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Original Research

Morphological Diversity of *Dorystoechas hastata*, a Relict Endemic Species, Across Habitat Variability

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Abstract

Dorystoechas hastata is a relict endemic species grown in Antalya, Turkey. The species is under risk of extinction due mainly to the uncontrolled mass collection for its pharmacological properties. The objectives of the study were to assess morphological diversity of *D. hastata* in its natural habitat, and the effect of habitat characteristics on the species diversity. The 59 genotypes representing 16 populations, encompassing the complete natural habitat, were morphologically characterized. Results revealed that the species was naturally located from sea level (4 m) up to 2000 m, in a wider geographic area than stated previously. It occupies different habitat structures ranging from forests, especially at lower altitudes, to the steppe regions with limestone slopes and stony sections at the higher altitudes. The majority of genotypes occupied either south, southeastern or southwest aspects. Results proved the existence of substantial variation within and among populations for morphological characteristics as confirmed by principal component and cluster analyses. The results are expected to aid better understanding of the genetic variation and distribution of *D. hastata* and may assist in cultivation of the species and selection of candidate genotypes for future conservation and breeding programs.

Keywords: medicinal plant, aromatic plant, Lamiaceae, ecological and edaphic traits

Introduction

Dorystoechas hastata Boiss. and Heldr. Ex Bentham is the only species in the Dorystoechas genus of Lamiaceae (Labiateae) [1]. The plant is a relict endemic to Antalya province of Turkey and protected as Vulnerable status in IUCN Red List Categories [2, 3]. As with many of the Lamiaceae members, it has dense volatile and aromatic oil content [4], known for its medicinal properties and used in medical and perfumery industry [3]. *D. hastata* leaves are used to make an aromatic tea locally named as "Çalba tea" used as a healing beverage against common cold or as a health drink by the local inhabitants. Its pharmacological properties including etheric oils [3], antioxidant activity and essential oil composition [3-5] have been reported.

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D. hastata is a woody shrub with unique aesthetic appearance presenting a great potential to be used as an ornamental plant. The species blooms between March and July, and flowers are borne on upright attractive flower spikes. All of its parts are densely aromatic, leaves are lanceolate, hastate, often soft pile, rough and edges are small lobed [1].

It is a member of East Mediterranean element and reported to be distributed in west and northwest part of the Antalya Province of Turkey between 650-2000 m altitudes [1]. It was stated that natural distribution area of *D. hastata* included Tahtali Mountain and Cukur Plateau (1525 m) located in Kemer district (650 m) and Termessos (1000 m) in Korkuteli district. The largest part of the distribution area is in Beydaglari (Olimpos) Coastal National Park known to inhabit endangered plant species [1, 2].

Plant populations in their natural habitats are an important resource for plant breeders since they harbor a considerable amount of variation [6, 7]. Large genetic diversity within a species offers preliminary selection materials that are important for crop improvement. Genetic diversity can be estimated from morphological, agronomical and physiological characters, in addition to molecular markers [7]. Morphological data have been used in estimating genetic diversity in many plant species [8, 9]. Despite the fact that many factors such as environmental conditions, plant developmental stage and polygenic inheritance have an influence on morphological characters [10, 11], it was accepted that morphological characterization is the first step before starting DNA-based studies [12]. There are several sets of phenotypic characters that may be used for morphological characterization [13]. In general, flower and leaf characteristics, valuable morphological characters for species cultivation in horticulture, along with habitat requirements aid to make informed decision to select the accessions for future use [14]. Moreover, assessment of the diversity, distribution range and habitat characteristics of a species is an essential part of establishing an effective conservation strategy for that species [15].

To the best of our knowledge, this is the first report on morphological diversity of this relict endemic species. Moreover, the species is under risk of extinction due mainly to uncontrolled mass collection for its pharmacological properties. Immediate domestication of this species as part of ex-situ conservation is suggested [16]. Cultivation or domestication of this species has yet to be initiated. Information regarding morphological diversity of *D. hastata,* and the ecological factors affecting its distribution are expected to assist in cultivation of the species and selection of candidate genotypes for future domestication programs. Thus, the objective of the study was to assess morphological diversity of *D. hastata* populations in Antalya, using a collection of 59 genotypes from 16 populations encompassing the whole natural distribution of the species.

Materials and Methods

Study Area and Habitat Characterization

The research area contains natural populations of *D. hastata* in Kemer-Kumluca-Korkuteli-Konyaaltı districts of Antalya located in Eastern Mediterranean region southwest of Turkey. Details of sampling localities and their habitat characteristics are presented in Table 1. Population localities were determined based on vertical and horizontal distances in order to represent whole natural distribution area of the species. The sample size ranged from 3 to 5 genotypes, at least 100 m apart, for each population depending on population size. The geographic location, altitude and aspect of each genotype were determined with global positioning system (GPS) (Table 1). The main vegetation type (i.e. steppe vegetation or pine forest) around each genotypes were assessed. The soil sample was taken from the top 20 cm of the soil profile at each site, air-dried in an oven at 65 °C, and analyzed at the soil chemistry laboratory. The pH, soil lime content, electrical conductivity (EC), soil texture based on saturation percentage, organic matter, available phosphorus (P), exchangeable potassium (K) and magnesium (Mg) contents and available iron (Fe), manganese (Mn) and Zinc (Zn) by diethylenetriaminepentaacetic acid method (DTPA) were determined.

Plant Material and Morphological Characteristics

The 59 genotypes derived from 16 different populations were studied. Field studies were conducted in 2016-2017 and measurements were taken between March and August, covering the flowering stage of the species. Fifteen morphological characteristics including plant height and diameter, leaf color, lengths of petiole and peduncle, widths and lengths of leaf, flower spike, calyx, corolla, and seed were determined. Flower, leaf and seed measurements were carried out on randomly selected 10 flower spikes with leaves per genotype using a digital caliper with 0.1 cm precision. The calyx and corollas were sampled from the middle part of the spikes. Leaf characteristics including leaf length, width and color were measured on the second pair of leaves from the apex of each sampled spike. The plant height was measured from the surface of the soil to the top of the plant. Plant diameter was measured across the widest diameter and two perpendicular measurements were averaged for each genotype. The CIELAB L*, a* and b* coordinate values were used for determining leaf color and measured using a CR-400 Chroma meter (Konica Minolta Sensing, Inc., Osaka, Japan). Three measurements were made on each sampled leaf and averaged. The hue angle or value which represents the leaf color was calculated using the formula by Banon et al. [17]. Hue is the attribute of color perception by which a color is judged to be red, orange, yellow, green, blue, purple, or intermediate between adjacent pairs of these colors, considered in a closed 360° ring or wheel. Hue angles of the four primary colors are: red, 0°; yellow, 90°; green, 180°; and blue, 270° [18].

Statistical Analysis

The data were analyzed using the variance analysis method in the GLM procedure of the SAS Statistics program (SAS version 9.0; SAS Institute, Cary, NC). Means were separated using Fisher's protected least significant difference procedure when the F test indicated significance at $P<0.05$. The PROC CORR procedure was used to perform correlation analyses among morphological and ecological parameters. Principle Component (PCA) and Cluster Analysis (CA) were performed to identify the relationship and variation between genotypes and populations using morphological and edaphic characteristics [19, 20]. Numerical Taxonomy Multivariate Analysis System (NTSYS) PC v. 2.01 [21] was used for cluster and principal component analyses after standardization procedure. Matrixes of similarity coefficients for each pair of characters were constructed using Pearson product-moment correlations. The CA dendrogram as SAHN with the unweighted pair-group method algorithm (UPGMA) was generated and plotted. A PCA was generated by using the SQRT (LAMBDA) parameter for computing eigenvectors and plotted. Contributions of the morphological and edaphic characters in PCA were determined using the FACTOR procedure of SAS Statistic program.

Results and Discussion

This study offers the first detailed analysis of natural distribution, morphological diversity and habitats characteristics of relict endemic *D. hastata* in Antalya-Turkey. Results showed that the species was naturally located from sea level (4 m) up to about 2000 m altitude distributed in a much wider geographic area than stated previously by Hedge [1] and Isık and Yucel [22] (Table 1). Moreover, the existence of *D. hastata* in Kumluca (Alakir) district was detected for the first time. There is

Table 1. Origin sites of *D. hastata* genotypes.

Origin site		Origin site code	Codes of genotypes	Altitude	Aspect	Latitude (N)/Longitude (E)		Habitat characteristics
KONYAALTI DISTRICT	Hacisekiler	HC	HC1	+231	Southwest	28º25,20’	40º79,757’	Rocky vegetation
			HC2	+233	Southwest	28º24,67’	40º79,789’	
			HC3	+235	Southwest	28º24,29’’	40º79,817’	
	Sivridag	S	S1	+1255	East	27º01,43’	40º83,868’	Rocky vegetation
			S2	+1250	East	27º02,79’	40º83,669’	
			S3	+1204	North	27º07,64’	40º83,530’	
	Feslikan	F	F1	+1862	Southwest	36º49,12’	30º23,830’	Steppe vegetation
			F2	+1853	Southwest	36º49,11’	30º23,832’	
			F3	+1853	Southwest	36º49,09’	30º23,810’	
			F4	+1853	Southwest	36º49,06’	30º23,782’	
	Tunektepe	TN	TN1	+40	North	28º18,18’	40º78,383’	Pine (*Pinus brutia*) forest vegetation
			TN2	+96	Southwest	28º10,11’	40º77,482’	
			TN3	+90	Northeast	28º04,77’	40º76,911’	
	Hisarcandir	H	H1	+964	Southeast	27º43,33’	40º72,232’	Rocky and pine (*Pinus brutia*) forest vegetation
			H2	+979	Southeast	27º44,88’	40º72,155’	
			H3	+937	East	27º43,63’	40º72,306’	
			H4	+906	East	27º43,27’	40º72,363’	
			H5	+904	East	27º43,82’	40º72,372’	
	Ucoluk	UC	UC1	+1087	Northwest	26º99,33’	40º58,499’	Rocky, maquis and pine (*Pinus brutia*) forest vegetation
			UC2	+1053	West	26º99,58’	40º55,952’	
			UC3	+1081	West	26º97,20’	40º57,623’	
			UC4	+1083	West	26º96,46’	40º58,214’	

Table 1. Continued.

KEMER DISTRICT	Beldibi	BL	BL1	+16	East	28º10,88’	40º69,170’	Pine (*Pinus brutia*) forest vegetation
			BL2	+61	Southwest	28º03,29’	40º63,036’	
			BL3	+7	North	28º02,61’	40º69,115’	
			BL4	+4	North	28º06,98’	40º69,157’	
			BL5	+46	South	28º09,74’	40º69,305’	
	Goynuk	GY	GY1	+62	East	27º99,35’	40º62,672’	Pine (*Pinus brutia*) forest vegetation
			GY2	+87	Southwest	27º93,42’	40º62,730’	
			GY3	+59	East	27º99,38’	40º62,671’	
	Kesme-bogazi	K	K1	+158	Northwest	27º51,73’	40º53,623’	Rocky vegetation
			K2	+104	North	27º56,25’	40º53,662’	
			K3	+109	Southeast	27º59,04’	40º53,514’	
	Beycik	BY	BY1	+743	Northeast	26º98,99’	40º42,820’	Stony slopes and pine (*Pinus brutia*) forest vegetation
			BY2	+1023	East	26º85,64’	40º43,212’	
			BY3	+1009	East	26º85,58’	40º43,181’	
			BY4	+ 956	Southwest	26º87,29’	40º43,101’	
	Tahtali	T	T1	+1094	Southwest	27º10,37’	40º58,478’	Stony slopes and pine (*Pinus brutia*) forest vegetation
			T2	+1102	Southwest	27º10,36’	40º58,519’	
			T3	+1105	East	27º08,47’	40º58,665’	
			T4	+1113	East	27º08,32’	40º58,686’	
KUMLUCA DISTRICT	Golcuk	GL	GL1	+1009	Northwest	27º43,86’	40º96,097’	Pine (*Pinus brutia*) forest vegetation
			GL2	+1008	Northeast	27º44,24’	40º96,102’	
			GL3	+971	North	27º22,60’	40º96,317’	
			GL4	+974	North	27º42,76’	40º96,316’	
	Altinyaka	A	A1	+1137	North	16º60,55’	40º55,696’	Stony slopes and pine (*Pinus brutia*) forest vegetation
			A2	+1125	Northwest	26º53,89’	40º54,633’	
			A3	+1106	Northwest	26º53,45’	40º54,648’	
	Sogutcumasi	SO	SO1	+1465	West	26º42,75’	40º67,287’	Pine (*Pinus brutia*) forest and rocky vegetation
			SO2	+1399	East	26º46,86’	40º66,214’	
			SO3	+1400	East	26º47,18’	40º66,202’	
	Alakir	AL	AL1	+1202	East	25º65,24’	40º57,796’	Rocky and pine (*Pinus brutia*) forest vegetation
			AL2	+1205	East	25º63,25’	40º57,401’	
			AL3	+1151	East	25º22,66’	40º53,718’	
			AL4	+1059	East	24º91,92’	40º48,308’	
KORKUTELI DISTRICT	Gulluk	GU	GU1	+1009	Southeast	27º43,86’	40º96,097’	Rocky and pine (*Pinus brutia*) forest vegetation
			GU2	+1008	Southwest	27º44,24’	40º96,102’	
			GU3	+971	Northwest	27º22,60’	40º96,317’	
			GU4	+974	Northwest	27º42,76’	40º96,316’	

no other known species within the family of Lamiaceae, limited only within the province of Antalya and no local endemic species with the distribution from sea level up to 2000 m.

Results showed that 57 % of the populations occupied south, southeastern and southwest aspects (Table 1). Slope aspect is one of the major landscape feature influencing microclimate and potential niche for vegetation [23]. It influences incident solar radiation, which in turn alters soil and air temperature, and soil moisture [24]. Preference for slope aspect as one of the indication of drought resistance might be useful in predicting response of the perennial species to drought. Kimball et al. [23] reported that perennial species occupying south facing slopes under Mediterranean climate had better performance under drought. The aspect preference of the *D. hastata* indicates both possible existence of variation in drought resistance and potentially presence of drought resistant genotypes. Therefore, *D. hastata* genotypes especially growing on steppe habitats with south aspects might possess higher drought resistance and be used for development of cultivars with better drought resistance.

It was found that *D. hastata* individuals occupied different habitat structures ranging from forests especially at lower altitudes to the steppe regions with limestone slopes and calcareous rocky habitat structures at the higher altitudes within the distribution regions. The 75% of the populations existed under or openings of forest dominated by *Pinus brutia* trees accompanied with rocky habitat structures (Table 1). When the distribution regions of *D. hastata* is evaluated with a floristic point of view, it is observed that the dune, maquis and forest characters dominate the coastal part of the research area including Antalya-Kumluca route. These floral elements and their dominance gradually decrease with the gradual ascent towards the upper altitudes. In the higher elevation, the sand dunes turn into maquis and forest accompanied with rocky habitat structures. The trees end at about 1800 m, leaving to the limestone slopes and stony parts as main habitats that are among the most important topographic and vegetative elements in the region.

Determination of the amount and distribution of genetic variation within and among populations of a given species might provide important basic information for breeding programs and for the establishment of programs to conserve genetic resources [25]. Analysis of variance revealed the existence of significant variation (P<0.0001) both within and among populations (Table 2). Both vegetative and generative plant structures differed substantially among populations. Within variation observed in some populations was also noteworthy. The most morphologically diverse genotypes were in Gulluk and Ucoluk, followed by Hisarcandir and Alakir populations. For instance, the genotypes within Gulluk population, varied in almost all morphological characters (Table 2). On the contrary, genotypes in Sogutcumasi and Altinyaka populations differed from each other only for four and five of the 15 morphological characteristics, respectively. Plant height and diameter along with flower spike length and width showed the highest variations among genotypes within populations. Although some of the morphological variation observed among populations might be attributed to the environmental differences

Table 2. Analysis of variance between and within populations for morphological characteristics of *D.hastata* genotypes. (PH: Plant height (cm), PD: Plant Diameter (cm), LW: Leaf width (Leaf width measured from the widest part of the leaves (cm)), LL: Leaf length (Leaf length measured from the longest part of the leaves (cm)), PETL: Petiole length (cm), SW: Spike width (Spike width measured from the widest part of the spike (cm)), SL: Spike length (cm), PEDL: Peduncle length (cm), CW: Calyx width (mm), CL: Calyx length (mm), COW: Corolla width (mm), COL: Corolla length (mm), HUE: Leaf color)

Source of variation	df	Mean square and *P* values												
		PH	PD	LW	LL	PETL	SW	SL	PEDL	CW	CL	COW	COL	Hue
Between populations	15	1560.5	36849.7	6.02	17.39	4.57	0.53	75.068	5.79	1.2	3.13	7.57	5.38	40.516
P value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
Error		571.9	2281	0.27	0.76	0.32	0.016	2.249	0.679	0.08	0.17	0.31	0.34	3.555
Within populations														
Tahtalı	3	6498.4	24198.4	0.594	2.458	0.457	0.059	10.58	1.18	0.058	0.46	4.23	0.06	9.189
		<.0001	0.004	0.022	<.0001	0.107	<.0001	<.0001	0.356	0.1751	0.0002	<.0001	0.238	<.0001
Kesmeboğazı	2	551.4	7100.0	0.595	3.374	0.51	0.035	1.069	0.72	0.02	0.31	1.49	0.95	18.613
		0.017	<.0001	0.198	0.026	0.418	0.49	0.87	0.253	0.845	0.262	<.0001	0.0108	0.0064

Table 2. Continued.

Gölcük	3	1266.7	6968.2	0.514	2.731	0.592	0.056	14.426	2.277	0.09	1.06	1.02	0.53	3.637
		0.016	0.008	<.0001	<.0001	0.0035	0.0192	<.0001	0.188	0.394	0.006	0.071	0.542	0.504
Beldibi	4	3420.8	39953.9	0.467	1.834	0.497	0.044	11.921	0.808	3.53	2.76	3.04	2.71	7.421
		0.0065	<.0001	0.004	<.0001	0.066	<.0001	<.0001	0.072	<.0001	<.0001	<.0001	<.0001	0.48
Beycik	3	1603	14110.9	0.989	2.123	1.811	0.088	48.224	3.76	0.16	0.57	2.35	3.18	12.44
		0.034	<.0001	0.366	0.476	0.015	0.0016	<.0001	0.002	0.0067	0.056	<.0001	<.0001	0.074
Altınyaka	2	204.2	35654.2	0.236	1.115	0.671	0.011	5.458	1.196	0.04	0.19	0.46	0.25	2.029
		0.037	0.0013	0.607	0.03	0.004	0.683	0.0006	0.216	0.289	0.144	0.225	0.637	0.804
Gulluk	3	927.3	19233.4	1.64	6.937	1.551	0.222	46.292	1.119	0.22	0.54	1.81	3.84	5.799
		0.001	0.0094	0.0017	<.0001	<.0001	<.0001	<.0001	0.473	<.0001	0.001	<.0001	<.0001	0.05
Hisarçandır	4	2492.4	1619.7	1.657	3.962	0.615	0.12	7.806	0.64	0.26	0.61	0.99	0.4	21.861
		0.0003	0.0004	<.0001	<.0001	0.003	<.0001	<.0001	0.07	0.603	0.0007	0.075	0.0374	0.0002
Üçoluk	3	757.5	12845.3	0.921	1.867	1.444	0.113	4.968	2.177	0.26	0.09	0.77	0.55	21.249
		0.21	0.002	<.0001	0.023	<.0001	<.0001	0.0011	0.0024	0.546	0.411	0.019	0.019	<.0001
Söğütcuması	2	678.7	14969.7	0.385	1.553	0.941	0.03	4.331	0.22	0.04	0.4	0.35	1.15	1.223
		0.02	0.015	0.447	0.062	0.176	0.237	0.209	0.211	0.157	0.036	0.548	0.088	<.0001
Sivridağ	3	951.3	1315.0	0.611	2.069	1.148	0.046	7.14	0.238	0.06	0.78	0.59	0.69	7.848
		0.0013	0.002	0.064	0.093	0.385	0.003	0.0001	0.006	0.002	<.0001	0.073	0.182	0.019
Feslikan	3	438.8	325.9	0.352	3.016	0.206	0.064	3.557	0.845	0.04	0.79	1.52	0.9	4.812
		<.0001	<.0001	0.337	0.002	0.571	0.0002	0.122	0.016	0.099	0.019	0.0015	0.252	0.222
Tünektepe	2	441.7	8541.	0.313	2.656	0.219	0.023	25.893	0.457	0.1	0.2	0.31	1.1	5.27
		0.03	0.05	0.016	0.003	0.79	0.123	<.0001	0.837	0.082	0.309	0.709	0.033	0.46
Alakır	3	2530.0	18300.9	0.129	2.01	0.527	0.121	13.361	3.205	0.13	0.37	1.07	1.33	7.998
		0.007	0.0014	0.263	<.0001	0.0019	<.0001	<.0001	0.0094	0.222	0.0669	0.0036	0.0001	0.0105
Göynük	2	635.7	13850.2	0.121	0.73	0.304	0.061	2.016	0.981	0.02	0.23	2.39	1.69	11.156
		0.003	0.0008	0.378	0.058	0.172	<.0001	0.221	0.075	0.897	0.0169	0.0002	<.0001	0.0284
Hacısekiler	2	679.2	73887.5	0.967	2.88	0.395	0.012	3.606	0.13	0.04	0.14	1.34	0.75	5.676
		0.03	<.0001	0.0404	0.056	0.026	0.254	0.395	0.477	0.165	0.475	<.0001	0.0006	0.0243

Table 3. Averages and standard deviations of morphological characteristics
(*PH: Plant height (cm) PD: Plant diameter (cm), LW: Leaf width (Leaf width measured from the widest part of the leaves (cm)) , LL: Leaf length (Leaf length measured from the longest part of the leaves (cm)), PETL: Petiole length (cm), SW: Spike width (Spike width measured from the widest part of the spike (cm)), SL: Spike length (cm), PEDL: Peduncle length (cm), CW: Calyx width (mm), CL: Calyx length (mm), COW: Corolla width (mm), COL: Corolla length (mm), HUE: Leaf color of *D. hastata* populations, Antalya-Turkey.

Population	PH	PD	LW*	LL (cm)	PETL (cm)	SW (cm)	SL (cm)	PEDL (cm)	CW (mm)	CL (mm)	COW (mm)	COL (mm)	HUE
Tahtali	91.9±54.8	194.4±109	2.16±0.59	4.50±1.03	1.86±0.57	1.02±0.17	7.44±2.09	1.67±1.03	2.00±0.21	3.69±0.45	3.70±1.21	5.34±0.70	118.279±2.052
Kesmebogazi	58.5±17.3	133.3±59.5	2.81±0.68	6.26±1.43	2.60±0.69	1.02±0.19	7.00±1.31	1.78±0.77	2.01±0.21	4.02±0.51	3.21±0.83	4.83±0.73	118.931±3.185
Golcuk	67.1±25.9	216.5±59.6	3.12±0.46	5.95±1.09	2.56±0.55	1.35±0.18	10.90±2.40	2.60±1.33	2.20±0.30	4.44±0.75	4.57±0.82	5.76±0.75	117.876±1.932
Beldibi	62.5±41.6	338.7±132.8	2.48±0.49	5.33±0.85	2.09±0.57	0.83±0.14	8.00±1.98	1.55±0.73	2.38±1.01	4.14±0.93	2.81±0.96	4.84±0.94	119.227±2.161
Beycik	58.5±29.9	251.9±80.7	4.16±0.95	7.86±1.46	3.54±1.01	1.38±0.21	14.90±4.45	2.50±1.36	2.26±0.30	4.71±0.61	4.74±0.96	5.83±1.10	118.866±2.574
Altinyaka	42.5±10.7	310.0±134.9	2.65±0.51	4.77±0.82	2.11±0.60	1.03±0.12	8.85±1.63	2.29±0.97	2.12±0.19	3.67±0.38	4.22±0.61	4.84±0.54	117.728±1.693
Gulluk	64.4±21.1	209.4±99.1	3.75±0.89	6.41±1.69	2.64±0.79	1.20±0.28	10.74±4.06	2.61±1.05	2.13±0.31	3.81±0.51	3.53±0.81	5.17±1.14	120.647±1.935
Hisarcandir	73.2±33.8	116.8±27.3	2.81±0.78	5.37±1.14	1.90±0.55	1.07±0.21	9.66±1.80	1.38±0.65	2.02±0.55	3.56±0.53	3.41±0.82	5.25±0.61	119.957±3.077
Ücoluk	51.1±23.3	181.3±79.1	1.58±0.62	3.62±1.04	1.26±0.76	0.75±0.21	7.83±1.53	1.51±1.04	1.71±0.53	3.22±0.31	2.82±0.67	4.54±0.56	119.823±2.91
Sogutcumasi	64.8±18.4	183.2±89.8	1.91± 0.61	4.24±1.01	1.71±0.85	0.82±0.16	8.70±1.85	1.19±0.42	1.78±0.18	3.78±0.52	2.94±0.62	5.26±0.89	120.114±0.681
Sivridag	51.3±21.4	82.5±25.8	1.87±0.63	4.18±1.19	1.64±1.03	0.80±0.15	7.67±1.77	1.08±0.35	1.87±0.17	3.68±0.57	3.00±0.62	4.88±0.07	121.8±2.125
Feslikan	51.3±14.2	60.0±12.2	2.38±0.56	4.49±1.22	1.78±0.47	0.97±0.17	7.10±1.60	1.85±0.69	2.00±0.18	3.89±0.68	3.30±0.86	4.88±0.87	116.794±1.961
Tunektepe	52.5±15.7	248.3±70.5	2.25±0.42	5.23±1.18	1.78±0.55	0.92±0.13	9.85±3.31	1.53±0.83	1.85±0.26	4.06±0.43	3.76±0.63	5.37±0.86	116.49±2.275
Alakir	75.0±35.7	196.9±94.1	2.82± 0.33	4.73±0.88	2.30±0.51	1.05±0.21	9.85±2.22	2.88±1.32	2.17±0.33	3.73±0.49	3.89±0.74	4.84±0.76	117.424±2.09
Goynuk	58.0±18.1	226.0±83.8	2.12±0.33	4.20±0.69	1.71±0.48	0.80±0.17	7.78±1.27	1.30±0.81	1.80±0.19	3.14±0.37	3.91±1.06	4.37±0.87	115.834±2.601
Hacisekiler	57.5±19.4	246.7±190	2.50±0.78	4.96±1.37	1.65±0.49	0.82±0.10	9.91±1.83	0.86±0.36	1.96±0.18	4.06±0.39	3.00±0.76	6.08±0.61	119.437±1.843
All populations	62.03±29.1	198.2±111	2.61±0.91	5.16±1.55	2.08±0.86	1.00±0.26	9.17±3.08	1.81±1.09	2.03±0.45	3.85±0.68	3.54±1.01	5.12±0.91	118.735±2.682
Max.	185.0	620.0	6.2	10.6	6.369	2.089	26.2	8.315	5.05	6.26	6.25	7.48	126.246
Min.	14.0	40.0	0.43	1.4	0.25	0.438	3.054	0.272	1	2	1.52	2.32	109.281
LSD (0.05)	33.1	130.9	0.68	1.37	0.69	0.23	3.29	0.82	0.53	0.69	1.09	1.01	2.41

[25], variations among individuals of a given location can be attributed to genetic diversity.

The means and standard deviations for morphological traits for each population are given in Table 3. A high diversity for morphological traits was evident among the *D. hastata* populations. The minimum vs maximum ranges were 13X, 16X, 14X, 25X, 9X and 30X for plant height, plant diameter, leaf width, petiole length, spike length, and peduncle length, respectively. In general, Beycik population had the widest leaves, spikes and corollas, longest leaves, petioles, spikes, peduncles and calyxes, with an above average plant height. Ucoluk population, on the other hand had the narrowest leaves, spikes and calyx, shortest leaves and petioles with a below average plant height and diameter (Table 3). Some of the morphological variations found among the populations can be attributed to differences in their habitat characteristics and altitude. As the many ecological concepts namely 'adaptive strategies' 'stress response syndrome' and 'plant ecology strategy scheme' [26] indicated that morphological characteristics in plants are correlated with adaptive response to environmental conditions of the habitat. *D. hastata* genotypes from more productive habitats (i.e. forest), often had larger structures and more robust than genotypes occupying less productive rocky habitats structures without forest cover. For instance, plant diameter values of genotypes grown in forest habitats of Beldibi population above the average of all populations (Table 3). Although both Beldibi and Kesmebogazi (Kemer) are under 500 m elevation, the populations exhibited drastically different plant diameter values due to soil type and fertility. Similarly, the effects of habitat characteristics on plant size and other morphological traits were previous reported for other species [26, 27].

In general, vegetative growth of *D. hastata* genotypes as indicated by higher plant diameter decreased with increasing altitudes (Table 3) as supported by correlation analysis (r = - 0.42) (Table 5). As it is expected, in Feslikan location (1855 m), mean plant diameter of individuals was the lowest and the mean of most of other morphological traits were lower than the populations' averages. The reason for this could be the following: The temperature at the higher altitude is lower resulting in a later commencement and earlier cessation of seasonal growth and topography that may have a greater effect on snowpack accumulation and hence soil water availability [28]. Moreover, light intensity and shortwave solar radiation increases with altitude [29] resulting with a reduction in photosynthesis and growth. The decrease in plan size as a result of increase in altitude was also reported with other plant species [30]. On the other hand, despite the gradual decrease to the upward locations, *D. hastata* height and diameter values are higher than expected at some populations (Beycik, Altinyaka and Tahtali) located at the stony-forest area (1000 m) formed by red pine (*Pinus brutia*). It is thought that the humidity level of forest closure provides a complementary effect to the optimal distribution regions formed by moving stony slopes. Thus, the plant diameter values were above the average in these forest habitat locations even at higher altitudes. The boundary values of the altitude are more distinctive in the local endemic members belonging to the genera such as *Salvia*, *Sideritis*, *Thymus*, *Origanum* and *Phlomis* of the Lamiaceae family. Except *D. hastata,* there is no other local endemic Lamiaceae species which have a distribution index around 2000 m from sea level in Antalya. At this point, it is noteworthy that the species can be distributed in open steppe areas (Feslikan location) without a forest vegetation structure at high sections.

The soil analysis results revealed that there were significant differences among populations for soil characteristics except for lime, salinity, structure, available Fe and Mn content (Table 4). The results indicated that the majority of populations grow mainly on clay soils with moderately alkaline pH, which ranged from 7.5 to 8.0. Organic matter content (OM) was between 2.5-5.1% where 63% of the populations grow on soil with minimum 4 % OM. The variation in soil P content was up to 26 times (0.42 to 10.8 kg/de), soil exchangeable K up to 8 times (37 to 279 kg/de), the Mg content was between 128-812 ppm (average 376 ppm), and the soil Zn content ranged from 0.39 to 7.1 ppm. The existence of substantial variation for soil macro and micro elements, and organic matter contents among locations suggests that this species has a wide adaptation and flexibility with respect to soil nutritional level. Edaphic factors had also effect on some of the morphological variation as supported by correlation analysis (Table 5). Results revealed that plant height was positively correlated with soil Fe (r = 0.49) and Mn content (r = 0.29). These results indicate that the genotypes in the habitats with higher Fe and Mn contents are more likely to become taller. The effect of edaphic characteristics on plant size and other morphological traits in our study closely matched with previous studies on other species [9, 31, 32].

The phylogenetic tree obtained from cluster analyses and PCA based on the morphological characters of *D. hastata* genotypes, confirmed the large variation between and within populations (Fig**s** 1-4). Cluster analysis allows relatively homogeneous groups of individuals to cluster together in a hierarchical way and visually displayed by a dendrogram [20]. The dendogram obtained from CA based on 17 morphological and 11 edaphic characters grouped genotypes into three different clusters with a mean similarity of 0.73 (Fig. 1). Geography-based clustering was not evident. Cluster I was divided in two subgroups. The K3 (Kesmebogazi3) and S3 (Sivridag3) genotypes formed a separate group within the cluster I. The BL2 (Beldibi2) genotype was the only member of Cluster III. Similar results were produced by the PCA (Fig. 2). The PCA allow the evaluation of multi-collinear data and determination of the traits most suitable for classification [19]. The first

Table 4. Analysis of variance between and within populations for edaphic characters of *D. hastata*. (L: Lime, EC: Salinity, TX: Soil texture (<%30 = Sand, %30-%50 = Loam, %50-%70 = Loamy clay, %70-%110 = Clay, %110< = Heavy clay), OM: organic matter, P: Phosphorous (ppm), K: Potassium (ppm), Mg: Exchangeable magnesium (ppm), Fe: Available iron, Mn: Available manganese, Zn: Available zinc and *df: degrees of freedom)

		Mean square and *P* values										
Source of variation	df	pH	L* (%)	EC (%)	TX (%)	OM (%)	P (ppm)	K (ppm)	Mg (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)
Between Population	15	0.081	388.611	0.018	861.26	2.008	31.32	10853.129	118843.687	221.92	101.112	12.572
P value		0.016	0.337	0.102	0.084	0.044	<.0001	0.0033	0.0084	0.322	0.205	0.0214
Error		0.036	335.593	0.011	514.38	1.061	7.223	3919.179	48450.684	188.608	74.71	5.877
Within Population		Average and standard deviations										
Tahtali		8.00±0.21	8.178±7.84	0.46±0.11	99.05±22.93	4.95±0.24	9.75±4.91	425.42±232.73	333.15±139.14	18.92±35.24	13.58±5.78	2.25±2.17
Kesmebogazi		7.47±0.06	35.37±30.94	0.223±0.06	51.63±14.23	2.52±1.22	2.27±1.07	286.68±199.67	303.54±254.26	5.84±4.16	10.31±5.77	0.39±0.07
Golcuk		7.77±0.09	1.96±0.90	0.35±0.05	77.00±9.70	4.60±0.31	14.72±2.46	197.75±86.88	648.65±601.24	28.64±30.03	18.28±14.50	0.59±0.25
Beldibi		7.55±0.05	24.53±2.76	0.26±0.16	59.29±3.44	3.70±0.81	3.04±2.69	123.37±38.94	217.87±11.78	8.02±5.98	4.86±0.89	0.49±0.056
Beycik		7.8±0.29	24.81±18.47	0.37±0.13	80.02±26.11	4.00±1.36	9.59±6.88	315.17±218.28	406.77±165.70	0.88±0.48	7.45±2.85	0.69±0.39
Altinyaka		7.85±0.05	41.92±40.16	0.435±0.035	95.7±7.26	4.95±0.25	17.36±2.34	436.07±114.58	371.85±42.85	1.32±0.06	6.50±1.13	1.90±1.03
Gulluk		7.85±0.19	27.66±19.20	0.39±0.07	86.68±17.47	4.86±0.42	18.85±0.63	395.31±225.16	211.25±61.07	6.70±10.19	16.20±14.87	4.03±2.95
Hisarcandir		7.68±0.19	17.82±15.35	0.32±0.10	71.28±22.13	3.31±1.29	5.80±4.42	456.17±301.06	413.06±159.45	8.65±5.85	17.27±8.96	0.53±0.41
Ücoluk		7.80±0.08	10.38±18.09	0.35±0.03	78.54±7.37	4.95±0.18	10.95±6.27	356.89±144.96	224.14±91.11	9.88±11.14	17.19±6.24	1.77±1.36
Sogutcumasi		7.6±0.17	2.62±0.41	0.27±0.084	62.41±19.57	3.59±1.64	16.19±2.64	439.24±175.90	268.00±127.92	7.143±6.06	15.81±12.74	1.12±0.55
Sivridag		7.65±0.10	24.61±28.32	0.31±0.07	67.02±11.58	4.34±1.06	13.97±5.28	249.82±136.89	127.73±48.66	8.96±7.73	11.26±6.07	0.98±0.59
Feslikan		7.97±0.21	9.74±9.09	0.48±0.13	102.87±25.70	4.84±0.32	13.82±5.89	706.12±168.53	574.27±342.78	15.88±6.53	20.72±12.73	5.96±5.54
Tunektepe		7.86±0.21	4.59±3.39	0.39±0.08	85.32±16.79	4.88±0.33	9.96±8.16	369.69±155.83	363.56±29.48	1.17±1.03	6.06±1.75	4.00±5.02
Alakir		7.73±0.32	17.79±20.12	0.37±0.21	81.78±43.28	3.99±1.63	12.02±5.92	242.15±68.33	313.8±221.09	11.79±16.74	3.86±3.90	1.49±1.446
Goynuk		7.6±0.26	14.11±3.77	0.27±0.15	61.23±30.69	2.75±2.07	0.73±0.61	166.15±110.21	811.63±268.36	1.89±0.67	11.09±11.08	0.77±0.93
Hacisekiler		8.03±0.21	12.61±17.68	0.46±0.11	112.22±40.18	5.11±0.07	18.60±3.20	921.42±505.45	509.50±348.82	4.64±4.91	16.01±6.15	7.06±4.85
Pop Mean		7.76±0.22	16.88±18.79	0.35±0.11	79.22±25.22	4.21±1.18	10.92±6.74	374.98±261.55	376.00±270.5	9.42±14.32	12.6±9.19	2.06±2.87
Min		7.4	0.8	0.15	35.2	1.48	0.19	59.14	55.29	0.35	1.02	0.14
Max		8.2	82.08	0.63	155.39	5.23	20.51	1299.17	1545	71.77	39.6	13.1

Table 5. Correlation coefficients among some morphological and ecological characteristics of *D. hastata* genotypes (AlT: Altitude, PD: Plant diameter, LW: Leaf width, LL: Leaf length, PETL: Petiole length, SW: Spike width, SL: Spike length, PEDL: Peduncle length, CW: Calyx width, CL: Calyx length, COW: Corolla width, COL: Corolla length).

Characters	ALT	LW	LL	PETL	SW	SL	PEDL	CW	CL	COW
PD	-0.42**									
LL	-0.20*	0.88**								
PETL	-0.15*	0.82**	0.81**							
SW	ns	0.74**	0.65**	0.69**						
SL	ns	0.63**	0.68**	0.61**	0.55**					
PEDL	ns	0.62**	0.50**	0.58**	0.62**	0.47**				
CW	ns	0.29*	ns	0.32*	0.35**	0.27*	0.26*			
CL	ns	0.37**	0.40**	0.44**	0.52**	0.37**	ns	0.66**		
COW	ns	0.36**	0.29*	0.47**	0.60**	0.36**	0.41**	ns	0.34**	
COL	ns	ns	0.28*	ns	0.37**	0.44**	ns	ns	0.45**	0.41**

*, ** and ns indicating significance at probability of 0.05 and 0.01, and nonsignificant at probability of 0.05, respectively.

two components of PCA respectively explained 83.3 % and 9.1% of the total variation.

Using population means, a UPGMA dendrogram was also produced by the similarity index (Fig. 3). The 16 populations were grouped into five clusters, containing 1 to 8 populations. The first group divided into two subgroups and Sivridag population was separated from the other 9 populations. Feslikan, Sivridag, and

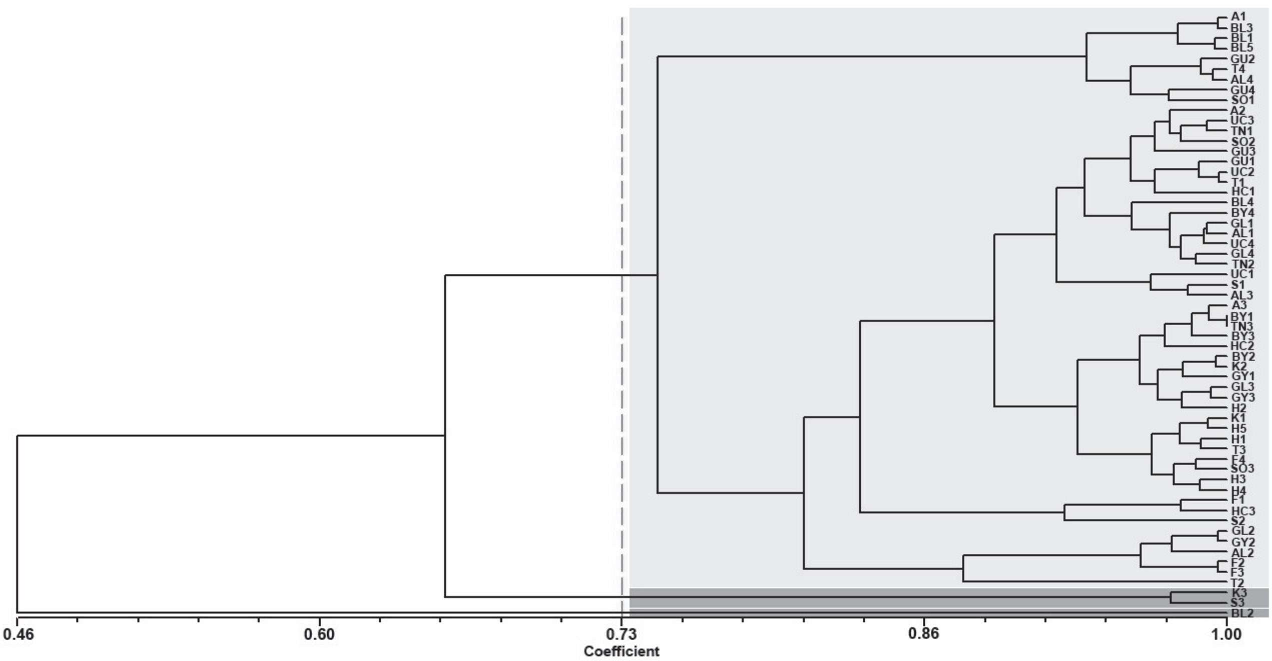

Fig. 1. Unweighted pair group method arithmetic average (UPGMA) dendrogram with similarity coefficients of *D. hastata* in genotype level. Data were based on the means of morphological and edaphic characters of *D. hastata* genotypes.
(Genotype codes: HC1: Hacisekiler1, HC2: Hacisekiler2, HC3:Hacisekiler3, S1: Sivridag1, S2: Sivridag2, S3: Sivridag3, F1: Feslikan1, F2: Feslikan2, F3: Feslikan3, F4: Feslikan14, TN1: Tunektepe1, TN2: Tunektepe2, TN3: Tunektepe3, H1: Hisarcandir1, H2: Hisarcandir2, H3: Hisarcandir3, H4: Hisarcandir4, H5: Hisarcandir5, UC1: Ucoluk1, UC2: Ucoluk1,2, UC3: Ucoluk3, UC4: Ucoluk4, BL1: Beldibi1, BL2: Beldibi2, BL3: Beldibi3, BL4: Beldibi4, BL5: Beldibi5, GY1: Goynuk1, GY2: Goynuk2, GY3: Goynuk3, K1: Kesmebogazi1, K2: Kesmebogazi2, K3: Kesmebogazi3, BY1: Beycik1, BY2: Beycik2, BY3: Beycik3, BY4: Beycik4, T1: Tahtali1, T2: Tahtali2, T3: Tahtali3, T4: Tahtali4, GL1: Golcuk1, GL2: Golcuk2, GL3: Golcuk3, GL4: Golcuk4, A1: Altinyaka1, A2: Altinyaka2, A3: Altinyaka3, SO1: Sogutcumasi1, SO2: Sogutcumasi2, SO3: Sogutcumasi3, AL1: Alakir1, AL2: Alakir2, AL3: Alakir3, AL4: Alakir4, GU1: Gulluk1, GU2: Gulluk2, GU3: Gulluk3, GU4: Gulluk4)

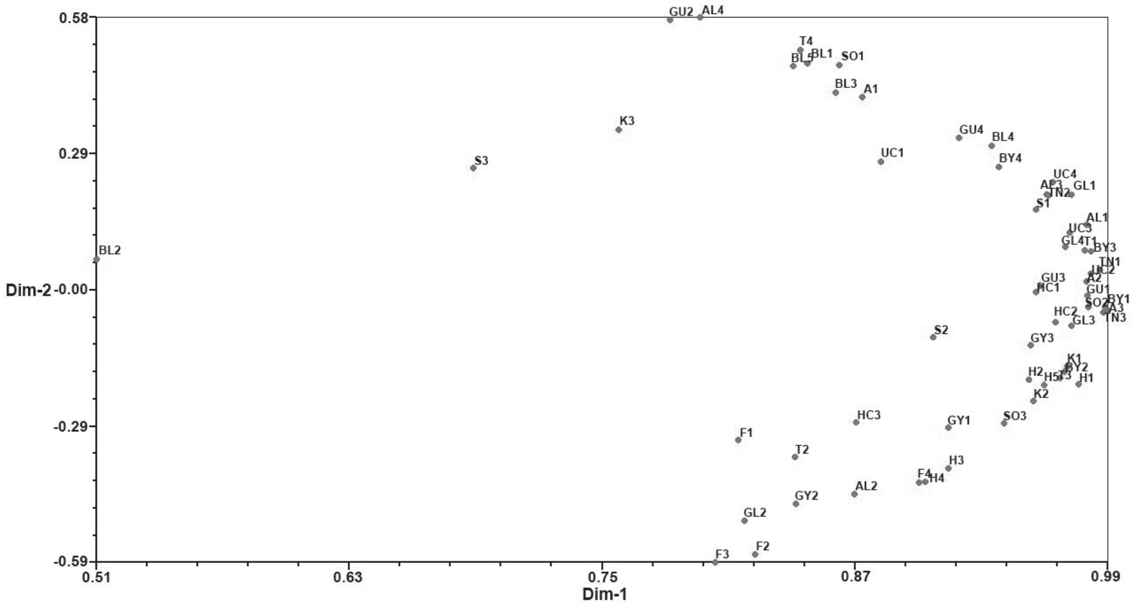

Fig. 2. Plot of principal components based on the means of morphological and edaphic characteristics of *D. hastata* genotypes. (Genotype codes: HC1: Hacisekiler1, HC2: Hacisekiler2, HC3:Hacisekiler3, S1: Sivridag1, S2: Sivridag2, S3: Sivridag3, F1: Feslikan1, F2: Feslikan2, F3: Feslikan3, F4: Feslikan14, TN1: Tunektepe1, TN2: Tunektepe2, TN3: Tunektepe3, H1: Hisarcandir1, H2: Hisarcandir2, H3: Hisarcandir3, H4: Hisarcandir4, H5: Hisarcandir5, UC1: Ucoluk1, UC2: Ucoluk1,2, UC3: Ucoluk3, UC4: Ucoluk4, BL1: Beldibi1, BL2: Beldibi2, BL3: Beldibi3, BL4: Beldibi4, BL5: Beldibi5, GY1: Goynuk1, GY2: Goynuk2, GY3: Goynuk3, K1: Kesmebogazi1, K2: Kesmebogazi2, K3: Kesmebogazi3, BY1: Beycik1, BY2: Beycik2, BY3: Beycik3, BY4: Beycik4, T1: Tahtali1, T2: Tahtali2, T3: Tahtali3, T4: Tahtali4, GL1: Golcuk1, GL2: Golcuk2, GL3: Golcuk3, GL4: Golcuk4, A1: Altinyaka1, A2: Altinyaka2, A3: Altinyaka3, SO1: Sogutcumasi1, SO2: Sogutcumasi2, SO3: Sogutcumasi3, AL1: Alakir1, AL2: Alakir2, AL3: Alakir3, AL4: Alakir4, GU1: Gulluk1, GU2: Gulluk2, GU3: Gulluk3, GU4: Gulluk4)

Beldibi populations were singled out while Golcuk and Goynuk populations were highly similar. Cluster analyses showed that *D. hastata* populations did not group based on geographic proximity. This clustering pattern of populations obtained on the basis of cluster analyses largely resembled the clustering of genotypes in the dendrogram obtained through PCA and cluster analyses (Figs 1 and 2). As a result of PCA based on morphological and edaphic characters, similarity matrix values were calculated, and spatial distribution graph of the populations was created (Fig. 4). According to Eigen values obtained from the PCA, the first and the second components explained % 91.1 and % 5.6 of the total variation among the populations. Characters that contributed to the first principal component (PCA1) include petiole length, leaf width and length, spike width and length, calyx width and length, peduncle length, corolla length and plant diameter. However, edaphic characters including soil pH, texture, salinity (EC), organic matter, potassium, phosphorus, available zinc and manganese contributed significantly to the variation of the second principal component 2 (Table 6). Feslikan, Beldibi, Sivridag, Goynuk populations differed from other populations. These results were consistent with the CA results. The rich diversity obtained suggests that selections for morphological characteristic as well as aromatic and medicinal properties may be possible in *D. hastata* populations.

Flower and leaf characteristics are valuable in horticulture; hence, along with ecological characters of habitat requirements, they help breeders to select the accessions to be utilized in hybridization program [18]. There were several significant positive correlations among leaf and flower characteristics of *D. hastata* genotypes (Table 5). Leaf width was highly and positively correlated with leaf length, petiole length, spike width and length, and peduncle length (r = 0.88, 0.82, 0.74, 0.63, 0.62, respectively). As one of the main morphological traits for the ornamental value of the species, spike size was positively correlated with leaf, calix and corolla diameters. For instance, spike length was positively correlated with leaf length, petiole length, spike width (r = 0.68, 0.61, 0.55, respectively). These correlations can be used as key factors to select desirable genotypes in a breeding program [33, 34]. The longer and wider flashy flower spikes as observed in some genotypes (i.e. Beycik population) are highly attractive and might increase the ornamental value of *D. hastata* and thus its potential use in planting design. The relatively high correlations between flower spike properties and leaf dimensions of *D. hastata* simply reflect the opportunity for spontaneous selection for the traits. Therefore, leaf texture might be used as a morphological marker for selection of plants with big flower spikes when they are still in vegetative stage.

The use of native species in planting designs has become increasingly important for creation of

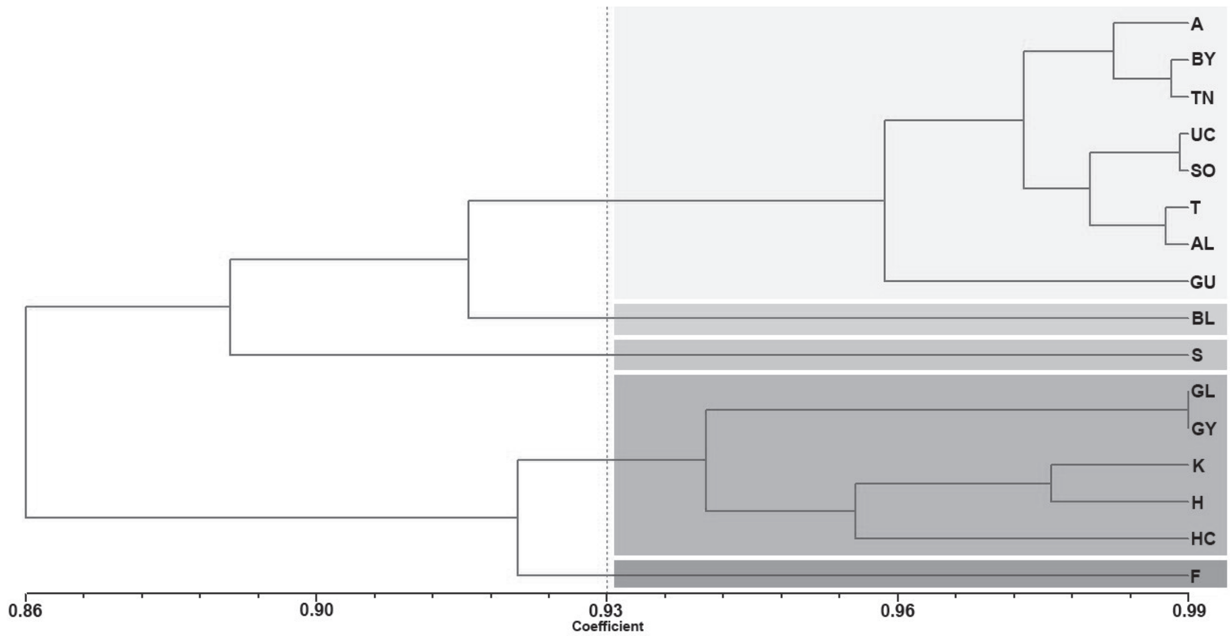

Fig. 3. Unweighted pair group method arithmetic average (UPGMA) dendrogram with similarity coefficients of *D. hastata* in population level. Data were based on the means of morphological and edaphic characters of *D. hastata* populations.
(Population codes: HC: Hacisekiler, S: Sivridag, F: Feslikan, TN: Tunektepe, H: Hisarcandir, UC: Ucoluk, BL: Beldibi, GY: Goynuk, K: Kesmebogazi, BY: Beycik, T: Tahtali, GL: Golcuk, A: Altinyaka, SO: Sogutcumasi, AL: Alakir, GU: Gulluk)

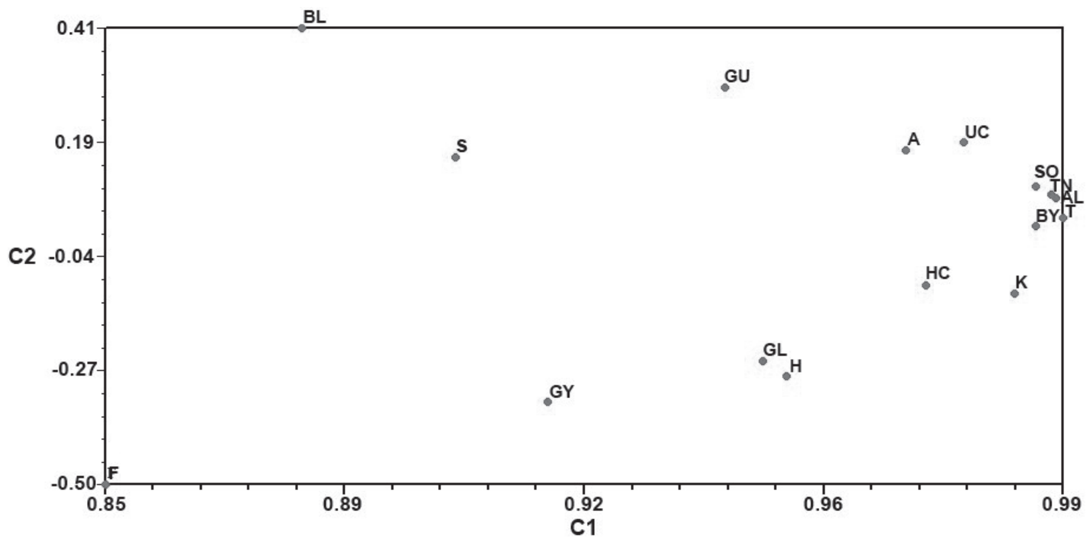

Fig. 4. Plot of principal components based on the means of morphological and edaphic characteristics of *D. hastata* populations.
(Population codes: HC: Hacisekiler, S: Sivridag, F: Feslikan, TN: Tunektepe, H: Hisarcandir, UC: Ucoluk, BL: Beldibi, GY: Goynuk, K: Kesmebogazi, BY: Beycik, T: Tahtali, GL: Golcuk, A: Altinyaka, SO: Sogutcumasi, AL: Alakir, GU: Gulluk)

more diverse and sustainable landscapes [35]. In this regard, the native species and genotypes with an ornamental plant potential need to be determined first, and then cultivated, improved through breeding and used at suitable ecologies. Although *D. hastata* is a local endemic species, it has been able to maintain its diversity with a wide morphological variation including growth habit ranging from short creeping types that can be used as ground cover to taller shrub formations. Some of the genotypes (such as from Beycik) with their large and numerous flashy flower spikes and lush green vegetation have a unique aesthetic appearance that should be exploited in ornamental plant industry. The variations offer opportunities to breeders to introduce new forms to ornamental plant sector. Moreover, the future presence of the species is under risk of extinction because of uncontrolled mass collection due to pharmacological properties in addition to grazing pressure and housing constructions. Hence, the natural populations are progressively decreasing

Table 6. Contribution of morphological and edaphic characters to main principal components in 16 populations of *Dorystoechas hastata*

Characters	PCA1	PCA2
Petiole length	**0.92835***	-0.20980
Leaf width	**0.92096**	-0.01018
Leaf length	**0.90768**	-0.11988
Spike width	**0.88208**	0.08002
Spike length	**0.81801**	0.19763
Calyx width	**0.81759**	-0.15814
Calyx length	**0.79108**	0.14848
Peduncle length	**0.71062**	-0.00984
Corolla length	0.55023	0.51924
Corolla width	-0.30601	-0.34107
Plant Diameter	**0.44501**	-0.18101
Plant height	0.33256	-0.31346
HUE (Leaf color)	0.01292	-0.04963
Soil lime content	0.21934	-0.40002
Soil pH	0.12911	**0.93183**
Soil texture	0.12585	**0.91679**
EC (Salinity)	0.15479	**0.89085**
Organic matter	0.09219	**0.84144**
Zn (Available zinc)	-0.11234	**0.84014**
K (Potassium)	-0.14712	**0.82008**
P (phosphorus)	0.14217	**0.75838**
Mn (Available manganese)	-0.24421	**0.54114**
Fe (Available iron)	0.07767	0.26313
Mg (Magnesium)	0.02593	0.17551

*Values greater than 0.44235 are bolded. Bold values indicate characters significantly contributing to the main principal components

in number and size. Unfortunately, we detected that some of the populations were lost within a year. Cultivation or domestication of this species has not been initiated yet. Therefore, *ex-situ* efforts including propagation, controlled crosses and cryopreservation should be undertaken to preserve *D. hastata* genotypes. Knowledge on current genetic diversity and ecological characteristics of its natural populations is required for both cultivation and breeding efforts and species conservation. Information obtained with this study can be beneficial for understanding the genetic variation and distribution of *D. hastata* and might assist in cultivation of the species and selection of candidate genotypes for future breeding programs.

Conclusions

The existence of substantial variation in *D. hastata* for morphological characteristic and natural distribution from sea level up to 2000 m may offer selection for various uses (i.e. medicinal, ornamental) throughout the World. The species occupies different habitat structures ranging from forests to the steppe regions with limestone slopes. The majority of genotypes occupied either south, southeastern or southwest aspects. There were significant positive and negative correlations among morphological and ecological characteristics of *D. hastata* genotypes. The results aid better understanding of the genetic variation and distribution of *D. hastata* and may assist in selection of candidate genotypes for conservation and breeding programs. Molecular genetic studies are justified to elucidate genetic diversity of *D. hastata* genotypes from the distribution area. The genetic variation for aromatic and medicinal characteristics among *D. hastata* genotypes should also be studied.

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Conflict of Interest

The authors declare no conflict of interest.

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