Arch. Biol. Sci., Belgrade, 65 (3), 1093-1103, 2013 DOI:10.2298/ABS1303093P

ANALYSIS OF INTRAPOPULATION VARIABILITY OF BALD CYPRESS (*TAXODIUM DISTICHUM* L. RICH.) IN A SEED STAND NEAR BAČKA PALANKA USING MORPHOMETRIC MARKERS

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Abstract – In this paper are presented the results of an analysis of intrapopulation variability using morphometric markers of 20 Bald cypress test trees originating from seed stand S 01.10.01.01 near Bačka Palanka. The morphometric characters of cones (length, width and number of grains) and seedlings (root collar diameter and height of seedling) that were produced by this seed were analyzed. A mutual biological similarity or distance of mother trees depending on the analyzed characters was tested. The determined values of the dimensions of cones and seedlings indicate the good genetic and adaptive potential of this species, which can be a starting point for the mass production of Bald cypress seed and planting materials in Serbia.

Key words: Bald cypress, cone, seed, seedling, variability, Bačka Palanka, Serbia

INTRODUCTION

The Bald cypress is a monoecious, long-lived, deciduous conifer. It belongs to the family *Taxodiaceae* and genus *Taxodium* that includes three species (Vukićević, 1987). In Serbia, there is only *Taxodium distichum* (L.) Rich. The capability of the Bald cypress to establish forest cultures on lowlands and floodplains in Serbia was recorded in the 1950s (Petrović, 1951; Špiranec, 1959, 1966). At the beginning of the 1980s, Stilinović and Tucović (1970) concluded that in our environmental conditions, the Bald cypress could be considered as a species that exhibits rapid growth and one of the few conifer species that may be suitable for introduction on lowland and floodplains where it can achieve high productivity.

On the territory of the Republic of Serbia, this species has practically never been out of the range of horticultural activities. Researches on the variability and adaptive potential of the Bald cypress in our conditions published to date refer to trees that grow individually and in smaller or larger groups mainly in the city green areas (Dražić, Batos, 2002; Ninić-Todorović, Ocokoljić, 2001, 2002; Tucović, Ocokoljić, 2005). The possibility of a wider application of Bald cypress as a forest species should be based on an assessment of its genetic and adaptive potential, as well as quantity and quality of yield, primarily at the level of the existing Bald cypress seed stand.

MATERIALS AND METHODS

Research was conducted in a Bald cypress seed stand in Bačka Palanka, registration number S 01.10.01.01, which is managed by FE Novi Sad, FA Bačka Palanka. The seed stand is within the MU "Palanačke Ade – Čipski poloj", Department 11, Sec-

tion a, with an area of 0.22 ha and 111 trees. Its origin is artificial, aged about 70 years, with measured taxation values of mean diameter ds = 51.7 cm and mean height, hs = 26.5 m. It is located on flat ground with an average altitude of 80 m, with a uniform slope and without clear exposure. Flooding is not present, but it is heavily influenced by underground wetting. The site on which the seed stand is located belongs to the coeno-ecological group of White willow and *Populus* (*Salicion albae*) forests on undeveloped semi-gley soils.

On the basis of phenotypic characteristics and abundance of yield in 2010, 20 test trees were selected and 200 cones were collected from each tree. The cones were placed in separate bags. By the method of random sampling, 50 cones per tree were taken for processing at the laboratory of Institute of Forestry. Cone opening was done in a dryer at a temperature of 40°C, and seed cleaning was done manually. The basic morphometric parameters of each cone (length and width) were measured by a caliper with an accuracy of 1 mm. In addition, after cone opening the number of grains was determined for each cone.

In April 2011, seed sowing was performed in 12 Bosnaplast containers, with 10 containers for each test tree. In October 2011, by the method of random sampling, 50 seedlings per each half-sib line were selected and the height and root collar diameter were measured for each of them. Measurements were made by a caliper with an accuracy of 1 mm in the measurement of height, and 0.01 mm in the measurement of root collar diameter.

The obtained data were processed in a computer program Statgraph 5.0.

RESULTS AND DISCUSSIONS

Cones and seeds

The variability in cone morphometric characters of 20 Bald cypress test trees is presented on Table 1.

Based on the statistical indicators (Table 1), it can be concluded that the highest mean value of cone length is shown by the test tree marked number 1 (31.56 mm), while the smallest mean value of cone length is tree 11 (28.41 mm). The highest mean value of cone width is that of tree 1 (28.67 mm) and the smallest mean value of cone width is that of tree 11 (25.27 mm). The highest mean value in the number of grains is that of tree 1 (28.5 pieces), and the smallest mean value in the number of grains is that of tree 15 (25.2 pieces). Tree 1 stands out as the best for all three characters, while tree 11 has the smallest mean value of cone length and width, but not number of grains. The values of the analyzed characters coincide with the values that were obtained by other authors. In the Bald cypress from the Motovun forest in Croatia, the cone diameter ranges from 20 to 25 mm; one cone contained from 18 to 30 grains (Špiranec, M. 1959.). Under Belgrade's environmental conditions, cone diameter range from 20 to 30 mm (Dražić, D., Batos, B. 2002). Under the environmental conditions of Bulgaria, cone diameters go up to 30 mm, cone lengths range from 20 to 40 mm, and cones contain approximately 20 to 25 grains (Milev, M., et al. 1999). In the Bald cypress population on the Veliko Ratno ostrvo island, cone diameters range from 22 to 39 mm; cones contain from 10 to 32 grains and on average about 20 grains (Šijačić-Nikolić, M., et al. 2011.). In its natural habitat, the Bald cypress reaches a cone diameter of 25 mm, and cones contain up to 30 grains. (Harvey, E., Kennedy, Jr. 1972).

The coefficient of variation can be used as an indicator of statistical set homogeneity. By analyzing the values of this coefficient, we can conclude that for the cone length character the most homogeneous is tree 16 (7.76), and the most heterogeneous tree no. 7 (20). For the cone width character, the most homogeneous is tree 20 (6.25), and the most heterogeneous is tree 9 (23.95). For the number of grains, the most homogeneous is tree no. 1 (5.28), and the most heterogeneous is tree 8 (14.82).

Analysis of variance shows that the differences between the mean values of cone width of the 20 Bald cypress test trees are statistically significant at

Table 1. – *Variability in cone morphometric characters of 20 tested Bald cypress trees.*

Trees	Parameter	Average (mm)	Min	Max	Standard deviation	Coefficient of variation
1	Cone length (mm)	31.56	22.5	38.7	4.25	18.08
	Cone width (mm)	28.67	20.9	36.5	4.14	17.14
	Number of seeds (pcs.)	28.5	22.0	32.0	2.30	5.28
2	Cone length (mm)	30.70	22.6	37.2	4.07	16.56
	Cone width (mm)	28.44	22.1	36.0	3.98	15.85
	Number of seeds (pcs.)	27.2	20.0	33.0	3.38	11.40
3	Cone length (mm)	29.67	22.4	38.4	4.21	17.76
	Cone width (mm)	27.77	21.3	34.5	3.40	15.97
	Number of seeds (pcs.)	27.5	21.0	34.0	3.01	9.03
4	Cone length (mm)	30.55	22.3	38.4	3.58	12.78
	Cone width (mm)	27.97	21.0	36.2	3.47	12.06
	Number of seeds (pcs.)	27.8	21.0	32.0	2.72	7.40
5	Cone length (mm)	30.67	22.6	37.6	4.01	16.07
	Cone width (mm)	27.96	19.1	34.6	3.89	15.10
	Number of seeds (pcs.)	27.1	20.0	33.0	3.35	11.24
6	Cone length (mm)	29.54	21.4	38.4	4.31	18.56
	Cone width (mm)	26.48	19.4	35.6	4.05	16.39
	Number of seeds (pcs.)	26.1	20.0	32.0	3.30	10.89
7	Cone length (mm)	30.25	21.5	38.4	4.47	20.00
	Cone width (mm)	26.97	18.6	35.1	4.26	18.15
	Number of seeds (pcs.)	26,7	20,0	33,0	3,59	12,88
8	Cone length (mm)	29,05	21,3	37,5	4,47	19,95
	Cone width (mm)	25,85	19,4	34,6	4,30	18,45
	Number of seeds (pcs.)	25,4	20,0	33,0	3,58	14,82

Table 1. *Continued*

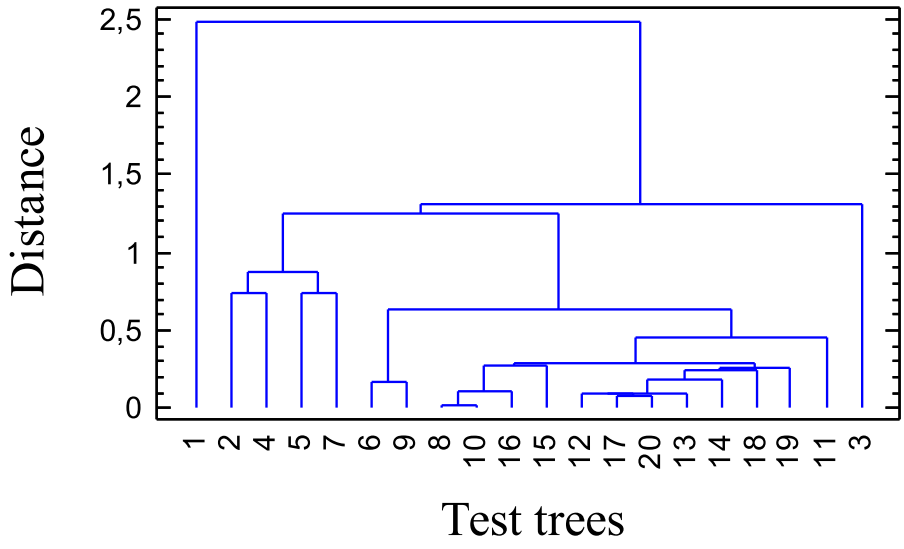
Trees	Parameter	Average (mm)	Min	Max	Standard deviation	Coefficient of variation
9	Cone length (mm)	29,84	20,6	37,1	4,15	17,20
	Cone width (mm)	26,01	8,0	33,8	4,89	23,95
	Number of seeds (pcs.)	25,9	21,0	32,0	3,60	12,95
10	Cone length (mm)	29,08	21,3	38,4	4,26	18,11
	Cone width (mm)	25,73	19,5	34,1	4,23	17,93
	Number of seeds (pcs.)	25,4	20,0	32,0	3,60	12,99
11	Cone length (mm)	28,41	22,3	36,5	3,37	11,35
	Cone width (mm)	25,27	20,1	33,2	3,38	11,45
	Number of seeds (pcs.)	25,8	20,0	33,0	3,28	10,76
12	Cone length (mm)	28,84	22,3	36,5	3,29	10,84
	Cone width (mm)	25,96	19,9	33,6	3,40	11,59
	Number of seeds (pcs.)	26,3	21,0	33,0	2,99	8,95
13	Cone length (mm)	28,73	21,8	34,3	3,00	9,00
	Cone width (mm)	25,82	19,9	31,8	2,98	8,89
	Number of seeds (pcs.)	26.1	20.0	33.0	3.15	9.95
14	Cone length (mm)	28.99	21.3	36.1	3.44	11.81
	Cone width (mm)	25.96	19.9	33.2	3.26	10.65
	Number of seeds (pcs.)	25.9	20.0	33.0	3.34	11.14
15	Cone length (mm)	28.64	23.6	35.2	3.27	10.71
	Cone width (mm)	25.58	20.9	31.5	3.19	10.20
	Number of seeds (pcs.)	25.2	20.0	33.0	3.73	13.88
16	Cone length (mm)	28.90	23.6	34.5	2.79	7.76
	Cone width (mm)	25.53	19.6	30.8	2.96	8.75
	Number of seeds (pcs.)	25.6	20.0	31.0	3.03	9.19

Table 1. *Continued*

Trees	Parameter	Average (mm)	Min	Max	Standard deviation	Coefficient of variation
17	Cone length (mm)	28.99	22.8	36.2	3.49	12.17
	Cone width (mm)	25.78	19.5	31.2	2.98	8.86
	Number of seeds (pcs.)	26.5	21.0	32.0	2.68	7.19
18	Cone length (mm)	29.13	23.6	35.2	2.96	8.74
	Cone width (mm)	26.35	21.2	32.3	2.81	7.90
	Number of seeds (pcs.)	26.7	22.0	32.0	2.48	6.16
19	Cone length (mm)	29.34	24.3	35.6	2.92	8.51
	Cone width (mm)	26.59	21.3	32.6	3.06	9.34
	Number of seeds (pcs.)	27.1	21.0	33.0	3.04	9.22
20	Cone length (mm)	29.07	23.0	35.9	2.80	7.85
	Cone width (mm)	26.05	21.0	32.1	2.50	6.25
	Number of seeds (pcs.)	26.4	21.0	32.0	2.47	6.12

Table 2 – Analysis of variance for cone width, cone length and number of grains.

Cone width			Cone length			Number of seeds		
Test trees	Mean	Homogeneous grups	Test trees	Mean	Homogeneous grups	Test trees	Mean	Homogeneous grups
11	25.27	X	11	28.41	X	15	25,2	X
16	25.53	X	15	28.64	X	8	25,4	XX
15	25.58	XX	13	28.73	X	10	25,44	XXX
10	25.73	XX	12	28.84	XX	16	25,56	XXXX
17	25.78	XX	16	28.90	XX	11	25,76	XXXX
13	25.82	XX	17	28.99	XX	14	25,86	XXXXX
8	25.85	XX	14	28.99	XX	9	25,9	XXXXX
12	25.96	XX	8	29.05	XX	6	26,08	XXXXXX
14	25.96	XX	20	29.07	XX	13	26,08	XXXXXX
9	26.01	XX	10	29.08	XX	12	26,3	XXXXXXX
20	26.05	XX	18	29.13	XXX	20	26,4	XXXXXXX
18	26.35	XXX	19	29.34	XXXX	17	26,46	XXXXXX
6	26.48	XXX	6	29.54	XXXX	7	26,66	XXXXXX
19	26.59	XXXX	3	29.67	XXXX	18	26,74	XXXXX
7	26.97	XXX	9	29.84	XXXX	5	27,06	XXXX
3	27.77	XXX	7	30.25	XXXX	19	27,08	XXXX
5	27.96	XX	4	30.55	XXX	2	27,22	XXX
4	27.97	XX	5	30.67	XX	3	27,5	XXX
2	28.44	X	2	30.69	XX	4	27,84	XX
1	28.67	X	1	31.56	X	1	28,5	X



Graph 1 – *Dendrograms of cluster analysis for 20 test trees based on the cone characters*

the confidence level p <0.05. The examined trees were grouped into 5 homogenous groups and this confirmed the variability of cone width of the trees. In the homogeneous group with the greatest cone width are trees 1 and 2, and in the group with the smallest cone width are trees 11 and 16 (Table 2).

Analysis of variance shows that the differences between the mean values of cone length of the 20 trees are statistically significant at a confidence level p<0.05. The trees are grouped into 5 homogenous groups, confirming the variability of the trees' cone lengths. In the homogeneous group with the greatest cone length are trees 1, 2 and 5, and in the group with the smallest cone length are trees 11, 15 and 13 (Table 2).

Analysis of variance shows that the differences between the mean values in the grain numbers of the 20 Bald cypress trees are statistically significant at the confidence level p<0.05. The trees are grouped into 9 homogenous groups, confirming the variability in the numbers of grains. In the homogeneous group with the greatest number of grains are trees 1, 4 and 3, and in the group with the smallest number of grains are trees 15, 8 and 10 (Table 2).

Based on cone length, cone width and number of grains, cluster analysis was performed for all three observed characters together (Fig. 1). With this analysis we tested the mutual biological similarity or distance of these three characters. We concluded that the greatest distance was between trees 1 and 3, while the shortest distance was between trees 8 and 10.

Seedlings

In Table 3 is shown the variability of morphometric characters of one-year-old seedlings at the level of 20 half-sib lines of Bald cypress.

Based on the statistical indicators (Table 3), it can be concluded that the highest mean value for the root collar diameter was that of the half-sib line number 1 (4.23 mm), while the smallest mean value was that of half-sib line 3 (3.36 mm). The highest mean value for seedling height has the half-sib line number 6 (52.1 mm), and the smallest mean value has the half-sib line number 2 (40.7 mm). The values of the analyzed characters, root collar diameter and height of seedling, coincides with the values that were obtained by other authors. The results of Vann

Table 3 – Variability of morphometric characters of one-year-old seedlings at the level of 20 half-sib lines of Bald cypress.

Half-sib linies	Parameter	Average (mm)	Min	**Max**	**Standard deviation**	**Coefficient of variation**
1	diameter	4.23	2.96	5.19	0.561091	13.275
	height	48.5	38.8	56.6	5.31117	10.9613
2	diameter	3.59	2.33	5.11	0.719332	20.013
	height	40.7	30.9	51.9	6.86922	16.8666
3	diameter	3.36	2.57	4.56	0.532613	15.8437
	height	42.8	29.7	60.0	7.3427	17.1492
4	diameter	3.77	2.17	5.56	0.737	19.5387
	height	46.0	36.4	58.6	5.61002	12.2028
5	diameter	3.37	1.96	5.44	0.847792	25.1521
	height	40.9	25.9	56.7	8.58841	20.9832
6	diameter	3.95	2.95	5.1	0.519168	13.1302
	height	52.1	41.3	71.2	6.44183	12.3707
7	diameter	3.75	2.09	5.25	0.994122	26.5335
	height	49.2	27.5	70.1	12.121	24.6596
8	diameter	3.76	2.68	5.2	0.637826	16.9499
	height	44.4	29.1	54.2	6.60005	14.8739
9	diameter	3.84	2.6	4.95	0.716557	18.6847
	height	45.0	33.6	55.4	6.16091	13.697
10	diameter	4.07	2.69	5.83	0.687461	16.8868
	height	51.2	32.2	67.4	7.62269	14.89
11	diameter	3.81	1.98	5.3	0.865346	22.6907
	height	44.8	18.1	63.1	10.7467	24.0078
12	diameter	3.82	2.51	5.78	0.913324	23.9299
	height	45.3	32.1	61.7	8.47028	18.6913
13	diameter	4.02	2.37	5.52	0.876257	21.783
	height	45.6	27.2	61.3	9.17183	20.1034
14	diameter	3.90	2.78	6.13	0.866953	22.2467
	height	50.1	36.8	64.7	7.75883	15.496
15	diameter	4.11	2.42	5.89	0.780426	18.9869
	height	49.2	37.6	64.8	6.4407	13.0784
16	diameter	3.93	3.11	5.52	0.546112	13.8971
	height	47.3	37.0	66.8	5.78152	12.2128
17	diameter	4.08	3.08	4.92	0.553136	13.5473
	height	49.6	32.2	62.9	7.19774	14.5262
18	diameter	3.71	2.7	4.82	0.574615	15.4897
	height	40.8	33.5	54.4	4.851	11.8761
19	diameter	3.42	2.1	5.88	0.86476	25.278
	height	43.4	26.7	57.7	9.57489	22.0484
20	diameter	4.10	2.65	5.21	0.688819	16.7991
	height	48.6	32.1	58.2	7.4075	15.2501

and Megonigal, (2002) show that one-year-old seedlings attain a height of about 50 cm and a diameter of about 4 mm. Mazher et al. (2006) stated that one-year-old Bald cypress seedlings attain heights up to 35 cm.

By analyzing the coefficients of variation as indicator of statistical set homogeneity, we conclude that for the root collar diameter, the most homogeneous is the half-sib line 6 (13.1302), and the most heterogeneous is the half-sib line 7 (26.5335). For seedling

Table 4 – *Analysis of variance for root collar diameter and height of seedlings.*

diameter			height		
Half-sib linies	**Mean**	**Homogeneous grups**	**Half-sib linies**	**Mean**	**Homogeneous grups**
3	3.36	X	2	40.7	X
5	3.37	X	18	40.8	X
19	3.42	XX	5	40.9	XX
2	3.59	XXX	3	42.8	XXX
18	3.71	XXXX	19	43.4	XXX
7	3.75	XXXX	8	44.4	XXXX
8	3.76	XXXX	11	44.8	XXXX
4	3.77	XXXX	9	45.0	XXX
11	3.81	XXX	12	45.3	XXXX
12	3.82	XXX	13	45.6	XXXXX
9	3.84	XXX	4	46.0	XXXXXX
14	3.90	XXXX	16	47.3	XXXXXX
16	3.93	XXXX	1	48.5	XXXXXX
6	3.95	XXXX	20	48.6	XXXXXX
13	4.02	XXX	7	49.2	XXXXX
10	4.07	XXX	15	49.2	XXXX
17	4.08	XXX	17	49.6	XXX
20	4.10	XX	14	50.1	XX
15	4.11	XX	10	51.2	XX
1	4.23	X	6	52.1	X

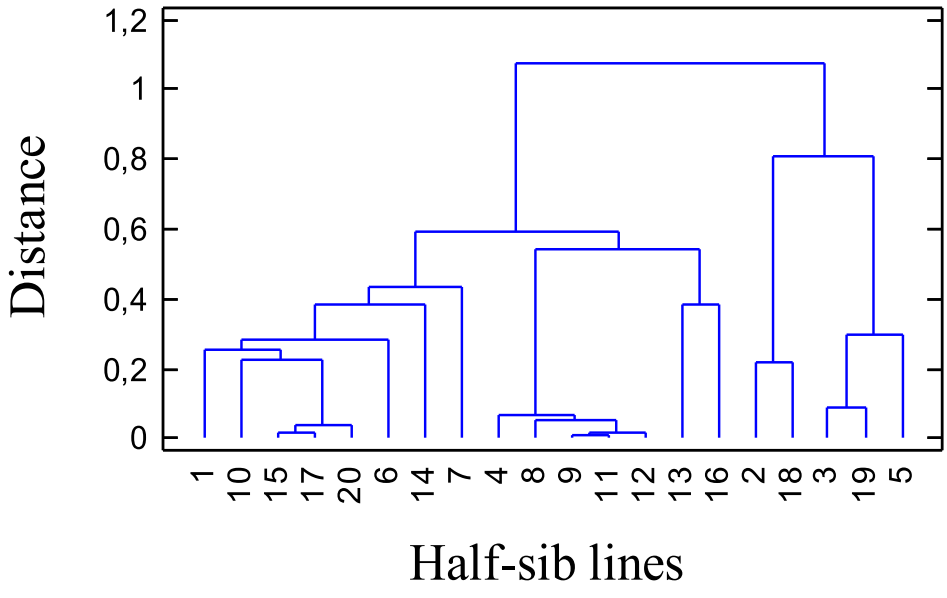
height, the most homogeneous is the half-sib line 1 (10.9613), and the most heterogeneous is the half-sib line 7 (24.6596).

Analysis of variance shows that the differences between the mean values of root collar diameter of 20 Bald cypress half-sib lines are statistically significant at a confidence level $p<0.05$. Half-sib lines are grouped into 6 homogenous groups, confirming the variability of the root collar diameters in the half-sib lines. In the homogeneous group with the greatest root collar diameter are half-sib lines nos. 1, 15, 20, 17, 10, 13, 6, 16 and 14, and in the group with the smallest root collar diameter are half-sib lines 3, 5, 19, 2 and 18 (Table 4).

Analysis of variance shows that the differences between the mean values of seedling height in half-sib lines are statistically significant at a confidence level $p <0.05$. Half-sib lines are grouped into 10 homogenous groups and this confirmed the variability of seedling heights in the half-sib lines. In the homogeneous group with the greatest seedling height are half-sib lines 6, 10, 14, 17, 15, 7, 20 and 1, and in the group with the smallest seedling height are half-sib lines 2, 18, 5, 3, 19 and 8 (Table 4).

Based on the root collar diameter and seedling height, cluster analysis was performed for both observed characters together (Fig. 2). The mutual biological similarity or distance regarding these two characters was tested. It was concluded that the greatest distance was between half-sib lines 1 and 5, while the shortest distance was between half-sib lines 9 and 11.

CONCLUSIONS



Graph 2 – Dendrograms of cluster analysis for 20 half-sib lines based on the seedling characters.

Variability in the quantity and quality of the yields of more important tree species has been the subject of research in forest science and profession for some time. However, examination of the genetic variability of the quantity and quality of forest trees seed yields, and the possibility of its optimal use in our country is still below actual needs, and is not in accordance with commercial importance. Thanks to the research results of Tucović, A. (1975), Mrva, F. (1976, 1984), Popnikola, N. (1978), Tucović, A., Stilinović, S. (1982), Tucović, A., Isajev, V. (1985), Isajev, V. (1987), Tošić, M. (1991), Mataruga, M. (2003), Lučić, A. (2007), Lučić, A. (2012) etc., our knowledge is gradually completing, and the relationships between the genetic constitution of populations and environmental conditions has been explained, as well as the morphological and physiological characters of the seeds. The following papers contributed to our improved understanding of the dependence of the variability of cone sizes with population, genotype and collection year in Scots pine (Tošić, 1991; Lučić, 2012), in Austrian pine (Lučić, 2007), in Serbian spruce (Isajev, 1987; Tucović et al., 1982; Šijačić-Nikolić, 2000; 2003) and in Spruce (Šijačić-Nikolić et al., 2010).

The results obtained from the analysis of variability of morphometric characteristics of cones in 20 test trees and one-year-old seedlings of 20 half-sib lines of Bald cypress originating from a seed stand near Bačka Palanka, have contributed to a better understanding of the relationships of the analyzed characters, as well as of the influence of the analyzed characters on the differentiation of the test trees. Based on these results, differences were observed in the values of the characters for each test tree individually. Tree no. 1 stands out with the highest value for all three observed characters; tree 11 has the smallest value for the characters cone length and cone width, while the smallest value for the number of grains is that of tree 15. When it comes to the seedlings, the greatest values for the character root collar diameter is that of the half-sib line 11, while the smallest values are those of the seedlings of half-sib line 3. The greatest values for the character seedling height are those of the seedlings of the half-sib line 6, while the smallest values are those of the seedlings of half-sib line 2.

Comparative analysis of the obtained results in the study of the variability of the morphometric characters of cones, seeds and seedlings of the Bald

cypress suggests that there is considerable intrapopulation variability that is directly dependent on the type of analyzed character. This suggests that the obtained results need to be supplemented and verified using genetic methods that are based on the use of biochemical and molecular markers.

Acknowledgments - This research was financed by the Ministry of Education, Science and Technological Development of the Republic of Serbia, Project TR 31070 "The development of technological procedures in forestry with a view to an optimum forest cover realization" (2011-2014).

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