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Morphological Traits of Silver Fir (*Abies alba* Mill.) in the Bosnian-Herzegovinian Provenance Test

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Abstract

Aim of study: This research aims to determine if there are statistically significant differences among provenances of silver fir (*Abies alba* Mill.) as one of the most important tree species in Bosnia and Herzegovina, to choose a provenance with the best productivity for further silvicultural activities of silver fir in the country.

Material and methods: The height and diameter at breast height were measured, and the basal area and volume of silver fir trees were calculated in the silver fir provenance test. The test contains nine provenances from Bosnia and Hezegovina and was launched in 1991, with 5-year-old seedlings (3+2). The data were collected in 2013.

Main results: Variance analysis for all traits showed statistically significant differences among provenances. Average breast height diameter in 27-year-old plants for all provenances amounted to 11.0 cm, average height 8.4 m, average basal area 0.010342 m^2, and average volume 0.070845 m^3

Highlights: The research results confirmed the existence of variability among silver fir provenances in Bosnia and Herzegovina, considering the morphological indicators. Provenance Bosanski Petrovac showed the highest values of all traits, which implies it is the best provenance for the further activities on seed collecting and producing planting material for afforestation in Bosnia and Herzegovina.

Keywords: Morphological Traits, Provenance Test, Silver Fir

Bosna-Hersek Orijin Testinde Gümüşi Göknarın (*Abies alba* Mill.) Morfolojik Özellikleri

Öz

Çalışmanın amacı: Bu araştırmada, Bosna Hersek'in önemli ağaç türlerinden biri olan Gümüşi Göknar'ın (*Abies alba* Mill.) farklı orijinleri arasında istatistiksel olarak önemli farklılıklar olup olmadığı ve bu sonuçlar neticesinde Gümüşi Göknar'ın ileri ki silvikültürel uygulamalar için hangi orijinin en iyi verimliliğe sahip olduğu belirlenmeye çalışılmıştır.

Materyal ve yöntem: Gümüşi Göknar'ın farklı orijinlerinde göğüs yüksekliğindeki boy ve çapları, göğüs yüzey alanı ve hacimleri hesaplanmıştır. Ölçümler, 1991 yılında Bosna Hersek'in 9 farklı orijininden alınan 5 yaşında ki (3+2) fidanlarda yapılmıştır. Daha sonra tüm veriler 2013 yılında toplanmıştır.

Temel sonuçlar: Tüm gruplar için varyans analizi yapılmış ve deney yapılan 9 orijin arasında istatistiksel olarak anlamlı farklılıklar bulunmuştur. 27 yaşındaki ağaçlarda tüm orijinler için ortalama göğüs yüksekliği çapı 11,0 cm, ortalama yükseklik 8,4 m, ortalama göğüs yüzey alanı 0,010342 m^2 ve ortalama hacim 0,070845 m^3 olarak belirlenmiştir.

Araştırma vurguları: Morfolojik göstergeler göz önüne alındığında araştırma sonuçları Bosna Hersek'teki Gümüşi Göknar orijinleri arasında farklılıklar olduğu saptanmıştır. Bosanski Petrovac orijinli deney örneklerinde tüm özellikler bakımından en yüksek değerler tespit edilmiş ve bu orijinin Bosna-Hersek'te tohum toplamada ve ağaçlandırmada kullanılmak üzere dikim materyali üretme ve daha sonraki faaliyetler için en iyi kaynak olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Morfolojik Özellikler, Orijin Testi, Gümüşi Göknar

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Introduction

Silver fir (*Abies alba* Mill.) is one of the most important species of forest trees from an economic and ecological point of view in Bosnia and Herzegovina (Ballian & Čabaravdić, 2005; Ballian & Halilović, 2016).

The main area of distribution of silver fir in Bosnia and Herzegovina is along the Dinaric mountains, in several separate, larger and smaller, areas (Fukarek, 1970). The total area of the forests where silver fir exists (pure and mixed forests), is 562.237 ha., or about 50% of all managed forests. The total growing stock of silver fir in these forests is 63.923.000 m^3, which is about 23% of the total wood stock in all managed forests (Usčuplić, 1992).

Provenance tests are widely known as a special type of plantation experiment that helps experts to understand how trees are adapted to different environmental conditions through genetic adaptation or phenotypic plasticity. For that reason, the Bosnian-Herzegovinian provenance test of silver was set in 1991.

The provenance that grows best can be considered best adapted to the planting site conditions and recommended for reforestation on sites that are similar to the test environment. Despite their useful results, provenance tests are very expensive long-term research, and comprehensive trial series is only possible for the most valuable forest tree species in the area.

The research aim is to evaluate the dynamics of the growth of silver fir provenances in Bosnia and Herzegovina by comparing morphological traits of height and breast height diameter, to choose a provenance with the best productivity for further silvicultural activities.

Material and Methods

The subject of this study were silver fir trees in the Bosnian provenance test. The provenance test was established on experimental plot Delimusa in forest management area Olovsko, forest management unit Krivaja, department 86, section a.

The experimental plot is located at an altitude of 970 m., on the northern exposure and inclination of the terrain in the interval of 10-20 degrees, on the deep acid brown soil on silicate substrate.

The starting material for the experiment originated from nine locations in Bosnia and Herzegovina (Bosanski Petrovac, Bugojno, Fojnica, Konjic, Olovo – Klis, Olovo-Palež, Pale, Prozor, and Sokolac) from positions between 850 and 1300 m. above sea level. The northernmost provenance comes from Bosanski Petrovac, while the southernmost comes from the area of Herzegovina - Konjic. the geographical distribution of populations used as starting material in the provenance test is shown in Figure 1, and their basic characteristics are showed in Table 1.

Figure 1. Geographical distribution of populations used as starting material

Table 1. Basic characteristics of populations used as starting material in provenance test

Provenance	Soil Type	Geological-petrographic Substrate	Altitude (m)	Exposure	Inclination (%)	Latitude	Longitude
Bosanski Petrovac	Rendsina calcocambisol pseudogley	Dolomites	900	N	2	44°29'16"	16°27'21"
Bugojno	Rendsina calcocambisol	Dolomites and Limestones	1.090	N-W	10 - 25	43°59'29"	17° 22'27"
Fojnica	Dystric cambisol	Rhyolite	1.010	N	10 - 15	43°55'57"	17°53'48"
Konjic	Calcocambisol calcomelanosol	Dense limestones	1.030	E-EN	10 - 22	43°32'22"	18°01'06"
Olovo - Klis	Calcocambisol luvisol	Limestones	850	N-W	13	44°08'12"	18°42'27"
Olovo - Palež	Calcocambisol luvisol	Limestones	960	N-E	12	44°03'04"	18°37'07"
Pale	Dystric cambisol calcomelanosol	Werfenian schists Sandstones Limestones	1.200	N-E	20	43°48'02"	18°32'51"
Prozor	Calcomelanosol luvisol	Limestone moraine	1.300	N-E	5 - 10	43°40'39"	17°37'31"
Sokolac	Calcocambisol calcomelanosol	Limestones	940	S-W	13	43°53'42"	18°42'17"

Collection of seed from these provenances was carried out in autumn 1985, after which sowing was done in the nursery Zavidovići. The seedlings of the age of 3 + 2 were planted in the experimental plot in the spring of 1991. A block system with five repetitions was chosen for planting. Dimensions of the plot are 173 m x 88 m = 1,522 ha, and on each side of the plot, two rows of the same tree species were planted. These rows serve as a protective band so that the total area of the experimental plot is approximately 2 hectares.

Each of the five blocks was divided into ten plots with dimensions 14 x 14 meters. There are 3-meter interspaces among plots on each side, and seedlings were planted with 2 meters' distance.

A total of 2880 seedlings (64 seedlings per provenance and block) were planted. Each provenance consists of 15 families, and each family has four plants.

In this research, we measured heights and diameters at breast height (DBH - 1.30 m from the ground) of silver fir trees in the provenance test. Basal area and volume of tress were read from Tables for measuring elements in high and coppice forests in Bosnia and Herzegovina (Matić et al., 1990), with two inputs: DBH and height. Measurements were made in 2013, at plant age 27 years.

We processed obtained data by statistical program SPSS 20.0. We calculated descriptive indicators (mean, minimum, maximum, standard deviation, coefficient of variability) and completed variance analysis and Duncan test per provenances. Univariate analysis was performed to include effects of blocks, provenances, and block x provenance interaction.

Results and Discussion

Descriptive statistics for DBH (cm) per provenances are shown in Table 2.

Table 2. Descriptive indicators for diameter at breast height (cm) per provenances

Provenance	N	Mean	Standard Deviation	Minimum	Maximum	Variability Coefficient (%)
Bosanski Petrovac	218	11.9	3.4	2.5	19.3	28.3
Bugojno	248	10.8	3.0	3.0	20.2	28.1
Fojnica	271	11.2	3.3	3.3	19.8	29.4
Konjic	258	10.7	2.8	4.3	21.3	25.8
Olovo-Klis	204	11.1	2.7	3.4	18.7	24.7
Olovo Palež	258	10.8	3.2	3.3	21.5	29.7
Pale	243	10.8	3.2	3.5	20.0	29.5
Prozor	251	10.8	3.2	3.5	21.6	30.0
Sokolac	248	11.2	3.2	1.7	18.2	28.2
Total	2199	11.0	3.1	1.7	21.6	28.5

The average DBH for all provenances was 11.0 cm. Konjic provenance had the lowest average breast height diameter, 10.7 cm, and Bosanski Petrovac provenance the highest, 11.9 cm.

The average coefficient of variability for all provenances was 28.5%. The highest coefficient of variation had the provenance of Prozor, 30.0%, and the lowest provenance of Olovo - Klis, 24.7%.

The variance analysis showed statistically significant differences among provenances for DBH at 0.05 level (Table 3).

Table 3. Analysis of variance for diameter at breast height

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	281.920	8	35.240	3.610	0.000
Within Groups	21378.254	2190	9.762		
Total	21660.174	2198			

According to Duncan's test for DBH (Table 4), provenances are divided into two groups, i.e. provenance Bosanski Petrovac separates from other provenances. Descriptive statistics for heights (m) per provenances are shown in Table 5. The average height in all the provenances was 8.4 m. Provenances Konjic, Olovo-Klis, and Pale had the lowest average height, 8.1 m, and Bosanski Petrovac the highest average height, 9.1 m.

Table 4. Duncan test for DBH

Provenance	N	Subset for Alpha = 0.05	
		1	2
Konjic	258	10.726	
Bugojno	248	10.760	
Olovo-Palež	258	10.784	
Pale	243	10.801	
Prozor	251	10.820	
Olovo-Klis	204	11.095	
Sokolac	248	11.202	
Fojnica	271	11.217	
B. Petrovac	218		11.946
Sig.		0.145	1.000

Table 5. Descriptive indicators for height (m) per provenances

Provenance	N	Mean	Standard Deviation	Minimum	Maximum	Variability Coefficient (%)
Bosanski Petrovac	218	9.1	2.7	1.5	14.7	29.4
Bugojno	248	8.2	1.9	2.0	13.6	23.1
Fojnica	271	8.6	1.9	2.5	12.9	22.4
Konjic	258	8.1	1.6	2.4	14.8	19.7
Olovo-Klis	204	8.1	1.4	2.5	11.0	17.1
Olovo Palež	258	8.2	2.0	1.8	16.6	24.5
Pale	243	8.1	1.9	1.8	12.9	23.3
Prozor	251	8.3	1.9	2.4	14.5	23.1
Sokolac	248	8.7	2.1	1.8	14.1	23.8
Total	2199	8.4	2.0	1.5	16.6	23.6

The average coefficient of variability for all provenances was 23.6%. The highest coefficient of variation had the provenance of Bosanski Petrovac, 29.4%, and the lowest provenance of Olovo - Klis, 17.1%.

The variance analysis for the height of plants (Table 6) showed statistically significant differences among provenances for height at 0.05 level (Fizr.>Ftab, Sig.<0.005).

Table 6. Analysis of variance for height

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	205.915	8	25.739	6.750	0.000
Within Groups	8351.463	2190	3.813		
Total	8557.378	2198			

Duncan's test divided provenances into three groups (Table 7).

Table 7. Duncan test for height

Provenance	N	Subset for Alpha = 0.05		
		1	2	3
Olovo-Klis	204	8.095		
Pale	243	8.119		
Konjic	258	8.143		
Bugojno	248	8.170		
Olovo Palež	258	8.230		
Prozor	251	8.260		
Fojnica	271		8.608	
Sokolac	248		8.681	
B. Petrovac	218			9.062
Sig.		0.427	0.679	1.000

Descriptive indicators for the basal area (m^2) per provenances are shown in Table 8.

The average basal area of trees for all provenances was 0.005630 m^2. Provenance Konjic had the lowest, and provenance Bosanski Petrovac the highest values for the basal area. The coefficient of variability was high for all provenances, from 47.4% for Olovo-Klis to 57.6% for provenances Pale and Prozor.

The variance analysis for the basal area (Table 9) showed statistically significant differences among provenances for height at 0.05 level (Fizr.>Ftab, Sig.<0.005).

Table 8. Descriptive indicators for basal area (m^2) per provenances

Provenance	N	Mean	Standard Deviation	Minimum	Maximum	Variability Coefficient (%)
Bosanski Petrovac	218	0.01213	0.00624	0.00071	0.02835	51.4
Bugojno	248	0.00981	0.00525	0.00071	0.03142	53.5
Fojnica	271	0.01079	0.00607	0.00071	0.03142	56.3
Konjic	258	0.00964	0.00495	0.00126	0.03464	51.3
Olovo-Klis	204	0.01029	0.00487	0.00071	0.02835	47.4
Olovo Palež	258	0.00999	0.00562	0.00071	0.03801	56.3
Pale	243	0.00998	0.00575	0.00126	0.03142	57.6
Prozor	251	0.01003	0.00578	0.00126	0.03801	57.6
Sokolac	248	0.01063	0.00563	0.00031	0.02545	53.0
Total	2199	0.01034	0.00563	0.00031	0.03801	54.4

Table 9. Analysis of variance for basal area

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	0.001	8	0.000	4.239	0.000
Within Groups	0.069	2190	0.000		
Total	0.070	2198			

Duncan's test divided provenances into two groups, i.e., as for the trait of breast height diameter, provenance Bosanski Petrovac separates from other provenances (Table 10).

Descriptive statistics for volumes (m^3) per provenances are shown in Table 11.

Table 10. Duncan test for basal area

Provenance	N	Subset for Alpha = 0.05	
		1	2
Konjic	258	0.00964	
Bugojno	248	0.00981	
Pale	243	0.00998	
Olovo Palež	258	0.00999	
Prozor	251	0.01003	
Olovo-Klis	204	0.01029	
Sokolac	248	0.01063	
Fojnica	271	0.01079	
B. Petrovac	218		0.01213
Sig.		0.052	1.000

Table 11. Descriptive statistics for volume (m^3) per provenances

Provenance	N	Mean	Standard Deviation	Minimum	Maximum	Variability Coefficient (%)
Bosanski Petrovac	218	0.089207	0.057383	0.00182	0.24102	64.3
Bugojno	248	0.066005	0.041781	0.00242	0.24852	63.3
Fojnica	271	0.075201	0.049310	0.00374	0.27351	65.6
Konjic	258	0.063745	0.039109	0.00592	0.33875	61.4
Olovo-Klis	204	0.066839	0.035996	0.00302	0.21102	53.9
Olovo Palež	258	0.067931	0.046590	0.00218	0.41075	68.6
Pale	243	0.067189	0.046327	0.00304	0.26019	69.0
Prozor	251	0.068083	0.046129	0.00412	0.36574	67.8
Sokolac	248	0.074876	0.047475	0.00142	0.24265	63.4
Total	2199	0.070845	0.046420	0.00142	0.41075	65.5

The average volume of trees for all provenances was 0.070845 m^3. Provenance Olovo-Klis had the lowest average value of the basal area, and provenance Bosanski Petrovac the highest. The average coefficient of variability was 65.5%.

The variance analysis for volume (Table 12) showed statistically significant differences among provenances for height at 0.05 level (Fizr.>Ftab, Sig.<0.005).

Duncan's test divided provenances into three groups. First two groups overlapped, and provenance Bosanski Petrovac separated into a different group, as shown in Table 13.

Table 12. Analysis of variance for volume

Source of Variation	Sum of Squares	DF	Mean Square	F	Sig.
Between Groups	0.112	8	0.014	6.637	0.000
Within Groups	4.624	2190	0.002		
Total	4.736	2198			

Table 13. Duncan test for volume

Provenance	N	Subset for Alpha= 0.05		
		1	2	3
Konjic	258	0.06375		
Bugojno	248	0.06600	0.06600	
Olovo-Klis	204	0.06684	0.06684	
Pale	243	0.06719	0.06719	
Olovo Palež	258	0.06793	0.06793	
Prozor	251	0.06808	0.06808	
Sokolac	248		0.07488	
Fojnica	271		0.07520	
B. Petrovac	218			0.08921
Sig.		0.375	0.056	1.000

To analyse the effects of blocks on the growth of silver fir in the provenance test, we performed univariate analysis (Table 14).

Table 14. Average values of DBH (cm) per provenances and blocks

Provenance	Block 1		Block 2		Block 3		Block 4		Block 5		Total	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
B. Petrovac	50	12.1	23	12.5	38	10.7	52	13.9	55	10.6	218	11.9
Bugojno	46	10.9	48	10.5	46	11.0	56	11.0	52	10.4	248	10.8
Fojnica	53	11.0	52	10.9	60	11.5	54	11.5	52	11.2	271	11.2
Konjic	41	11.5	57	10.8	52	9.6	56	10.6	52	11.3	258	10.7
Olovo-Klis	25	11.6	42	12.2	53	11.1	52	10.0	32	11.1	204	11.1
Olovo Palež	50	9.6	42	11.1	58	11.0	54	11.5	54	10.6	258	10.8
Pale	36	10.2	52	8.8	47	12.1	50	11.8	58	11.0	243	10.8
Prozor	43	11.1	56	11.7	53	10.2	47	10.7	52	10.4	251	10.8
Sokolac	42	11.4	53	11.0	49	10.5	50	12.4	54	10.8	248	11.2
Total	386	11.0	425	10.9	456	10.9	471	11.5	461	10.8	2199	11.0

The highest average value of DBH for all provenances was in block 4 (11.5 cm), and lowest in block 5 (10.8 cm).

Tests of Between-Subjects Effects table (Table 15) for DBH showed the presence of a statistically significant effect of interaction between blocks and provenances (Fizr.>Ftab., Sig.<0.005), which means that even though the environmental conditions are similar in the whole surface of provenance test, small differences in microclimate caused the differences among provenances regarding values of diameter at breast height.

Table 15. Tests of between subject effects for breast height diameter

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Corrected Model	1549.746[a]	44	35.221	3.773	0.000
Intercept	258132.102	1	258132.102	27648.170	0.000
Block	133.100	4	33.275	3.564	0.007
Provenance	268.601	8	33.575	3.596	0.000
Block * Provenance	1135.665	32	35.490	3.801	0.000
Error	20110.429	2154	9.336		
Total	288954.960	2199			
Corrected Total	21660.174	2198			

a. R Squared = .072 (Adjusted R Squared = .053)

In the graphical representation of estimated marginal means for the trait of DBH (Figure 1), it is visible that there is a statistically significant interaction between blocks and provenances. Provenance Bosanski Petrovac showed the highest estimated marginal mean values in block 1, block 2, and block 4, but the value among others in block 3 and block 5. Provenance Pale showed the lowest estimated marginal mean in block 2, but the highest in block 3 (Table 16).

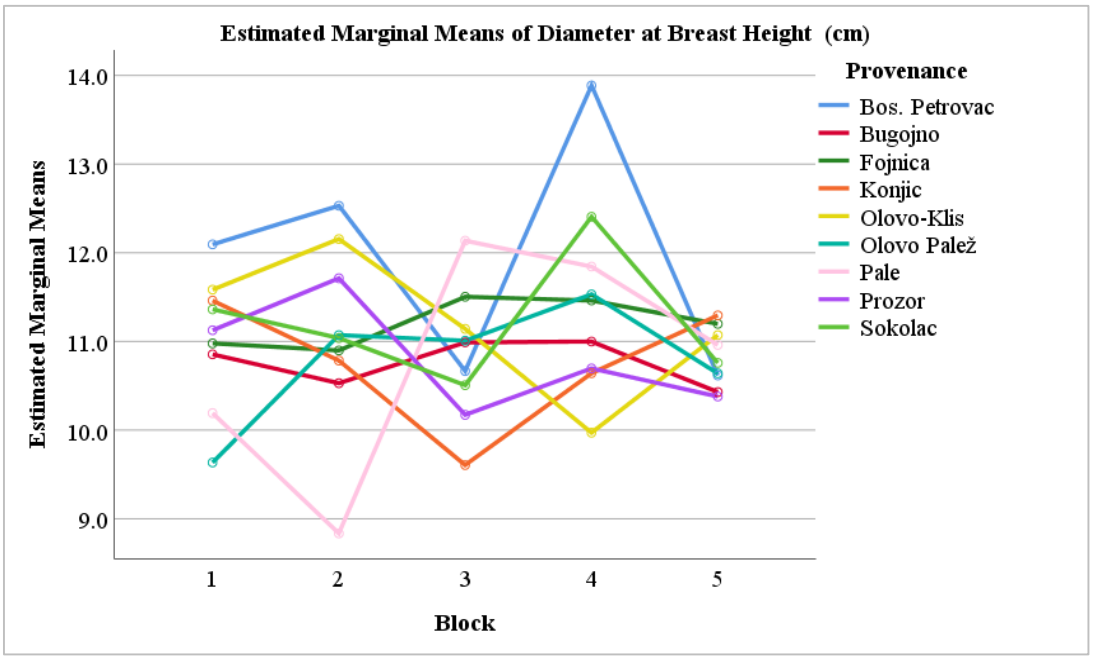

Figure 1. Estimated marginal means of DBH

Table 16. Average values of height (m) per provenances and blocks

Provenance	Block 1		Block 2		Block 3		Block 4		Block 5		Total	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
B. Petrovac	50	9.6	23	8.3	38	7.7	52	11.5	55	7.5	218	9.1
Bugojno	46	8.1	48	7.9	46	8.4	56	8.5	52	7.9	248	8.2
Fojnica	53	8.4	52	8.5	60	9.3	54	8.5	52	8.3	271	8.6
Konjic	41	8.4	57	8.0	52	7.6	56	8.1	52	8.6	258	8.1
Olovo-Klis	25	8.1	42	8.5	53	8.0	52	7.6	32	8.4	204	8.1
Olovo Palež	50	7.4	42	8.2	58	8.8	54	8.5	54	8.2	258	8.2
Pale	36	7.5	52	6.7	47	8.7	50	9.2	58	8.3	243	8.1
Prozor	43	8.2	56	8.8	53	8.8	47	7.5	52	7.9	251	8.3
Sokolac	42	8.7	53	8.2	49	8.1	50	10.2	54	8.3	248	8.7
Total	386	8.3	425	8.1	456	8.4	471	8.8	461	8.1	2199	8.4

The highest average value of height for all provenances was in block 4 (8.8 m), and lowest in block 2 and block 5 (8.1 m).

Tests of Between-Subjects Effects table (Table 17) for the trait of height showed that there is a statistically significant interaction between blocks and provenances (Fizr.>Ftab., Sig.<0.005), which means that even though the environmental conditions are similar in the whole surface of provenance test, small differences in microclimate caused the differences among provenances regarding values of diameter at breast height.

Table 17. Tests of between subject effects for height

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Corrected Model	1330.396[a]	44	30.236	9.012	0.000
Intercept	147578.326	1	147578.326	43985.682	0.000
Block	147.643	4	36.911	11.001	0.000
Provenance	159.503	8	19.938	5.942	0.000
Block * Provenance	970.777	32	30.337	9.042	0.000
Error	7226.982	2154	3.355		
Total	162668.920	2199			
Corrected Total	8557.378	2198			

a. R Squared = 0.155 (Adjusted R Squared = .138)

In the graphical representation of estimated marginal means for the trait of height (Figure 2), it is visible that there is a statistically significant interaction between blocks and provenances. Provenance Bosanski Petrovac showed the highest estimated marginal mean values in block 1, and block 4, but the value among others in block 2 and block 3, and the lowest value in block 5 (Table 18).

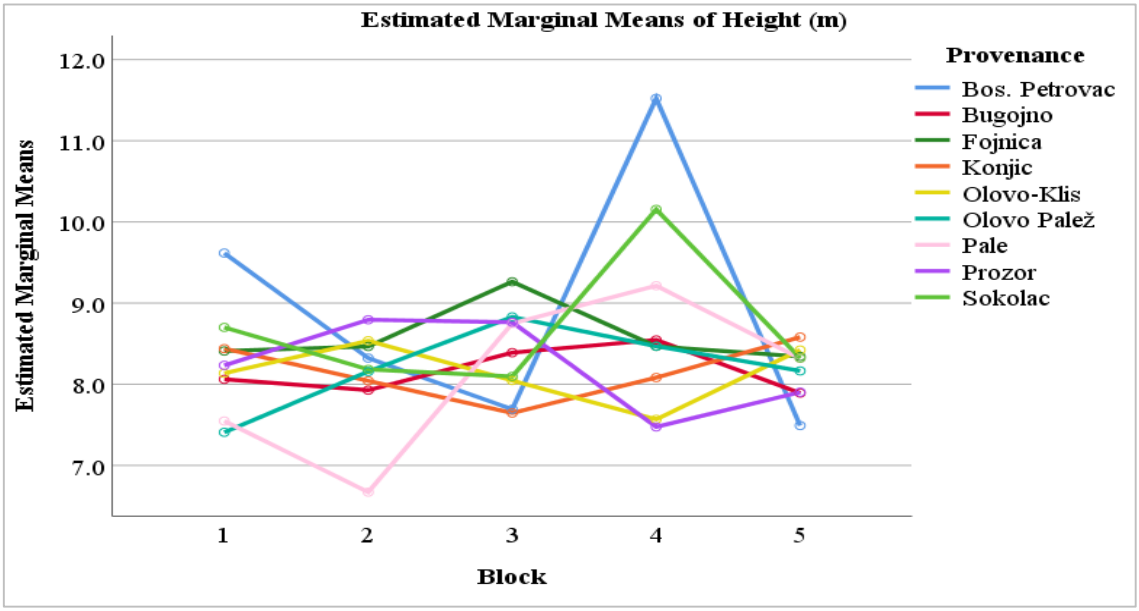

Figure 2. Estimated marginal means of height

Table 18. Average values of basal area (m^2) per provenances and blocks

Provenance	Block 1		Block 2		Block 3		Block 4		Block 5		Total	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
B. Petrovac	50	0.01204	23	0.01299	38	0.00989	52	0.01592	55	0.00983	218	0.01213
Bugojno	46	0.00964	48	0.00927	46	0.01066	56	0.01023	52	0.00925	248	0.00981
Fojnica	53	0.01006	52	0.01004	60	0.01128	54	0.01141	52	0.01108	271	0.01079
Konjic	41	0.01053	57	0.00982	52	0.00777	56	0.00948	52	0.01079	258	0.00964
Olovo-Klis	25	0.01091	42	0.01238	53	0.01022	52	0.00848	32	0.01011	204	0.01029
Olovo Palež	50	0.00786	42	0.01066	58	0.01028	54	0.01140	54	0.00972	258	0.00999
Pale	36	0.00835	52	0.00664	47	0.01260	50	0.01177	58	0.01031	243	0.00998
Prozor	43	0.01067	56	0.01158	53	0.00857	47	0.01024	52	0.00915	251	0.01003
Sokolac	42	0.01133	53	0.01006	49	0.00937	50	0.01310	54	0.00949	248	0.01063
Total	386	0.01013	425	0.01017	456	0.01007	471	0.01131	461	0.00996	2199	0.01034

As expected, the highest average value of the basal area was in block 4, and lowest in block 5, as for the traits of breast height diameter.

Tests of between-subjects effects table (Table 19) for the trait of basal area showed that there was a statistically significant interaction between blocks and provenances (Fizr.>Ftab., Sig.<0.005), as it was the case with the diameter at breast height which we used for the calculation of basal area, where the small differences in environmental conditions among blocks cause differences in growth of provenances.

Table 19. Tests of between subject effects for basal area

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Corrected Model	.005[a]	44	0.000	4.160	0.000
Intercept	.228	1	0.228	7640.357	0.000
Block	.001	4	0.000	4.738	0.001
Provenance	.001	8	0.000	4.139	0.000
Block * Provenance	.004	32	0.000	4.008	0.000
Error	.064	2154	2.981E-5		
Total	.305	2199			
Corrected Total	.070	2198			

a. R Squared = .155 (Adjusted R Squared = .138)

In the graphical representation of estimated marginal means for the trait of basal area (Figure 3), it is visible that there is a statistically significant interaction between blocks and provenances.

Provenance Bosanski Petrovac showed the highest estimated marginal mean values in block 1, block 2 and block 4, but the value among others in block 3 and block 5. Provenance Pale showed the lowest estimated marginal mean in block 2, but the highest in block 3.

Results of average volume per provenance and blocks are shown in Table 20.

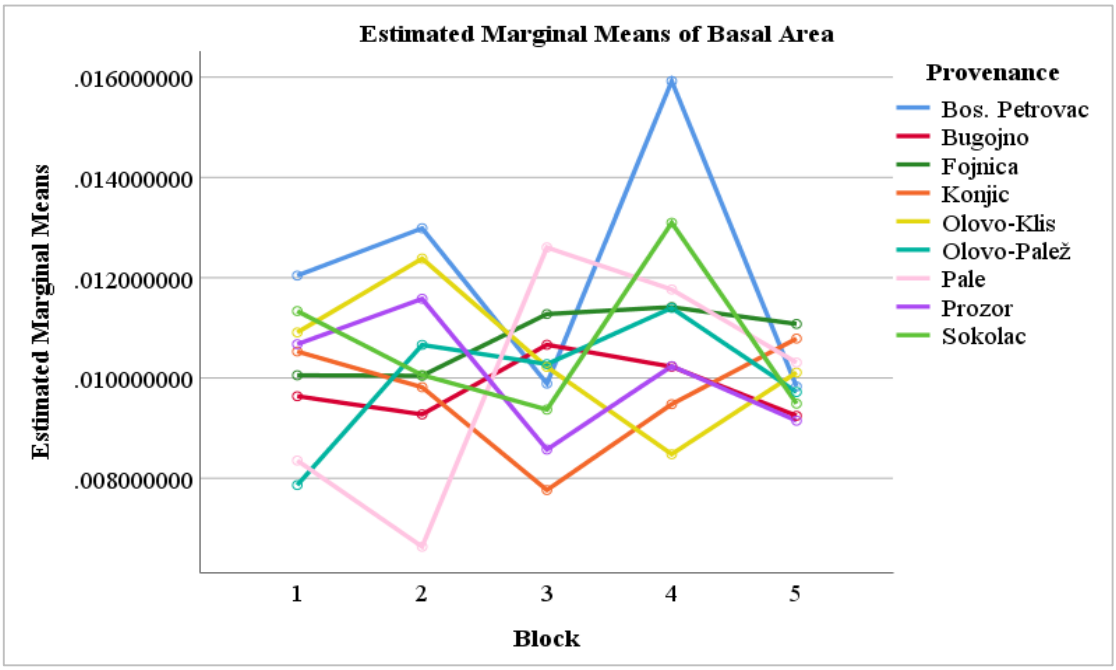

Figure 3. Estimated marginal means of basal area

Table 20. Average values of volume (m^3) per provenances and blocks

Provenance	Block 1		Block 2		Block 3		Block 4		Block 5		Total	
	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean	N	Mean
B. Petrovac	50	0.08973	23	0.08673	38	0.06544	52	0.13485	55	0.06304	218	0.08921
Bugojno	46	0.06336	48	0.06067	46	0.07526	56	0.07114	52	0.05955	248	0.06601
Fojnica	53	0.06696	52	0.06944	60	0.08255	54	0.07877	52	0.07717	271	0.07520
Konjic	41	0.06959	57	0.06373	52	0.04993	56	0.06236	52	0.07447	258	0.06375
Olovo-Klis	25	0.07064	42	0.08287	53	0.06580	52	0.05354	32	0.06615	204	0.06684
Olovo Palež	50	0.04872	42	0.07328	58	0.07211	54	0.07985	54	0.06516	258	0.06793
Pale	36	0.05140	52	0.03948	47	0.08788	50	0.08444	58	0.07019	243	0.06719
Prozor	43	0.07179	56	0.08075	53	0.06080	47	0.06726	52	0.05954	251	0.06808
Sokolac	42	0.08104	53	0.06596	49	0.06289	50	0.10342	54	0.06329	248	0.07488
Total	386	0.06826	425	0.06772	456	0.06930	471	0.08151	461	0.06653	2199	0.07085

As expected, the highest average value of volume was in block 4, and lowest in block 5, as for the traits of breast height diameter and height.

Tests of between-subjects effects table (Table 21) for the trait of volume showed that there was a statistically significant interaction between blocks and provenances (Fizr.>Ftab., Sig.<0.005), as it was the case with the traits of the diameter at breast height and the height, where differences in environmental conditions among blocks caused the differences in the growth of provenances.

Table 21. Tests of between subject effects for volume

Source	Type III Sum of Squares	DF	Mean Square	F	Sig.
Corrected Model	0.526[a]	44	0.012	6.122	0.000
Intercept	10.639	1	10.639	5443.656	0.000
Block	0.069	4	0.017	8.804	0.000
Provenance	0.095	8	0.012	6.066	0.000
Block * Provenance	0.344	32	0.011	5.502	0.000
Error	4.210	2154	0.002		
Total	15.773	2199			
Corrected Total	4.736	2198			

a. R Squared = .155 (Adjusted R Squared = 0.138)

In the graphical representation of estimated marginal means for the trait of volume (Figure 4), it is visible that there is a statistically significant interaction between blocks and provenances. Provenance Bosanski Petrovac showed the highest estimated marginal mean values in block 1, block 2 and block 4, but the value among others in block 3 and block 5. Provenance Pale showed the lowest estimated marginal mean in block 2, but the highest in block 3.

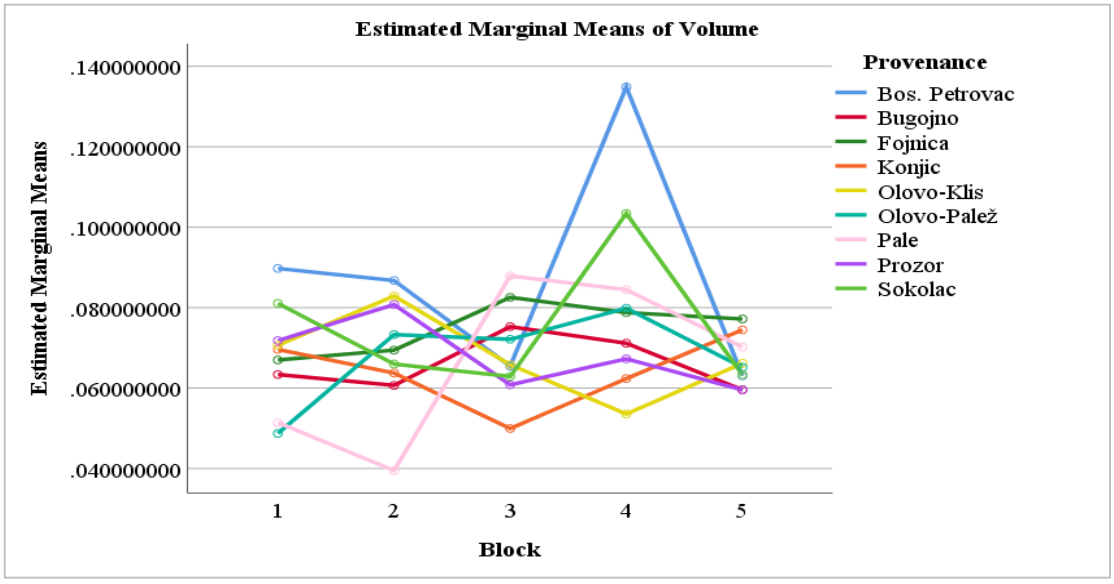

Figure 4. Estimated marginal means of volume

Discussion

Provenance tests of silver fir in Europe started in Switzerland and were focused on the research of individual growth of trees (Engler, 1905).

Larsen (1986) investigated the geographic variability of silver fir and found that provenances from South-East Europe showed significant differences in increment between each other, and also comparing to Carpathian provenances.

Mekić (1988) found a high variability of morphological and physiological indicators of Calabrian provenances, while the Central European provenances showed homogeneity.

Investigations of morphological traits in provenance cultures from central and southern Italy showed significant intrapopulation and interpopulation variation of silver fir (Ducci, 1991).

Mekić & Larsen (1991) researched the geographic variability of silver fir in Europe in 15 provenances when they were six-year-old. Italian provenances had a significantly higher increment of height and diameter than provenances from Central and Eastern Europe.

In France, the provenance trial of common fir was founded in 1963 with 19 French and two Romanian provenances (Lapus and Prahova). Foreign provenances with their characteristics were control populations to local ones. The range of height increment variability was up to 27% higher in foreign than in local provenances (Kajba, 2001).

Ratknić *et al*. (2002) researched the provenance test of silver fir in Serbia and found statistically significant differences among observed provenances.

Ivanković *et al*. (2006) researched in provenance test in Croatia, which included 18 provenances from Croatia and two from Slovenia. By variance analysis, they found statistically significant differences between provenances in growth dynamics.

Memišević et. al. (2016) researched phenological phases of leafing of silver fir in the same provenance tests. They didn't found statistically significant differences among provenances for dates of starting of individual phases, nor for the duration of phases.

Halilović (2008), Halilović *et al*. (2009a, 2009b, 2013) researched the younger age of plants on the same provenance test and found statistically significant differences in morphological indicators among provenances.

In this research, we analyzed morphological traits of 27-year-old trees from nine provenances on Delimusa experimental plot.

The variance analysis showed statistically significant differences among provenances for two measured traits (breast height diameter, height, and two calculated traits (basal area and volume).

Konjic provenance had the lowest, and Bosanski Petrovac provenance the highest average DBH. Obtained results are similar to those of research of Halilović (2008) on 20-year-old plants in the same experimental plot, where Pale provenance also had the lowest, and provenance of Bosanski Petrovac the highest average DBH.

Provenances Konjic, Olovo-Klis, and Pale had the lowest, and Bosanski Petrovac the highest average height. The results correspond to results obtained by Halilović (2008) in the same provenance test of 20-year-old plants when Olovo Klis provenance had the lowest, and Bosanski Petrovac the highest average height. In research of the same provenances on three-, four- and five-year-old seedlings, Mekić (1991) found statistically significant differences in height among provenances in the age of three and four, while there were no statistically significant differences among provenances at age five. Ratknić et al. (2002), in the test of same provenances in Priboj, Serbia, obtained the lowest average height for the Olovo-Klis provenance, and the highest for Bosanski Petrovac, as in this research. As for the trait of diameter at breast height, provenance Konjic had the lowest, and provenance Bosanski Petrovac the highest average value of the basal area.

Provenance Olovo-Klis had the lowest average value of volume, and provenance Bosanski Petrovac the highest.

Variance analysis for all traits showed statistically significant differences among provenances.

Univariate analysis showed the effects of blocks and interaction block x provenance. Maximum average values for all traits provenances showed in block 4. It means that small differences in ecological conditions can cause differences in the growth of silver fir.

This research included a small part of the silver fir natural distribution range, so we did not expect significant differences among provenances, especially because of the young age of the provenance test.

The Dinaric Mountains region is very specific when it comes to environmental conditions. On a very small area, there is a variety of climatic, edaphic, orographic, and

other factors affecting the differentiation of ecotypes, especially in the area of Central Bosnia (Stefanović et al., 1983). Therefore, experts consider that forest tree species from the Dinaric Mountains show higher variability compared to the same species from the north (Ballian & Čabaravdić, 2005; Ballian & Halilović, 2016)

Conclusion

Based on the written above, we can conclude that the results of this research confirmed the existence of variability of Bosnian-Herzegovinian provenances of silver fir regard to morphological traits. In other words, there are differences among populations from different ecological niches, i.e. differences in the ecology of habitats cause morphological differentiation among populations.

Provenance Bosanski Petrovac showed the highest values of the height, diameter at breast height, basal area, and volume of the trees, which implies it is the best provenance for the further activities on seed collecting and producing planting material for afforestation in Bosnia and Herzegovina.

Morphological research of provenances on this experimental plot should be continued to obtain more reliable results of morphological traits at older plants, as well as determine the juvenile-adult correlation for these traits.

Ethics Committee Approval

N/A

Peer-review

Externally peer-reviewed.

Author Contributions

Conceptualization: D.B., M.M.H.; Investigation: D.B., M.M.H., V.H., A.A.; Material and Methodology: D.B., M.M.H., V.H., A.A.; Supervision: D.B.; Visualization: M.M.H., A.A; Writing-Original Draft: M.M.H.; Writing-review & Editing: D.B., M.M.H., V.H., A.A.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare.

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