

Variability of Physiological Parameters of European Beech Provenances in International Provenance Trials in Serbia

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Abstract – In this study, the variability of physiological parameters of five provenances of European beech (*Fagus sylvatica*), which were planted at two locations with different ecological conditions at Fruška Gora and Debeli Lug, was estimated. Provenance trials were established in the framework of COST Action E52: "Evaluation of Beech Genetic Resources for Sustainable Forestry". 2-3 years old seedlings originating from Croatia, Germany, Bosnia, Austria and Serbia were planted in blocks of fifty plants with a spacing of 2 x 1 m. Physiological parameters such as net photosynthesis, rate of transpiration and stomatal conductance were measured with a portable gas analysis system. Generally, provenances from Fruška Gora Mountain showed higher intensity of all physiological parameters than provenances located at site Debeli Lug. High correlations among rates of net photosynthesis and transpiration, on one side, and stomatal conductance, on the other side, were found. ANOVA test indicates that variability of net photosynthesis, transpiration and stomatal conductance of investigated provenances, at the two locations, was influenced both by environmental conditions of sites and genetic constitution of provenances.

beech provenances / net photosynthesis / transpiration / stomatal conductance.

1 INTRODUCTION

According to IPCC data, presented in 2001, the global Earth temperature has increased by 0.6 ± 0.2 °C in the 20th century. Future projections indicate even more radical changes. According to those estimations, global air temperature will increase by 1.4–5.8 °C by 2100 (IPCC 2001). Due to possible scenarios about global climate changes, there is great interest and concern regarding beech ecosystems. The decline of rainfall during the vegetation period, accompanied by the intensification of summer drought and increasing concentrations of CO₂, will negatively affect beech, which is known as a species sensitive to drought (Geßler et al. 2007; Rose et al. 2009).

European Beech is the most common tree species in Serbia. According to the National Forest Inventory, pure and mixed stands of beech cover 660,400 hectares or 29.3% of the

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forest area. In total volume, beech is represented with 40.5%, while in the total volume increment beech is represented with 30.6% (Banković et al. 2009).

Networks of European beech provenance trials, which were established in six rounds so far, were aimed at research of genetic variability of populations originating from different regions, of the possibility of adaptation of different provenances at local site conditions and the study of the main environmental factors that determine the degree of adaptability of a population to specific habitat conditions (von Wuehlisch 2004). The study of adaptability of beech is particularly important as due to global climate change beech will become endangered or even lost in the course of the succession of species, in many parts of the beech range.

Previous studies have shown that the net photosynthesis is an important indicator of the vitality and competitive ability of a species at a given site (Aranda et al. 1996). Together with other gas exchange parameters in plants, net photosynthesis can be used as a criterion in the early selection of trees, in the process of breeding (Kundu – Tigerstedt 1998).

The research aimed at the study of variability of physiological parameters (net photosynthesis, transpiration and stomatal conductance) of beech plants in two international provenance trials in Serbia.

2 MATERIALS AND METHODS

2.1 Experimental fields

Beech provenance trials at Fruška Gora Mt (N 45°10'09.86", E 19°47'53.45") and Debeli Lug (N 44°19'34.01", E 21°52'20.39") were established in spring of 2007, in the framework of COST Action E52: "Evaluation of the Genetic Resources of Beech for Sustainable Forestry". Site characteristics of locations are given in *Table 1*.

Table 1. Site characteristics of "Fruška Gora" and "Debeli Lug" trials

Locality	Altitude	Exposition	Slope	Yearly average temperature	Average temperature during vegetation period	Yearly average precipitation	Average precipitation during vegetation period
	(m)		(°)	(°C)	(°C)	(mm)	(mm)
Fruška Gora	370	N	30	11.0	17.9	782	351
Debeli Lug	742	N-NE	5-7	8.8	15.1	829	455

2.2 Plant material

The tests were established by planting 2 and 3 years old seedlings in a spacing of 2 m between rows and 1 m between plants. Geographic and climatic characteristics of provenances are shown in *Table 2*.

Table 2. Site characteristics of provenances

Provenance	Country	Longitude		Latitude		Altitude (m)	Exposition	Yearly average temperature (t °C)	Average temperature during vegetation period (t °C)	Yearly average precipitation (mm)	Average precipitation during vegetation period (mm)
		Deg	Min	Deg	Min						
Vranica-Bistrica	BA	17	49	43	33	750	N	8.8	14.8	826	383
Fruška Gora	SRB	19	55	45	10	370	N-NE	11.2	17.9	782	351
Scharnstein, Mitterndorf	AUT	13	58	47	54	480	W	7.4	14.6	1263	706
Höllerbach	DE	13	14	49	1	755	—	5	11.7	1200	580
Sjeverni Dilj Čaglinski	CRO	18	1	45	17	350	NE	10.8	17.2	779	360

2.3 Physiological parameters

Net photosynthesis (A), transpiration (E) and stomatal conductance (gs) were measured in the second half of July 2009., using ADC Bioscientific Ltd. LCPro+ portable gas analysis system specialised for measurements of plant gas exchange parameters. Measurements were made on five plants from each provenance, in five replications per plant. The leaves were fully formed and located in the upper third part of the crown, oriented towards the south-southwest. Measurements were done in sunny and clear weather, in the period between 09:00 and 11:00 hours. Photosynthetic active radiation (PAR) has been set to volume of $1000 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$, while the temperature, humidity and the concentration of CO_2 were measured on the spot.

2.4 Statistical analyses

The following statistical parameters and statistical analysis were applied: mean (\bar{x}), coefficient of variation (CV), standard deviation (*StD*), coefficient of correlation and ANOVA test. The data were processed by the software package "Statistica 9.1".

3 RESULTS

First the results of variability of net photosynthesis, transpiration and stomatal conductance measured in the provenance trial at Fruška Gora Mt (*Table 1*) are discussed. The highest rates of net photosynthesis ($12.40 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and stomatal conductance ($0.33 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) were measured on the local provenance („Fruška Gora“). The highest intensity of transpiration was measured for provenance „Höllerbach“ from Germany ($4.49 \text{ mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$). On the other hand, the Croatian provenance „Sjeverni Dilj Čaglinski“ had the lowest value of net photosynthesis ($10.41 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and rate of transpiration ($3.74 \text{ mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$), while the lowest stomatal conductance ($0.22 \text{ mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) was recorded for the provenance "Scharnstein, Mitterndorf" from Austria.

The provenance „Höllerbach“ has shown the highest interprovenance variability, regarding net photosynthesis (16.93%) and stomatal conductance (19.31%). The Croatian provenance „Sjeverni Dilj Čaglinski“ had the highest coefficient of variation regarding transpiration (11.91%). The lowest interprovenance variability regarding net photosynthesis (10.71%) and transpiration (2.17%) was observed on provenance „Fruška Gora“, while the provenance "Vranica-Bistrica" showed the lowest variability of stomatal conductance (5.70%).

Table 3. Net photosynthesis, transpiration and stomatal conductance in the provenance trial at Fruška Gora Mt

Provenance	Net photosynthesis ($\mu\text{mol m}^{-2} \text{s}^{-1}$)			Transpiration ($\text{mmol m}^{-2} \text{s}^{-1}$)			Stomatal conductance ($\text{mol m}^{-2} \text{s}^{-1}$)		
	\bar{x}	CV	StD	\bar{x}	CV	StD	\bar{x}	CV	StD
Sjeverni Dilj Čaglinski	10.41	16.82	1.75	3.74	11.91	0.45	0.24	18.23	0.04
Fruška gora	12.40	10.71	1.33	4.14	2.17	0.09	0.33	6.96	0.02
Höllerbach	11.35	16.93	1.92	4.49	11.68	0.53	0.24	19.31	0.05
Scharnstein, Mitterndorf	11.05	12.42	1.37	4.17	3.83	0.16	0.22	9.61	0.02
Vranica-Bistrica	11.14	11.32	1.26	3.94	3.27	0.13	0.30	5.70	0.02

Table 4. presents the results of variability of net photosynthesis, transpiration and stomatal conductance in the provenance trial Debeli Lug. Unlike Fruška Gora Mt., where the minimum value of net photosynthesis was registered for the provenance "Sjeverni Dilj Čaglinski, in the Debeli Lug, this provenance had the highest value of this parameter ($12.61 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$). The lowest rate of net photosynthesis was measured for the provenance "Höllerbach" ($9.88 \mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$). The highest rate of transpiration ($4.81 \text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) and stomatal conductance ($0.21 \text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$) was shown by provenance "Vranica-Bistrica" from Bosnia and Herzegovina. The lowest values of both parameters had provenance "Fruška Gora" ($E = 2.33 \text{mmol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$; $g_s = 0.16 \text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$).

Coefficient of variation regarding net photosynthesis (11.73%) and stomatal conductance (21.24%) was highest for provenance "Höllerbach", while the provenance "Fruška Gora" showed the highest variation coefficient of transpiration (19.48%). The lowest coefficient of variation for net photosynthesis was found for provenance "Vranica-Bistrica" (7.77%). Provenance "Scharnstein, Mitterndorf" had the lowest coefficient of variation for transpiration (4.76%) and stomatal conductance (7.3%).

Table 4. Net photosynthesis, transpiration and stomatal conductance in provenance trial at Debeli Lug.

Provenance	Net photosynthesis ($\mu\text{mol m}^{-2} \text{s}^{-1}$)			Transpiration ($\text{mmol m}^{-2} \text{s}^{-1}$)			Stomatal conductance ($\text{mol m}^{-2} \text{s}^{-1}$)		
	\bar{x}	CV	StD	\bar{x}	CV	StD	\bar{x}	CV	StD
Sjeverni Dilj Čaglinski	12.61	11.48	1.45	3.50	9.92	0.35	0.20	19.15	0.04
Fruška gora	11.23	10.66	1.20	2.33	19.48	0.45	0.16	16.12	0.03
Höllerbach	9.88	11.73	1.16	3.36	10.69	0.36	0.18	21.24	0.04
Scharnstein, Mitterndorf	10.61	10.94	1.16	3.01	4.76	0.14	0.19	7.30	0.01
Vranica-Bistrica	10.64	7.77	0.83	4.81	8.83	0.43	0.21	9.74	0.02

Results of ANOVA test for net photosynthesis, transpiration and stomatal conductance are given in *Tables 5, 6 and 7*. Significant differences were recorded among provenances (P) regarding all investigated parameters. In the case of location (L), significant differences were recorded for rate of transpiration and stomatal conductance. The interaction between provenance and locality (PxL) was statistically significant, as well.

Table 5. Analysis of variance for net photosynthesis in the studied beech provenance trials

Source	d.f.	Sum of squares	Mean square	F value
Location	1	2.859	2.859	0.7723
Error	28	103.669	3.702	
Provenance	4	30.923	7.731	5.3830***
P x L	4	63.047	15.762	10.9753***
Error	112	160.845	1.436	
Total	149	361.343		

Table 6. Analysis of variance for rate of transpiration in the studied beech provenance trials

Source	d.f.	Sum of squares	Mean square	F value
Location	1	17.944	17.944	115.541***
Error	28	4.348	0.155	
Provenance	4	21.914	5.478	50.306***
P x L	4	32.127	8.032	73.751***
Error	112	12.197	0.109	
Total	149	88.529		

Table 7. Analysis of variance for stomatal conductance in the studied beech provenance trials

Source	d.f.	Sum of squares	Mean square	F value
Location	1	0.228	0.228	180.308***
Error	28	0.035	0.001	
Provenance	4	0.055	0.014	15.856***
P x L	4	0.091	0.023	26.203***
Error	112	0.098	0.001	
Total	149	0.508		

The correlation analysis was performed between investigated physiological parameters (*Table 8*). Results indicate a high positive correlation between net photosynthesis and stomatal conductance. Positive correlation exists also between intensity of transpiration and stomatal conductance.

Table 8. Coefficient of correlation among net photosynthesis, transpiration and stomatal conductance

	Transpiration	Stomatal conductance
Net photosynthesis	0.419	0.927
Transpiration	–	0.515

4 DISCUSSION

The synthesis and accumulation of organic matter are achieved by the process of photosynthesis, and thus the influence of factors determining plant productivity could be better assessed if photosynthetic potential of individual leaves is determined (Bugbee and Salisbury, 1988). Research of numerous authors (Sheriff et al. 1986, Vaitkus et al. 1993, Kundu – Tigerstedt 1998, Orlović et al. 2001, Orlović et al. 2006) on different tree species have shown that research of net photosynthesis can provide useful information about growth potential of genotype and plant productivity. If a good correlation between growth and unit rates of photosynthesis and respiration can be established, than the effect of environment or heredity on present and even future growth may be determined easier (Bourdeau 1957).

The results of the research of net photosynthesis, intensity of transpiration and stomatal conductance of the five provenances indicate that there were highly significant differences between provenances regarding all parameters. In the case of transpiration and stomatal conductance, there was significant difference between locations as well. Adaptability of study provenances was also assessed. All parameters showed a statistically highly significant genotype x environment (PxL) interaction which indicates the existence of significant potential for adaptation.

The results of this research are corresponding with research of Ivankovic et al. (2008), who investigated variability of height growth in beech provenance trials established in Croatia and Slovenia. The authors concluded that there was a significant influence of site characteristics on height of seedlings and that different provenances had different abilities to adapt to given environmental conditions.

5 CONCLUSION

At the provenance trial established at Fruška Gora Mt., the highest rate of net photosynthesis was recorded for provenance "Fruška Gora". The local provenance had the highest stomatal conductance as well. Transpiration rate was the highest for the provenance "Höllerbach".

The lowest values of net photosynthesis and transpiration were measured for Croatian provenance "Sjeverni Dilj Čaglinski", while the lowest stomatal conductance was recorded for provenance "Scharnstein, Mitterndorf".

The highest interprovenance variability, regarding all studied parameters, was shown by the provenances "Sjeverni Dilj Čaglinski" and "Höllerbach".

At the site Debeli Lug, provenance "Vranica-Bistrica" showed the highest rate of transpiration and stomatal conductance, while the provenance "Fruška Gora" showed the lowest. Net photosynthesis was highest for provenance "Sjeverni Dilj Čaglinski", and the lowest for provenance "Höllerbach".

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