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Genetic control of wood density, tracheid dimension and annual ring traits – an analysis of genetic and phenotypic correlation in European larch

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Abstract: *Genetic control of wood density, tracheid dimension and annual ring traits – an analysis of genetic and phenotypic correlation in European larch.* We determined the genetic and phenotypic correlations between wood density traits and tracheid dimensions for 161 European larches aged 25, growing in a seed orchard in northern Poland. Wood density traits were determined using the analysis of x-ray images of properly prepared wood samples. The size of tracheids in juvenile wood were indicated using an optical fiber analyzer. The width of an annual ring and its elements (earlywood and latewood width), were moderately negatively correlated with the diameter of the tracheids and with the cell wall thickness. As for the wood density of an annual ring and its elements (earlywood and latewood density) and the sizes of tracheids, no special correlations were observed. Only the earlywood density was negatively correlated with the sizes of tracheids.

Keywords: European Larch, wood density, tracheid dimension, genetic correlations

INTRODUCTION

The relation between wood properties, wood density traits, annual ring width and the anatomical properties of wood: the size of tracheids falls within the scope of interest of scientists involved in the studies on silviculture and the selection of forest trees [5, 6, 16, 10, 8]. The impact of genetic factors on the development of wood density traits has been confirmed in literature. It allowed for the assumption that the relation between the size of anatomical elements of wood and wood properties also has a genetic background [2, 15, 14]. Due to the increasing interest in the wood of European larch as a fast-growing coniferous species, the analysis of genetic factors affecting the development of wood properties in trees growing in seed orchards may contribute to the improvement of procedures aiming at selecting reproductive materials adjusted to the expectations of particular consumers [13].

MATERIAL AND METHODS

Research material was based on the increment cores sampled from European larches (*Larix decidua* Mill.) growing in a seedling seed orchard established in 1985 in the Młynary Forest District, in the northern part of Poland. Wood density and tracheid dimensions measurements were carried out for 161 trees - the progeny of 8 plus trees. From each tree at the height of 1.3 m an increment core with the diameter of 5 mm was sampled, covering juvenile and mature wood. The increment cores were used for the determination of wood density traits. Short increment cores were also sampled, covering the 5 youngest annual rings - those samples were used for the determination of dimensions of tracheids in juvenile wood. Increment cores were cut lengthwise with a double blade circular saw in order to obtain parallel surfaces and a uniform thickness of wood samples in accordance with the wood density measurement procedure [9]. Another stage preceding the measurements of wood density was the extraction of resins from wood samples in distilled water [4]. The content of water in the samples was stabilised at the level of 5-15%. On the basis of a computer analysis of x-ray images a set of wood density traits and annual ring width were obtained for each annual ring [1]. Tracheid dimensions measurements: tracheid width, cell wall thickness, were preceded by maceration of wood samples in a 25% solution of hydrogen peroxide (H_2O_2) and acetic acid (CH_3COOH), at a temperature of 90-100° C for 20-24 hours [3]. Macerated wood was mechanically diluted in order to obtain a uniform solution. The dimensions of tracheids (tracheid diameter, cell wall thickness) were indicated using the Kajaani FiberLab 3.5 optical fiber analyzer [7].

$$AW = \frac{\sum n_i w_i}{\sum n_i} \; [\mu m]$$

$$ACWT = \frac{\sum n_i CWT_i}{\sum n_i} \; [\mu m]$$

where:
AW – average tracheid diameter,

$ACWT$ – average cell wall thickness,

n_i – fiber count in class I,

w_i – average fiber width in width class I,

CWT_i – average width in cell wall class I.

For each trait the variant components were calculated using the SAS 9.2 Pl VARCOMP procedure and the covariant components between the analysed traits were determined using the MANOVA formula [11]. Coefficients of genetic and phenotypic correlations were calculated using the following formulas [12]:

$$r_{G_{xy}} = \frac{Cov_{F_{xy}}}{\left(\sigma_{F_x}{}^2 \times \sigma_{F_y}{}^2\right)^{\frac{1}{2}}}$$

$$r_{P_{xy}} = \frac{\left(Cov_{F_{xy}} + Cov_{E_{xy}}\right)}{\left[\left(\sigma_{F_x}{}^2 + \sigma_{E_x}{}^2\right) \times \left(\sigma_{F_y}{}^2 + \sigma_{E_y}{}^2\right)\right]^{\frac{1}{2}}}$$

where:

$r_{G_{xy}}$ – genetic correlation,

$r_{P_{xy}}$ – phenotypic correlation,

$\sigma_{Fx}{}^2$ – family variance components for traits X and Y, respectively,

$\sigma_{Ex}{}^2$ – error variance components for traits X and Y, respectively,

Cov_{Fxy} – family covariance components for traits X and Y,

Cov_{Exy} – error covariance components for traits X and Y.

RESULTS

According to our expectations we observed a negative correlation between the width of an annual ring of juvenile wood and the width of tracheids (-0.18 and -0.25, respectively) (Fig. 1). A similar trend was observed in case of the correlation with the tracheid cell wall thickness (-0.24 and -0.30, respectively) (Fig. 2). Correlation between the width of tracheids, tracheid cell wall thickness and the proportion of earlywood was of negative nature, while the correlation with the proportion of latewood was positive (-0.44; -0.45; 0.29; 0.30, respectively). Correlation between the size of tracheids and wood density traits was very weak and only in case of the correlation with the earlywood density an explicit nature of the correlation was observed. In both cases - the correlation with the width of tracheids and with the cell wall thickness - the dependency was moderately negative (-0.29 and -0.49, respectively). Contrary to our expectations, the correlation between the wood density of an annual ring and the tracheid dimensions was not very strong. Only for the correlation between wood density and the width of tracheids a weak positive trend was observed (0.12).

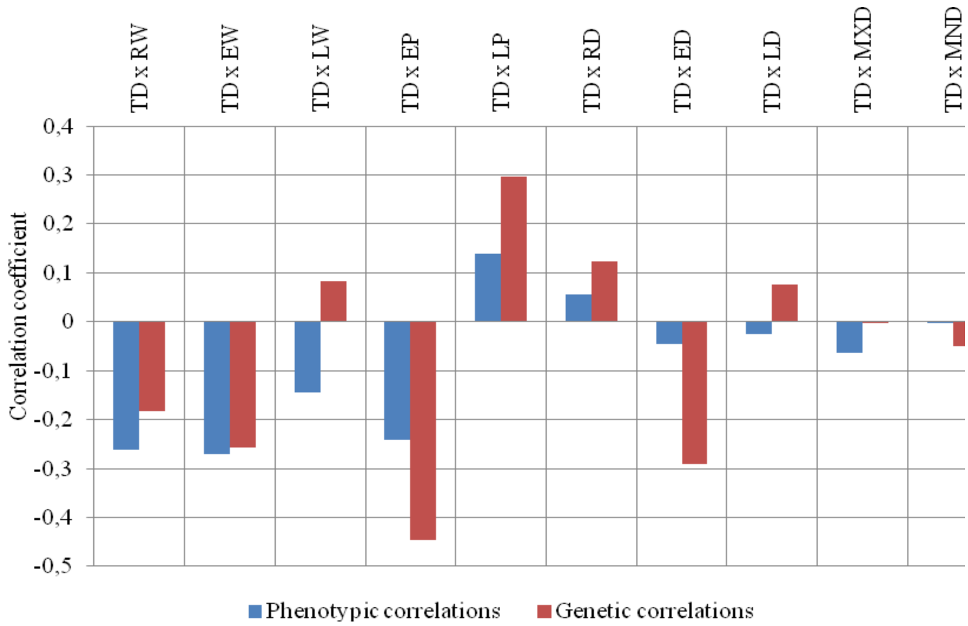

Fig 1 Genetic and phenotypic correlation between wood density components and tracheid diameter (TD). Ring width (RW), earlywood width (EW), latewood width (LP), earlywood percent (EP), latewood percent (LP), overall ring density (RD), earlywood density (ED), latewood density (LD), maximum wood density (MAX), minimum wood density (MIN).

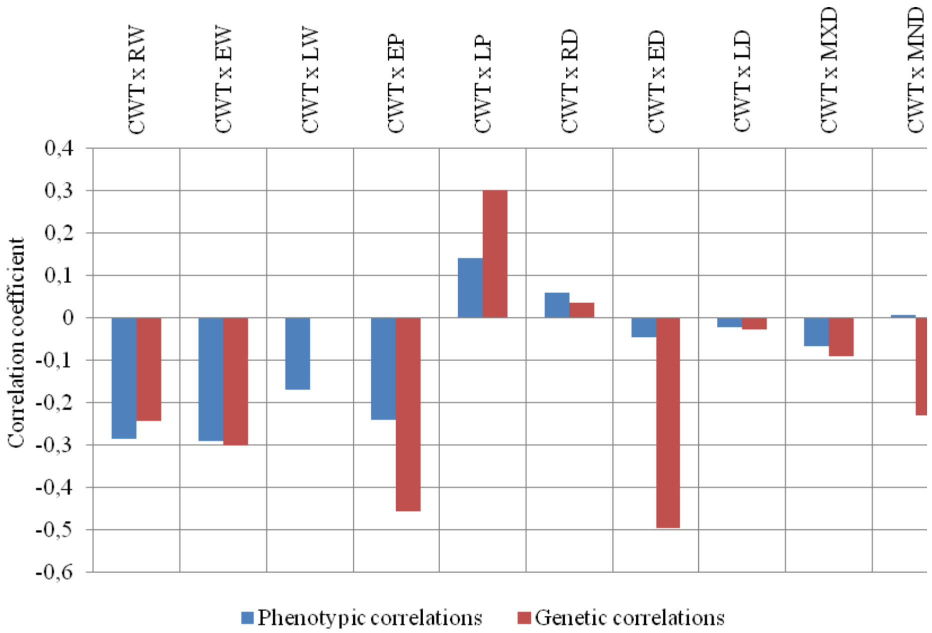

Fig 2 Genetic and phenotypic correlation between wood density components and tracheid diameter (TD). Ring width (RW), earlywood width (EW), latewood width (LP), earlywood percent (EP), latewood percent (LP), overall ring density (RD), earlywood density (ED), latewood density (LD), maximum wood density (MAX), minimum wood density (MIN).

CONCLUSIONS:

Presented results were only partly confirmed in research published by other authors. Hannrup et al. [5], when analysing the traits of Norway spruce also observed a negative genetic correlation between the width of tracheids and wood density for the entire annual ring and also a correlation with the density of earlywood and latewood. Those researchers also highlight a strong positive correlation between the tracheid cell wall thickness and the density of earlywood and latewood. Negative correlation between the width of tracheids and the density of wood was also observed for Maritime pine [10] and Scots pine [6]. On the other hand, Zubizaretta Gerendiain et al. [16] in studies on Norway spruce observed weak, positive phenotypic correlation between annual ring wood density and the tracheid cell wall thickness. Similar values of genetic correlation were obtained by Hennrup et al. [6] during their research on Scots pine. Presented results of studies on the relations between the traits of wood of the European larch in comparison to the recent knowledge on this subject indicate the supraspecies nature of genetic factors affecting the development of wood properties. It is still necessary to continue the studies on the relations between the technical traits of wood and the anatomical construction of its elements in terms of genetic factors.

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Streszczenie: *Uwarunkowania genetyczne gęstości drewna, wymiarów cewek i szerokości słoja rocznego – analiza korelacji genetycznych i fenotypowych u modrzewia europejskiego.* Dla 161 drzew modrzewia europejskiego w wieku 25 lat rosnących na plantacyjnej uprawie nasiennej w północnej Polsce określono współczynniki korelacji genotypowych i fenotypowych pomiędzy cechami gęstości drewna a wymiarami cewek. Cechy gęstości drewna określono z wykorzystaniem analizy zdjęć rentgenograficznych odpowiednio przygotowanych prób drewna. Wymiary cewek dla drewna młodocianego określono za pomocą optycznego analizatora włókien. Szerokość słoja rocznego i jego elementów: drewna wczesnego i późnego umiarkowanie, negatywnie korelowały zarówno z szerokością cewek jak i grubością ściany komórkowej. Natomiast dla gęstości drewna słoja i jego elementów (gęstość drewna wczesnego i gęstość drewna późnego) oraz wymiarów cewek nie zaobserwowano wyraźnych zależności. Jedynie gęstość drewna wczesnego negatywnie korelowała z wymiarami cewek.

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