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5 authors, including:

Vladan Popovic
Institute of Forestry

Sanja Jovanović

Katarina Mladenovic
Institute of Forestry

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Original Article

The Variability of Turkish Hazel (*Corylus colurna* L.) Populations in Serbia According to Morphological Nut Traits

Vladan Popović[1], Aleksandar Lučić[1], Sanja Jovanović[1], Katarina Mladenović[2], Ljubinko Rakonjac[3]

[1]Department of Seed Production, Nursery Production, Plant Breeding, Genetics, Institute of Forestry, Belgrade, Serbia
[2]Department of Forest Protection, Institute of Forestry, Belgrade, Serbia
[3]Department of Forest Establishment, Silviculture and Ecology, Institute of Forestry, Belgrade, Serbia

ABSTRACT

The analyses of morphological seed traits of Turkish hazel have been performed in the marginal part of its natural range for the purpose of familiarizing with the variability of its natural populations. In September 2020, the seeds were collected in one cultivated and seven natural populations of Turkish hazel for the purpose of research. The inter-population variability was determined based on five measured morphometric parameters and one derived ratio. Nut length ranges from 15.24 to 17.76 mm, width from 14.17 to 15.80 mm, thickness from 10.92 to 12.38, and weight from 1.23 to 1.45 g. The obtained results showed the presence of significant variability of morphological seed traits and indicated high phenotypic variability of the researched traits and genetic differentiation of Turkish hazel populations in Serbia. The Južni Kučaj population has the largest nuts, so it can be recommended as a future seed source. The Sokolovica population has the smallest nuts. The highest variability was determined in the populations of Vukan-Krilaš and Divčibare. Therefore, the selection of these two populations for seed facilities has been confirmed as right in the conducted analyses. The results of the analysis of variance showed statistically significant differences among the researched populations for all observed traits. The available gene pool of Turkish hazel is characterized by a satisfactory degree of genetic variability, representing a good starting point for the further breeding process. The studied populations must be included in continuous conservation and breeding processes, especially by forms of in situ and ex situ conservation.

Keywords: Population, Turkish hazel, variability

Introduction

Turkish hazel (*Corylus colurna* L.) is an element of the Euro-Siberian flora (Molnar, 2011) and a species classified in the low-risk category according to the IUCN Red List (Shaw et al., 2014). It was overexploited in the past due to its precious wood, which resulted in the loss and reduction of the natural range of distribution (Šeho & Huber, 2018). Therefore, now it can be found in Turkey only in isolated and very small populations within its natural distribution area (Ayan et al., 2016). The importance of the remaining populations and individual trees is huge for the conservation of the species and expansion of the distribution area, and in the long term, they should be used as natural sources of seed. Climate change affects all forest ecosystems and services and goods provided by forests (Šeho et al., 2019). Establishing mixed-species forests is a good strategy for the stabilization and adaptation of stands to altered environmental conditions. In order to reduce these risks, it is necessary to expand the list of potential tree species used for establishing forests. Proper selection of sources and origin of forest reproductive material is crucial for adaptation to environmental conditions (Šeho et al., 2019). Currently, Turkish hazel is one of the most valuable alternative species for afforestation in Europe (Šeho & Huber, 2018).

Turkish hazel is a penumbral species that can build mixed stands with other species (Matović & Obratov, 1992). It is characterized by tolerance toward other species and low invasive potential. Also, it can be used for planting on agricultural land for the purpose of protection and stabilization (Arslan, 2005; Tosun, 2012), and especially for remediation of arid soils (Palashev & Nikolov, 1979; Polat, 2014; Yilmaz, 1998). It shows a high tolerance to adverse environmental conditions and can withstand both low temperatures (−20°C) and high temperatures, drought, and emissions of harmful gasses (Arslan, 2005). It occurs naturally in habitats with limestone and siliceous substrate, at the altitudes between 100 and 1400 m above sea level with minimal precipitation of 500 mm per year and average annual temperatures between 5 and 13°C (Palashev & Nikolov, 1979).

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Corresponding Author:
Sanja Jovanović
e-mail:
jovanovic.s289@gmail.com

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The introduction of Turkish hazel into Central Europe was initiated in the 17th century. Since then, it has been grown to a very small extent in Italy, Austria, Germany, Poland, Ukraine, and Hungary (Šeho et al., 2019). In Hungary, it is a valuable reserve fast-growing tree species. In many Central European countries, it is known only as a garden and amenity tree. In the countries of origin, the use of Turkish hazel for afforestation is quite rare (Šeho et al., 2019). It is of great importance as a valuable source of rootstocks for the grafting of cultivated varieties of common hazel (Ninić-Todorović et al., 2012).

Given that Serbia is located near the northwest boundary of the species natural range, the selection and research of natural populations in this area are justified and necessary for the conservation and directed use of its genetic resources. The vitality and survival of populations of forest woody species in altered habitat conditions are conditioned by conservation of a high level of their genetic diversity as a basis for adaptation and evolutionary processes (Šijačić-Nikolić & Milovanović, 2012). In order to establish a basis for the conservation of the Turkish hazel gene pool and quality management of its genetic resources, detailed research of the degree, pattern, and cause of genetic diversity is necessary.

The objective of this research was to determine the level and pattern of phenotypic variability of morphological nut traits in natural populations of Turkish hazel in Serbia and thus contribute to the knowledge of the variability of natural populations in the marginal part of the natural range. The results obtained by this research can represent the basis for further research of genetic variability, the commencement of breeding of the species, assisted migration, and genetic conservation of this valuable tree species in its natural distribution area.

Methods

For the purpose of the research, the nuts were collected in one cultivated and seven natural populations of Turkish hazel in the Republic of Serbia (Table 1, Figure 1). Each population was represented by more than ten trees. In each population, 2–3 kg of ripe and fully developed nuts were collected. All nuts have been dried to 15% moisture. Only physiologically mature trees that bore fruit in September 2020 were sampled (trees between 40 and 60 years of age with a diameter at breast height of 25–40 cm).

The analyses of measured and derived morphometric traits were performed on a random sample comprised of 50 nuts per population. NL, nut length (mm); NWi, nut width (mm); NT, nut thickness (mm); SH, scar height (mm); and NWe, nut weight (g) were measured. Nut length, width and thickness, and scar height were measured by vernier caliper with an accuracy of .01 mm, and weight was measured by the electronic scale with an accuracy of .01 g. Based on the measured values, SI (shape index) was calculated using the formula {(width + thickness): 2}: length.

Table 1.
Basic Data on the Studied Populations of Turkish Hazel

Population Mark	Population	Mean Altitude (m)	Latitude WGS84	Longitude WGS84
A	Đerdap	580	44.59958	22.292802
B	Južni Kučaj	766	43.903055	21.689411
C	Vukan-Krilaš	450	44.32001	21.528631
D	Divčibare	815	44.108611	19.911944
E	Sokolovica	940	43.071218	21.390634
F	Žagubica	560	44.180003	21.806389
G	Kunovo	700	42.710728	21.99055
H	Košutnjak	110	44.782781	20.424726

Statistical Analysis

The morphological nut traits were described by descriptive statistical indicators, namely, arithmetic mean (x), minimum (min), maximum (max), standard deviation, coefficient of variation (CV%). The one-way analysis of variance (ANOVA) was used for the purpose of determining inter-population variability. The population was then analyzed by the variability factor. Additional testing using Fisher's multiple least significant difference (LSD) tests was conducted for the purpose of determining populations that statistically differ significantly from each other. All the above statistical analyses are performed using the statistical program STATISTICA 7.0 (StatSoft Inc., OK, USA) (StatSoft Inc., 2004).

Results and Discussion

Descriptive statistics of six different traits of randomly selected samples of Turkish hazelnuts from eight different populations are presented in Table 2.

The mean value of nut length (NL) was 16.32 mm. The highest mean value was determined in the population of the Košutnjak (17.76 mm) and the lowest in the population of Đerdap (15.24 mm). The highest value of the nut length was recorded in the population of the Košutnjak (20.53 mm) and the lowest in the Sokolovica population (12.47 mm). Divčibare population had the lowest coefficient of variation (6.71%), and the Žagubica population had the highest (10.19%) (Table 2). Miletić et al. (2007) determined in their research that the average value of nut length was 14.7 mm. Srivastava et al. (2010) determined that nut length varied between 16.28 and 18.13 mm. In addition, Miletić et al. (2005) determined the mean value of nut length of 16.3 mm. In the research of Ninić-Todorović & Cerović (1987), nut length ranging from 16.4 to 18.6 mm was reported. Based on the research of traits of nuts originating from four populations in Turkey, it was determined that the nut length varied between 15.16 and 15.92 mm (Ayan et al., 2018). If we compare the results of the abovementioned studies, it can be concluded that nut length values are similar in different regions.

The mean value of nut width (NWi) amounted to 14.83 mm. The population of Južni Kučaj had the highest mean value of nut width (15.80 mm) and the Vukan-Krilaš population had the lowest (14.17 mm). The highest value of nut width was recorded in the population of the Košutnjak (18.63 mm) and the lowest (7.90 mm) in the Kunovo population. The coefficient of variation ranged from 8.53% in the population of Žagubica to 11.99% in the Vukan-Krilaš population (Table 2). In the research of Srivastava et al. (2010), it was determined that nut width ranged from 16.36 to 17.88 mm. Ayan et al. (2018) found that nut width was 15.53 mm. Miletić et al. (2007) determined the mean value of nut width of 14.1 mm. Ninić-Todorović & Cerović (1987) found that the nut width ranged from 14.4 to 17.8 mm.

The mean value of nut thickness (NT) amounted to 11.55 mm. The highest mean value of nut thickness was determined in the Južni Kučaj population (12.38 mm) and the lowest (10.88 mm) in the Sokolovica population. The highest value of nut thickness was determined in the Divčibare population (16.07 mm) and the lowest (8.21 mm) in the Sokolovica population. The highest value of the coefficient of variation was determined in the Vukan-Krilaš population (12.63%) and the lowest (8.75%) in the

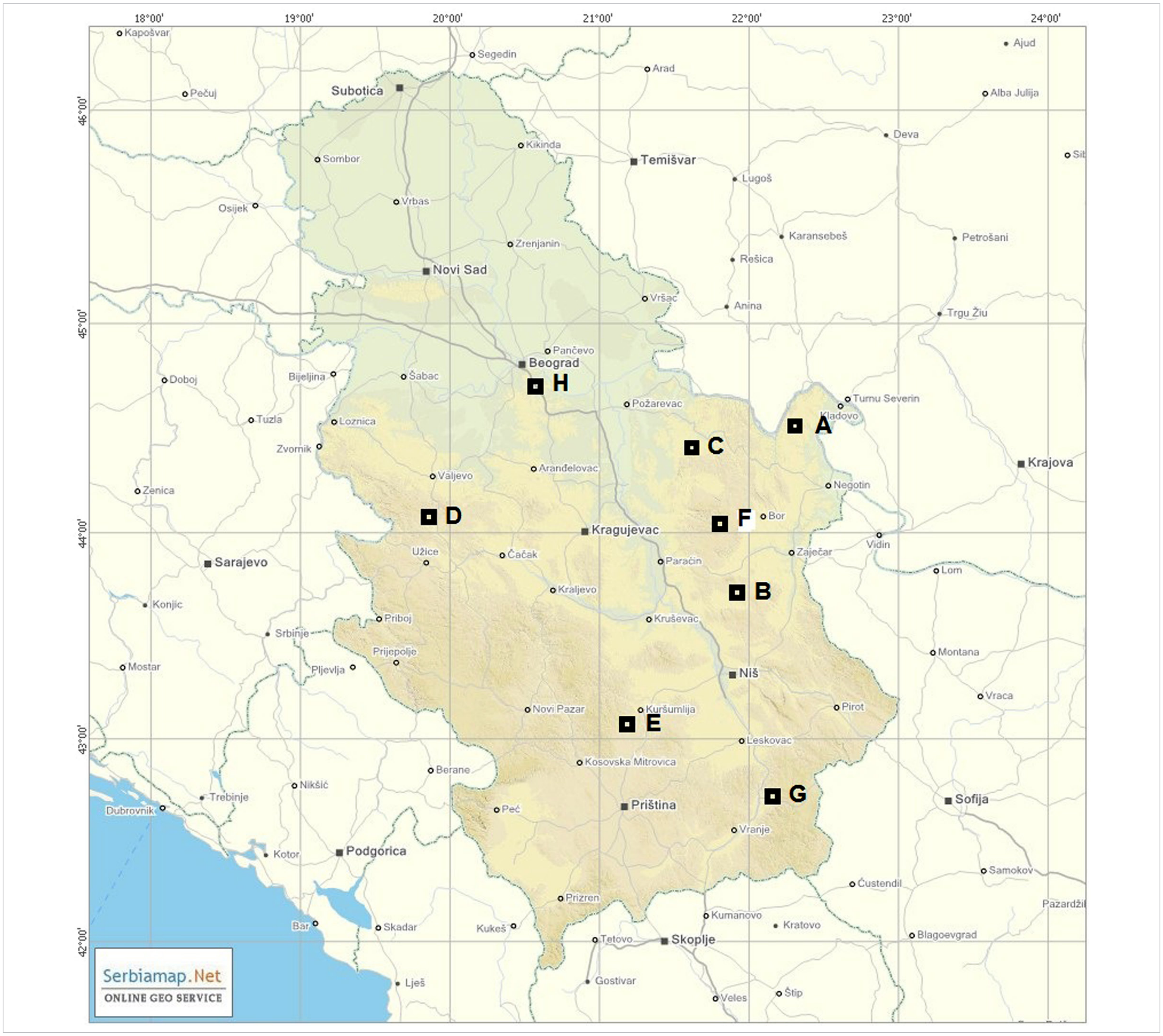

Figure 1.
Map of Spatial Distribution of Studied Provenances (A, Đerdap; B, Južni Kučaj; C, Vukan-Krilaš; D, Divčibare; E, Sokolovica; F, Žagubica; G, Kunovo; H, Košutnjak).

Đerdap population (Table 2). In the research of Miletić et al. (2007), it is stated that the mean value of nut thickness was 12.1 mm. Srivastava et al. (2010) stated that nut thickness ranged from 11.67 to 12.54 mm. In the research of Ninić-Todorović & Cerović (1987), it was stated that the see nut thickness varied between 11.0 and 15.8 mm. The mean nut thickness of 12.04 mm was determined in the research of Ayan et al. (2018).

The mean value of nut scar height (SH) amounted to 9.90 mm. The highest mean value of nut scar height was determined in the Sokolovica population (10.59 mm) and the lowest (9.00 mm) in the Žagubica population. The highest value of nut scar height was recorded in the Sokolovica population (14.13 mm) and the lowest (5.27 mm) in the population of Žagubica. The highest value of the coefficient of variation was determined in the Žagubica population (19.22%) and the lowest (8.77%) in the Južni Kučaj population (Table 2).

The mean value of nut weight (SWe) amounted to 1.31 g. The population of Južni Kučaj had the highest mean value of nut weight (1.45 g) and the Vukan-Krilaš and Sokolovica populations had the lowest (1.18 g). The highest value of nut weight was measured in the Divčibare population (2.54 g) and the lowest (.41 g) in the Vukan-Krilaš population. The coefficient of variation was the highest in the Divčibare population (31.16%) and the lowest (15.91%) in the Kunovo population (Table 2). In research of Turkish provenances of Turkish hazel Ayan et al. (2018) determined that the nut weight varied between .61 and 2.61 g. Ninić-Todorović & Cerović (1987) stated in their research that the nut weight ranged from 1.17 to 2.54 g. In the study of Miletić et al. (2007), the stated mean value of nut weight was 1.15 g. Srivastava et al. (2010) stated that nut weight ranged from 1.29 to 1.75 g. Erdoğan & Aygün (2005) determined that the nut weight varied between 1.33 and 2.91 g.

Table 2.
Basic Indicators of Descriptive Statistics of Nut Morphological Parameters at the Level of Population

Descriptive Parameters	Population[1]	Trait					
		NWe[2] (g)	NL[3] (mm)	NWi[4] (mm)	NT[5] (mm)	SH[6] (mm)	SI[7]
X[8]	A	1.23	15.24	14.72	11.25	9.56	.86
	B	1.45	16.60	15.80	12.38	10.75	.85
	C	1.18	16.18	14.17	11.11	10.33	.78
	D	1.42	15.85	14.83	12.63	9.54	.87
	E	1.18	15.36	14.35	10.88	10.59	.83
	F	1.39	16.79	14.97	11.61	9.00	.80
	G	1.24	16.80	14.54	10.92	9.75	.76
	H	1.43	17.76	15.23	11.60	9.68	.76
	Mean	1.31	16.32	14.83	11.55	9.90	.81
Min[9]	A	.72	13.06	11.70	9.08	7.66	.64
	B	.92	13.98	12.90	10.44	8.79	.68
	C	.41	13.38	10.42	8.95	8.16	.65
	D	.52	12.94	11.46	8.76	6.60	.69
	E	.63	12.47	11.80	8.21	8.10	.66
	F	.73	12.86	12.41	9.57	5.27	.63
	G	.77	14.21	7.90	9.03	7.49	.60
	H	.68	15.13	11.30	9.24	7.63	.57
	Mean	.67	13.50	11.24	9.16	7.46	.64
Max[10]	A	1.92	17.88	17.07	13.58	13.26	1.00
	B	2.24	19.72	18.15	15.03	13.02	1.05
	C	1.99	19.37	17.56	14.31	14.00	.97
	D	2.54	18.17	17.77	16.07	11.66	1.07
	E	1.67	18.10	17.80	12.64	14.13	1.05
	F	2.47	20.45	18.46	14.57	12.15	1.02
	G	1.62	20.03	16.33	14.18	11.45	0.93
	H	1.89	20.53	18.63	13.60	11.95	1.00
	Mean	2.04	19.28	17.72	14.25	12.70	1.01
SD[11]	A	.27	1.09	1.33	.98	1.17	.08
	B	.33	1.36	1.38	1.12	0.94	.09
	C	.37	1.52	1.70	1.40	1.22	.09
	D	.44	1.06	1.28	1.49	1.16	.09
	E	.23	1.38	1.32	1.15	1.31	.10
	F	.35	1.71	1.28	1.20	1.73	.09
	G	.20	1.24	1.49	1.04	.98	.07
	H	.25	1.22	1.47	1.06	.88	.08
	Mean	.30	1.32	1.41	1.18	1.17	.09
CV[12] (%)	A	21.80	7.17	9.04	8.75	12.22	9.29
	B	22.86	8.19	8.74	9.02	8.77	10.75
	C	31.01	9.39	11.99	12.63	11.82	10.91
	D	31.16	6.71	8.63	11.82	12.18	10.86
	E	19.78	8.97	9.21	10.61	12.33	12.43
	F	25.06	10.19	8.53	10.37	19.22	11.25
	G	15.91	7.38	10.22	9.49	10.03	9.81
	H	17.63	6.86	9.67	9.10	9.08	10.88
	Mean	23.15	8.11	9.50	10.22	11.96	10.77

Note: [1]Column explained in Table1; [2]Nut weight; [3]Nut length; [4]Nut width; [5]Nut thickness; [6]Scar height; [7]Shape index; [8]Arithmetic mean; [9]Minimum; [10]Maximum; [11]Standard deviation; [12]Coefficient of variation.

The mean value of SI amounted to .81. The highest mean value of the shape index was determined in the Divčibare population (.87) and the lowest (.76) in the populations of Kunovo and Košutnjak. The highest value of the shape index was found in the Divčibare population (1.07) and the lowest (.57) in the population of the Košutnjak. The highest value of the coefficient of variation was determined in the

Sokolovica population (12.43%) and the lowest in the Đerdap population (9.29%) (Table 2). In the research of Miletić et al. (2007), the determined shape index was .89. In the research of Srivastava et al. (2010), the determined range of shape index was from .79 to .91.

The results of the conducted ANOVA showed that the populations differ significantly according to all researched traits. The populations showed statistically significant differences at the level of significance of .01 for all observed morphological nut traits (Table 3). Thereafter, additional testing using Fisher's multiple tests (LSD) was conducted for all pairs of populations aimed at determining which exact populations statistically differ significantly from each other (Table 4). Based on the obtained results it can be concluded that the pairs of populations that differ most from each other are populations of Sokolovica and the Košutnjak, Kunovo and the Košutnjak (significant differences for all observed traits), then populations of Đerdap and Južni Kučaj, Južni Kučaj and the Košutnjak, Južni Kučaj and Kunovo, Vukan-Krilaš and Divčibare, Divčibare and Sokolovica, Sokolovica and Žagubica (significant differences for five out of six observed traits). The populations most similar to one another are Đerdap and Sokolovica (significant difference only for one trait), then populations of Đerdap and Kunovo, Vukan-Krilaš and Sokolovica, Vukan-Krilaš and Kunovo (significant differences for two observed traits).

The results obtained in this research confirmed the existence of significant variability of morphological traits of nuts and indicated high phenotypic variability of Turkish hazel populations in Serbia. The high level of phenotypic diversity of Turkish hazelnuts was also determined in other studies (Ayan et al., 2018; Miletić et al., 2005, 2007; Srivastava et al., 2010).

The Južni Kučaj population has the largest nuts, so it can be recommended as a future seed source. The Sokolovica population has the smallest nuts. The highest variability was determined in the populations of Vukan-Krilaš and Divčibare. Therefore, the selection of these two populations for seed facilities has been confirmed as right in the conducted analyses. Based on the obtained results, it can be stated that the available gene pool of Turkish hazel in Serbia is characterized by a satisfactory degree of genetic variability and represents a good starting point for the process of further breeding. For the needs of forestry, Turkish hazel seedlings are produced in a generative manner. Therefore, the characteristics of nuts are one of the key factors of the quality production of forest reproductive material. The selection of suitable stands where nuts can be harvested plays a crucial role in the success of afforestation. Therefore, the knowledge of phenotypic and genotypic traits of stands is especially important.

In order to protect all forest ecosystems and services and goods provided by forests from potential future climate change, mixed-species forests should be established (Šeho et al., 2019). For future adaptation during climate change, the populations in which nuts will be harvested should have high genetic diversity, higher growth rates, and higher wood quality (Šeho et al., 2019).

For the purpose of conservation and directed use of the Turkish hazel gene pool in some areas, first of all, it is necessary to be familiarized with its genetic diversity and structure. Knowing the genetic diversity

Table 3.
Analysis of Variance of Morphological Nut Traits

Population[1]	Trait					
	NWe[2] (g)	NL[3] (mm)	NWi[4] (mm)	NT[5] (mm)	SH[6] (mm)	SI[7]
A	1.23[a]	15.24[a]	14.72[abcd]	11.25[ab]	9.56[b]	.86[de]
B	1.45[b]	16.60[de]	15.80[e]	12.38[c]	10.75[c]	.85[de]
C	1.18[a]	16.18[cd]	14.17[a]	11.11[a]	10.33[c]	.78[ab]
D	1.42[b]	15.85[bc]	14.83[bcd]	12.63[c]	9.54[b]	.87[e]
E	1.18[a]	15.36[ab]	14.35[ab]	10.88[a]	10.59[c]	.83[d]
F	1.39[b]	16.79[e]	14.97[cd]	11.61[b]	9.00[a]	.80[bc]
G	1.24[a]	16.80[e]	14.54[abc]	10.92[a]	9.75[b]	.76[a]
H	1.43[b]	17.76[f]	15.23d	11.60[b]	9.68[b]	.76[a]
p	.0000	.0000	.0000	.0000	.0000	.0000

Note: [1]Column explained in Table1; [2]Nut weight; [3]Nut length; [4]Nut width; [5]Nut thickness; [6]Scar height; [7]Shape index.
[a,b,c,d,e]Values with the same letters do not differ significantly.

Table 4.
Results of Populations Pairwise Comparisons

Comparison of Populations[1]	Trait					
	NWe[2]	NL[3]	NWi[4]	NT[5]	SH[6]	SI[7]
A–B	<.01	<.01	<.01	<.01	<.01	.94
A–C	.49	<.01	.08	.55	<.01	<.01
A–D	<.01	<.01	.65	<.01	.95	.42
A–E	.32	.64	.17	.09	<.01	.14
A–F	<.01	<.01	.33	.11	.06	<.01
A–G	.85	<.01	.53	.10	.39	<.01
A–H	<.01	<.01	.07	.10	.57	<.01
B–C	<.01	.15	<.01	<.01	.06	<.01
B–D	.71	<.01	<.01	.35	<.01	.41
B–E	<.01	<.01	<.01	<.01	.50	.19
B–F	.35	.53	<.01	<.01	<.01	<.01
B–G	<.01	.44	<.01	<.01	<.01	<.01
B–H	.71	<.01	<.05	<.01	<.01	<.01
C–D	<.01	.22	<.05	<.01	<.01	<.01
C–E	.91	<.01	.56	.38	.30	<.05
C–F	<.01	.06	<.01	.06	<.01	.46
C–G	.38	<.05	.26	.45	0<.01	.14
C–H	<.01	<.01	<.01	.05	<.01	.12
D–E	<.01	<.05	.07	<.01	<.01	<.05
D–F	.67	<.01	.59	<.01	.07	<.01
D–G	<.01	<.01	.29	<.01	.35	<.01
D–H	.92	<.01	.16	<.01	.52	<.01
E–F	<.01	<.01	<.05	<.01	<.01	<.05
E–G	.17	<.01	.51	.87	<.01	<.01
E–H	<.01	<.01	<.01	<.01	<.01	<.01
F–G	<.01	.98	.12	<.01	<.01	<.05
F–H	.50	<.01	.36	.96	<.01	<.05
G–H	<.01	<.01	<.01	<.01	.72	.88

Note: [1]Column explained in Table 1; [2]Nut weight; [3]Nut length; [4]Nut width; [5]Nut thickness; [6]Scar height; [7]Shape index.

of Turkish hazel in remaining populations is insufficient and modest researches have been conducted so far. The initial studies of genetic diversity research showed clear differences between provenances from the Balkan Peninsula and Turkey (Šeho et al., 2018). Ayan et al. (2018) stated that due to relatively narrow genetic distance among populations and their scattered distribution protection programs should be focused, on the one hand, on in situ conservation of natural populations while, on the other hand, the selected genotypes or populations can be conserved in ex situ conservation facilities. Conservation and improvement of the condition of the available gene pool of Turkish hazel should have a key role in the future sustainable development of forests in all countries where this species occurs (e.g., Turkey, Bulgaria, Romania, Serbia, Bosnia, and Herzegovina, and Georgia). The characteristics it possesses and the traits it shows can recommend it for use in volatile climate conditions as an original tree species for stabilization of endangered forest stands (Ayan et al., 2016, 2018; Isajev et al., 2006; Petkova et al., 2016, 2017; Šeho et al., 2018; Vukin et al., 2008).

Conclusion

The results of this research have shown that there is significant variability of morphological nut traits and indicated high phenotypic variability of the researched traits and genetic differentiation of Turkish hazel populations in Serbia. The analysis of morphological nut traits provided basic insight into the level of inter-population variability and expanded the knowledge about this rare and valuable woody species. Nut length ranges from 15.24 to 17.76 mm, width from 14.17 to 15.80 mm, thickness from 10.92 to 12.38, and weight from 1.23 to 1.45 g.

The obtained results are a basis for the continuation of the research which is necessary to conduct in order to provide guidelines and recommendations for conservation and directed use of genetic resources of Turkish hazel in the territory of Serbia and the Balkan Peninsula. The Južni Kučaj population has the largest nuts, so it can be recommended as a seed source. The Vukan-Krilaš and Divčibare populations are seed facilities characterized by the highest variability of the studied traits, so it is justified to use them in the future as the sources of the reproductive material.

In order to make the results clearer, it is necessary to investigate the genetic diversity and structure of the populations by performing analyses of various phenotypic traits in specially designed experiments (e.g., provenance tests, progeny tests) as well as analyses of appropriate DNA markers.

Since the conservation of genetic variability is one of the basic conditions for preserving the adaptive capacity of species, the studied populations must be included in continuous processes of conservation and breeding, especially through appropriate forms of in situ and ex situ conservation.

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