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INTRA-AND INTER-PROVENANCE VARIABILITY OF *OSTRYA CARPINIFOLIA* SCOP. SEEDLINGS

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Abstract: Hop Hornbeam (*Ostrya carpinifolia* Scop.) seedlings from 45 half-sib lines, from three provenances were analyzed. Intra-population variability between half-sib lines was found for morphological attributes of two-year seedlings. In this sense, maternal (seed) trees with the greatest potential for the production of reproductive material may be selected. Inter-population variability between provenances was found for morphological and physiological attributes, except for the height and dry mass of the two-year seedlings. The influence of half-sib lines and provenances on the concentration of the studied nutrients should be further examined in a larger number of samples. Despite its large potential, Hop Hornbeam is not used for afforestation in Serbia. In those terms, we should work to change attitudes in the selection of the common types of reforestation species.

Key words: Hop Hornbeam, *Ostrya carpinifolia*, seedling quality, variability, half-sib lines

INTRODUCTION

Hop Hornbeam is a very important component of pioneer communities in protective forests. These communities are located on steep slopes, bare limestone blocks, the moraines and heavily degraded sites. Hop Hornbeam primarily inhabits sites on limestone and rarely sites on serpentine geological substrate (Jovanović, 2000). In addition to limestone, Hop Hornbeam could be found on dolomite substrates, in the zone of oak forests and it is the most widespread in the western part of Serbia (Kojić, Vilotić, 2006). The range of Hop Hornbeam covers the Western Balkans from Greece, Albania, Bosnia and Herzegovina, Croatia, Serbia and southern Hungary and extends to the southern area of the Alps. It occurs in Provence and Italy including Sardinia and Corsica. In the southeast part of its areal Hop Hornbeam extends across Asia Minor to the Caucasus and Lebanon (Jovanović, 2000; Korkut, Korkut, 2008). Hop Hornbeam trees in Serbia reach the height of up to 17 *m*, diameter of up to 25 *cm* and an age of up to 100 years (Jovanović, 2000). Gerçek *et al*., (1998) reported that in Turkey Hop Hornbeam trees reach the height of up to 21 *m* and a diameter of up to 30 *cm*.

Despite wide possibilities for its use in afforestation (Jović *et al*., 1998; Tomić *et al*., 2011), foresters neglect Hop Hornbeam. In Serbia, there are neither certified seed sources of Hop Hornbeam nor an organized production of reproductive material (Ivetić *et al*., 2010). Use of the best trees for seed production at half-sib level in nurseries, results in genetic gain by incorporating their genetic potential in the next generation (Isajev *et al.*,

1996). In this regard, a better understanding of the genetic potential of this species is important for the production of improved reproductive material.

MATERIAL AND METHOD

A total of 45 seed trees, 15 from each of the three provenances located in southern Serbia, in Kosovo and Metohija, northeast of Gazivodsko Lake and in the Management Unit "Crni vrh-Deževska": Jagnjenica (720 *m* elevation), Junaci (950 *m* elevation) and Vojmisliće (1160 *m* elevation) were individually selected by the method of phenotype evaluation. A total of 6 phenotype characteristics were evaluated, i.e. height, diameter, crown shape, trunk shape, branching and leaf shape. Additional selection criteria were health, frequency and the amount of seed production and phenology (time of buds formation and opening).

Stratified seeds from each seed tree were sown in a separate container (45 containers), in the mixture of quartz, sand and peat in the ratio of 2:1. Containers were in greenhouse until germination was finished and then moved to the growing area of the nursery on an open field. After the first growing season, seedlings were transplanted into 3 modified seedbeds, in a mixture of peat and dolomite stone. Beds were fertilized before seedlings transplanting with NPK 15:15:15 solid fertilizer. In both growing seasons seedlings were irrigated regularly if there was no rainfall in the previous two days. After the first and second growing seasons, the height (H1 and H2), root collar diameter (D1 and D2), the number of buds after the first (NBd) and the number of branches after the second year (NBr) and dry mass (DM) were measures in a total of 945 seedlings (21 from each of the 45 half-sib lines). Dry mass was measured after the drying of seedlings in a thermostat cabinet at a temperature of 68^{o} C for 48 hours.

The concentrations of nitrogen (N), phosphorus (P) and potassium (K) in shoot (s) and root (r) were measured at the end of the second growing season. Sample preparation for the determination of P and K was performed with a wet combustion of plant material in nitric acid and hydrogen peroxide. From the obtained extract, P was determined by the colorimetric method with the use tin chloride and ammonium molybdate. K was determined by flame photometry. N content was determined by the Kjeldahl method.

The results of measurement were analyzed by descriptive statistics, i.e. mean value, standard deviation, range of variation, minimum and maximum values. The significance of differences between mean values within (between half-sib lines) and between provenances was tested using the One-Way ANOVA test. The differences between the groups, and the homogeneity of groups were examined by the post hoc multiple comparison test (Tukey HSD test). The participation of components of variability (half-sib lines and provenances) in the total relative variance was calculated by Variance Components and Mixed Model ANOVA. Statistical analysis and tests were performed in STATISTICA 7 (StatSoft. Inc., USA).

RESULTS

INTRA-PROVENANCE VARIABILITY

The largest range of H_1 and H_2 was observed in seedlings from Jagnjenica (Table 1). After the first growing season the highest mean value of height (H_1) was recorded in half-sib line JU15, and the lowest in JU8 (Table 2). The largest mean value of H_2 again was recorded in JU15 (Table 2), and the lowest in line VO14 (Table 3). As with height, the largest range of D_1 and D_2 was observed in Jagnjenica provenance, table 1. The largest mean value of D_1 and D_2 was recorded in JU15 (Table 2), while the lowest was found in VO14 (Table 3). The largest range of NBd and NBr was recorded in Jagnjenica (Table 1). The highest mean value of NBd and NBr was recorded in VO9 (Table 3). The lowest mean value of NBd was recorded in lines JA1 and JA2, where branches were not observed in the second year (Table 1). The largest range of Dm was observed in Jagnjenica (Table 1). The highest mean value of DM was recorded in JU15 and the lowest in JU8 (Table 2). The highest variability of seedling origin of Jagnjenica is reflected in the highest values of standard deviation in all observed indicators of quality, except for the number of buds and number of branches.

Table 1: The mean values of height (H_1) and diameter (D_1) after the first year, the number of buds (NBd), height (H_2) and diameter (D_2) after the second year, the number of branches (NBr) and dry mass (DM), as well as standard deviation (in parentheses) of 15 half-sib lines from the provenance Jagnjenica

Line	H_1	D_1	NBd	H_2	D_2	NBr	DM
JA1	6,22 (3,09)^{a}	1,03 (0,35)^{a}	1,00 (0,00)^{a}	17,34 (7,55)^{a}	2,28(0,79)^{a}	0,00 (0,00)^{a}	0,40 (0,29)
JA2	5,81 (1,80)^{a}	1,11 (0,50)^{ab}	1,00 (0,00)^{a}	17,17(12,14)^{a}	2,46 (1,14)^{ab}	0,00 (0,00)^{a}	0,49 (0,63)
JA3	8,37 (3,71)^{ac}	1,30 (0,68)^{ab}	1,88 (1,72)^{ac}	22,75 (12,60)^{ab}	2,87 (1,53)^{ab}	1,35 (2,05)^{ac}	0,84 (0,88)
JA4	6,30 (3,61)^{a}	1,20 (0,57)^{ab}	1,33 (0,96)^{ab}	21,61 (16,84)^{ab}	2,64(1,27)^{ab}	0,47 (1,24) ^{ab}	0,67 (0,96)
JA5	7,21 (2,37)^{ab}	1,47 (0,50)^{ab}	1,70 (0,86)^{ab}	25,80 (11,51)^{ab}	3,22 (1,11)^{ab}	0,92 (1,15) ^{abc}	0,77 (0,76)
JA6	10,89 (4,86)^{bc}	1,70 (0,45)^{b}	2,95 (2,74)^{bc}	32,72 (11,99)^{b}	3,75 (1,01)^{b}	1,95 (2,74) ^{ab}	1,10 (0,68)
JA7	9,45 (7,35)^{ac}	1,48 (0,67)^{ab}	2,33 (2,78)^{ac}	29,16 (17,20)^{ab}	3,28 (1,46)^{ab}	1,33 (2,78) ^{ac}	1,12 (1,48)
JA8	7,11 (2,73)^{ab}	1,35 (0,41)^{ab}	1,86 (1,42)^{ac}	24,66 (11,13)^{ab}	2,99 (0,91)^{ab}	0,85 (1,42) ^{ac}	0,72 (0,57)
JA9	8,07 (3,73)^{ac}	1,51 (0,52)^{ab}	1,62 (1,11)^{ab}	23,58 (6,59)^{ab}	3,30 (1,16)^{ab}	0,62 (1,11) ^{ab}	1,02 (0,92)
JA10	6,95 (5,66)^{ab}	1,10 (0,62)^{ab}	1,85 (1,87)^{ac}	21,31 (15,92)^{ab}	2,41 (1,37) ^{ab}	0,86 (1,87) ^{ac}	0,78 (1,45)
JA11	6,67 (3,42)^{ab}	1,52 (1,00)^{ab}	2,30 (1,83)^{ac}	23,98 (17,05)^{ab}	3,30 (2,21) ^{ab}	1,24 (1,81) ^{ac}	1,01 (1,14)
JA12	11,75 (4,12)^{c}	1,69 (0,55)^{b}	3,42 (2,06)^{c}	28,14 (9,50)^{ab}	3,64 (1,20)^{b}	2,43 (2,06) ^{c}	0,96 (0,57)
JA13	7,70 (3,27)^{ab}	1,33 (0,48)^{ab}	2,00 (1,41)^{ac}	21,17 (10,47)^{ab}	2,94 (1,06) ^{ab}	1,52 (1,80) ^{ac}	0,60 (0,47)
JA14	6,13 (2,07)^{a}	1,11 (0,34)^{ab}	1,43 (1,02)^{ab}	16,81 (7,23)^{a}	2,43 (0,76) ^{ab}	0,76 (1,37) ^{ac}	0,36 (0,23)
JA15	6,49 (3,44)^{a}	1,43 (0,67)^{ab}	1,57 (1,39)^{ab}	24,57 (15,48)^{ab}	3,14 (1,49) ^{ab}	0,85 (1,74) ^{ac}	0,89 (1,20)
Average	7,66 (4,12)	1,36 (0,60)	1,88 (1,68)	23,37 (13,04)	2,99 (1,32)	1,01 (1,79)	0,78 (0,88)
min-mix	2,30-36,00	0,50-3,20	1,00-12,00	5,00-71,50	1,00-7,00	0,00-11,00	0,03-6,22

Mean values in the same column followed by different letters are significantly different at p<0.05 - post hoc Tukey test.

Table 2: The mean values of height (H_1) and diameter (D_1) after the first growing season, the number of buds (NBd), height (H_2) and diameter (D_2) after the second growing season, the number of branches (NBr) and dry mass (DM), as well as standard deviation (in parentheses) of 15 half-sib lines from the provenance Junaci

Line	H_1	D_1	NBd	H_2	D_2	NBr	DM
JU1	8,93 (3,36)^{d}	1,61 (0,42)^{ef}	2,38 (1,28)^{ac}	30,37 (11,98)^{cd}	3,52 (1,01)^{de}	2,24 (1,48)^{bc}	1,11 (0,85)^{bd}
JU2	6,28 (1,63)^{ad}	1,09 (0,37)^{ac}	1,60 (0,94)^{ac}	25,81 (11,03)^{ad}	2,68 (0,91)^{ad}	1,25 (1,25)^{ac}	0,71 (0,78)^{ac}
JU3	5,69 (1,75)^{ab}	1,35 (0,35)^{bf}	1,71 (1,35)^{ac}	28,14 (10,75)^{bd}	3,02 (1,08)^{be}	1,19 (1,69)^{ac}	0,84 (0,70)^{ad}
JU4	7,60 (1,82)^{ad}	1,48 (0,33)^{cf}	2,47 (1,57)^{bc}	28,81 (7,68)^{bd}	3,27 (0,87)^{be}	2,43 (1,63)^{c}	0,91 (0,54)^{ad}
JU5	8,23 (3,86)^{bd}	1,54 (0,50)^{df}	2,57 (2,02)^{c}	27,20 (12,91)^{bd}	3,33 (1,17)^{ce}	2,33 (2,24)^{c}	1,15 (0,96)^{cd}
JU6	6,21 (1,81)^{ad}	1,27 (0,40)^{ae}	1,95 (1,53)^{ac}	21,98 (7,88)^{ac}	2,97 (0,86)^{be}	1,57 (1,83)^{ac}	0,64 (0,46)^{ac}
JU7	6,59 (3,07)^{ad}	1,29 (0,39)^{ae}	2,25 (1,71)^{ac}	21,42 (9,63)^{ac}	2,73 (1,19)^{ad}	1,85 (2,06)^{ac}	0,71(0,54)^{ac}
JU8	5,21 (2,05)^{a}	0,85 (0,32)^{a}	1,20 (0,52)^{ab}	15,70 (6,06)^{a}	1,91 (0,76)^{a}	0,60 (0,88)^{ab}	0,27 (0,23)^{a}
JU9	6,01 (1,55)^{ac}	1,13 (0,39)^{ad}	1,85 (1,39)^{ac}	20,90 (7,82)^{ac}	2,63 (0,77)^{ad}	1,40 (1,73)^{ac}	0,47 (0,27)^{ab}
JU10	8,47 (2,92)^{bd}	1,29 (0,37)^{ae}	1,65 (0,93)^{ac}	27,69 (10,53)^{bd}	2,89 (0,86)^{ae}	1,25 (1,29)^{ac}	0,83 (0,67)^{ad}
JU11	8,54 (2,96)^{cd}	1,11 (0,33)^{ad}	1,52 (0,68)^{ac}	22,94 (8,24)^{ac}	2,49 (0,78)^{ac}	0,95 (1,16)^{ac}	0,52 (0,29)^{ac}
JU12	6,63 (2,23)^{ad}	1,03 (0,46)^{ab}	1,33 (0,79)^{ac}	19,02 (8,18)^{ab}	2,26 (1,04)^{ab}	0,57 (1,16)^{a}	0,45 (0,40)^{a}
JU13	6,43 (2,25)^{ad}	1,06 (0,43)^{ac}	1,25 (0,72)^{ab}	19,20 (8,28)^{ab}	2,34 (0,97)^{ac}	0,60 (1,05)^{a}	0,43(0,29)^{a}
JU14	7,87 (3,12)^{ad}	1,19 (0,48)^{ae}	1,10 (0,31)^{a}	23,40 (9,37)^{ad}	2,67 (1,02)^{ad}	0,40 (0,68)^{a}	0,66 (0,47)^{ac}
JU15	12,37 (3,96)^{e}	1,77 (0,55)^{f}	2,62 (1,36)^{c}	33,19 (12,12)^{d}	3,88 (1,22)^{e}	2,38 (1,69)^{c}	1,38 (0,91)^{d}
Average	7,42 (3,15)	1,28 (0,47)	1,84 (1,31)	24,43 (10,58)	2,85 (1,08)	1,41(1,64)	0,74 (0,66)
min-max	3,00-19,50	0,40-2,70	1,00-8,00	5,00-59,00	1,00-6,00	0,00-8,00	0,02-3,52

Mean values in the same column followed by different letters are significantly different at p<0.05 - post hoc Tukey test.

Table 3: The mean values of height (H_1) and diameter (D_1) after the first growing season, the number of buds (NBd), height (H_2) and diameter (D_2) after the second growing season, the number of branches (NBr) and dry mass (DM), as well as standard deviation (in parentheses) of 15 half-sib lines from the provenance Vojmisliće

Line	H_1	D_1	NBd	H_2	D_2	NBr	DM
VO1	5,48 (2,11)^{a}	1,12 (0,46)	1,15 (0,37)^{a}	18,00 (8,18)^{ab}	2,42 (1,03)^{ab}	0,15 (0,37)^{a}	0,43 (0,30)^{ab}
VO2	6,66 (2,85)^{ac}	1,33 (0,48)	2,10 (1,45)^{ac}	24,21 (11,84)^{ac}	2,91 (1,07)^{b}	1,10 (1,45)^{ac}	0,68 (0,53)^{ab}
VO3	8,47 (2,15)^{ad}	1,24 (0,36)	1,81 (0,98)^{ac}	24,39 (8,43)^{ac}	2,70 (0,74)^{ab}	0,81 (0,98)^{ac}	0,65 (0,39) ^{ab}
VO4	9,67 (2,91)^{bd}	1,08 (0,44)	1,76 (1,26)^{ab}	21,97 (8,94)^{ac}	2,33 (1,00)^{ab}	0,76(1,26)^{ab}	0,56 (0,46)^{ab}
VO5	10,82 (5,07)^{d}	1,35 (0,55)	2,20 (2,26)^{ac}	28,61 (12,30)^{bc}	2,95 (1,20)^{b}	1,20 (2,26)^{ac}	0,91 (0,74)^{ab}
VO6	8,93 (2,45)^{ad}	1,31(0,33)	1,80 (0,95)^{ac}	22,82 (6,06)^{ac}	2,87 (0,68)^{b}	0,80 (0,95)^{ac}	0,67 (0,34)^{ab}
VO7	10,23 (5,53)^{cd}	1,34 (0,68)	2,76 (2,47)^{ac}	28,75 (17,93)^{bc}	2,94 (1,54)^{b}	1,76 (2,47)^{ac}	1,11 (1,12)^{ab}
VO8	9,39 (3,27)^{bd}	1,19 (0,46)	2,40 (1,70)^{ac}	24,51 (10,44)^{ac}	2,61 (1,04)^{ab}	1,40 (1,70)^{ac}	0,69 (0,52)^{ab}
VO9	11,47 (2,51)^{d}	1,37 (0,48)	3,57 (2,04)^{c}	29,78 (8,71)^{c}	3,02 (1,03)^{b}	2,57 (2,04)^{c}	0,89 (0,49)^{ab}
VO10	10,58 (3,38)^{d}	1,15 (0,62)	2,65 (1,95)^{ac}	24,13 (11,82)^{ac}	2,50 (1,36)^{ab}	1,65 (1,95)^{ac}	0,81 (0,96)^{b}
VO11	9,57 (4,99)^{bd}	1,28 (0,71)	2,67 (2,61)^{ac}	25,51 (15,99)^{bc}	2,78 (1,57)^{ab}	1,67 (2,61)^{ac}	0,84 (1,06)^{ab}
VO12	10,66 (3,00)^{d}	1,24 (0,57)	3,47 (1,87)^{bc}	25,73 (10,43)^{ac}	2,70 (1,24)^{ab}	2,47 (1,87)^{bc}	0,76 (0,57)^{ab}
VO13	10,20 (3,16)^{cd}	1,31 (0,54)	2,85 (1,84)^{ac}	25,53 (9,94)^{bc}	2,85 (1,20)^{ab}	1,85 (1,84)^{ac}	0,70 (0,53)^{ab}
VO14	6,32 (2,26)^{ab}	0,80 (0,31)	1,75 (1,12)^{ac}	13,44 (5,48)^{a}	1,64 (0,69)^{a}	0,75 (1,12)^{ac}	0,32 (0,30)^{a}
VO15	7,93 (3,42)^{ad}	1,13 (0,54)	2,09 (1,41)^{ac}	21,60 (11,98)^{ac}	2,43 (1,22)^{ab}	1,09 (1,41)^{ac}	0,58 (0,56)^{ab}
Average	9,09 (3,77)	1,22 (0,52)	2,33 (1,80)	23,94 (11,55)	2,65 (1,16)	1,33 (1,80)	0,71 (0,66)
min-max	3,00-24,30	0,40-3,00	1,00-10,00	7,00-72,00	0,80-6,50	0,00-9,00	0,06-4,67

Mean values in the same column followed by different letters are significantly different at $p<0.05$ - post hoc Tukey test.

Table 4: The analysis of variance (One-Way ANOVA) of the morphological attributes of seedlings between half-sib lines of the provenances Jagnjenica, Junaci and Vojmisliće

	SS	df	MS	SS	df	MS	F	p
Jagnjenica								
H_1	897,581	14	64,1129	4166,75	283	14,7235	4,354465	0,000001
D_1	12,493	14	0,8924	94,70	283	0,3346	2,666740	0,001117
NBd	127,188	14	9,0849	716,45	282	2,5406	3,575886	0,000019
H_2	5692,652	14	406,6180	44842,06	283	158,4525	2,566182	0,001725
D_2	57,569	14	4,1121	461,98	283	1,6325	2,518973	0,002112
NBr	124,212	14	8,8723	825,02	283	2,9153	3,043387	0,000212
DM	17,038	14	1,2170	216,49	283	0,7650	1,590937	0,080910
Junaci								
H_1	933,738	14	66,6955	2104,68	293	7,18322	9,284909	0,000000
D_1	17,482	14	1,2487	49,77	292	0,17046	7,325549	0,000000
NBd	78,055	14	5,5753	447,83	293	1,52843	3,647758	0,000013
H_2	6766,855	14	483,3468	27582,14	293	94,13699	5,134504	0,000000
D_2	76,690	14	5,4779	281,30	293	0,96007	5,705738	0,000000
NBr	146,157	14	10,4398	676,30	293	2,30818	4,522943	0,000000
DM	27,149	14	1,9392	108,40	293	0,36996	5,241751	0,000000
Vojmisliće								
H_1	900,856	14	64,3468	3428,92	288	11,9060	5,404587	0,000000
D_1	6,273	14	0,4481	76,94	288	0,2672	1,677073	0,059686
NBd	123,542	14	8,8244	857,11	288	2,9761	2,965116	0,000297
H_2	4939,854	14	352,8467	35376,27	288	122,8343	2,872543	0,000449
D_2	34,964	14	2,4974	373,91	288	1,2983	1,923621	0,023880
NBr	123,542	14	8,8244	857,11	288	2,9761	2,965116	0,000297
DM	10,904	14	0,7789	120,28	288	0,4176	1,864945	0,029877

Marked effects are significant at $p<0.05$.

The analysis of variance, with half-sib lines as a treatment, showed that the variability of the morphological attributes are derived from the effects of treatment; except for DM ($p = 0.08$) in seedlings from Jagnjenica and D_1 ($p = 0 . 06$) from Vojmisliće (Table 4).

Table 5: The mean value of the height (H_1) and diameter (D_1) after the first growing season, the number of buds (NBd), height (H_2) and diameter (D_2) after the second growing season, the number of branches (NBr) and the dry mass (DM); as well as standard deviations (in parentheses) of Hop Hornbeam seedlings from the three provenances.

provenance	H_1	D_1	NBd	H_2	D_2	NBr	DM
JAGNJENICA	7,66 (4,13)^a	1,36 (0,60)^a	1,88 (1,69)^a	23,37 (13,04)	2,99 (1,32)^b	1,01 (1,79)^a	0,78 (0,89)
JUNACI	7,42 (3,15)^a	1,28 (0,47)^{ab}	1,84 (1,31)^a	24,44 (10,58)	2,85 (1,08)^{ab}	1,41 (1,64)^b	0,74 (0,66)
VOJMISLICE	9,09 (3,79)^b	1,22 (0,52)^a	2,33 (1,80)^b	23,94 (11,55)	2,65 (1,16)^a	1,33 (1,80)^{ab}	0,71 (0,66)
average	8,06 (3,77)	1,28 (0,54)	2,01 (1,62)	23,92 (11,75)	2,83 (1,20)	1,25 (1,75)	0,74 (0,74)
min-mix	2,30-36,00	0,40-3,20	1,00-12,00	5,00-72,00	0,80-7,00	0,00-11,00	0,02-6,22

Mean values in the same column followed by different letters are significantly different at p<0.05, post hoc Tukey test.

Table 6: The analysis of variance (One-Way ANOVA) of the morphological attributes of seedlings from the three provenances

	SS	df	MS	SS	df	MS	F	p
H[1]	491,1121	2	245,5561	12432,5	906	13,7224	17,89450	0,000000
D_1	3,2777	2	1,6389	257,7	905	0,2847	5,75619	0,003280
NBd	44,6409	2	22,3205	2350,2	905	2,5969	8,59512	0,000201
H_2	174,1910	2	87,0955	125199,8	906	138,1897	0,63026	0,532686
D_2	17,8266	2	8,9133	1286,4	906	1,4199	6,27747	0,001961
NBr	26,9754	2	13,4877	2752,3	906	3,0379	4,43981	0,012056
DM	0,7977	2	0,3989	500,3	906	0,5522	0,72238	0,485874

Marked effects are significant at p<0.05.

The mean value of H_1 of all seedlings is 8.06 cm and ranges from 7.42 *cm* (Junaci) to 9.09 *cm* (Vojmisliće) (Table 5). The mean value of H_2 from all seedlings is 23.92 *cm*. The mean value of H_2 by provenances ranges from 23.37 *cm* (Jagnjenica) to 24.44 *cm* (Junaci). The mean value of D_1 from all seedlings is 1.28 *mm* and ranges from 1.22 *mm* (Vojmisliće) to 1.36 *mm* (Jagnjenica). The mean value of D_2 from all seedlings is 2.83*mm*. The mean value of D_2 by provenances ranges from 2.65 *mm* (Vojmisliće) to 2.99 *mm* (Jagnjenica). The mean value of NBd from all seedlings is 2.01 *mm* and ranges from 1.84 (Junaci) to 2.33 (Vojmisliće). The mean value of NBr from all seedlings is 1.25. The mean value of the NBr by provenances ranges from 1.01 (Jagnjenica) to 1.41 (Junaci). The mean value of DM of all seedlings is 0.77 g. The mean value of DM by provenances ranges from 0.71 (Vojmisliće) to 0.78 (Jagnjenica). The analysis of variance with provenance as treatment showed that the differences between mean values of the morphological attributes are derived from the effects of treatment, except for H_2 (p=0.53) and DM (p=0.48) (Table 6).

Table 7: Relative variance components (in %) of the morphological attributes: height (H_1) and diameter (D_1) seedlings after the first growing season, the number of buds (NBd), height (H_2) and diameter (D_2) of seedlings after the second growing season, the number of branches (NBr), and dry mass (DM).

Estimated relative variance (%)	H_1	D_1	NBd	H_2	D_2	NBr	DM
(1) half-sib line	18,3	10,4	10,2	10,2	9,3	10,7	7,1
(2) provenance	4,0	0,9	1,8	0	1,1	0,4	0
1*2	0	0	0	0	0	0	0
error	77,6	88,7	88,0	89,8	89,6	88,9	92,9

Table 8: The mean value, standard deviation (in parentheses), the maximum and minimum content (below) of the nitrogen (N), phosphorus (P) and potassium (K) concentration in shoot (s) and root (r)

Provenance	Ns (%)	Nr (%)	Ps (%)	Pr (%)	Ks (%)	Kr (%)
Jagnjenica	1,795 (0,196)	1,585 (0,145)	0,021 (0,011)	0,020 (0,013)	0,343 (0,080)	0,388 (0,145)
	1,567-2,079	1,369-1,775	0,000-0,050	0,000-0,040	0,149-0,506	0,141-0,739
Junaci	1,674 (0,127)	1,511 (0,207)	0,057 (0,020)	0,040 (0,026)	0,251 (0,044)	0,211 (0,039)
	1,489-1,898	1,134-1,926	0,020-0,120	0,004-0,120	0,116-0,349	0,149-0,307
Vojmisliće	1,863 (0,140)	1,658 (0,156)	0,017 (0,008)	0,007 (0,010)	0,312 (0,070)	0,236 (0,080)
	1,639-2,040	1,514-2,002	0,000-0,030	0,000-0,020	0,224-0,457	0,191-0,730
Average	1,774 (0,170)	1,582 (0,178)	0,037 (0,024)	0,030 (0,024)	0,302 (0,076)	0,279 (0,125)
	1,489-2,079	1,134-2,002	0,000-0,120	0,000-0,120	0,116-0,506	0,141-0,739

Table 9: The analysis of variance (one-way ANOVA) of nitrogen (N), phosphorus (P) and potassium (K) concentrations in shoot (s) and root (r) of seedlings from all three provenances

	SS	df	MS	SS	df	MS	F	p
Ns	0,175886	2	0,087943	0,608648	25	0,024346	3,61223	0,041873
Nr	0,102500	2	0,051250	0,748883	25	0,029955	1,71088	0,201194
Ps	0,032394	2	0,016197	0,022222	92	0,000242	67,05556	0,000000
Pr	0,009517	2	0,004758	0,035121	78	0,000450	10,56765	0,000087
Ks	0,197423	2	0,098712	0,580233	132	0,004396	22,45634	0,000000
Kr	0,830472	2	0,415236	1,275268	132	0,009661	42,98007	0,000000

Marked effects are significant at $p<0.05$.

The results of the variance components analysis indicate a significantly greater impact of half-sib lines on the total relative variance, compared to provenances (Table 7). The variance component estimated for half-sib lines ranges from 7.1% (DM) to 18.3% (H_1). The variance component estimated for provenances ranges from 0.4% (NBr) to 4.0% (H_1). The variance component estimated for H_2 and Dm with provenance as a dependent variable is zero.

The mean value of Ns from the three provenances is 1.774% (Table 8). The mean value of Nr from the three provenances is 1.582%. Seedlings from provenance Junaci have the lowest mean value of Ns (1.674%) and Nk (1.511%). Seedlings from provenance Vojmisliće have the highest mean value of Ns (1.863%) and Nr (1.658%).

The mean value of Ps from the three provenances is 0.037% (Table 8). The lowest mean value of Ps was found in seedlings from the provenance Vojmisliće (0.017%) and the highest in seedlings from Junaci (0.057%). The mean value of Pr from the three provenances is 0.030%. The lowest mean value of Pr was found in seedlings from the provenance Vojmisliće (0.007%) and the highest from the Junaci (0.040%).

The mean value of Ks from all three provenances is 0.302% (Table 8). The lowest mean value of Ks was found in seedlings from the provenances Junaci (0.251%) and the highest in seedlings from Jagnjenica (0.343%). The mean value of Kr from the three provenances is 0.279%. The lowest mean value of Kr was found in seedlings from the provenance Junaci (0.211%) and the highest in seedlings from Jagnjenica (0.388%). The analysis of variance (Table 9) showed that differences in the mean values of nitrogen (N), phosphorus (P) and potassium (K) in shoots and roots are derived from the effect of treatment (provenance), except for Nr (p=0,20). In addition, the influence of provenance to Ns is weak (p=0.04).

DISCUSSION

The high variability among half-sib lines was confirmed for a large number of species and by numerous authors (Mataruga *et al*., 2000; Tucović, Isajev, 2000; Tucović, Vilotić, 2001; Knežević, 2002; Knežević, Šijačić-Nikolić, 2005; Ocokoljić, Anastasijević, 2005; Ocokoljić, 2007; Šijačić-Nikolić *et al*., 2008, 2009). High variability among half-sib lines of tree species is a good basis for breeding programs. Given the economic importance of Hop Hornbeam, the need for breeding of this species is small and unlikely. Therefore, this variation should be used in the selection of seed trees for the production of reproductive material, based on progeny tests in a nursery. The results of this research show that the seed tree JU15 should be used for seed production, due to the largest mean values of morphological characteristics. Unlike that, the seed trees JU8 and VO14 should be avoided.

In addition to intra-provenance variability among half-sib lines in forest tree species pronounced inter-provenance variability was also recorded (Šijačić-Nikolić *et al*., 2007, 2012; Ivetić *et al*., 2012). On the basis of this research, it is not conclusive which provenance can be recommended as the best for seed and seedlings production. Given the higher values of D_1, D_2 and Dm, the provenance of Jagnjenica could be distinguished. On the other hand, seedlings from this provenance recorded the lowest values of H_2 and NBr. Seedlings from Vojmisliće have the highest mean value of H_1 and NBd, while seedlings from Junaci have the highest mean values of H_2 and NBr. Seedlings from Vojmisliće may be considered the weakest, given the lowest mean values of D_1, D_2 and Dm, and this provenance should be avoided for further seed production. The influence of the provenance on the morphological attributes of a seedling and juvenile tree plantations was previously studied (Ivetić, 2004; Ivetić *et al*., 2005; Mataruga *et al*., 2011). Given the economic importance of Hop Hornbeam in Serbia, there is no need to define the regions of the provenance. In the choice of the seed source, a local origin should be preferred and general recommendations for the transfer of forest reproductive material should be followed (Ivetić *et al*., 2009; Ivetić, 2009, 2013). However, in a changing environment, current guidelines for the transfer of seedling material need revision.

The highest nitrogen concentration in shoots and roots was recorded in seedlings from Vojmisliće, which is interesting, given the very poor results of morphological attributes compared to the other provenances. This can be the result of the very high N:P ratio which indicates P deficit in nutrition. The seedling N:P ratio in all three provenances is high, indicating that biomass production is P-limited (Güsewell, 2004; Koerselman, Meuleman, 1996). The highest phosphorous concentration in shoots and roots was recorded in seedlings from Junaci, which is consistent with the highest values of H_2 and the NBr. The highest content of potassium in the shoots and roots was recorded in seedlings from Jagnjenica, consistent with the highest values of D_1 and D_2, which is a reliable indicator of root development.

Differences in the concentration of analyzed elements between the shoots and roots are not high, as well as between different provenances, but still statistically significant, except for Nk, whose differences between provenances can be attributed to chance rather than provenance. In addition, the influence of provenance on Ns can be considered week.

CONCLUSION

Despite its large potential, Hop Hornbeam is not used for afforestation in Serbia. In that sense, we should work to change the attitudes in the selection of the common types of afforestation and reforestation species. In addition to matching the species to the site, the selection of reproductive material at lower levels of genetic diversity has a great influence on afforestation success. Maternal (seed) trees of Hop Hornbeam with the highest potential for the production of reproductive material can be selected, due to intra-population variability. At the population level, inter-population variability between provenances indicates the importance of provenance selection.

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REZIME

Crni grab je vrlo značajna vrsta pionirskih zajednica zaštitnog karaktera, ali je do sada zapostavljan u izboru vrsta za pošumljavanje iako postoje široke mogućnosti njegove upotrebe. U Srbiji ne postoje izdvojeni semenski objekti crnog graba, kao ni organizovana proizvodnja reproduktivnog materijala. Ispitivanje genetičke varijabilnosti crnog graba na nivou linija polusrodnika iz dela njegovog areala doprinosi upoznavanju potencijala vrste i predstavlja osnovu za izbor adekvatnog reproduktivnog materijala za potrebe masovnog pošumljavanja. Individualna selekcija po 15 semenskih stabala za potrebe ovih istraživanja obavljena je na tri lokaliteta: Jagnjenica, Junaci i Vojmisliće; severoistočno od Gazivodskog jezera, gazdinska jedinica Crni vrh−Deževski. Ukupno je analizirano 945 sadnica, iz 45 linija polusrodnika. Na dvogodišnjim sadnicama crnog graba postoji varijabilnost istraživanih pokazatelja kvaliteta između linija polusrodnika. U tom smislu se jasno mogu izdvojiti semenska stabla sa najvećim potencijalom za proizvodnju reproduktivnog materijala. U sprovedenom istraživanju, kao materinsko stablo sa najkvalitetnijim potomstvom može se izdvojiti linija 15 iz provenijencije Junaci. Na dvogodišnjim sadnicama crnog graba postoji varijabilnost istraživanih pokazatelja kvaliteta između provenijencija, osim za visinu nakon druge godine i ukupnu masu sadnica u suvom stanju. Zbog najvećih vrednosti prečnika korenovog vrata u prvoj i drugoj godini, kao i mase sadnica u suvom stanju, može se izdvojiti provenijencija Jagnjenica, naročito zbog pretežne namene sadnica crnog graba za sadnju na teškim terenima. Uticaj linija polusrodnika i provenijencije na koncentraciju istraživanih hranljivih materija treba dalje ispitivati na većem broju uzoraka. U tom smislu ohrabruje činjenica da najveće koncentracije kalijuma u nadzemnom delu i korenu imaju sadnice iz provenijencije Jagnjenica, koje ujedno pokazuju i najveće vrednosti prečnika, što je pouzdan pokazatelj razvijenosti korena.