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POPULATION VARIABILITY OF COMMON HORNBEAM (*Carpinus Betulus* L.) IN NORTH-EASTERN PART OF TURKEY ACCORDING TO THE INVOLUCRE MORPHOLOGY

POPULACIJSKA VARIJABILNOST OBIČNOGA GRABA (*Carpinus Betulus* L.) U SJEVEROISTOČNOM DIJELU TURSKE PREMA MORFOLOŠKIM OBILJEŽJIMA OVOJA

Fahrettin ATAR*

SUMMARY

The objective of this study was to investigate involucre morphological variability of common hornbeam (*Carpinus betulus* L., Betulaceae) populations in Turkey. In total, 12 natural populations of common hornbeam located in four different watersheds of the Eastern Black Sea Region were sampled from three different altitude zones up to 1200 m a.s.l. Involucres have been examined biometrically by analyzing 13 morphological characteristics. High phenotypic variability was determined both among and within the studied populations. Furthermore, grouping of populations according to the eco-geographic principle was revealed. Variation in most of involucre characteristics from the Camlıhemşin, Çaykara and Trabzon-Maçka watersheds appeared to be related mostly to altitude. The trees in the higher elevations were characterized with the smaller involucres than those in the lower elevations. However, this trend has not been observed in the populations from the Giresun-Espiye watershed. Moreover, trees from that region at lower altitude had the smallest involucres. Overall, our results confirm the Eastern Black see region as one of the hot spots of biodiversity and that the involucre morphological variability is the result of the complex evolutionary process related to the adaptation and plasticity.

KEY WORDS: common hornbeam, morphology, altitude, variation, population

1. INTRODUCTION
1. UVOD

The hornbeam (*Carpinus* L., Betulaceae) genus comprises about 40 species that are native to the temperate regions of Northern Hemisphere (Hillier, 1991; Suszka et al., 1996; Li and Skvortsov, 1999). In Turkish flora two species from this genus can be found: *Carpinus betulus* L. (common hornbeam) and *Carpinus orientalis* Mill. (Oriental hornbeam). In Turkey, common hornbeam is distributed in the Marmara and Black Sea Region, and sporadically in the Amanos Mountains (Yaltırık, 1982; Anşin and Özkan, 2006). Usually in these areas common hornbeam forests can be found on the north facing slopes and riverbeds from the see level up to 1200-1300 m a.s.l.

It is well known that the abiotic and biotic factors in heterogeneous habitats can have strong influences on plants' adaptation (Miner et al., 2005; Matesanz et al., 2010). Consequently, plant morphological characteristics depend on spatial or temporal changes of environmental variables (Shen et al., 2008; Herrera and Bazaga, 2013). However,

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constraints related to these variables may not only influence plants' morphology, but anatomical and physiological characteristics as well (Gianoli and Valladares, 2010; Nascimbene and Marini, 2015). Ecological conditions such as atmospheric pressure, clear-sky turbidity, temperature, hours of sunshine, wind, season length, precipitation and soil change accompany altitudinal changes to which plant populations adapt (Austrheim, 2002; Wang et al., 2003; Körner, 2007). Thus, altitude can significantly influence plant morphology and physiology (Cordell et al., 1998; Gönüz and Özgörücü, 1999; Körner, 1999; Özbucak et al., 2013). For instance, adaptation to local environmental conditions in the higher elevations can result in a lower growth rate and smaller leaf morphotypes which increase the species' competitive ability and long-term success (Poljak et al., 2018). This is the result of plant adaptation to factors such as water and nutrient deficiency, high light and UV radiation, large temperature variations, and so on (Vitousek, 1982).

Diverse results in plant morphometric studies have been revealed (Alcántara-Ayala et al., 2020; Adamidis et al., 2021). The changes of factors such as soil depth, slope, relative humidity, precipitation, temperature, and light can have major impact on morphological variability. Forest trees usually adapt to environmental conditions at multiple scales (Savolainen et al., 2007), and the phenotype of a single tree is affected by genotype, environment and interactions between them (Falconer and Mackay, 1996). In other words, the evolutionary response of a phenotype to selection depends on genetic control, heritability and differential fitness of different morphotypes in different environmental conditions (Price, 1970). Furthermore, morphological characteristics can vary significantly within the same tree, especially in cases of large trees (Viscosi et al., 2012; Hagemeier and Leuschner, 2019). In addition, the type of management (Poljak et al., 2022), habitat and soil acidity (Poljak et al., 2012), and type of forest community can affect morphological variability as well (Adamidis et al., 2021).

Studies on the relationship between altitude and plant morphology are extremely beneficial for ecological researchers, and morphological knowledge is still very important in many fields of plant sciences, including: population variability (Douaihy et al., 2012; Zebec et al., 2015; Brus et al., 2016; Poljak et al., 2018), different taxon delimitation (Sękiewicz et al., 2016), morphological and physiological seed characterization (Powell, 2010; Güney et al., 2013; Drvodelić et al., 2015; Daneshvar et al., 2016; Atar et al., 2017, 2020), morphological involucre variation (Brunken, 1979; Boratyński et al., 2007; Koutecký, 2007; Xue et al., 2020), cultivar characterization (Ertan, 2007; Poljak et al., 2016) and selection (Polat and Özkaya, 2005; Solar et al., 2005), and variation of macro- and micro-morphological leaf (Bruschi et al., 2003; Paridari et al., 2013; Poljak et al., 2015; Amer et al., 2016; Güney et al., 2016; Bayraktar et al., 2018) and fruit traits (Atar and Turna, 2018; Eminagaoglu and Ozcan, 2018). Overall, morphological variability and plasticity can be used to predict population dynamics and the evolutionary adaptations of plants to a novel environment (Nicotra et al., 2010).

The aim of this study was: (1) to evaluate morphological variability of involucre in common hornbeam populations depend on altitude; (2) to determine involucre variations among and within populations; and (3) to reveal the morphological plasticity of the seed involucre traits according to the eco-geographic principle.

2. MATERIALS AND METHODS
2. MATERIJALI I METODE

Natural populations of common hornbeam located in four different watersheds of the Eastern Black Sea Region in Tur-

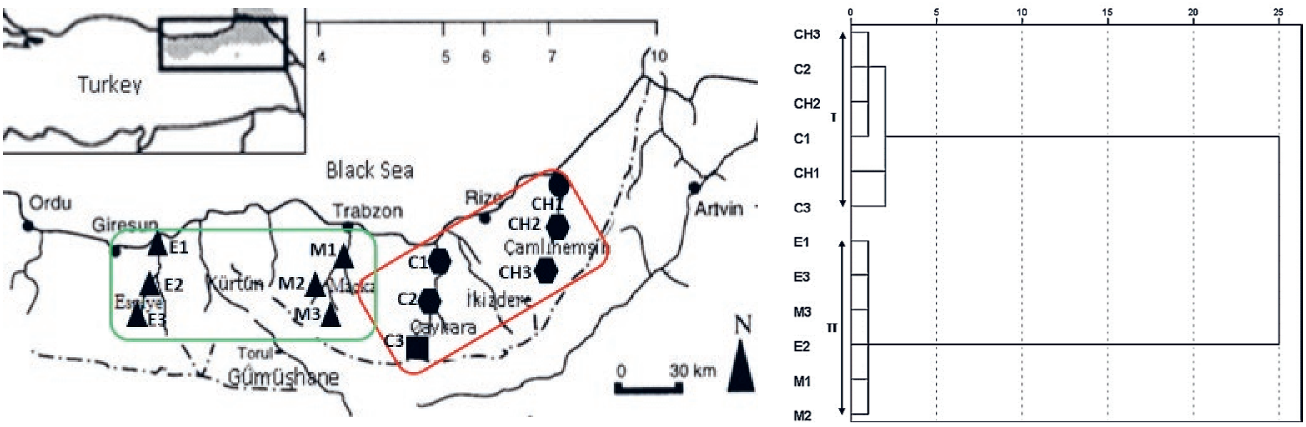

Figure 1. Results of the multivariate statistical methods and locations of the 12 sampled common hornbeam populations. (A) Geographical distribution of two groups of populations detected from K-means clustering method; (B) Tree diagram of researched populations. Acronyms of watersheds: CH=Çamlıhemşin; C= Çaykara; M= Maçka; E=Espiye.

Slika 1. Rezultati multivarijatnih statističkih metoda i lokacije 12 istraživanih populacija običnoga graba. (A) Geografski raspored dvije skupine populacija utvrđen K-means metodom; (B) Dendrogram istraživanih populacija. Akronimi slivova: CH=Çamlıhemşin; C= Çaykara; M= Maçka; E=Espiye.

Table 1. Information about geographical characteristics of the studied populations.
Tablica 1. Podaci o geografskim karakteristikama istraživanih populacija.

Watershed *Sliv*	Population *Populacija*	Latitude *Zemljopisna* širina	Longitude *Zemljopisna dužina*	Altitude (m) Nadmorska visina (m)
Çamlıhemşin	CH1	41° 04′ 39″ N	41° 01′ 27″ E	400
	CH2	41° 03′ 15″ N	41° 01′ 11″ E	800
	CH3	40° 58′ 57″ N	40° 59′ 05″ E	1200
Çaykara	C1	40° 45′ 53″ N	40° 15′ 08″ E	400
	C2	40° 42′ 34″ N	40° 12′ 28″ E	800
	C3	40° 41′ 36″ N	40° 11′ 52″ E	1200
Maçka	M1	40° 49′ 52″ N	39° 41′ 11″ E	400
	M2	40° 47′ 32″ N	39° 40′ 15″ E	800
	M3	40° 43′ 19″ N	39° 36′ 26″ E	1200
Espiye	E1	40° 52′ 48″ N	38° 45′ 45″ E	400
	E2	40° 48′ 02″ N	38° 47′ 45″ E	800
	E3	40° 45′ 08″ N	38° 46′ 35″ E	1200

Table 2. List of the studied morphological characters.
Tablica 2. Popis istraživanih morfoloških značajki.

Acronyms *Akronimi*	Morphological characters (unit of measurement) *Morfološke značajke (mjerna jedinica)*
IL	Involucre length (cm) *Dužina ovoja (cm)*
WCLo	Width of central lobe (cm) Širina središnjeg režnja *(cm)*
IA	Involucre area (cm^2) *Površina ovoja (cm^2)*
DBCOLo	Distance between top and outer base of central lobe (cm) *Udaljenost između vrha i vanjske osnove središnjeg režnja (cm)*
DBCILo	Distance between top and inner base of central lobe (cm) *Udaljenost između vrha i unutarnje osnove središnjeg režnja (cm)*
AnBCOLo	Angle between central and outer lobe (°) *Kut između središnjeg i vanjskog režnja (°)*
OLoL	Length of outer lobe (cm) *Dužina vanjskog režnja (cm)*
DTBOLo	Distance between top and base of outer lobe (cm) *Udaljenost između vrha i osnove vanjskog režnja (cm)*
WOLo	Width of outer lobe (cm) Širina vanjskog režnja *(cm)*
AnBCILo	Angle between central and inner lobe (°) *Kut između središnjeg i unutarnjeg režnja (°)*
ILoL	Length of inner lobe (cm) *Dužina unutarnjeg režnja (cm)*
DTBILo	Distance between top and base of inner lobe (cm) *Udaljenost između vrha i osnove unutarnjeg režnja (cm)*
WILo	Width of inner lobe (cm) Širina unutarnjeg režnja *(cm)*

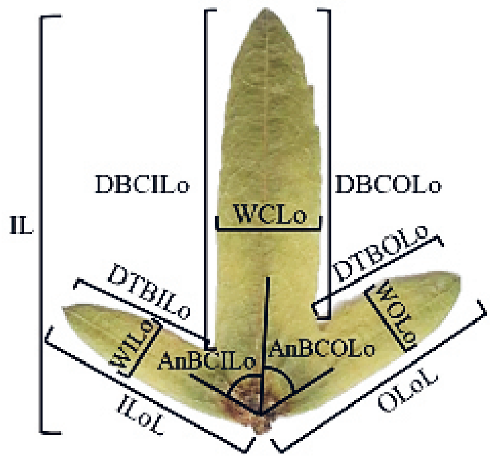

Figure 2. Measured involucre characters. Acronyms for studied involucre morphometric traits as in Table 2.
Slika 2. Mjerene značajke ovoja. Akronimi istraživanih morfometrijskih značajki ovoja kao u tablici 2.

key were sampled for this study: Trabzon-Maçka, Trabzon-Çaykara, Rize-Çamlıhemşin and Giresun-Espiye (Table 1, Figure 1A). In total, 12 populations determined in three different altitude zones up to 1200 m a.s.l., and 180 trees were included in the study: 45 trees from Maçka (M1, M2, M3), 45 trees from Çaykara (C1, C2, C3), 45 trees from Çamlıhemşin (CH1, CH2, CH3) and 45 trees from Espiye (E1, E2, E3). Each tree was represented by 100 involucres from the outer (light exposed) part of the crown. The samples were collected in October 2018.

Involucres have been examined biometrically (Jentys-Szaferowa, 1964; Bialobrzeska, 1970; Boratyński et al., 2007), and a total of 13 characteristics were analyzed (Table 2, Figure 2). The involucres were scanned using a scanner (Hewlett Packard Scanjet G4010) at 1200 dpi resolution. Then, these digital images were processed with the ImageJ (Image Analysis Software) program to determine morphological characters of involucres.

The standard descriptive statistical parameters (arithmetic means and coefficients of variation) were calculated for the particular trait for each population in order to determine the range of their variation. Analysis of variance (ANOVA) was used to determine if there were significant differences in the measured variables due to populations and trees nested in populations. Overall population variability of involucre morphological characteristics was examined using the hierarchical cluster analysis, K-means clustering method and principal component analysis. The data were analyzed using the "Windows SPSS Software 23.0" and "R v.3.4.3" statistical package programs.

3. RESULTS
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Results of the descriptive statistical analysis (arithmetic means and coefficient of variation) and analysis of variance of the involucre characters in sampled populations are summarized in Table 3. In general, the average values for the populations from the Camlıhemşin, Çaykara and Maçka regions clearly shows that trees in the higher elevations have smaller involcres than those in the lower elevations. In contrast, in the Espiye region the highest values were generally detected at low altitude populations. The overall coefficients of variation for the studied morphological characteristics ranged from 15.49% (IL) to 38.76% (AnBCILo). In general, the lowest morphological variation was observed for majority of studied involucre characteristics among lower altitude populations.

The degree of similarity or dissimilarity among studied populations was determined by the hierarchical cluster analysis and the K-means clustering method. The populations from the Maçka and Espiye regions grouped together into cluster A (Figure 1A; green rectangle), and the populations from Çamlıhemşin and Çaykara region grouped together into cluster B (Figure 1B; red rectangle). The results obtained with the K-means clustering method were congruent with the tree diagram presented in the Figure 1B. In other words, the populations belonging to the neighboring watersheds have formed groups with each other.

The results of the conducted principal component (PC) analysis are presented in the Table 4 and Figure 3. PC analysis showed that 79.1% of the total variation was explained by the first five principal components. The first principal component explained 21.4%, followed by the next four PC's 16.9%, 16.8%, 15.0%, and 9.0% respectively. Five involucre size parameters (IL, IA, ILoL, DTBILo and WILo) were in strong positive correlation with the first PC axis. The second PC axis was highly positively correlated with the three involucre parameters (OLoL, DTBOLo and WOLo). Furthermore, two involucre shape parameters (DBCOLo and DBCILo) were positively correlated with the third PC and two parameters (WCLo and AnBCILo) with the fourth PC. Only one measured characteristic, AnBCOLo, was positively correlated with the fifth PC axis. From the graph in the Figure 3 two main groups can be distinguished, in which trees of Çaykara and Çamlıhemşin populations are mostly in one group, and trees of Maçka and Espiye populations in the second group.

4. DISCUSSION
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The conducted research established high variability of the morphological characteristics, and the differences between the trees both within and between populations were confirmed for all the studied characteristics. Our results indicated that the populations are not homogeneous in term of the involucre characteristics.

The average values of the common hornbeam involucres in this study did not differ drastically from the data reported in previously published papers. In this study, it was determined that involucre length (IL) in all populations varied between 2.96 to 3.39 cm, and width of central lobe (WCLo) between 0.79 to 0.96 cm. Similar results were reported by Boratyński et al. (2007) for 29 common hornbeam populations from Poland. However, we obtained a much lower range of coefficient of variation in our study. The overall coefficients of variation for the morphological characteristics examined in this study ranged from approximately 15% to 39%. Boratyński et al. (2007) stated that the coefficients of variation of all measured morphological characters in Poland populations varied between 7% and 170%.

Different environmental factors such as altitude can affect the variability of morphological characteristics in most woody plants (Akbarian et al., 2011). Likewise, in this study we revealed that the morphological characteristics of involucres of common hornbeam in the regions of Çamlıhemşin, Çaykara and Maçka varied between different altitude zones, and that the variation of the studied characteristics appeared to be related mostly to altitude. We found out that the populations from lower altitudes had larger seed involucres than populations from high altitudes. Similar results were reported by Paridari et al. (2013) in a common hornbeam leaf morphometric study. They found out that trees in the higher elevations have smaller leaf lamina than those in the lower elevations. Furthermore, a study investigating the effects of altitude on density and biometric properties of hornbeam wood, showed significant effects of altitude variations on the studied properties (Kiaei et al., 2019). Across elevation gradients, changes in abiotic and biotic factors probably lead to strong divergent selection, which resulted in a local adaptation of common hornbeam populations (Halbritter et al., 2018).

The fact that the increase in altitude generally decreases the leaf length, width and area have been reported for different plant species. In a studies conducted on the *Alnus subcordata* C.A. Mey. (Akbarian et al., 2011) and *A. incana* (L.) Moench subsp. *incana* (Poljak et al., 2018) it was reported that the values of leaf blade area and petiole length were in a negative correlation with the altitude. Similarly, Yousefezadeh et al. (2010) determined that values such as leaf width, number of leaf pairs and leaf vein angle in *Parrotia*

Table 3. The results of descriptive statistics and analysis of variance for the studied common hornbeam populations. Acronyms for studied involucre morphometric traits as in Table 2. Acronyms of watersheds: CH=Çamlıhemşin; C= Çaykara; M= Maçka; E=Espiye.

Tablica 3. Rezultati deskriptivne statističke analize i analize varijance za istraživane populacije običnoga graba. Akronimi istraživanih morfometrijskih značajki ovoja kao u tablici 2. Akronimi slivova: CH=Çamlıhemşin; C= Çaykara; M= Maçka; E=Espiye.

Measured Characters *Mjerene značajke*	Statistical parameters *Deskriptivni pokazatelji*	Studied Populations *Istraživane populacije*												Total *Ukupno*	ANOVA, *p*-value	
		CH1	CH2	CH3	C1	C2	C3	M1	M2	M3	E1	E2	E3		Population *Populacija*	Tree (Population) *Stablo (Populacija)*
IL (cm)	Mean	3.23	3.05	3.13	3.40	3.27	2.96	3.38	3.14	3.08	3.25	3.27	3.22	3.20	0.000	0.000
	CV(%)	13.68	16.01	12.30	13.32	17.29	19.49	10.07	11.28	13.96	15.01	16.45	14.75	15.49		
WCLo (cm)	Mean	0.81	0.79	0.85	0.89	0.86	0.81	0.91	0.81	0.85	0.84	0.93	0.96	0.85	0.000	0.000
	CV(%)	14.65	16.20	14.97	16.37	19.58	15.26	14.90	17.86	17.07	18.57	20.21	27.17	18.81		
IA (cm^2)	Mean	3.40	3.03	3.19	3.76	3.61	3.02	3.90	3.33	3.37	3.41	3.67	3.60	3.44	0.000	0.000
	CV(%)	25.54	33.45	17.66	24.69	34.46	30.71	17.77	27.03	22.20	29.19	28.83	35.05	29.19		
DBCOLo (cm)	Mean	2.35	2.20	2.21	2.25	2.26	2.04	2.46	2.28	2.15	2.27	2.23	2.27	2.25	0.000	0.000
	CV(%)	15.90	19.36	15.16	16.54	20.73	27.96	13.46	12.4	15.70	15.91	18.30	15.54	18.65		
DBCILo (cm)	Mean	2.72	2.49	2.52	2.62	2.58	2.33	2.72	2.57	2.49	2.59	2.53	2.65	2.56	0.000	0.000
	CV(%)	14.90	17.53	13.90	14.11	20.48	25.67	12.65	12.33	15.65	15.01	15.87	18.15	17.50		
AnBCOLo (°)	Mean	50.48	46.69	49.08	46.53	49.89	52.86	50.44	49.48	48.48	45.92	46.84	48.19	48.81	0.000	0.000
	CV(%)	20.69	16.36	20.73	20.04	20.32	18.32	16.29	15.81	16.76	18.65	19.27	24.56	19.48		
OLoL (cm)	Mean	1.60	1.36	1.42	1.73	1.53	1.37	1.71	1.67	1.72	1.70	1.66	1.67	1.58	0.000	0.000
	CV(%)	20.53	18.88	13.78	20.31	20.37	20.61	12.06	16.83	19.46	22.47	17.73	20.59	20.99		
DTBOLo (cm)	Mean	0.78	0.59	0.62	0.83	0.74	0.63	0.77	0.79	0.77	0.79	0.70	0.74	0.72	0.000	0.000
	CV(%)	28.86	36.85	22.83	29.08	24.46	30.02	24.74	23.07	31.15	30.65	27.71	26.42	29.99		
WOLo (cm)	Mean	0.52	0.44	0.48	0.55	0.51	0.50	0.59	0.56	0.55	0.52	0.53	0.56	0.52	0.000	0.000
	CV(%)	24.01	23.94	16.51	21.13	22.30	18.71	15.46	22.10	18.88	22.07	21.28	21.52	22.01		
AnBCILo (°)	Mean	34.70	29.30	29.27	31.50	30.30	27.55	54.68	58.98	56.04	53.41	56.13	52.51	41.23	0.000	0.000
	CV(%)	34.39	16.06	12.30	13.62	17.61	20.29	21.31	20.91	18.41	26.52	23.98	28.21	38.76		
ILoL (cm)	Mean	1.42	1.36	1.33	1.56	156	1.32	1.58	1.48	1.55	1.55	1.48	1.54	1.47	0.000	0.000
	CV(%)	16.57	21.04	13.81	21.12	20.98	21.29	13.91	17.27	17.20	20.42	17.71	17.58	19.82		
DTBILo (cm)	Mean	0.88	0.76	0.77	0.93	0.92	0.77	0.85	0.80	0.80	0.94	0.85	0.79	0.84	0.000	0.000
	CV(%)	23.16	32.59	19.41	31.15	28.14	31.25	18.54	23.73	27.30	31.88	27.15	23.45	28.82		
WILo (cm)	Mean	0.43	0.41	0.43	0.45	0.45	0.42	0.50	0.47	0.46	0.47	0.48	0.48	0.45	0.000	0.000
	CV(%)	22.82	24.21	20.78	34.94	25.39	25.65	18.75	22.90	16.34	39.39	24.78	17.52	35.47		

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Table 4. Results of the principal component analysis.
Tablica 4. Rezultati analize glavnih sastavnica.

Measured Characters *Mjerene značajke*	PC—Principal Components PC-*glavne sastavnice*				
	PC1	PC2	PC3	PC4	PC5
IL (cm)	0.510				
WCLo (cm)				0.800	
IA (cm^2)	0.598				
DBCOLo (cm)			0.954		
DBCILo (cm)			0.942		
AnBCOLo (°)					0.944
OLoL (cm)		0.865			
DTBOLo (cm)		0.891			
WOLo (cm)		0.658			
AnBCILo (°)				0.580	
ILoL (cm)	0.887				
DTBILo (cm)	0.874				
WILo (cm)	0.641				
Eigen value	4.864	1.813	1.345	1.236	1.031
Variation %	21.36%	16.90%	16.84%	15.01%	9.04%

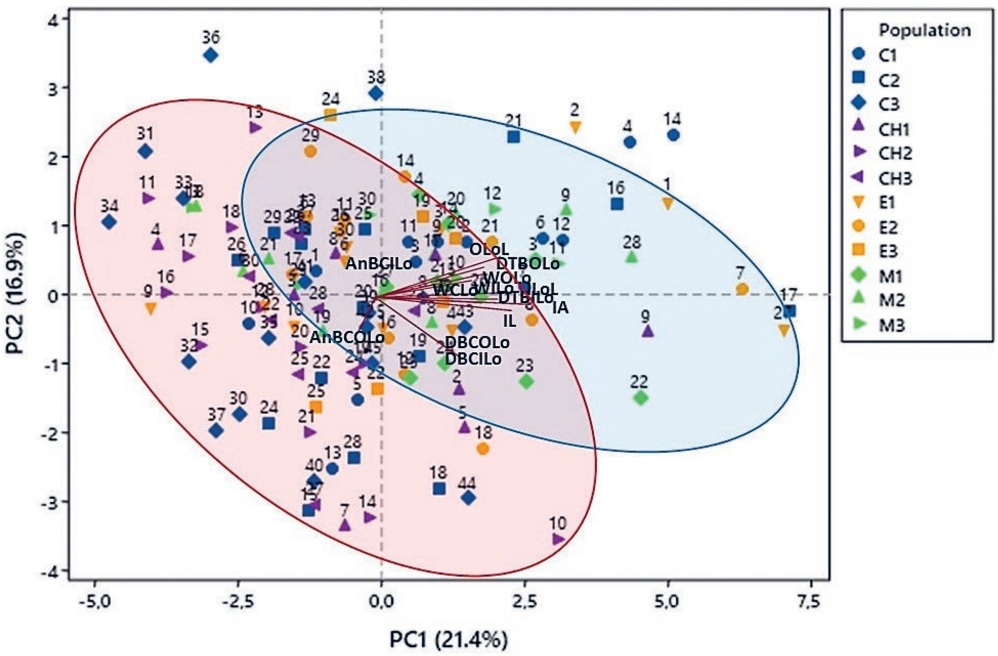

Figure 3. Results of the principal component (PC) analysis based on 13 invoclure morphometric traits in studied common hornebeam populations. Acronyms for invoclure morphometric traits as in Table 2.
Slika 3. Rezultati analize glavnih sastavnica na temelju 13 morfometrijskih značajki ovoja istraživanih populacija običnoga graba. Akronimi istraživanih morfometrijskih značajki ovoja kao u tablici 2.

persica C.A. Mey. show significant changes depending on the altitude. The leaves of *P. persica* decrease in base angle and dry mass with increasing altitude. Furthermore, Körner et al. (1986) shown that distinct altitudinally-related changes in several physiological and anatomical characteristics of leaves exist in plants from the mountains of New Zealand. As elevation increases, leaf size and specific leaf area decrease, whereas stomatal conductance, nitrogen content per unit leaf area, stomatal frequency and leaf thickness all increase. Similar results were reported by Joel et al. (1994). They revealed that leaf mass per area increases and leaf length per area decreases along environmental gradients in Hawaiian *Metrosideros polymorpha* Gaudich. In addition, Abdusalam and Li (2018) examined the morphological characteristics, biomass distribution and variations in morphological plasticity of 17 *Primula nivalis* Pall. populations at different altitudes. They concluded that plant height, petiole and leaf length showed a significant negative correlation with altitude. In contrast, Poljak et al. (2020) reported negative correlations between altitude and *Pinus sylvestris* L. cone morphometric characteristics. The mentioned authors stated that populations from lower altitudes had smaller cones as compared to the populations from higher altitudes.

Although in this study variation in most of the studied involucre characteristics from the studied populations from the Çamlıhemşin, Çaykara and Maçka watersheds appeared to be related mostly to the altitude, that was not the case with the populations from the Giresun-Espiye watershed. In that region the trees in the higher elevations were characterized with the largest involucres. The generally smaller involucres obtained at low altitudes may be due to the several reasons: most probably to the type of management and habitat conditions related to the soil properties. Two types of management are specific for hornbeam forests: high forest and coppice. In most of the studied populations, hornbeam forests are operated as high forests and are generally found in mixed stands with beech, alder, and sweet chestnut. However, this is not the case with the lower altitude populations from the Giresun-Espiye watershed where tree stems are repeatedly cut down and renewed from dormant buds of the stump. In this management type, a canopy is usually formed from multiple stems from a common stump. Similar results were reported by Poljak et al. (2022). These authors revealed that the sweet chestnut fruits in coppice populations are smaller than in the high forest populations. In addition, the type of habitat, soil acidity and type of forest community can affect fruit size (Poljak et al. 2012). Smaller fruits have been observed in acidic and drier sites, and larger fruits in more mesophilic sites. On the north-facing slopes of the Eastern Black Sea region, the soil is washed due to the excess precipitation and the lime is removed from the soil. Therefore, the soil is acidic in character. In addition to the management type, changes in the habitat, such as soil acidification, could significantly influence the involucre sizes in Giresun-Espiye watershed. In a study conducted on *Pyrus pyraster* (L.) Burgsd., Vidaković et al. (2022) reported that despite being exposed to high temperatures and precipitation levels, the westernmost populations surprisingly had the smallest leaf dimensions. The authors concluded that small-leaf morphotypes are probably the result of phenotypic plasticity and adaptation to karstic, well drained soils, flysch and high thermophilicity of the studied area. Similarly, the results of a study investigating the morphological characteristics of common yew (*Taxus baccata* L.) needles in the Hyrcanian forests of Iran (Hematzadeh et al., 2021) showed that most of morphological characteristics of yew needles, except the form factor, were the lowest in the regions with the steep slopes (loss of soil depth) and western aspects (decrease in relative humidity). Nevertheless, the possible genetic background, adaptation of the populations to driers sites or origin from different glacial refugia, also cannot be excluded. For instance, Tumpa et al. (2022a) revealed that the morphological variability in the *Taxus baccata* populations in the northwestern part of the Balkan peninsula is strongly influenced by the genetic background rather than by the ecological conditions and altitude. Furthermore, the same authors (Tumpa et al. 2022b) revealed that the large-leaved almond leaved willow populations were found in continental and sub-Mediterranean climates, while small-leaved populations were found in smaller karstic rivers.

5. CONCLUSIONS
5. ZAKLJUČCI

As a conclusion, genetic variability is a fundamental component of adaptation and therefore stability of forest ecosystems. This is especially important when the long-term stability of forest ecosystems is increasingly threatened by environmental stress and poor management. Therefore, determination of the population variability of common hornbeam and all other natural forest resources is an important step especially for the implementation of *in-situ* and *ex-situ* conservation activities. This study indicates that altitude, type of management and habitat conditions related to the soil properties, represents an important driving force in morphological variation of common hornbeam involucre. However, larger-scale studies and common garden experiments are needed to understand the altitude adaptation, and environmental and genetic components of common hornbeam variation (Bresson et al., 2011).

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SAŽETAK

Cilj ovoga istraživanja bio je istražiti varijabilnost populacija običnoga graba (*Carpinus betulus* L., Betulaceae) u Turskoj prema morfološkim obilježjima ovoja. Ukupno je uzorkovano 12 prirodnih populacija običnoga graba, smještenih u četiri različita sliva istočnog Crnog mora iz tri različite visinske zone do 1200 m n.v. Ovoji su ispitani biometrijski, analizom 13 morfoloških karakteristika. Provedenim istraživanjem utvrđena je velika varijabilnost morfoloških obilježja, a za sve proučavane karakteristike potvrđene su razlike na međupopulacijskoj i unutarpopulacijskoj razini. Nadalje, otkriveno je grupiranje populacija prema eko-geografskom načelu. Varijabilnost ovoja iz slivova Camlıhemşin, Çaykara i Trabzon-Maçka bila je povezana s promjenom nadmorske visine. Stabla na višim nadmorskim visinama karakterizirali su sitniji ovoji u odnosu na stabla na nižim nadmorskim visinama. Međutim, ovaj trend nije uočen na području regije Giresun-Espiye. Štoviše, stabla na tom području na nižim nadmorskim visinama imala su manje ovoje u odnosu na stabla s viših nadmorskih visina. Sveukupno, naši rezultati potvrđuju da je regija istočnog Crnog mora jedno od žarišta biološke raznolikosti te da je morfološka varijabilnost ovoja rezultat složenog evolucijskog procesa povezanog s prilagodbom i plastičnošću.

KLJUČNE RIJEČI: obični grab, morfologija, nadmorska visina, varijabilnost, populacija