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Dendrometric analyses and determining biological characteristics of needles for the purpose of conservation and directed utilization of the spruce in southeastern Serbia

Original Article

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Abstract:

This paper analyzes the morphological and dendrometric characteristics of three 97 years old European spruce trees, on Čemernik mountain, in the municipality of Crna Trava, where European spruce is not autochthonous. The examined parameters were compared with 5 test European spruce trees, aged about 50 years, which are grown in the population, within a radius of 100 m, in identical environmental conditions. The results of this study confirm the excellent vitality of hundred-year-old trees at the researched location, which can be brought into direct correlation with the current climate changes. The selected trees have confirmed the best combinatorial ability, which is why they stand out as a good base for selection and production of planting material for establishing purpose culture, afforestation, application in landscape architecture, and also for timber production. The research confirmed that the analyzed hundred-year-old spruce trees are in excellent condition and high decorative value, with a crown formed from the ground, which is why they are proposed for protection as a natural monument of botanical character.

Key words:
European spruce, Crna Trava, vitality, selection, genetic potential, conservation

Apstrakt:

Dendrometrijska naliza i utvrdjivanje bioloških svojstava četina smrče u cilju konzervacije i usmerenog korišćenja vrste u jugoistočnoj Srbiji

U radu su analizirane morfološke i dendrometrijske karakteristike tri stabla smrče starosti 97 godina, na Čemerniku, na teritoriji opštine Crna Trava na kojoj smrča nije autohtona. Istraživani parametri su poređeni sa pet test stabala smrče, starosti oko 50 godina, odgajenih u populaciji, u radijusu od 100 m, u identičnim uslovima. Dobijeni rezultati potvrđuju odličnu vitalnost stogodišnjih stabala na istraživanoj lokaciji što se može dovesti u direktnu korelaciju sa aktuelnim klimatskim promenama. Selektovana stabla potvrdila su kombinatornu sposobnost zbog čega se izdvajaju kao polazna za oplemenjivanje i proizodnju sadnog materijala, za podizanje namenskih kultura, pošumljavanje, pejzažnoarhitektonsku primenu, ali i dobijanje drvne mase. Istraživanje je potvrdilo da su analizirana stogodišnja stabla smrče odličnog stanja i dekorativnosti, sa formiranom krošnjom od samog tla, zbog čega se predlažu za zaštitu kao spomenik prirode botaničkog karaktera.

Ključne reči:
smrča, Crna Trava, vitalnost, selekcija, genetski potencijal, konzervacija

Introduction

Picea A. Dietr. is a genus of evergreen coniferous trees in the family of Pinaceae Spreng. ex F. Rudolphi. It comprises 37 spruce species (POWO, 2022), one of which is European or Norway spruce - *Picea abies* (L.) H. Karst. Besides European spruce, other autochthonous and allochthonous spruce species are also found in Serbia. They include *Picea omorika* (Pancic) Purk., *Picea orientalis* (L.) Peterm., *Picea pungens* Engelm., *Picea laxa* (Münchh.) Sarg., *Picea engelmannii* Parry ex Engelm. and *Picea sitchensis* (Bong.) Carrière. (Jovanović, 1970; Schmidt-Vogt, 1974; Matović & Vujković, 1994; Skrøppa, 2003; Galović, 2015; Cvjetićanin et al., 2016). The natural range of European spruce distribution

stretches from Siberia across the Ural Mountains and extends to northern Europe and high mountain regions of central and southern Europe (Fukarek, 1970). Fukarek (1970) stated that European spruces could not be found in the Apennines and Pyrenees. However, research conducted in 2016 (Di Pierro et al., 2016) confirmed the presence of European spruce in the far north of the Apennines. In the south of Europe, European spruce grows in two directions (Cvjetković, 2018): eastwards (from the Carpathian Mountains, over the high mountains of western Serbia and Bulgaria to the Rhodopes) and westwards (from the slopes of the eastern Alps, across the Dinaric Alps, to the Shar Mountains and Mount Korab). However, it should be emphasized that throughout history spruce has undergone a significant shift in its range, as confirmed by pollen analyses according to which European spruce was limited to several refugia during the Last Glacial Period, while the current range has resulted from its expansion from the refugia in the Carpathians, Dinaric Alps and Moscow region (Huntley & Birks, 1983). In Serbia, European spruce is widely distributed in the mountains, such as Tara, Zlatibor, Golija, Zlatar, Prokletije, and Kopaonik, while it is not so common in the eastern and southern parts of the country: Stara Planina, Suva Planina, Kučajske Planine, Beljanica and Shar Mountains (Ivetić, 2004; Banković et al., 2009; Cvjetićanin et al., 2016).

The range of distribution and genetic structure of European spruce are thought to have been shaped by historical events related to the last glaciation and postglacial colonisation processes (Lagercrantz & Ryman, 1990). While there was a decline in the natural distribution of European spruce in the past, there was a growing trend in the conversion of broadleaved forest habitats and abandoned agricultural land into coniferous forests.

Despite the high intrapopulation variability and adaptability of European spruce, abrupt distribution shifts are anticipated due to climate change. They will be reflected in the extinction of populations, primarily the edge populations growing along the distribution boundaries. According to some scenarios, numerous habitats in southern Europe will be affected by climate change and European spruce will migrate north (Falk & Hempelmann, 2013). These predictions should cause some alarm since European spruce is one of the most common coniferous species in European forests; it is also a very important economic species; it has been widely naturalised outside its distribution range; in Serbia, it covers 86,400 ha and accounts for about 5.2% of wood volume. Bearing in mind the above and the fact that, due to its physical-geographical location, Serbia is significantly affected by climate change, the research conducted in European spruce plantations on Mount Čemernik is of great importance.

Materials and Methods

According to Morgenstern (1996), research on forest species can be divided into two categories: short-term and long-term tests. Our research applied long-term tests of open-grown trees over 30 years of age. The suitability of the selected methods can be proved by Kapeller et al. (2013) according to which the tests conducted at the age of 10 to 30 yield the most valuable research results related to species variability and adaptability.

Our research was conducted in a group of three solitary trees of *Picea abies* (L.) H. Karst. The trees were 97 years old (**Fig. 1**). They were planted in the village of Brod (42°84’88’’ north latitude and 22°28’39’’ east longitude) in 1925. The village is on Mount Čemernik, Crna Trava municipality, at an altitude of 856 m. The five control trees grew in a nearby spruce culture (within a 100 m radius) founded in the 1970s.

Fig. 1. Three 100-year-old *Picea abies* (L.) H. Karst. trees

Tree height, diameter at breast height (1.30 m), trunk girth, crown diameter, tree age, needle length, needle width, adaptability and vitality of the three analysed trees were taken as indicative values together with the differences between the group of three trees and five control trees that should facilitate the assessment of the species vitality. A total of 400 needles were collected for each tree (i.e. three 100-year-old trees and five control trees) which means that 3200 dimensions were measured for the length and another 3200 dimensions for the width of needles (**Fig. 2**).

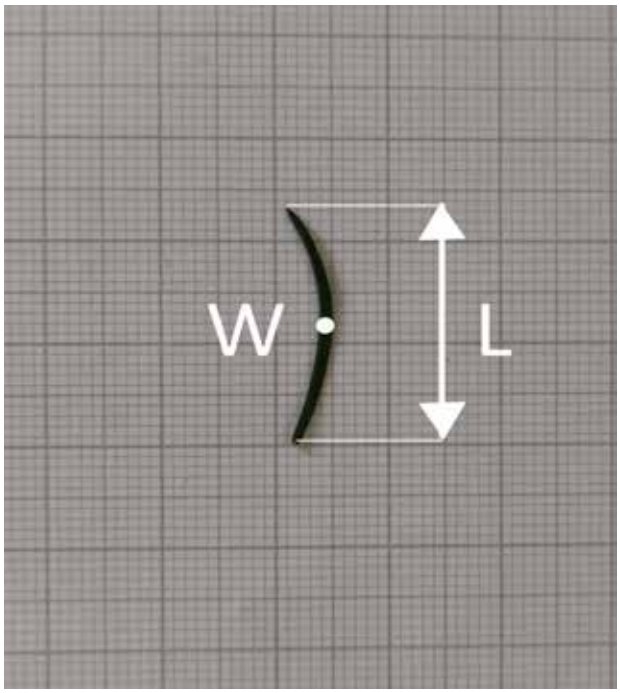

Fig. 2. Analysed parameters of *Picea abies* (L.) H. Karst: length (L) and width (W)

Quantitative characteristics that included tree height, diameter at breast height, trunk girth, crown diameter and needle length and width (**Tab. 1**, **Tab. 2**) were biometrically processed using the STATISTICA 10.0 software program and their limit of variability (minimum-maximum), medium values ($\bar{x}$), standard deviations (S), coefficients of variation (V) and errors ($S_{\bar{x}}$, SS, SV) were determined.

Results and discussion

Field research in the municipality of Crna Trava in the village of Brod recorded three trees of *Picea abies* (L.) H. Karst. of exceptional growth habit, excellent vitality and high decorative values. The three trees growing in a group stood out for their differential properties. **Tab. 1** shows the results of a comparative analysis of the growth elements of three investigated European spruce trees and five control trees.

Tree 1 reached a height of 52.9 m, a diameter at breast height of 118 cm and a crown diameter of 11.98 m. Tree 2 reached a height of 53.1 m, a diameter at breast height of 103 cm and a crown diameter of 17.64 m. Tree 3 reached a height of 50.94 m, a diameter at breast height of 84 cm and a crown diameter of 11.24 m. All three trees were around 100 years old and had abundant to moderately abundant yields and the highest ratings of vitality and decorativeness (5 and 5). They had broadly pyramidal crowns and shallow-cracked gray to gray-brown bark. The five control trees at the age of about 50 years old, which is the age suitable for the comparison of values, had significantly different dendrometric characteristics. The average parameters for the five control trees were as follows: trunk height – 24.16 m, diameter at breast height – 63.8 m, trunk girth – 2.01 m, and crown diameter – 8.2 m.

Table 1. Comparative characteristics of three 100-year-old *Picea abies* (L.) H. Karst. trees and five trees planted in the 1970s

Tree	Tree age (years)	*h* (m)	*d*1,30 (cm)	Trunk girth (m)	Crown diameter (m)	Fructification	Vitality (1-5)	Decorative value (1-5)
1	97	53.1	118	3.71	11.98	medium	5	5
2	97	52.9	103	3.24	17.64	abundant	5	5
3	97	50.94	84	2.66	11.24	abundant	5	5
4	~50	19.8	49	1.54	5.76	medium	3	2
5	~50	27.3	86	2.69	9.92	abundant	5	5
6	~50	26.6	74	2.33	8.74	abundant	5	4
7	~50	23.48	53	1.68	10.22	medium	4	4
8	~50	23.6	57	1.79	6.38	medium	3	3

Table 2. Statistical parameters of morphological characteristics of European spruce needles in the village of Brod

Locality	Tree age (years)	Limit value	$\bar{x}\pm S_{\bar{x}}$	$S\pm S_S$	$V\pm S_V$
(a) needle length (mm)					
Tree 1	97	12-32	22.49 ± 0.05	3.25 ± 0.79	0.14 ± 0.01
Tree 2	97	15-32	22.17 ± 0.05	3.21 ± 0.78	0.14 ± 0.01
Tree 3	97	14-30.5	22.96 ± 0.06	3.25 ± 0.81	0.14 ± 0.00
Tree 4	~50	9-21	15.19 ± 0.04	2.61 ± 0.54	0.17 ± 0.01
Tree 5	~50	8-27	18.53 ± 0.05	3.68 ± 0.66	0.20 ± 0.01
Tree 6	~50	10-25	18.04 ± 0.04	2.44 ± 0.64	0.13 ± 0.00
Tree 7	~50	10-20	15.42 ± 0.04	2.20 ± 0.55	0.14 ± 0.00
Tree 8	~50	8-20	14.83 ± 0.04	2.69 ± 0.52	0.18 ± 0.01
(b) needle width (mm)					
Tree 1	97	0.8-2	1.26 ± 0.00	0.28 ± 0.04	0.22 ± 0.01
Tree 2	97	0.9-2	1.11 ± 0.00	0.24 ± 0.04	0.22 ± 0.01
Tree 3	97	0.8-15	1.22 ± 0.00	0.74 ± 0.04	0.60 ± 0.02
Tree 4	~50	0.5-1.2	0.80 ± 0.00	0.19 ± 0.03	0.24 ± 0.01
Tree 5	~50	0.5-2	1.02 ± 0.00	0.29 ± 0.04	0.28 ± 0.01
Tree 6	~50	0.5-1.5	0.93 ± 0.00	0.18 ± 0.03	0.19 ± 0.01
Tree 7	~50	0.5-1	0.77 ± 0.00	0.17 ± 0.03	0.22 ± 0.01
Tree 8	~50	0.5-1	0.80 ± 0.00	0.21 ± 0.03	0.27 ± 0.01

The analysis of statistical parameters (**Tab. 2**) for the two characteristics of needles measured in trees at the age of 100 determined that the three investigated trees had the limit values of needle length ranging from 12 to 32 mm and from 0.8 to 2 mm for needle width. On the other hand, the five control trees aged 50 had the limit values ranging from 8 to 25 mm for needle length and from 0.5 to 1.5 mm for needle width. According to the literature (Gajić & Korać, 1972; Ocokoljić & Ninić-Todorović, 2003; Gebauer et al., 2011; Caudullo et al., 2016; Gebauer et al., 2019), spruce needles can be up to 25 mm long and more than 1 to 2 mm wide. As can be observed, the three investigated trees have significantly higher values.

According to the results, the mean values of the needle length obtained for Tree 1 were 22.49±0.05, Tree 2 22.17±0.05, and Tree 3 22.96±0, 06. The mean values of the needle width obtained for Tree 1 were 1.26±0.00 for Tree 2 1.11±0.00, and Tree 3 1.22±0.00. On the other hand, the mean values of the needle length obtained for the five control trees (Trees 4, 5, 6, 7 and 8) were 16.4±0.01 and the mean values of the needle width were 0.86±0.00. The obtained difference between the mean values was statistically significant.

Looking at the differential characteristics of the group of three European spruce trees about 100 years old, it can be observed that these trees are more adaptive and ornamental than those planted 50 years later and growing in forest conditions. The data presented in **Tab. 1** and **Tab. 2** points to obvious differences in the analyzed properties between the three veteran trees and the five control trees. These differences can affect the cultivation of European spruce since the three selected veteran trees that stand out for their distinctive characteristics have considerable potential. As plus trees with a superior phenotype, they enable more successful and easier cultivation, due to better growth, higher level of adaptability, and remarkable decorativeness (compact crown formed from the ground level).

Further comparison of the phenotypic characteristics of the investigated 100-year-old spruce trees in the village of Brod with literature data (Caudullo et al., 2016; Cvjetićanin et al., 2016) reveals that the analysed trees have reached maximum values, and thus can be used as starting material in the production of forest and ornamental seedlings. Based on the conducted research, which included the age of trees, their vitality, decorativeness and position (sunny location for sciophilic European spruce), and their historical significance, all three trees are proposed to be protected as a botanical

natural monument.

Conclusions

In the village of Brod in the municipality of Crna Trava, three European spruce trees were recorded at the age of 97. Our research revealed great vitality and exceptional morphological characteristics of the three European spruce trees. This finding pointed out the necessity of preserving the trees so that their genetic potential can be fully exploited. The study of these 100-year-old trees also revealed their potential role in forestry. They can be of great significance in the production of planting material that would make a valuable forest resource with long-term adaptability to local environmental conditions. The analysed European spruce trees can also be greatly utilised in landscape architecture and horticulture where they can serve as starting material in breeding, pollen collection, controlled hybridisation and vegetative propagation, as well as in the identification of a new lower taxon of compacta type.

The analyzed 100-year-old trees should also be protected in order to preserve the national biodiversity of species for which indigenous species are extremely important. They are also important for genetic variation, i.e. as well-adapted genotypes of specific phenotype, they greatly contribute to genetic diversity. Their significance is supported by research studies that stress the issue of European spruce extinction due to climate change, and the issue of reproductive material transfer which is usually unknown, and in Europe, it is mostly from geographically and ecologically undefined sources. Therefore, effort must be put in to find new resistant and productive genotypes and through plant breeding, preserve the species and increase its productivity. The exquisite habit, outstanding features, high condition ratings, age, and historical significance these three 100-year-old spruce trees have for Čemernik and Serbia make them worthy candidates for a botanical natural monument designation.

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References

Banković, S., Medarević, M., Pantić, D., Petrović, N. 2009: *Nacionalna inventura šuma Republike Srbije - šumski fond Republike Srbije*. Ministarstvo poljoprivrede šumarstva i vodoprivrede Republike Srbje, Uprava za šume. Beograd. 244 p.

Caudullo, G., Tinner, W., de Rigo, D. 2016: *Picea abies in Europe: distribution, habitat, usage and threats. European Atlas of Forest Tree Species*. Publications Office of the European Union. Luxembourg. 114-116 p.

Cvjetićanin, R., Brujić, J., Perović, M., Stupar, V. 2016: *Dendrologija*. Univerzitet u Beogradu, Šumarski fakultet. 557 p.

Cvjetković, B. 2018: *Genetičko-fiziološka varijabilnost smrče (Picea abies Karst.) u testovima potomstva u Bosni i Hercegovini*. Doktorska disertacija. Univerzitet u Beogradu, Šumarski fakultet. 351 p.

Di Pierro, E.A., Mosca1, E., Rocchini, D., Binelli, G., Neale, D.B., La Porta, N. 2016: Climate-related adaptive genetic variation and population structure in natural stands of Norway spruce in the South-Eastern Alps. *Tree Genetics & Genomes*, 12(2): 1-16.

Falk, W., Hempelmann, N. 2013: Species favourability shift in Europe due to climate change: A case study for *Fagus sylvatica* L. and *Picea abies* (L.) Karst. based on an ensemble of climate models. *Journal of Climatology*, 2013: 1-18.

Fukarek, P. 1970: Areali rasprostranjenosti bukve, jele i smrče na području Bosne i Hercegovine. Akademija Nauka i Umjetnosti Bosne i Hercegovine. *Knjiga 11*: 235-256.

Gajić, M., Korać, M. 1972: Varijabilnost četina smrče (*Picea excelsa* L.) u odnosu na različita staništa na planini Goliji. Simpozijum povodom proslave 50-godišnjice osnivanja i rada Šumarskog fakulteta, Beograd: 33-37.

Galović, V., Šijačić-Nikolić, M., Šafhauzer, R., Čortan, D., Orlović, S. 2015: Genetic differantion of Norway spruce (*Picea abies* (L) Karst.) trees with differnet crown types from the montain Golia. *Genetika*, 47(3): 849–861.

Gebauer, R., Volařík, D., Urban, J., Børja, I., Nagy, N., Drabløs, T., Krokene, P. 2019: Effects of mild drought on the morphology of sun and shade needles in 20-year-old Norway spruce trees. *iForest - Biogeosciences and Forestry*, 12: 27-34.

Gebauer, R., Volarík, D., Urban, J., Børja, I., Nagy, N., Eldhuset, T., Krokene, P. 2011: Effect of thinning on anatomical adaptations of Norway spruce needles. *Tree physiology*, 31: 1103-1113.

Huntley, B., Birks, H.J.B. 1983: *An atlas of past and present pollen maps for Europe, 0-13.000 years ago*. Cambridge University Press. 650 p.

Ivetić, V. 2004: *Uticaj staništa i provenijencija na*

razvoj juvenilnih kultura smrče (Picea albies /L./ Karst) na Goliji. Magistarski rad. Univerzitet u Beogradu, Šumarski fakultet. Beograd.

Jovanović, B. 1970: Rod *Picea* A. Dietr. In: Josifović M. (Ed.), *Flora SR Srbije*, 1. Srpska Akademija Nauka i Umetnosti, Beograd.

Kapeller, S., Schüler, S., Huber, G., Božič, G., Wohlgemuth, T., Klumpp, R. 2013: Provenance Trials in Alpine Range – Review and Perspectives for Applications in Climate Change. In: Cerbu, G.A., Hanewinkel, M., Gerosa G., Jandl, R. (Eds.), *Management Strategies to Adapt Alpine Space Forests to Climate Change Risks*: 233-256, In tech.

Lagercrantz, U., Ryman, N. 1990: Genetic structure of Norway spruce (*Picea abies*), concordance of morphological and allozymic variation. *Evolution*, 44: 38-53.

Matović, M., Vujković, Lj. 1994: Nova forma smrče (*Picea abies* /L./ Karst.) i njene ekološko-morfološke i dekorativne karakteristike. *Savetovanje "Zelenilo u urbanističkom razvoju grada Beograda", Zbornik radova, Udruženje inženjera Beograda*: 277 - 284.

Morgenstern, E. 1996: *Geographic variation in forest trees, genetic basis and application of knowledge in silviculture*. UBC Press. Vancouver. 214 p.

Ocokoljić, M., Ninić-Todorović, J. 2003: *Priručnik iz Dekorativne dendrologije*. Univerzitet u Beogradu, Šumarski fakultet. Beograd. 169 p.

POWO - The International Plant Names Index and World Checklist of Selected Plant Families 2022. Published on the Internet at http://www.ipni.org and http://apps.kew.org/wcsp/

Schmidt-Vogt, H. 1974: Das natürliche Verbreitungsgebiet der Fichte (*Picea abies* (L.) Karst.) in Eurasien. *Allgemeine Forstund Jagdzeitung*, 145: 185–197.

Skrøppa, T. 2003: *EUFORGEN Technical Guidelines for genetic conservation and use for Norway spruce (Picea abies)*. International Plant Genetic Resources Institute. Rome. 6 p.