black	Membranous, black	Membranous, black
LS (cm)	22.5–73.2	15–43	20–60
NL	1–4	2–4	2–4
WL	2–3	2–3	0.5–3
SoL	Semiterete, fistulose	Semiterete, fistulose	Semiterete, fistulose
NSV	2–3	2–3	2
LSV	10	12–13	10–15
SSV	Ovate	Ovate	Lanceolate
UD	20–35	15–20(–25)	25–45
SoU	Globose	Globose	Globose-hemispherical
LPd (mm)	3–25	2–17	5–15
SPr	Campanulate	Oblong-campanulate	Campanulate
CPr	Pink	Purple	Pink
LOPr (mm)	3–8	5–7.5	8.5
WOPr (mm)	1–2.7	1.5–2	2.5–3
SOPr	Ovoid-oblong	Oblong	Lanceolate
IOPr	Scabrid	Scabrid	Glabrous
LIPr (mm)	3.5–9.5	5.5–8.5	9.5–10
WIPr (mm)	0.7–3	1.7–2.5	2.5–3
SIPr	Lanceolate	Oblong-spathulate	Lanceolate
IIPr	Glabrous	Papillose	Glabrous
IoF	Ciliate at base	Ciliate at base	Ciliate at base
LOFl (mm)	4–9.5	3.5–7.5	5.5
WOFl (mm)	0.5–1.5	0.7–1	---
LMC (mm)	4–8	3.5–5.5	Less than 10
LLC (mm)	5–10	5–7.5	Less than 10
WIFl (mm)	0.7–1.5	1–1.5	---
CAn	Purple	Pale yellow	Yellow
LOv (mm)	1.5–5	2–4	---
WOv (mm)	0.7–3	0.7–2.5	---
SoO	Ovoid	Ovoid	Ovoid
LSt (mm)	1.5–7.5	0.5–4	---
LoC	4–5	3–4	4–5
SoC	Ovoid	Ovoid	---

Definitions of the abbreviations in the characters column are given in the Abbreviations section and Tables 4.

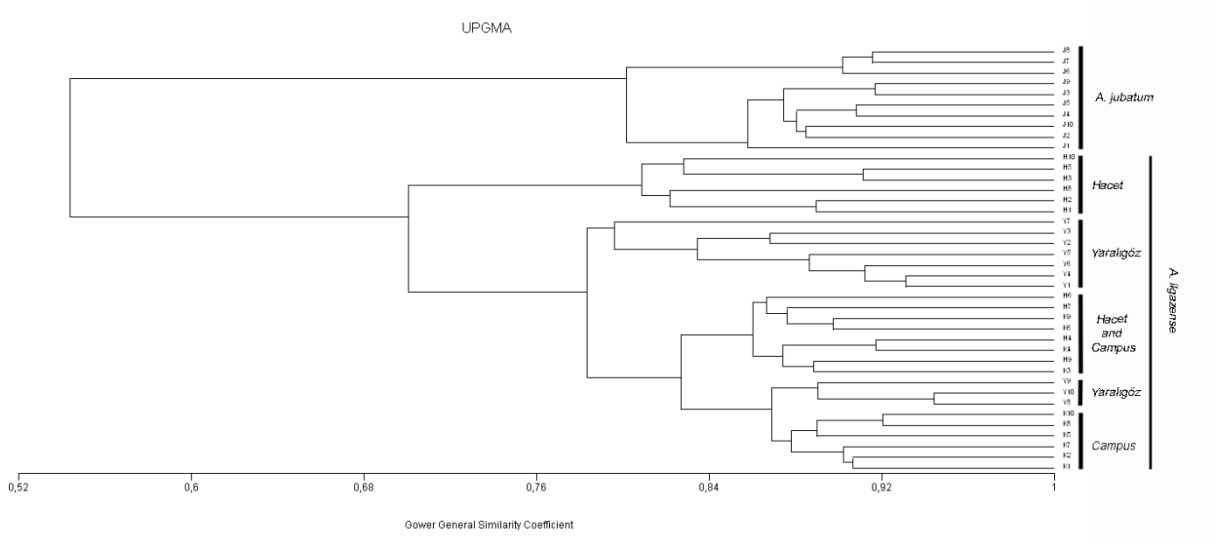

Fig 2. Dendrogram showing the phonetic relationships among the studied samples, using the matrix of morphological similarities with the UPGMA.

Table 3. Comparison of *A. ilgazense*, *A. jubatum* and *A. heldreichii* in terms of their diagnostic characters.

Characters	*A. ilgazense*	*A. jubatum*	*A. heldreichii*
SSV	Ovate	Ovate	Lanceolate
CPr	Pink	Purple	Pink
SOPr	Ovoid-oblong	Oblong	Lanceolate
IOPr	Scabrid	Scabrid	Glabrous
SIPr	Lanceolate	Oblong-spathulate	Lanceolate
IIPr	Glabrous	Papillose	Glabrous
LOFl	Slightly exserted	Included	Included
CAn	Purple	Pale yellow	Yellow

Definitions of the abbreviations in the characters column are given in the Abbreviations section and Table 4.

Table 4. List of morphological characters.

Character abbreviations	Character definitions
*SoB	Shape of bulb
BDm (mm)	Bulb diameter
*OMB	Outer membrane of bulb
LS (cm)	Length of scape
NL	Number of leaves
*WL	Width of leaves
*SoL	Shape of leaves
*NSV	Number of spathe valves
*LSV	Length of spathe valves
*SSV	Shape of spathe valve
*UD	Umbel diameter
*SoU	Shape of umbel
LPd (mm)	Length of pedicel
SPr	Shape of perianth
CPr	Colour of perianth
LOPr (mm)	Length of outer perianth segment
WOPr (mm)	Width of outer perianth segment
SOPr	Shape of outer perianth segment
*IOPr	Indumentum of outer perianth segment
LIPr (mm)	Length of inner perianth segment
WIPr (mm)	Width of inner perianth segment
SIPr	Shape of inner perianth segment
*IIPr	Indumentum of inner perianth segment
*IoF	Indumentum of filament
LOFl (mm)	Length of outer filament
WOFl (mm)	Width of outer filament
LMC (mm)	Length of median cusp
LLC (mm)	Length of lateral cusp
WIFl (mm)	Width of Inner Filament
CAn	Colour of anther
LOv (mm)	Length of ovary
WOv (mm)	Width of ovary
*SoO	Shape of ovary
LSt (mm)	Length of style
*LoC	Length of capsule
*SoC	Shape of capsule

comments in Flora of Turkey. According to the description of *A. heldreichii* in Flora Europeae, the perianth segments 8.5–10 mm and stamens are included in the perianth (i.e. less than 10 mm) (Tutin et al., 1980) (Table 2). Hence, it is clear that the length of the filaments is not diagnostic between *A. ilgazense* and *A. heldreichii* as mentioned in Flora of Turkey (Davis et al., 1988). According to the morphological measurements performed within this study, a more appropriate diagnosis of *A. ilgazense* can be defined as follows: *A. ilgazense* differs from *A. jubatum* by its pink perianth segments (not purple); lanceolate (not oblong-spathulate) and glabrous (not papillose) inner perianth segments; slightly exserted filaments (not included) and purple anthers (not pale yellow). It differs from *A. heldreichii* by its ovate spathe valves (not lanceolate); ovoid-oblong (not lanceolate) and verrucose-scabrid (not glabrous) outer perianth segments; slightly exserted filaments (not included) and purple anthers (not yellow) (Table 3). At the end of the morphological investigations, it was understood that the quantitative characters were significantly variable. Some of the most significant characters for the discrimination of the *Allium* species were the colour and indumentum of the perianth segments, exserted or included filaments, and colour of the anthers (Kollmann, 1984). Consequently, according to the new findings and the UPGMA analysis, those important characters were not very variable and they still clearly separate these 3 taxa.

Table 5. List of the characters and caharacter states used for the cluster analysis.

Number	Character abbreviations	Characters
A1	BDm (mm)	Bulb diameter
A2	LS (cm)	Length of scape
A3	NL	Number of leaves
A4	LPd (mm)	Length of pedicel
A5	SPr	Shape of perianth
Campanulate (0); oblong-campanulate (1)		
A6	CPr	Colour of perianth
Pink (0); purple (1)		
A7	LOPr (mm)	Length of outer perianth segment
A8	WOPr (mm)	Width of outer perianth segment
A9	SOPr	Shape of outer perianth segment
Ovate-oblong (0); oblong (1)		
A10	LIPr (mm)	Length of Inner perianth segment
A11	WIPr (mm)	Width of inner perianth segment
A12	SIPr	Shape of inner perianth segment
Lanceolate (0); oblong-sphatulate (1)		
A13	LOFl (mm)	Length of outer filament
A14	WOFl (mm)	Width of outer filament
A15	LMC (mm)	Length of median cusp
A16	LLC (mm)	Length of lateral cusp
A17	WIFl (mm)	Width of inner filament
A18	CAn	Colour of anther
Purple (0); yelow (1)		
A19	LOv (mm)	Length of ovary
A20	WOv (mm)	Width of ovary
A21	LSt (mm)	Length of style

Furthermore, according to the UPGMA results, there was no discrimination observed among the populations of *A. ilgazense*. Although the individuals grow under different ecological conditions, their intermixing among the clusters is an expected result. Eventually, all of the individuals belong to the same species. If a significant discrimination was observed among the populations, then we should recognise them as the infraspecific taxa.

Materials and Methods

The investigated materials comprise our collections and the specimens of ANK, ANKE, and GAZI herbaria. A total of 10 randomly selected representatives from three different populations distributed in separate locations of *A. ilgazense* were used for the morphological investigations and the UPGMA analysis. Moreover, 10 randomly selected individuals of *A. jubatum* collected from Çankırı Province were investigated for the same purposes expressed above.

Examined specimens for the morphological investigations

Specimens from Hacet Hill (A. ilgazense)

Type A4 Kastamonu: Ilgaz Mountain, stony slopes, 2000 m, 29.7.1983, N. and E. Özhatay 51918 (ISTE). A4 Kastamonu: Kastamonu-Çankırı, Ilgaz Mountain, Hacet Hill, 01.08.1993, M. Koyuncu 17845 (ANKE); stony slopes, roadsides in forest, 1770 m, 03.08.1995, Z. Aytaç 2486 and N. Adıgüzel (GAZI); 1785 m, 25.08.2010, S. Acar (ANKE).

Specimens from the Campus Area (A. ilgazense)

A4 Kastamonu: Campus of Kastamonu University, around Kastamonu Vocational School of Higher Education, forest clearing, 840 m, 09.07.2010, S. Acar 25948 (ANKE)

Specimens from Yaralıgöz Hill (A. ilgazense)

A4 Kastamonu: Devrekani, Yaralıgöz Mountain, *Juniperus nana* woodlands, 1950 m, 09.07.1991, E. Yurdakulol 3502 (ANKE); Kastamonu, Devrekani-Yaralıgöz Mountain, limestone slopes, 26.07.199, E Yurdakul 3201 (ANKE); Devrekani-Hacı İhsan, 5. km, *Carpinus betulus* forest, 1400 m, 23.07.1990, M. Koyuncu 3199 (ANKE); Kastamonu-Küre yolu, 22. km, stony places, 1000 m 01.08.1993, M. Koyuncu 10631 (ANKE); Yaralıgöz Mountain, oak forest, 1380 m, 29.07.2010, S. Acar (ANKE).

Specimens of A. jubatum

A3 Bolu: Bolu-Yedigöller, 21. km, 1200 m, 3.07.1982, N. and E. Özhatay 49209 (ANKE); A4 Çankırı: Çerkeş-

Table 6. Data obtained from the cluster analysis.

Node	Group 1	Group 2	Similarity level	Objects in the group
1	Y8	Y10	0.944	2
2	Y1	Y4	0.931	2
3	K8	K10	0.92	2
4	K4	H4	0.917	2
5	J3	J9	0.917	2
6	J7	J8	0.915	2
7	Node 2	Y6	0.912	3
8	H3	H5	0.911	2
9	J4	J5	0.908	2
10	K1	K2	0.906	2
11	Node 10	K7	0.902	3
12	J6	Node 6	0.902	3
13	K6	K9	0.898	2
14	Node 1	Y9	0.89	3
15	K5	Node 3	0.89	3
16	H1	H2	0.889	2
17	K3	H9	0.888	2
18	Node 7	Y5	0.886	4
19	J2	J10	0.885	2
20	Node 19	Node 9	0.88	4
21	Node 11	Node 15	0.878	6
22	Node 13	H7	0.876	3
23	Node 20	Node 5	0.874	6
24	Node 17	Node 4	0.874	4
25	Node 21	Node 14	0.869	9
26	Y2	Y3	0.868	2
27	Node 22	H6	0.866	4
28	Node 24	Node 27	0.86	8
29	J1	Node 23	0.858	7
30	Node 18	Node 26	0.835	6
31	Node 8	H10	0.828	3
32	Node 25	Node 28	0.827	17
33	Node 16	H8	0.822	3
34	Node 33	Node 31	0.809	6
35	Node 29	Node 12	0.802	10
36	Node 30	Y7	0.796	7
37	Node 32	Node 36	0.783	24
38	Node 37	Node 34	0.7	30
39	Node 38	Node 35	0.544	40

K1-10: number of each sample collected from the Campus area. Y1-10: number of each sample collected from the Yaralıgöz Hill. H1-10: number of each sample collected from the Hacet Hill. J1-10: number of each sample of *A. jubatum*.

İsmetpaşa, stony places, 1000 m, 12.07.1992, M. Koyuncu 9266 (ANKE). A cluster analysis of the data was carried out to examine the similarities of the studied specimens and species. To construct the phenogram, the MVSP program was used. In order to group the studied individuals and species based on their morphological similarities, UPGMA clustering method was performed. All of the morphological characters used for the statistical analysis and the other morphological investigations (marked by an asterisk) are listed in Table 4 (a total of 36 characters). For the cluster analysis, there are a total of 21 selected characters, 5 of which are qualitative and the remaining 16 are quantitative (Table 5). The character states for each sample are shown in Supplementary Table 1. The data obtained from the cluster analysis, similarity level of each of the specimens and groups are shown in Table 6. For the identification of the specimens and for more information about *A. ilgazense* and *A. jubatum*, Flora of Turkey and the East Aegean Islands was used (Kollmann, 1984; Davis et al., 1988; Özhatay and Tzanoudakis, 2000). However, we only used the relevant literatures for *A. heldreichii* (Tutin et al., 1980; Davis et al., 1988). All of the measured characters of the specimens of *A. ilgazense* (10 individuals per populations) and *A. jubatum* (10 individuals) used in this study are given in Tables 7–10 (Tutin et al., 1980; Kollmann, 1984; Davis et al., 1988).

Conclusion

The quantitative characters revealed that *A. ilgazense* is a polymorphic species. The species is clearly distinguishable from its close relatives, but any significant specialization among its different populations was not observed. Moreover, it is clear that the consistency of the diagnostic characters of any species depends on detailed and intensive studies of well-determined variation limits of it and its closest relatives.

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Table 7. Measurements of the morphological characters of the specimens collected from the Campus area (*A. ilgazense*).

		Specimens									
Characters	Character number	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10
BDm (mm)	A1	10	8	8	8	1	9	8	6	6	8
LS (cm)	A2	38.6	27.3	31.2	31	37.8	33	32	39.7	31	37.5
NL	A3	2	1	2	3	1	3	2	2	2	2
LPd (mm)	A4	1.7	1.2	1.7	1.2	1.5	1	1.3	1.2	0.4	0.8
SPr	A5	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate
CPr	A6	Pimk	Pimk	Pimk	Pimk	Pimk	Pimk	Pimk	Pimk	Pimk	Pimk
LOPr (mm)	A7	6	5.5	6	5.5	5	6.5	5.5	6	7	6
WOPr (mm)	A8	2.5	2	2	1.5	1.7	2	2.5	2	2.5	1.7
SOPr	A9	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong
LIPr (mm)	A10	7.5	6.5	6	6.5	6.5	6	7	6.5	5.5	7
WIPr (mm)	A11	2.5	2.2	1.5	2	2.5	3	2.5	2.5	2	2.5
SIPr	A12	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate
LOFl (mm)	A13	6	6.5	5.7	6.5	6	6	6.5	6.5	5.5	6
WOFl (mm)	A14	0.7	0.7	0.5	0.5	1	0.7	1	1	0.7	0.8
LMC (mm)	A15	6.5	7	7	7	7	6.5	7	7	6.5	6
LLC (mm)	A16	8	8	8	8	8	8	7.5	7.5	8	7.5
WIFl (mm)	A17	1	1	1	1	1	1	1	1	1	1
CAn	A18	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple
LOv (mm)	A19	3.5	3.5	2.5	2	3.5	2.5	4	3	2.5	2.5
WOv (mm)	A20	2.5	2.5	1.5	0.7	2	1.2	2.5	1.5	1.2	1.2
LSt (mm)	A21	7	6.5	4	4.5	4.5	3	5	5	4.5	5

Definitions of the abbreviations in the characters column are given in the Abbreviations section, Tables 4 and 5. **A1-21:** number of each characters used for the cluster analysis. **K1-10:** number of each sample collected from the Campus area.

Table 8. Measurements of the morphological characters of the specimens collected from Yaralıgöz Hill (*A. ilgazense*).

		Specimens									
Characters	Character number	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10
BDm (mm)	A1	1	1.4	1	1	1.4	1.4	0.9	0.9	1.2	1
LS (cm)	A2	44	57.9	54.6	39.7	46.7	53	32.5	32.5	28.1	25
NL	A3	3	4	2	3	2	3	3	3	4	3
LPd (mm)	A4	1.6	2.1	1.8	1.4	1.6	1.9	1.4	1.1	1	1.3
SPr	A5	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate
CPr	A6	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink
LOPr (mm)	A7	7	7	7	6	6	6.5	6.5	6	5.5	6
WOPr (mm)	A8	2	1.2	1.5	2	1.7	2	2	2.5	2.5	2.7
SOPr	A9	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong
LIPr (mm)	A10	8	8.5	9	7.5	7.5	8	8	7.5	7	6.5
WIPr (mm)	A11	1	1.5	1.5	1.4	1.8	1.5	1	3	2.5	2.5
SIPr	A12	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate
LOFl (mm)	A13	7.5	7	7.5	7	7	7	8	7	5.5	6.5
WOFl (mm)	A14	0.5	1	0.5	0.5	0.5	0.5	0.7	1	1	1
LMC (mm)	A15	7	7.5	8	7	7.5	7.5	5	6.8	7	6.7
LLC (mm)	A16	8.5	10	10	8	8	9	7.5	9	7.2	8.5
WIFl (mm)	A17	1	1	1	1	0.7	1	1.5	1	1	1
CAn	A18	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple
LOv (mm)	A19	3.5	4.5	4	3.5	3.2	4	5	3.5	3	3.5
WOv (mm)	A20	2	2.5	2.5	1.5	1.5	2	2.5	1.7	2	1.5
LSt (mm)	A21	3.5	4	4	5	3.7	6	4.5	5.8	4.5	5.8

Definitions of the abbreviations in the characters column are given in the Abbreviations section, Tables 4 and 5. **A1-21:** number of each characters used for the cluster analysis. **Y1-10:** number of each sample collected from the Yaralıgöz Hill.

Table 9. Measurements of the morphological characters of the specimens collected from Hacet Hill (*A. ilgazense*).

		Specimens									
Characters	Character number	H1	H2	H3	H4	H5	H6	H7	H8	H9	H10
BDm (mm)	A1	1.6	1.8	0.8	0.9	0.7	0.8	0.3	1	1.1	1
LS (cm)	A2	73.2	63	47.8	34.4	37.7	30.8	30.5	46.5	24	51.5
NL	A3	2	2	2	3	2	4	2	3	2	2
LPd (mm)	A4	2.3	2.5	1	0.8	1	0.6	0.3	2.5	0.7	1.4
SPr	A5	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate	Campanulate
CPr	A6	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink	Pink
LOPr (mm)	A7	4	3.5	4	5	3.5	5	5.5	3.5	5	5
WOPr (mm)	A8	1	1	1	1.7	1	2.3	2	1	2	2
SOPr	A9	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong	Ovate-oblong
LIPr (mm)	A10	4	3.5	4	5.5	3.5	6.5	6.5	4	6	4.5
WIPr (mm)	A11	1	1	0.7	1.7	1	2	2	1	2	1.5
SIPr	A12	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate	Lanceolate
LOFl (mm)	A13	5	4	5	5.5	5	7	6.5	4	6	4
WOFl (mm)	A14	0.5	0.5	0.7	0.5	0.7	0.7	0.7	0.7	0.5	0.7
LMC (mm)	A15	5	4	5	6.5	5	7	7	4	6.5	5
LLC (mm)	A16	7	6.5	8	7	5	8	7.5	5	7	9.5
WIFl (mm)	A17	1.5	1	1	1	0.7	1	0.7	0.7	0.8	1
Can	A18	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple
LOv (mm)	A19	3	2	1.5	1.5	2	2.3	2.5	4	2.5	3
WOv (mm)	A20	1.7	1.5	1	0.7	1	1.5	1	2	2	1.5
LSt (mm)	A21	2	2.5	3	3.5	22	6	2.5	2	5	2.5

Definitions of the abbreviations in the characters column are given in the Abbreviations section, Tables 4 and 5. **A1-21:** number of each characters used for the cluster analysis. **H1-10:** number of each sample collected from the Hacet Hill.

Table 10. Measurements of the morphological characters of the specimens of *A. jubatum*.

		Specimens									
Characters	Character number	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10
BDm (mm)	A1	1	1	1	1	1	0.8	0.8	0.8	1.2	1.2
LS (cm)	A2	39	35	38	43	24	22.5	22	25	34	29.5
NL	A3	3	3	4	3	4	2	2	2	4	3
LPd (mm)	A4	1.5	1	1.2	1.7	1	1	0.7	1	1.2	1.2
SPr	A5	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate	Oblong-campanulate
CPr	A6	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple	Purple
LOPr (mm)	A7	6.5	7	6	6	6	5	5.5	5.5	6	6.5
WOPr (mm)	A8	2	2	2	2	1.7	1.5	2	1.5	2	2
LIPr (mm)	A10	7.5	7	6.5	6	7	5.5	5.5	6	6.5	7
WIPr (mm)	A11	2.5	2	2.5	2	2	1.7	2	2	2.5	2.5
SIPr	A12	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate	Oblong-spathulate
LOFl (mm)	A13	5.5	7	5.5	5	5	4	4.5	4	4.5	5
WOFl (mm)	A14	1	0.7	0.7	0.8	0.7	0.7	0.7	0.7	1	0.7
LMC (mm)	A15	5	5.5	5	4.5	5.5	3.5	4.5	3.5	5.5	5
LLC (mm)	A16	7	7.5	6.5	7	7	5.5	5.3	5	6.5	7.5
WIFl (mm)	A17	1.5	1	1	1	1	1	1	1	1	1
CAn	A18	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow	Pale yellow
LOv (mm)	A19	3.5	3	3	3	3.5	2	2.5	3.5	3.5	4
WOv (mm)	A20	2.5	1.8	1.5	2.5	2.5	0.7	2	2.5	1	2
LSt (mm)	A21	3.5	4	3.5	2	2	1.5	2	0.5	2.5	1

Definitions of the abbreviations in the characters column are given in the Abbreviations section, Tables 4 and 5. **A1-21:** number of each characters used for thecluster analysis**. J1-10:** number of each sample of *A. jubatum*.

checking the correctness of the manuscript's grammar and spelling.

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