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EFFECT OF TREE PROVENANCE ON BASIC WOOD DENSITY OF NORWAY SPRUCE (*PICEA ABIES* [L.] KARST.) GROWN ON AN EXPERIMENTAL PLOT AT SIEMIANICE FOREST EXPERIMENTAL STATION

The paper presents a comparison of the density of seven provenances of spruce trees, grown on an experimental plot located at Siemianice Forest Experimental Station. This plot is a unique research area on which observations concerning the growth of spruce trees of different provenances have been conducted for 41 years. The conditions in which the trees grow are very similar and it may be assumed that provenance is the element differentiating growth and wood properties. Trees growing on this plot have reached such large dimensions that it was possible to collect experimental material in the form of blocks, from which wood samples for further tests were obtained. Analyses were conducted on 651 samples collected from spruce trees of 7 provenances (Orawa, Międzygórze, Nowe Ramuki, Istebna Bukowiec, Kartuzy, Zwierzyniec 281B, Zwierzyniec Lubelski). The results indicated that wood of each individual provenance differed significantly in terms of the analysed trait. It was found that wood coming from Zwierzyniec Lubelski had the greatest values of basic density, while the lowest values were recorded for the Orawa provenance. Moreover, the examined provenances were divided into four groups, thus creating a ranking list of provenances in terms of the basic wood density of Norway spruce.

Keywords: wood density, Norway spruce, provenance, physical properties of wood

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Introduction

The genetic resources of Norway spruce in Poland have not been comprehensively researched [Barzdajn 1994]. A variation of spruce populations depends on many factors, including e.g. the length of the vegetation period, mean total precipitation, altitude, the occurrence of early or late frost, snow pressure etc. Long-term provenance studies need to be conducted in order to determine the variations between trees of individual provenances.

The aim of studies on variations in the traits between trees of different provenances (growing under comparable conditions) is to broaden current knowledge in terms of the ecological adaptations of specific populations. These experiments are to provide insight into phenotypic plasticity or the contrary – into the adaptation of individual tree species (provenances) to local and more extreme conditions [Barzdajn 2003].

Results recorded on provenance plots may provide a tool to support the decision-making process concerning the future productivity of commercial forests [Kulej 2001]. In the case of spruce, the results of provenance studies are of particular value due to the use of spruce timber on a commercial-scale by industry.

Provenance experiments on Norway spruce, in which the wood was analysed, have been conducted particularly by Scandinavian researchers. Gerendiain et al. [2008] carried out experiments on 20 Norway spruce clones in south-eastern Finland, with the aim of identifying the correlations between different traits (growth, fibre properties and wood density). In another study, researchers investigated the dependencies between the cambial age, clone and climate [Zubizarreta-Gerendiain et al. 2012]. A similar study was presented by Grenadin et al. [2009a], who considered the genetic characters, in addition to growth traits, density and many other traits. In that study, a total of 20 clones were analysed (10 Finnish provenances, 2 Russian, as well as hybrids). Other experiments conducted on clones of *Picea glauca* and including several wood characteristics (e.g. density, proportions of late and early wood, and microfibril angle (MFA)) were performed by Park et al. [2012]. The international team of Hannrup et al. [2004] estimated the genetic parameters and heritabilities of wood and the growth traits in two 19-yr-old clonal trials and a 40-yr-old full-sib progeny trial of Norway spruce. The authors tested the wood density traits, lignin content, number of internal cracks, growth traits, spiral grain and number of resin canals.

Analyses of tree traits and spruce wood properties are an important subject for scientific investigations and research projects [Raiskila et al. 2006; Gerendiain et al. 2009b; Steffenrem et al. 2009]. In addition, there are some studies concerning the same topic but from other regions, such as Canada [Blouin et al. 1994], Germany [Isik et al 2010], and Romania [Sofletea et al. 2012]. The scope of Polish research in the field of wood analyses is limited, comprising thematically similar studies by Kobyliński [1967] and Barzdajn [1996]. Spruce populations in

Poland have been analysed in terms of external characteristics, making it possible to distinguish characteristic provenances [Giertych 1998] and correlations of different traits, primarily related to growth [Barzdajn 1994, 2003]. Many publications in Polish literature on the subject focus rather on the quality attributes of the round wood [Michalec 2007, 2011], Michalec et al. [2013], Barszcz and Michalec [2007] than on the characteristics of the wood themselves. This paper fills the gap in research and provides new information from a plantation sufficiently mature for wood analyses.

This paper presents the results of analyses conducted on material collected from a unique experimental plot located at Siemianice Forest Experimental Station. The aim of this study was to investigate and analyse the basic wood density of Norway spruce of seven selected Polish provenances. The analyses focused on the basic wood density of Norway spruce trees from the experimental plot located at Siemianice Forest Experimental Station.

Materials and methods

The experimental plot, from which the materials for the analyses were collected, was established in 1975 in Compartment 89 m, situated in the Marianka Forest District of Siemianice Forest Experimental Station, within the framework of the IUFRO 1972 experiment. The experimental plot, measuring 378 × 96 m, was divided into 5 complete blocks of 20 randomly-placed populations of Norway spruce of different provenances. Each such sub-plot was 324 m^2 in area. A total of 144 seedlings at a spacing of 1.5 × 1.5 m were planted on each sub-plot.

The range of diameter at breast height was from 17 to 23 cm. The height was very similar – between 18 and 19 m. Only trees with a regular and healthy crown were cut.

Field analyses began with a preliminary examination of the experimental plot and an accurate identification of the boundaries between the individual provenance sub-plots. Following this analysis, trees of seven provenances were selected:

- Orawa (O)
- Międzygórze (M)
- Nowe Ramuki (NR)
- Istebna Bukowiec (IB)
- Kartuzy (K)
- Zwierzyniec 281 B (Z)
- Zwierzyniec Lubelski (ZL).

The name of the provenance refers to the region from which the trees planted on the experimental plot originated. A total of 12 model trees of each provenance were selected with a diameter (measured at breast height) of approx. 21 cm. The parameters of the model trees were calculated based on the Urich II method

[Grochowski 1973]. The northerly direction and a height of 1.3 m were marked on the trees. Upon felling of the marked specimens, logs of approx. 70 cm were cut, starting from the identified breast height. Following this, boards were cut from the central part (including the pith) of the produced logs along the north-south axis. Bars of 20 × 20 × 30 mm were cut. A basic density was calculated according the equation [Kokociński 2004]:

$$\rho_u = \frac{m_o}{V_{max}} \tag{1}$$

where: ρ_u – basic density [kg·m^{-3}]
m_o – the oven-dry mass of a wood sample
V_{max} – green volume − the solid volume of a wood sample when it is in equilibrium with surrounding water.

The density was the subject of statistical analysis. An analysis of variance and Duncan's test were used to verify the differences between the provenances.

Results and discussion

Analyses were conducted on a total number of 647 samples. The number of samples differed between provenances (table 1), due to necessary selection in terms of wood defects. On average, the number of samples was approx. 100 which provided a satisfactory sample for statistical analyses. The mean wood density for the entire studied population was 390 kg·m^{-3}. In turn, the difference between the lightest and heaviest samples was as high as 318 kg·m^{-3}, which is a considerable value and indicates great variation in the populations. The scattering of values within the entire population was rather symmetrical, since the median was 388 kg·m^{-3}, i.e. almost identical to the mean. Differences between the provenances were marked and confirmed statistically. The ZL provenance, with a density of 417 kg·m^{-3}, was the population with the greatest wood density. This population differed markedly from all the others, which was confirmed statistically (table 2). Duncan's test also indicated other populations differing significantly from one another, with statistically significant differences found between the O and K provenances (table 2). The difference between the means was 41 kg·m^{-3} (between O and Z), while in the other cases, the means were similar (fig. 1). Based on Duncan's test, similar results could be grouped into sets (table 2). Four groups were distinguished. The first group comprised provenances from O, M, NR and IB. This was the set with the lowest wood density. The second set was composed of the M, NR, IB and K provenances. The third set consisted of the NR, IB, K and Z provenances, while the fourth set comprised only the ZL provenance (table 3).

Table 1. Basic density [kg·m^{-3}] of wood of individual provenances. Descriptive statistics

Provenance	N	Maximum	Mean	Standard deviation	Median	Minimum
O	94	478	376	42	373	306
M	92	455	379	33	375	289
NR	102	473	381	36	381	312
IB	83	470	389	41	389	292
K	98	597	391	53	388	279
Z	86	490	394	37	393	334
ZL	92	556	417	43	414	338

Table 2. Duncan's test – differences between provenances (the level of probability)

Provenance	O	M	NR	IB	K	Z	ZL
O	-	0.5404	0.3832	0.0510	0.0222*	0.0070*	0.0000*
M	0.5404	-	0.7486	0.1545	0.0813	0.03289*	0.0000*
NR	0.3832	0.7486	-	0.2334	0.1346	0.06097	0.0000*
IB	0.0510	0.1545	0.2334	-	0.6923	0.4259	0.0000*
K	0.0222*	0.0813	0.1346	0.6923	-	0.6480	0.0000*
Z	0.0070*	0.03289*	0.06097	0.4259	0.6480	-	0.0002*
ZL	0.0000*	0.0000*	0.0000*	0.0000*	0.0000*	0.0002*	-

Tabele 3. Groups of populations identified on the basis of Duncan's test

Provenance	Density [kg·m^{-3}]	Group 1	Group 2	Group 3	Group 4
O	376	X	-	-	-
M	379	X	X	-	-
NR	381	X	X	X	-
IB	389	X	X	X	-
K	391	-	X	X	-
Z	394	-	-	X	-
ZL	417	-	-	-	X

The above results may be compared to the earlier studies by Kobyliński [1968] and Barzdajn [1996], conducted on similar provenances of spruce in Poland. Among the populations mentioned in this study there were only five of seven, i.e. O, M, NR, IB and Z. When considering only those five provenances, O had the lowest density and it was the only case in which the results were confirmed, whereas in the other cases there was no consistency. While between three provenances (M, NR, IB) the differences in the means were slight, and these populations were similar in terms of density, the situation was rather different in the case of Z.

Two samples were prepared, of which one had a relatively low density, while the other had an average density. However, both cases indicated a lower wood density in the Z provenance than in M and NR. To conclude, both types of analyses performed on the numerous samples showed different results. Wood density changes with cambial age and Kobyliński collected samples for analyses from mature trees considerably varied in age (90–170 years), while growth conditions for those stands were different. While analysing data presented by Kobyliński, it was not possible to state which provenance had the highest density.

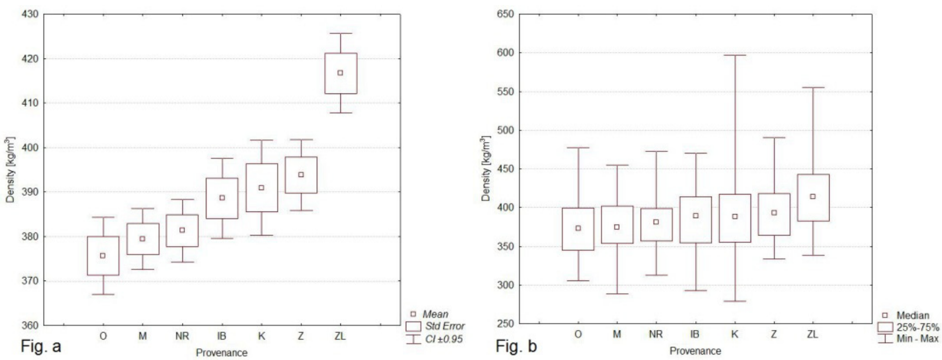

Fig. 1. Average density of different provenances of spruce for the provenance experiment at Siemianice Forest Experimental Station – a) mean values, b) median values.

At this stage of both stand development and progress in wood tissue examination, it is very difficult to point out which factor decides the differentiation in basic density among provenances. The results obtained simply allow the statement that trees from different provenances have different densities despite growing in the same conditions. The differentiation may come from the microscopic or even submicroscopic structure of the wood.

Conclusions

Differences in the basic wood density of Norway spruce (*Picea abies* [L.] Karst.) were found between provenances at the Siemianice Forest Experimental Station.

The greatest mean wood density among the seven analysed populations was recorded for the provenance from Zwierzyniec Lubelski (ZL). This density was markedly higher and it was significantly different from all the investigated provenances.

Significant differences were also observed between the populations coming from Międzygórze (M) and Zwierzyniec 281 B (Z), Orawa (O) and Zwierzyniec 281 B (Z), as well as Orawa (O) and Kartuzy (K).

References

Barszcz A., Michalec K. [2007]: Spruce timber quality in trees with different thickness from the Beskidy Mts. Acta Scientiarum Polonorum Silvarum Colendarum Ratio et Industria Lignaria 6 [3]: 5–15

Barzdajn W. [1994]: Dwudziestoletnie doświadczenie proweniencyjne ze świerkiem (*Picea abies* [L.] Karsten) serii IUFRO 1972 w Leśnym Zakładzie Doświadczalnym Siemianice. I cechy wzrostowe (Twenty years of provenance experience with Norway spruce of IUFRRO 1972 series at Siemianice Forest Experimental Station. I Growth features). Sylwan 11: 25–35

Barzdajn W. [1996]: Zmienność gęstości drewna świerka pospolitego (*Picea abies* [L.] Karsten) w Polsce (Variability of Norway spruce wood density in Poland). Poznańskie Towarzystwo Przyjaciół Nauk, Wydział Nauk Rolniczych i Leśnych, Prace Komisji Nauk Rolniczych i Komisji Nauk Leśnych. Tom 82: 7–14

Barzdajn W. [2003]: Świerk pospolity (*Picea abies* [L.] Karst.) w 30-letnim doświadczeniu proweniencyjnym serii IUFRO 1972 w Nadleśnictwie Doświadczalnym Siemianice (Norway spruce – 30-years of provenance experience at Siemianice Forest Experimental District). Sylwan 7: 24–30

Blouin D., Beaulieu J., Daoust G., Poliquin J. [1994]: Wood quality of Norway spruce grown in plantations in Quebec. Wood and Fiber Science 26 [3]: 342–353

Gerendiain A.Z., Peltola H., Pulkkinen P., Jaatinen R., Pappinen A. [2008]: Differences in fibre properties in cloned Norway spruce (*Picea abies*). Canadian Journal of Forest Research 38 [5]: 1071–1082

Gerendiainn A.Z., Peltola H., Pulkkinen P. [2009a]. Growth and Wood Property Traits in Narrow Crowned Norway Spruce (*Picea abies f. pendula*) Clones Grown in Southern Finland. Silva Fennica 43 [3]: 369–382

Gerendiain A.Z., Peltola H., Pulkkinen P., Kellomaki S. [2009b]. Effects of genetic entry and competition by neighbouring trees on growth and wood properties of cloned Norway spruce (*Picea abies*). Annals of Forest Science 66 [8]: 806

Giertych M. [1998]: Zmienność proweniencyjna i dziedziczenie (Provenance variation and inheritance). [in]: Bugała W., Boratyński A. (ed.) Biologia świerka pospolitego. Bogucki WN. Poznań 213–23

Grochowski J. [1973]: Dendrometria (Dendrometry). Powszechne Wydawnictwo Rolnicze i Leśne, Warszawa

Hannrup B., Cahalan Ch., Chantre G., Grabner M., Karlsson B., Le Bayon I., Jones G.L., Müller U., Pereira H., Rodrigues J.C., Rosner S., Rozenberg P., Wilhelmsson L., Wimmer R. [2004]: Genetic Parameters of Growth and Wood Quality Traits in *Picea abies*. Scandinavian Journal of Forest Research 19: 14–29

Isik K., Kleinschmit J., Steiner W. [2010]: Age-age correlations and early selection for height in a clonal genetic test of Norway spruce. Forest Science 56 (2): 212–221

Kobyliński F. [1967]: Studies on the specific gravity of wood in a completely dry state [in:] Tyszkiewicz S. (ed.), Population studies of Norway spruce in Poland. Forest Research Institute, Warsaw

Kokociński W. [2004]: Drewno. Pomiary właściwości fizycznych i mechanicznych (Wood. Measurement of physical and mechanical properties). Wydawnictwo Prodruk, Poznań

Kulej M. [2001]: Zmienność oraz wartość hodowlana modrzewi różnych pochodzeń z terenu Polski w warunkach siedliskowych Beskidu Sądeckiego (Variation and silvicultural quality of larch of different Polish provenances under site conditions of the

Sądecki Beskid range). Zeszyty Naukowe Akademii Rolniczej im. H. Kołłątaja w Krakowie [273]: 1–157

Michalec K. [2007]: Jakość surowca świerkowego (Picea abies [L.] Karst) pochodzącego z głównych ośrodków i zasięgów jego występowania w Polsce (The quality of spruce round wood from main locations and ranges in Poland). Drewno 50 [177]: 57–78

Michalec K. [2011]: Kształtowanie się jakości surowca świerkowego w zależności od wysokości nad poziomem morza i wystawy (The effect of altitude and exposure on the quality of spruce timber). Sylwan 155 [6]: 373–383

Michalec K., Barszcz A., Wąsik R. [2013]: Jakość surowca świerkowego pochodzącego z drzewostanów naturalnych (rezerwatowych) i drzewostanów pełniących funkcje gospodarcze (The quality of spruce timber from natural stands (forest reserves) and managed stands). Drewno 189 [56]: 25–37

Park Y.S., Weng Y.H., Mansfield S.D. [2012]: Genetic effects on wood quality traits of plantation-grown white spruce (*Picea glauca*) and their relationships with growth. Tree Genetics & Genomes 8 [2]: 303–311

Raiskila S., Saranpaa P., Fagerstedt K., Laakso T., Loija M., Mahlberg R., Paajanen L., Ritschkoff A.C. [2006]: Growth rate and wood properties of Norway spruce cutting clones on different sites. Silva Fennica 40 [2]: 247–256

Sofletea N., Budeanu M., Parnuta G. [2012]: Provenance variation in radial increment and wood characteristics revealed by 30 year old Norway spruce comparative trials. Silvae Genetica 61 [4–5]: 170–178

Steffenrem A., Kvaalen H. Høibø O., A., Edvardsen Ø., M., Skrøppa T. [2009]: Genetic variation of wood quality traits and relationships with growth in *Picea abies*. Scandinavian Journal of Forest Research 24: 15–27

Zubizarreta-Gerendiain A., Gort-Oromi J., Mehtatalo L., Peltola H., Venalainen A., Pulkkinen P. [2012]: Effects of cambial age, clone and climatic factors on ring width and ring density in Norway spruce (*Picea abies*) in southeastern Finland. Forest Ecology and Management 263: 9–16

GĘSTOŚĆ UMOWNA DREWNA ŚWIERKA POSPOLITEGO (*PICEA ABIES* [L.] KARST.) POCHODZĄCEGO Z POWIERZCHNI DOŚWIADCZALNEJ ZLOKALIZOWANEJ NA TERENIE LEŚNEGO ZAKŁADU DOŚWIADCZALNEGO SIEMIANICE

Streszczenie

Artykuł zawiera porównanie gęstości siedmiu proweniencji świerka wyrosłych na powierzchni doświadczalnej na terenie LZD Siemianice. Powierzchnia ta jest unikatowym obiektem badawczym, na którym od wielu lat prowadzone są obserwacje dotyczące wzrostu świerka różnych pochodzeń. Warunki, w których wzrastają drzewa są do siebie bardzo zbliżone i można przyjąć, że elementem różnicującym wzrost i właściwości drewna jest ich pochodzenie. Drzewa rosnące na powierzchni osiągnęły na tyle duże rozmiary, że możliwym było pozyskanie materiału badawczego w formie wyrzynków, z których wyrobiono próbki drewna do dalszych badań. Badania przeprowadzono na 651 próbkach pozyskanych z 7 pochodzeń (Orawa, Międzygórze, Nowe Ramuki, Istebna Bukowiec, Kartuzy, Zwierzyniec, Zwierzyniec Lubelski). Uzyskane wyniki pozwalają stwierdzić, że drewno z poszczególnych pochodzeń istotnie różni się w zakresie badanej cechy. Ustalono, że w zakresie gęstości umownej najwyższe wartości przyjmuje drewno pochodzenia Zwierzyniec Lubelski, a najmniejsze wartości z prowieniencji Orawa. Dokonano również podziału badanych pochodzeń na cztery grupy, tworząc tym samym „listę rankingową" najlepszych pochodzeń świerka pospolitego.

Słowa kluczowe: gęstość drewna, świerk pospolity, proweniencja, właściwości fizyczne drewna