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MEASURING PLANT SPECIES DIVERSITY IN ALPINE ZONES: A CASE STUDY AT THE KAZDAĞI NATIONAL PARK, IN TURKEY

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Abstract - Biodiversity includes three main concepts: genetic diversity, species diversity and ecosystem diversity. Species diversity: mountain ecosystems, alpine regions above the timberline, have to be rich in terms of plant compositions and plant species diversity. Richness and evenness are two main factors in measuring the diversity of a habitat. Richness takes into account individual species, while evenness contributes towards the relative abundance of each species. According to the results of this study, 52% of the total endemic plant taxa of the Kazdağı National Park is determined in the alpine regions and therefore the alpine zones, with their rich endemic and rare plant species, are important from the aspect of biodiversity and species conservation. In addition, this study describes the relation between environmental factors and plant species diversity and evenness.

*Key words***:** Species diversity measurement, endemic plant species, alpine vegetation, Kazdaği National Park, Turkey

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INTRODUCTION

Biodiversity encompasses several facets, including genetic diversity, endemism, agro-biodiversity, species diversity and ecosystem diversity (Dirzo and Mendoza, 2008). Endemism describes taxa that are distributed in particular areas. Areas where the distribution of two or more taxa overlaps are called areas of endemism (Morrone, 2008). Alpine vegetation is characterized by relatively high biodiversity due to its fragmentation on isolated mountains (Harmsen, 2008). Regions that harbor a great diversity of endemic species are biodiversity hotspots (Anonymous, 2010). The Kazdağı Mountain has a high degree of endemism with around 32 endemic species, including varieties identified only in Kazdağı and its adjacent areas. Total taxa of Kazdağı are nearly 800, 32 of them are endemic to the mountain and 78 of them are categorized as being "endangered" in the red list (Özhatay et al., 2003).

Some studies reveal strong correlations between diversity and variables such as elevation, exposure, slope and latitude. Among these variables, elevation is the most statistically significant and positively correlated with diversity (Jiang et al., 2007). The study area is located at the intersection of three floristic regions; namely, the Euxin subregion of Euro-Siberian, Irano-Turanian and Mediterranean floristic regions. The characteristics of the Mediterranean region can be clearly observed (Özhatay et al., 2003). In addition, location of the area may also have an impact on the high endemism ratio. Based on elevation classification, the highest endemism ratio has been observed from above the timberline, in the alpine region. Fifty two percent of the total endemic plant taxa of the Kazdağı National Park is observed in the alpine regions; 76.2% of their habitat are also alpine regions, according to Flora of Turkey and the East Aegean Islands. In the Kazdağı National Park the timberline begins at approximately 1400 m. In the

elevation classification of the Kazdağı National Park, considering the respective plant compositions, there are five distinctive plant composition belts. Olive (*Olea europaea* L. var. *europaea*) groves can be observed starting from sea-level up to 250-400 m. Pine-tree (*Pinus brutia* Ten.) woodlands are present from sea-level up to 650 m. Between 650-800 m, pine-trees are mixed with oak trees (*Quercus infectoria* Oliv., *Q. frainetto* Ten., *Q. cerris* L. var. *cerris*). Between 800-1200 m black pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) woodlands are mixed with oak trees. Between 1200-1450 m, pure black pine woodlands can be clearly observed. Above 1450 m, dwarf, spiny and beds form alpine plant species like *Astragalus* sp. can be observed (TÜSTAŞ, 1995).

The study area has been subjected in the past to grazing, lumber felling, harvesting of medical plants, firewood cutting, hunting etc. Even today, illegal activities including; poaching, illicit grazing and medical plant harvesting still continue. The mountain also has a special importance for its indigenous inhabitants' sacred beliefs. Each year thousands of worshippers visit the area to stay for three weeks on the summit of Kazdağı. The activities of the pilgrims also have a potentially damaging effect on the rare, endangered and endemic plant species.

METHODS AND MATERIALS

Study area

The study area is located in the Edremit district of Balıkesir Province in the northwestern part of Turkey. The Edremit Gulf is situated at the southern end of the area. The coordinates of the area are between: 39°34′ and 39°44′ latitudes and 26°44′ and 26°59′ longitudes, covering the southern and summit part of the Kazdağı (Fig. 1). The study area is approximately 21.300 hectares in size.

The area lies between the Mediterranean and submediterranean climatic regions. The climatic characteristics are warm to hot dry summers and mild cool wet winters. The Mediterranean climatic region can be divided into three distinct sub regions:

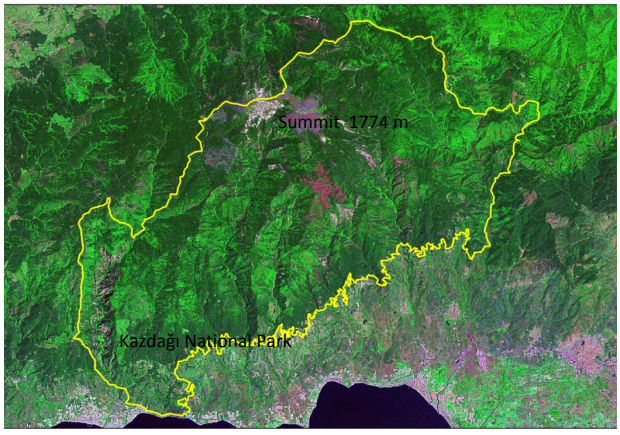

Fig. 1. Map shoving the study area, and its location in northern west part of Turkey.

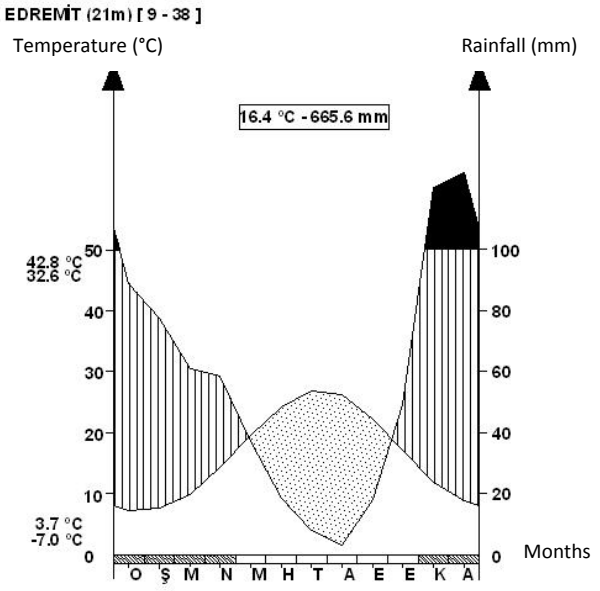

Fig. 2. Climate Diagram (following Walter, 1979) for Kazdağı in Edremit Province of Balıkesir

an arid region to the south; semi-arid regions in the eastern littorals, the western Spanish coast and the large islands, namely Sardinia, Sicily, Crete and Cyprus; and a humid region to the north (Makhzoumi and Pungetti, 1998). The study area is located in the distinct semi-arid region of the Mediterranean. The annual average temperature in the Edremit province is 16.4°C, and the annual rainfall is 665.6 mm. Rainfall increases in November and December. According to the Walter climatic diagram (Fig. 2) of the

Fig. 3. An appearance from the summit area of Kazdağı National Park

Fig. 4. An endemic species of Kazdağı National Park, Hypericum kazdaghensis Gemici & Leblebici

Edremit province, the dry period lasts for nearly 5.5 months, from the beginning of May to the beginning of October.

Vegetation analysis

We implemented vegetation analysis on 4 quadrats, the size of 20 m x 10 m sampled areas within the arboreal, shrubby and herbaceous communities in the homogeneous vegetation structure of alpine region. The size of the area was determined according to Ellenberg (1956). The quadrats were located in a typically representative section of each community. The plant species composition on the sample areas was characterized by classical phytosociological plots according to Braun-Blanquet cover-abundance values (Braun-Blanquet, 1964), which means that total coverage for each species (vertical projection onto the ground) was estimated visually and recorded within seven cover classes: r: 1 or 5 individuals; +: few individuals (< 20) with cover < 5 %; 1: many individuals (20–100) with cover < 5 %; 2: 5 % –25 % cover; 3: 25 %–50 % cover; 4: 50 %–75 % cover; 5: 75 %–100 % cover (Braun-Blanquet, 1964; Godefroid and Koedam, 2004). In addition to the floristic composition of the plant community of the alpine region, we recorded the following environmental variables in each sample: elevation, exposure, slope and location, and all of them were measured on site. Also the botanical nomenclature follows the "Flora of Turkey and East Aegean Islands" of Davis (Davis, 1965-1985).

Data analysis

To quantify the relationship between species diversity (plant diversity), plant compositions of sample quadrats' similarity on the alpine regions, the Shannon-Weaver (Shannon and Weaver, 1949) and Sørensen (Sørensen, 1948) indexes were used.

Shannon-Weaver (H') and Simpson's (D) indexes are measures of diversity and mostly used in ecological diversity measurement research. If we compare the two, the Shannon index takes into account rare individuals, while Simpson's index gives more weight to predominant individuals. Prior to analysis by Shannon (Shannon and Weaver, 1949) and Simpson index, Braun–Blanquet scores were transformed to relative cover (r: 0.01; + : 0.02; 1: 0.04; 2: 0.15; 3: 0.375; 4: 0.625; 5: 0.875) (Fontaine et al., 2007). Shannon index, Simpson index, Simpson's index of diversity and Simpson's reciprocal index were selected to characterize diversity indices of plant compositions.

$$H=-\sum_{i=1}^{n}(pilnpi)\sum_{i=1}^{n}(pilnpi)$$

where *H* is the Shannon-Weaver index representing diversity level of a plant composition, $pi\ pi$ is the relative of each species recorded in the quadrat, and n the number of species in the particular quadrat.

Simpson's diversity index (D) is one of a number of diversity indices used to measure diversity. In ecology, it is often used to quantify the biodiversity of a habitat. For plant species the percentage cover in a quadrat is usually used. S is the number of species, N is the total percentage cover or total number of organisms and n is the percentage cover of a species. A low Simpson index value equals higher diversity, whereas a high value correlates to a lower diversity.

$$D = \frac{\sum_{i=1}^{S} ni\,(ni-1)}{N(N-1)}$$

Simpson's index of diversity (1-D) is calculated by subtracting D from 1. The value of this index ranges between 0 and 1. The index represents the probability that two individuals randomly selected from a sample belong to different species. Diversity is in direct proportion with the value calculated. The lowest value of Simpson's reciprocal index (1/D) index is 1. The value represents community richness. Diversity is also in direct proportion with the value. Finally, the Sørensen index is calculated from:

$$QS = \frac{2.C}{A+B}$$

where C is the number of species shared by two samples; and A and B are the numbers of species contained in samples A and B.

RESULTS AND DISCUSSION

The significance of Mediterranean forests can be seen with regards to their environmental impact in protecting watersheds, stabilizing the soil and to their role of providing a repository of genetic and species diversity (Makhzoumi and Pungetti, 1998). Kazdağı National Park can be seen as a repository of the genetic and species diversity of the area with its rich endemism ratio which is an indication of species diversity. To reiterate the statistical data findings: 32 taxa of nearly 800 taxa, including varieties, are endemic to Kazdağı. The ratio of endemism in Kazdağı is nearly 4% and the distribution of endemic species is as generally observed in the alpine regions. The vegetation type in the alpine regions, including the summit which begins approximately at 1450 m, is dwarf, spiny and bed form alpine shrub and meadows.

In the Mediterranean-Montane region, black pine dominates as the general vegetation type. It is an important type of forest in the Mediterranean region, as well as in the Central European region. It usually forms woods at the mountain level as it can withstand winter frost as well as hot dry summers. It grows on most types of dry soil, as long as they are well drained, but it is most commonly found on "poor" siliceous soil where other tree species cannot compete. The black pine, subspecies *pallasiana,* is the most widespread of the black pines in southeastern Europe (Polunin and Walters, 1985). Kazdağı National Park is spread over the south part of the Kazdağı and on the northern side of the mountain where there is more humidity. A type of endemic fir, *Abies nordmanniana* (Steven) Spach. subsp. *equitrojani* (Aschers. & Sint. Ex Boiss.) Code & Cullen, which has been thought of as a hybrid of *Abies cephalonica* Loud. and *Abies bornmülleriana* Mattf. generally spreads on the northern side and near the summit area of the southern side of the mountain mixed with black pine. The companion species to the black pine on the tree, shrub and field layers are; *Quercus cerris* L. var. *cerris*, *Populus tremula* L., *Castanea sativa* Miller, *Quercus frainetto* Ten.; in shady and humid regions these are: *Abies equitrojani* and *Fagus orientalis* Lipsky, *Styrax officinalis* L., *Crataegus monogyna* Jacq., *Sorbus torminalis* (L.) Crantz, *Juniperus communis* L. subsp. *nana* Syme, *Verbascum vacillans* Murb., *Digitalis trojana* Ivan., *Lathyrus laxiflorus* (Desf.) O. Kuntze, *Asperula involucrate* auct. Non Wahlenb., *Veronica chamaedrys* L., *Cicer montbretii* Jaub. & Spach, *Luzula forsteri* (Sm.) DC., *Pteridium aquilinum* (L.) Kuhn.

Table 1. Endemic species of Kazdağı, their habitat and presence on the Alpine region.

Endemic species to Kazdağı	Habitat	Existence on alpine region
Abies nordmanniana subsp. equi-trojani	North slopes, 1000-1700 m	-
Ferulago idae	Siliceous (schistose) rocks, open stony places, 1750 m	-
Ferulago trojana	Open places in Pinus brutia, Olea europae, Quercus sp., and Sparteum junceum, 100-650 m	-
Achillea frasii var. trojana	Open rocky places in Pinus nigra, 1500 m	-
Centaurea odyssei	Rocky slopes, Pinus nigra clearings, above tree line, 160 m	+
Cirsium steirolepis	Pinus nigra forests, 1350-1400 m	+
Hieracium marmaricola	Rocky slopes in open Pinus nigra forests	-
Hieracium scamandris	Pinus nigra forests	-
Jasione idae	Rocky slopes, 1350-1700 m	+
Silene balanthoides	Grazed alpine grassland, 1700 m	-
Astragalus idae	Mountain steppes, 1600-1700 m	+
Hypericum kazdaghensis	Scree, schist places, 1500-1700 m	+
Nepeta sibthorpii	Rocky slopes open in Pinus nigra forests	-
Sideritis trojana	Stony mountain slopes, limestone, 1500-1720 m	+
Thymus pulvinatus	Rocky slopes, 1300-1500 m	+
Allium kurtzianum	Mountain slopes on marble, 1500-1750 m	+
Armeria trojana	Siliceous (schistose) rocks, stony places, 1500-1700 m	-
Asperula sintenisii	Limestone, 1600-1750 m	+
Galium trojanum	Rocky places in Pinus nigra forests	+
Digitalis trojana	Bushy slopes, Limestone cliffs, Fields, 90-800 m	+
Hesperis theoprastii subsp. sintenisii	Marble rocky places	
Hieracium idea	Rocky places	-
Hieracium phaeochristum	?	-
Peucedanum arenarium subsp. urbanii	Steep slopes, 1500 m	-
Verbascum scamandri	hillsides	+
Hesperis balansae subsp. mytilensis	Marble rocks, rubbles, rocky places, 900-950 m	+
Papaver somniferum var. pullatum	?	-
Linum boissieri	Limestone, serpentine rocks, 1700-2200 m	-
Acer hyrcanum subsp. keckianum	Groves, woods, 110-1600 m	-
Carduus nutans subsp. trojanus	Fields, fallow fields, garigues, 0-2700 m	-
Thymus cherlerioides var. cherlerioides	Open rocks and gravelly places, 1600-2600 m	+
Rhamnus rhodepus subsp. anatolicus	Rocks, meadows, 100-900 m	-

In the alpine region, the dominant species are *Hypericum kazdaghensis* Gemici & Leblebici, *Juniperus communis* L. subsp. *nana* Syme, *Ranunculus illyricus* L., *Dianthus arpadianus* Ade & Bornm., *Asperula sintenisii* Ascherson ex Bornm., *Thymus cherlerioides* Vis., *Lotus corniculatus* L. There are also some of the characteristic species of Astragalo-Brometea and Daphno fectucetea class, such as *Koeleria cristata* (L.) Bertol., *Scabiosa columbaria* L., *Acantholimon ulicinum* (Willd ex Schultes) Boiss., and *Daphne oleoides* Schreber.

As shown in Table 1, 13, of the 32 endemic species of Kazdağı were determined on the alpine region. This shows the species diversity ratio of the alpine regions. A similar study shows that the highest richness is found on Helen Mountain in the alpine region between 1700-2200 m. This altitudinal belt not only has a high species richness level, but also highly diversified vegetation types. (Jiang et al., 2007). Another study which indicates the relation between altitude and plant species diversity was implemented by Özkan (2003). Alpha-diversity values are calculated

Table 2. Plant species, cover-abundance scales and environmental features of quadrats on the alpine vegetation in Kazdağı National Park.

Quadrats		1	2	3	4	
Size of quadrat (m²)		200 m²	200 m²	200 m²	200 m²	
Altitude (m)		1674 m	1385 m	1770 m	1748 m	
Exposure		S	S	SE	SW	
Inclination (%)		5%	% 0	25%	10%	
Geological structure		Marble	Marble	Marble	Marble	
Coverage of the tree layer (%)			3%			
Coverage of the shrub layer (%)		3%	8%	3%	3%	
Coverage of the herb layer (%)		75%	80%	75%	70%	
Layers	**Characteristic and differential species of alpine vegetation formations**					
H	Hypericum kazdaghensis	1	1	r	+	4
H	Juniperus communis subsp. nana	3	2	+		3
H	Ranunculus illyricus	r	+		+	3
H	Dianthus arpadianus		1	+	+	3
H	Verbascum vacillans	+	+		r	3
H	Asperula sintenisii	3		+	+	3
H	Thymus cherlerioides var. cherlerioides	2		1	+	3
H	Lotus corniculatus	r		+	1	3
H	Scilla bifolia	1	1			2
H	Acinos alpinus	r			+	2
H	Potentilla kotschyana			1	+	2
H	Chamaecytisus eriocarpus			1	1	2
H	Galium trojanum			+	+	2
H	Minuartia garckeana	+		+		2
H	Astragalus idae				1	1
H	Asperula lilaciflora subsp. lilaciflora		1			1
H	Centaurea odyssei	1				1
H	Draba bruniifolia subsp. olympica	2				1
H	Sedum lydium		+			1
H	Thymus pulvinatus		1			1
	Characteristic species of QUERCETEA PUBESCENTIS					
S	Pinus nigra subsp. pallasiana		2	r	r	3
H	Pinus nigra subsp. pallasiana		1	+	+	3
T	Pinus nigra subsp. pallasiana		+			1
T	Quercus cerris var. cerris		+			1

Table 2. Continued

H	Digitalis trojana		+			1
	Characteristic species of ASTRAGALO-BROMETEA					
H	Koeleria cristata	1		1		2
H	Scabiosa columbaria subsp. ochroleuca var. webbiana		1	+		2
H	Allium flavum subsp. tauricum var. tauricum		+			1
H	Centaurea urvillei subsp. urvillei	+				1
H	Dactylis glomerata subsp. hispanica		1			1
H	Pilosella hoppeana subsp. troica		+			1
H	Sanguisorba minor subsp. muricata		1			1
H	Teucrium chamaedrys subsp. chamaedrys		1			1
	Characteristic species of DAPHNO-FESTUCETEA					
H	Acantholimon ulicinum var. ulicinum	r		+	1	3
H	Asyneuma limonifolium subsp. limonifolium	r		r	r	3
H	Daphne oleoides subsp. oleoides	1		+		2
H	Astragalus angustifolius subsp. angustifolius	+				1
	Characteristic species of PINO-CISTION					
H	Genista lydia var. lydia	1				1
H	Trifolium caudatum	2				1
	Companions					
H	Viola tricolor	1	1		1	3
H	Anthemis pseudocotula		1	+	1	3
S	Sorbus umbellata var. cretica	r		r	r	3
H	Festuca ustulata	1		+	1	3
H	Bromus squarosus		1	1		2
H	Genista anatolica			1	1	2
H	Plantago lanceolata			1	+	2
H	Scrophularia myriophylla			+	+	2
H	Muscari bourgaei	r			+	2
H	Poa alpina		1		+	2
H	Anthemis wiedemanniana	+				1
H	Centaurea athoa				r	1
H	Cirsium steirolepis		+			1
H	Cerastium alpinum			+		1

Table 2. Continued

H	Arenaria serppyllifolia			+		1
H	Crocus gargaricus	2				1
H	Hesperis balansae				+	1
H	Echium russicum				+	1
H	Thymus sipyleus var. sipyleus		2			1
H	Veronica caespitosa var. caespitosa	1				1
S	Salix caprea	+				1
H	Allium guttatum subsp. guttatum		+			1
H	Anthyllis vulneraria subsp. praepropera	2				1
H	Centaurea cyanus		1			1
H	Carex distachya var. distachya			1		1
H	Poa bulbosa				1	1
H	Chamaecytisus hirsitus		2			1
H	Jasione idaea		1			1
H	Anthemis arvensis				1	1
H	Orchis anatolica		r			1
H	Rosa canina	+				1
H	Rosa pulverulenta		1			1
H	Rubus canascens var. glabratus		1			1
H	Salvia tomentosa		1			1
H	Sedum pallidum var. bithynicum	1				1
H	Sideritis athoa		+			1
H	Sideritis trojana	1				1
H	Silene dichotoma subsp. dichotoma		1			1

Table 3. Sørensen index values of quadrats

Quadrats	1	2	3
1			
2	0.205882		
3	0.40678	0.222222	
4	0.42623	0.246154	0.607143

Table 4. Shannon index, Simpson index, Simpson's index of diversity and Simpson's reciprocal index values of the quadrats.

Sample areas	Shannon diversity index (H')	Simpson diversity index (D)	Simpson's index of diversity (1-D)	Simpson's reciprocal index (1/D)
1	2.05666	0.27859	0.72141	3.58949
2	3.30758	0.04797	0.95203	20.8452
3	3.20245	0.04408	0.95592	22.6875
4	3.26689	0.04146	0.95854	24.1196

from vegetation analysis of the area at 1200-1900 m and a direct proportion up to 2000 meters, determined between altitude and species diversity (Özkan & Gürsoy, 2008).

Plant species varieties, cover abundance values and environmental factors of the quadrats of Kazdagi National Park can be clearly seen in Table 2.

According to the Sørensen index values, the highest similarity (60%) was found between the third and the fourth quadrats. On the other hand, the lowest similarity (20%) was found between the first and the second quadrats. The similarity indices of the first with the third and fourth quadrats were the same (40%). In general, the second quadrat's Sørensen indices are lower than the others. This is relevant with the number of species included in the second quadrat. Other environmental factors, such as geological structure, inclination, exposure, are similar. Quadrats on the alpine region have homogeneity, but there were plant composition differences between the quadrats; for this reason. The Sørensen index value variants T were between 20-60% (Table 3).

As the Shannon index takes into account rare individuals, i.e. only the number of species without evenness, it can be seen on Table 4 that the highest Shannon index (H') value was found on the second quadrat because the highest number of species is determined on the second quadrat. The lowest value determined is on the first quadrat. The third and fourth quadrats are nearly the same in their Shannon index values. The lowest Simpson diversity index (D) value was found on the first sample area. Simpson's index gives more weight to abundant species. Thus that, as the species evenness is low, the Simpson diversity value (D) is low. Low relative abundances of plant species on the first quadrat is correlated with the quadrat's location (Baba Dağ) which has a high level of human activity (pilgrims on the mountain). The Simpson index essentially considers population size, i.e. the evenness of the species. In tThe other quadrats the values of the Simpson diversity index are high and similar. All diversity index values for the first quadrat are the lowest. The second, third and fourth quadrats are all similar to each other. As the first, third and fourth sample areas' species numbers are the same, their Shanon index values are not the same because of the first quadrat's low evenness of plant species. Three of them have 16 plant species and; only the second one has 20 plant species. From the aspect of plant species richness, the second quadrat comes first.

Many endemic plant species with their colorful flowers can be seen in June. Marble bedrocks cover the area. In patches, gneiss bedrock is also seen between the marble (Fig. 3). Between these calciferous rocks, small flowers can be observed clearly. Land use of the summit area is extensive because of the sacred beliefs of the inhabitants. For instance, *Sideritis trojana* Bornm. and *Thymus pulvinatus* Čelak species are endemic to Kazdağı and their habitat is only on the summit and it's adjacent areas. Inhabitants harvest *Sideritis trojana* leaves used in making traditional tea. *Thymus pulvinatus* inhabits a localized area on the summit. Both plants are considered critically (CR) endangered according to red book data. Another endangered (EN) category species is *Hypericum kazdaghensis* (Fig. 4). This plant is harvested for the paint industry. For this reason, with the example of Kazdağı National Park, summit areas and alpine zones must be considered a priority for biodiversity conservation.

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