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HEIGHT AND ROOT-COLLAR DIAMETER GROWTH VARIABILITY OF EUROPEAN BEECH PROVENANCES FROM SOUTHEAST EUROPE

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Abstract: Variation in seedlings height and diameter in the zone of root collar of nine European beech provenances from southeast Europe was examined at two trial sites in Serbia (Fruška Gora and Debeli Lug). Provenance trials were established during the spring of 2007 and arranged in randomized complete block design. Results are presented for the seedlings age of 10 years. Provenance means for the studied traits were 267.2 cm and 49.09 mm at site Fruška Gora; and 230.8 cm and 33.53 mm, at site Debeli Lug, respectively. Significant site ($p < 0.001$) and provenance ($p < 0.001$) effects were detected in the studied traits. Two out of nine provenances (RS60 and RS69) changed their ranks in height growth across the two sites. The greatest mean value for height growth, at both trial sites, was observed in Serbian provenance RS67 (302.4 cm and 268.4 cm, respectively). The same provenance had the highest mean values of diameter in the zone of root collar (55.9 mm and 39.6 mm, respectively), as well. The presented provenance research results are important for future activities on tree breeding and conservation of the European beech genetic pools.

Keywords: European beech, provenance trial, height growth, diameter growth.

VARIJABILNOST VISINA I PREČNIKA SADNICA RAZLIČITIH PROVENIJENCIJA BUKVE POREKLOM IZ JUGOISTOČNE EVROPE

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Izvod: Varijabilnost visinskog rasta i prečnika u zoni korenovog vrata kod devet provenijencija bukve poreklom iz jugoistočne Evrope je ispitivano u provenijeničnim testovima osnovanim na dva lokaliteta – Fruška gora i Debeli Lug. Provenijenični ogledi su osnovani u proleće 2007. godine i organizovani po slučajnom blok sistemu. Rezultati su prezentovani za starost sadnica od 10 godina. Prosečne visine sadnica su iznosile 267.2 cm i 230.8 cm na Fruškoj gori i u Debelom Lugu, kod svakog ponaosob, dok su prosečne vrednosti prečnika u zoni korenovog vrata bile 49.09 mm, odnosno 33.53 mm. Statistički značajne razlike su utvrđene između provenijencija ($p < 0.001$) i lokaliteta ($p < 0.001$). Dve od devet provenijencija (RS60 i RS69) su menjale rang u pogledu vrednosti visina na dva lokaliteta. Najveća prosečna visina sadnica je u oba testa konstatovana kod srpske provenijencije RS67 (302.4 cm u ogledu na Fruškoj gori i 268.4 cm u ogledu u Debelom Lugu). Ista provenijencija se karakterisala i najvećim prosečnim prečnikom u zoni korenovog vrata, koji je na Fruškoj gori iznosio 55.9 mm, a u Debelom Lugu 39.6 mm. Rezultati istraživanja su značajni sa aspekta oplemenjivanja bukve i konzervacije genetičkih resursa vrste.

Ključne reči: bukva, provenijenični test, visina, prečnik.

INTRODUCTION

European beech is one of the most widespread and economically most important tree species in Europe. However, although covering a wide range of environments (e.g. acid and calcareous soil, boreal and mediterranean climate, etc.) within its natural range, beech is also known to be vulnerable to drought. The projections of future climate change for the region of southern Europe suggest an annual mean temperature increase, while summer precipitation is projected to decline (Lindner et al., 2010). Therefore, the identification of most productive and best adapted provenances for commercial use in such circumstances will be of the highest importance (Cundall et al., 2003).

Information about genetic variation and genotype by environment interaction ($G \times E$) is essential for carrying out efficient breeding activities (Karlsson and Hogberg, 1998). Recently conducted studies in European beech common garden experiments showed the existence of genetic variability between provenances regarding growth traits (Jazbec et al., 2007; Andra Nicoleta, 2009; Ivanković et al., 2011), as well as presence of significant provenances \times site interaction for these traits (Ivanković et al., 2008; Barzdajn, 2009; Stojnić et al., 2015a).

The aim of the present study was to evaluate the magnitude of $G \times E$ effect on diameter and height growth of nine European beech provenances originating from southeast Europe. Moreover, the results will show, how well provenances are adapted to certain trial-site environmental features in the juvenile development stage.

MATERIAL AND METHODS

European beech provenance trials in Serbia were established during spring of 2007 as a part of a series of pan-European provenance trials. The trials are founded at two sites: Debeli Lug (Eastern Serbia) and Fruška Gora (Northern Serbia) (Table 1). Both trials are arranged in a randomized complete block design replicated three times. Fifty seedlings per plot were planted with 1×2 m spacing.

Table 1. Environmental features of the trial plots (Stojnić et al. 2012a)

Tabela 1. Stanišni uslovi u provenijencijskim testovima bukve (Stojnić et al. 2012a)

Parameter <i>Parametar</i>	Debeli Lug	Fruška Gora
Latitude N <i>Širina N</i>	44°19'34.01"	45°10'9.86"
Longitude E <i>Dužina E</i>	21°52'20.39"	19°47'53.45"
Altitude (m a.s.l.) <i>Visina (mnv)</i>	742	370
Precipitation (mm) <i>Padavine (mm)</i>	829	624
Temperature (°C) <i>Temperatura (°C)</i>	8.8	11.1
Soil depth (cm) <i>Dubina zemljišta (cm)</i>	57	42
Soil type <i>Tip zemljišta</i>	Brown soil on limestone <i>Smeđe zemljište na krečnjaku</i>	Acid brown soil <i>Kiselo smeđe zemljište</i>
pH value <i>pH vrednost</i>	6.07	5.38
Water retention <i>Retencija vlage</i>	34.36	29.81
Humus content (%) <i>Sadržaj humusa (%)</i>	4.78	4.15
C (%)	2.77	2.46
N (%)	0.38	0.17
C/N	7.29	14.47
P ₂ O ₅ (mg/100g)	12.37	9.77
K ₂ O (mg/100g)	37.62	7.87

Study involved nine provenances originating from Bosnia and Herzegovina (3), Romania (2) and Serbia (4) (Table 2). Total height and diameter in the zone of root collar (4 cm above the ground) were measured in October 2014 on the 10-year-old seedlings.

Statistical analyses were carried out using Statistica 10 (StatSoft, Inc.) software. The estimation of statistical importance of different level sources of phenotypic variance was conducted by two-factorial ANOVA procedure, as locality is set as a fixed factor (amount of phenotypic plasticity), provenance as random

factor (genetic variation between the provenances) and the interaction between locality and provenance (genetic variation for plasticity between the provenances). Significances were determined at $p < 0.05$ throughout.

Table 2. European beech provenances involved in the study

Tabela 2. Provenijencije bukve obuhvaćene istraživanjem

Code Oznaka	Provenance Provenijencija	Country Zemlja porekla	Latitude (dd.mm.) Geografska širina (ss.mm.)	Longitude (dd.mm.) Geografska dužina (ss.mm.)	Altitude (m) Visina (m)	Sum of precipitation (mm) Suma padavina (mm)	Mean air temperature (°C) Prosečna temp. vazduha (°C)
BA59	Vranica- Bistrica	Bosnia	43°33'	17°49'	750	826	8.8
BA60	Crni Vrh	Bosnia	44°33'	17°59'	500	1069	9.6
BA61	Grmeč	Bosnia	44°45'	16°14'	720	1304	10.3
RO63	Alesd	Romania	47°11'	22°15'	490	800	8.5
RO64	Alba-Iulia	Romania	46°10'	23°05'	860	850	8.0
RS66	Avala	Serbia	44°23'	20°45'	475	800	11.9
RS67	Boranja	Serbia	44°01'	19°45'	410	668	10.9
RS68	Fruška Gora	Serbia	45°10'	19°50'	370	624	11.1
RS69	Cer	Serbia	44°12'	19°50'	745	782	10.9

RESULTS AND DISSCUSION

The highest mean height, at both trial sites, was observed in Serbian provenance RS67 – Boranja. At the Fruška Gora, mean height of seedlings was 302.4 cm, whereas at the Debeli Lug mean height amounted 268.4 cm. The same provenance had the highest values of mean diameter in the zone of root collar (55.9 mm and 39.6 mm, respectively), as well. On the other hand, the lowest mean height was observed in local provenance RS68 – Fruška Gora (234.7 cm), at Fruška Gora, and two Romanian provenances RO64 - Alba-Iulia (177.0 cm) and RO63 - Alesd (197.6 cm), at Debeli Lug. The lowest mean root-collar diameter was recorded in provenance RO64, at the both sites (43.2 and 26.4 cm, respectively).

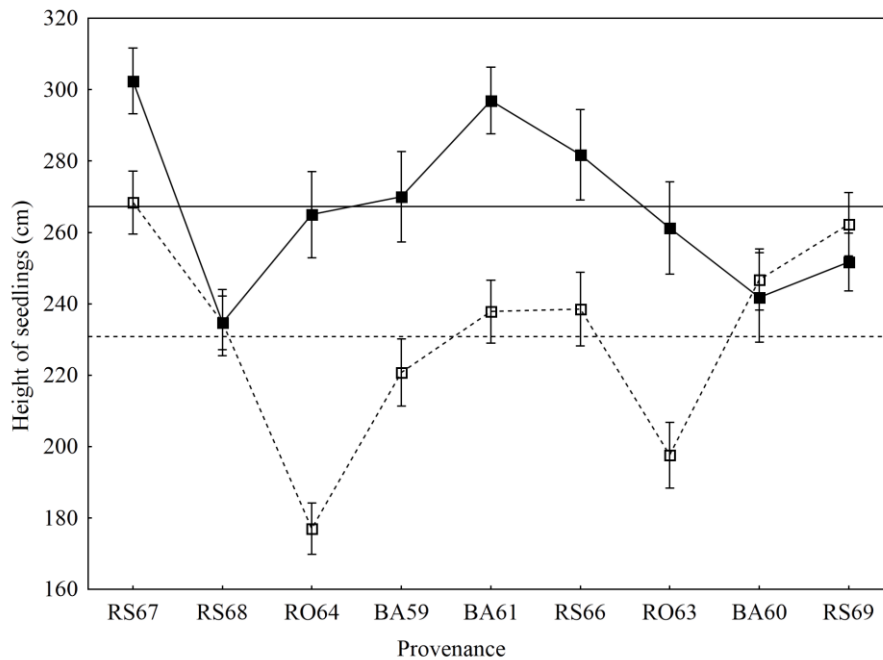
Comparing seed quality, seedling development rate and morphometric traits between four Serbian provenances (Avala, Boranja, Fruška Gora and Cer) grown in common garden experiment, Šijačić-Nikolić et al., (2007) reported that provenance Boranja showed the highest values for the most of studied traits. Studying diameter and height growth among 22 beech provenances which belong to the same network of provenance trials like ours, Ballian and Zukić, (2011) evidenced the lowest seedlings mean height in Romanian provenances RO63 and RO64, as well. The authors also showed that Romanian provenance RO64 had the smallest mean diameter in the zone of root collar.

Results of the study showed significant "provenance" effect for height ($F=8.46$; $p < 0.001$) and root-collar diameter ($F=8.74$; $p < 0.001$) growth (Figures 2 and 3). Likewise, locality conditions significantly affected the traits studied ($F_{\text{diameter}}=84.6$; $p < 0.001$; $F_{\text{height}}=55.05$; $p < 0.001$). Two-factorial ANOVA revealed a

significant effect of "provenance by locality interaction" for seedlings height ($F=5.99$; $p<0.001$) and root-collar diameter growth ($F=2.06$; $p=0.04$), although only two out of the nine provenances changed their ranking in height growth across the two sites (BA60 and RS69).

Figure 1. Height growth variability of European beech in the provenance trials Fruška Gora (closed squares, solid line) and Debeli Lug (open square, dash line). Horizontal lines represent provenance means for Fruška Gora (solid line) and Debeli Lug (dash line). The error bars represents the standard error

Grafikon 1. Varijabilnost visinskog rasta bukve u provenijeničnim testovima na Fruškoj gori (crni kvadrat, puna linija) i u Debelom Lugu (beli kvadrat, isprekidana linija). Horizontalne linije predstavljaju srednje vrednosti za Frušku goru (puna linija) i Debeli Lug (isprekidana linija). Vertikalni stubovi predstavljaju standardnu grešku merenja

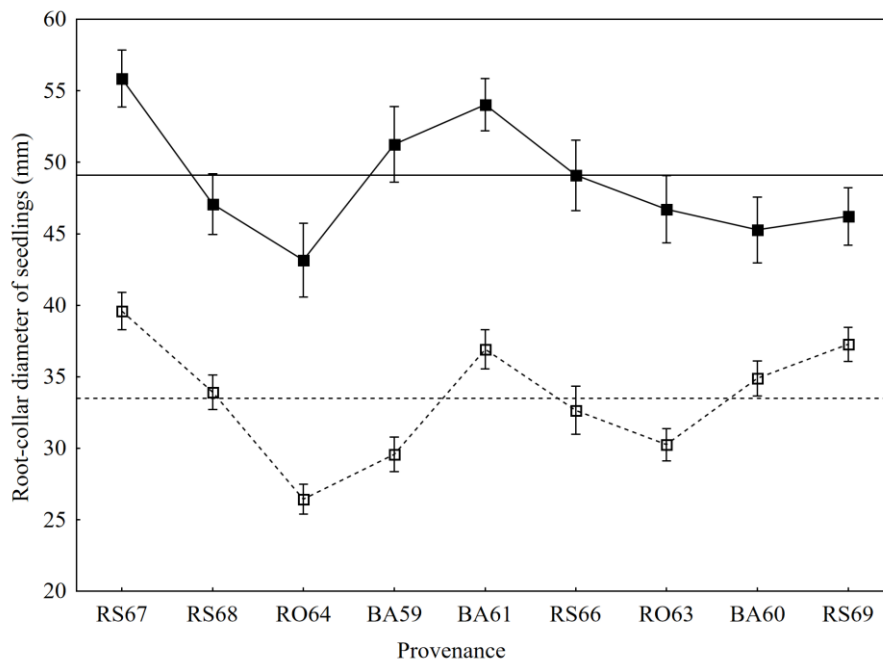


The differences between provenances in examined growth traits are probably the result of differences in genetic make-up of studied provenances (Stojnić et al., 2015b). This is in accordance with the results of Ballian and Zukić, (2011) who found notable differences in height and diameter growth among 22 beech provenances cultivated at trial site Kakanj (BA). Likewise, Višnjic, (2010) reported significant differences for height, breast diameter, branching and shape of the tree between 16 beech provenances. Significant effects of "provenance by locality interaction" on height and diameter growth point to existence of genetic variation in plastic provenances response to prevailing environmental conditions. Provenances RS67 and BA61 were found to be the most

plastic, showing good performance in both sites. Studying beech performances across five trial sites in France at the age of 11, Teissier du Cross et al., (1988) found that height difference between the most vigorous and the weakest provenance is roughly equivalent to a one-year terminal shoot length. Ivanković et al., (2008) also observed significant "site × provenance" effect in two beech provenance trials established in Croatia and Slovenia, where some provenances exhibited a general adaptability and phenotypic stability, while other provenances were phenotypically instable (i.e. exhibited specific adaptability).

Figure 2. Root-collar diameter growth variability of European beech in the provenance trials Fruška Gora (closed squares, solid line) and Debeli Lug (open square, dash line). Horizontal lines represent provenance means for Fruška Gora (solid line) and Debeli Lug (dash line). The error bars represents the standard error

Grafikon 2. Varijabilnost prečnika u zoni korenovog vrata bukve u provenjeničnim testovima na Fruškoj gori (crni kvadrat, puna linija) i u Debelom Lugu (beli kvadrat, isprekidana linija). Horizontalne linije predstavljaju srednje vrednosti za Frušku goru (puna linija) i Debeli Lug (isprekidana linija). Vertikalni stubovi predstavljaju standardnu grešku merenja



Distinct performances of beech provenances cultivated in common gardens have been confirmed by other authors for some physiological, morphological and anatomical traits, as well (Stojnić et al., 2012b; Šijačić-Nikolić et al., 2013; Štajner et al., 2013; Eilmann et al., 2014; Stojnić et al., 2015c; Stojnić et al., 2015d). According to Mátyás et al., (2009) phenotypic response to

macroclimatic changes depends on the inherited adaptive potential of the population and on the magnitude and direction of experienced environmental change.

Considering that beech presents tree species with a continuous growth, currently achieved growth values do not reflect full potential of certain provenances and may not be reliable for predicting G×E at mature age (Ballian and Zukić, 2011; Gwaze et al., 2001), although there are some opinions that data from early tests might provide valuable information on the provenances growth potential in the later development stages (Larsen, 1985). Nevertheless, some authors believe that growth potential of beech can be estimated reliably only after 40 years in the field (Kleinschmit and Svobla, 1995), or even later (i.e. after 60 years in the field; according Muhs et al., 2010). Thus, present results must be careful interpreted and confirmed in the later phases of development. Nevertheless, presence of substantial genetic variability between provenances is particularly important from the perspective of improvement and preservation of beech genetic diversity, since genetic diversity plays a crucial role in the adaptation processes of tree populations to environmental changes.

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Sažetak

VARIJABILNOST VISINA I PREČNIKA SADNICA RAZLIČITIH PROVENIJENCIJA BUKVE POREKLOM IZ JUGOISTOČNE EVROPE

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Varijabilnost visinskog rasta i prečnika u zoni korenovog vrata kod devet provenijencija bukve poreklom iz jugoistočne Evrope je ispitivano u provenijencijskim testovima osnovanim

na dva lokaliteta – Fruška gora i Debeli Lug. Provenijenični ogledi su osnovani u proleće 2007. godine i organizovani po slučajnom blok sistemu. Rezultati su prezentovani za starost sadnica od 10 godina. Prosečne visine sadnica su iznosile 267.2 cm i 230.8 cm na Fruškoj gori i u Debelom Lugu, kod svakog ponaosob, dok su prosečne vrednosti prečnika u zoni korenovog vrata bile 49.09 mm, odnosno 33.53 mm. Statistički značajne razlike su utvrđene između provenijencija ($p < 0.001$) i lokaliteta ($p < 0.001$). Dve od devet provenijencija (RS60 i RS69) su menjale rang u pogledu vrednosti visina na dva lokaliteta. Najveća prosečna visina sadnica je u oba testa konstatovana kod srpske provenijencije RS67 (302.4 cm u ogledu na Fruškoj gori i 268.4 cm u ogledu u Debelom Lugu). Ista provenijencija se karakterisala i najvećim prosečnim prečnikom u zoni korenovog vrata, koji je na Fruškoj gori iznosio 55.9 mm, a u Debelom Lugu 39.6 mm. Rezultati dobijeni u juvenilnoj fazi razvoja biljaka upućuju na potencijal određenih provenijencija, te se iz tog razloga preporučuje da se ovi rezultati provere i u kasnijim fazama razvoja. Pojedini autori smatraju da se realni potencijal provenijencija može proceniti u starostima preko 40 godina, dok pojedini autori čak smatraju da je za realnu procenu potrebno da biljke budu stare i preko 60 godina.