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PHENOTYPIC VARIABILITY OF DOUGLAS FIR (*PSEUDOTSUGA MENZIESII* (MIRB.) FRANCO) IN BELARUS PLANTINGS

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Abstract

Finding ways to assess the productivity of exotic species under the new climatic conditions is an important part of the successful introduction of silvicultural practices. The purpose of this research is assessment of intra-population polymorphism in Douglas fir stands in terms of seasonal development, color of female strobili and anthers, and bark texture (structure). Concerning the seasonal development and phenology, the following phenotypes were distinguished: very early, early, middle, late and very late; according to the color of female strobili – green, greenish-brown and purple; according to the color of anthers – yellow, orange, purple and brown; and according to bark texture (structure) – deep fissured cork (coarse bark), middle fissured cork (transitional) and shallow fissured cork (plane bark) phenotype. Each of the plants was characterized by a highly individual phenotypic spectrum. The most informative and accessible for practical use were phenotypes on of bark structure: coarse bark phenotype – bark cork, light, in the form of massive plates of thickness greater than 5 cm with cavities, divided by deep fissures. At the age of 70–75 years the bark in the butt-log part gradually peels off and falls to a height of 2–3 m. A new bark is formed actively instead of the fallen one. Transitional phenotype – bark is relatively dense, thickness up to 4–5 cm, shaked, moderately deep fissures. There is a detachment of the bark at the root collar to a height of 0.7–1.0 m. Plane bark phenotype – bark is dense, thin, thickness up to 2–3 cm, small plates, cloven by shallow fissures, not exfoliate. Morphological polymorphism of Douglas fir under bark texture (structure), clearly expressed in the form of introduction populations, notably characterized by growth index. Trees of deep fissured cork (coarse bark) phenotype are considered as the most productive. At the age of 71, their average height is 30.8 m, average diameter – 42.7 cm. Trees of middle fissured cork (transitional) demonstrated lower height by 8 % and diameter by 20 %. Both phenotypes had a small degree of tapering and a well-developed crown. Trees of shallow fissured cork (plane bark) phenotype ranked below in height by 25 % and by 42 % in diameter and are characterized by higher values of variation coefficients. They form a canopy in the second planting as a regrowth. Thus, deep fissured cork (coarse bark) and middle fissured cork (transitional) phenotypes are the most promising for planting.

Key words: bark type, phenotype, productivity.

Introduction

Plant interpopulation and intrapopulation variability is the subject of numerous modern research reports (Leiblein-Wild and Tackenberg 2014, Sattarian et al. 2011). Special attention is given to polymorphism in coniferous species populations

(Martinez-Meier et al. 2011, Agundez et al. 1992, Turna and Güney 2009, Urbaniak et al. 2003, O'Reilly and Farmer 1991, Jianxun et al. 2003 Putenikhin et al. 2004, Kuzmina 2004, Vidyakin 2007, Barchenkov 2010). Experimental studies important for identifying stable diagnostic features, gaining new information about the species taxonomy and intraspecific diversity, revealing of the adaptive potential, as well as for the purpose of breeding and afforestation. Not only studies on natural populations, but also on plantations of introduced species, developing in new edaphic and climatic conditions in complete isolation from the mainland and under the influence of anthropogenic factors are particularly important.

Intraspecific variation of *Pseudotsuga menziesii* (Mirb.) Franco in forest plantations in Western Europe has been studied since the first half of 20th (Göhre 1958, Rohmeder and Schönbach 1959). Different forms of intraspecific variation of *Pseudotsuga menziesii* (Mirb.) Franco were identified in Russia by Schepotiev (1982), in Latvia by Pirags (1979), and in forest plantations in Ukraine by Kholyavko (1981). In Belarus, Shkutko (1970) was the first who drew the attention to polymorphic species, and later on Fedoruk (1980) performed a study on the cultivated dendroflora of the region.

The aim of the present research was to study phenotypic variability of *Pseudotsuga menziesii* in populations introduced to Belarus, to identify the most informative and accessible features allowing to assess the productivity of plantations.

Materials and Methods

Objects of study were pure and mixed plantations with on the participipation of *Pseudotsuga menziesii* (Table 1).

Continuous inventory of the stand was carried outin the area of plantations. Collection of materials was performed according to procedures generally accepted in forestry and forest inventory. Age of trees was estimated on refined wood cores, obtained with an increment borer. The study of phenotypic variability of traits in plantations was based on the method of phenes. Phenes are considered as discrete alternative variations of traits and were studied using methodological approaches of Zhivotovsky (1982) and Egorov (1997, 2001).

The most informative and clearly expressed trait in the introduced populations

Table 1. Characteristics of experimental plantationgs of *Pseudotsuga menziesii*.

Habitat (plantation composition)	Age, years	Average height, m	Average diameter, cm	Site index	Number of trunks, ha^{-1}	Standing timber volume, m^3/ha
State forest reserve (SFR) "Priluksky" sq. 66 alloc. 2; N53.79, E27.37 (70 % Douglas-fir; 20 % Larch; 10 % Spruce)	71	30.1	34.7	Ia	488 (total 677)	630 (total 820)
State Scientific Institution (SSI) "Central Botanical Garden of NAS of Belarus", the sector of North America sq. 91; N53.91, E27.62 (100 % Douglas-fir)	73	24.1	42.4	I	405	710

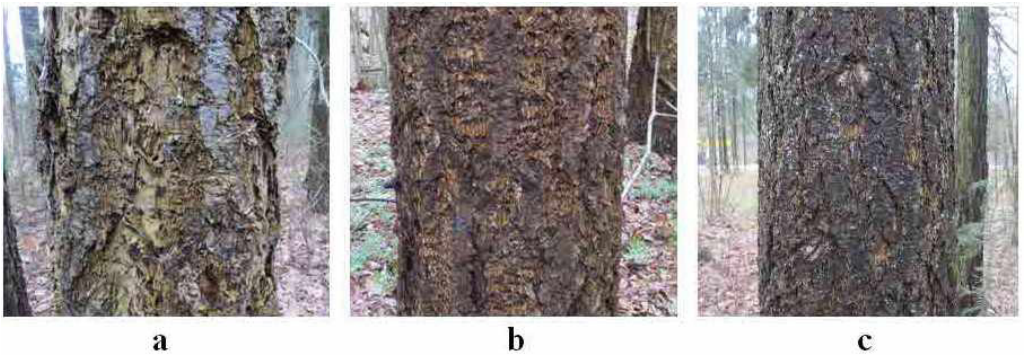

Fig. 1. Phenotypes of *Pseudotsuga menziesii* in bark structure.
Legend: a) coarse bark; b) transitional; c) plane bark.

was the morphological polymorphism in bark texture (structure). On this basis the trees in plantations were represented by three phenotypes: deep fissured cork (coarse bark), middle fissured cork (transitional) and shallow fissured cork (plane bark) (Fig. 1).

The coarse bark phenotype included bark cork, light, in the form of massive plates of thickness greater than 5 cm with cavities (Fig. 2), divided by deep fissures. At the age of 70–75 years the bark in the butt-log portion gradually peels off and falls to a height of 2–3 m. Replacing the fallen bark actively forms the new one (Fig. 3).

In the transitional phenotype, the bark is relatively dense, with a thickness up to 4–5 cm, shaked, with moderately deep fissures (Fig. 1b). There is a detachment of the bark at the root collar to a height of 0.7–1.0 m.

In the plane bark phenotype, the bark is dense, thin, with thickness up to 2–3 cm, small plates, cloven by shallow fissures, not exfoliate (Fig. 1c).

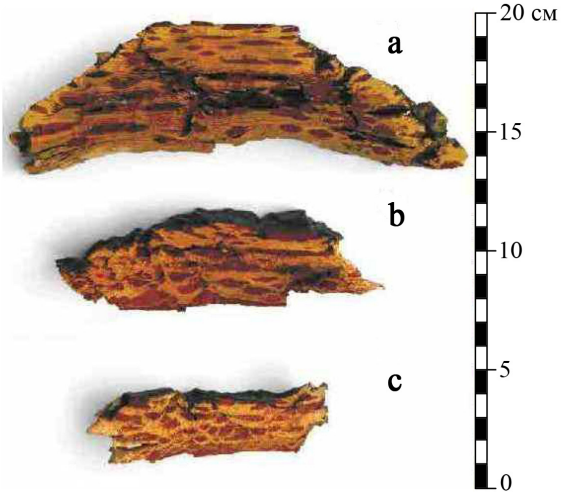

Fig. 2. Cross-section cut of bark plates of *Pseudotsuga menziesii* phenotypes.
Legend: a) coarse bark; b) transitional; c) plane bark.

Fig. 3. Type of trunk with coarse bark phenotype of *Pseudotsuga menziesii* before falling (a) and after falling (b) of the bark.

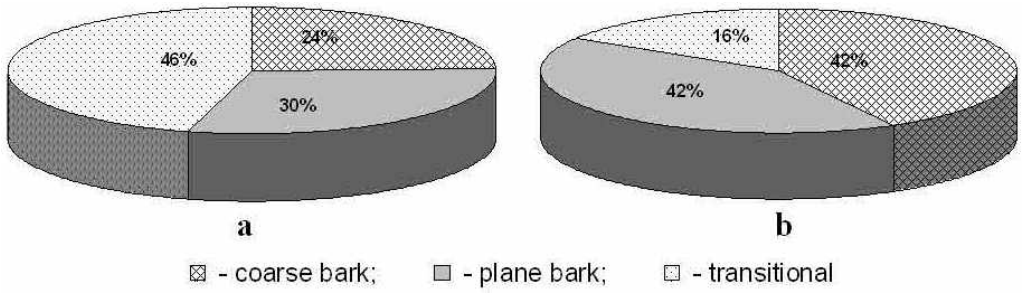

Fig. 4. Frequency of bark structure phtnotypes in the plantations *Pseudotsuga menziesii* .
Note: a) SFR "Priluksky"; b) SSI "Central Botanical Garden of NAS of Belarus".

Processing of experimental data was performed using ANOVA and standard methods of descriptive statistics. Significance of differences between samples was determined using U-Mann-Whitney test.

Results and Discussion

The results showed that intra-population polymorphism of *Pseudotsuga menziesii* was well expressed mostly in the seasonal development (distinguished very early, early, middle, late and very late), color of female strobili (green, greenish-brown and purple), color of anthers (yellow, orange, purple and brown), and bark texture (structure). There were other differences, but it wa's often quite difficult to take them into account due to the high density of plantations, making the assessment of their phenotypic structure difficult.

The frequency of the studied phenotypes in bark structure differed in the two studied plantations. In the mixed forest plantations in SFR "Priluksky" the middle fissured cork (transitional) phenotype prevaileds (46 %). In the pure plantation in SSI "Central Botanical Garden of NAS of Belarus" the deep fissured cork (coarse bark) and shallow fissured cork (plane bark) had the same frequency (42 %). Significant differences in frequency were observed also between the other phenotypes (Fig. 4).

According to Rohmeder and Schönbach 1959) the tree phenotype with deeply fissured bark is more susceptible to pathogenic fungus *Polyporus schweinitzii* Fr., causing stem rot. However, in studied plantations no infected trees were identified. At the same time, due to the development of a thick bark, this phenotype is more fire resistant and winter hardy (Kohnle et al. 2012). Plane bark *Pseudotsuga menziesii* differeds from the others in developing thinner branches, thus having better wood quality and being less prone to fungal diseases (Schepotiev 1982).

Identified morphological polymorphisms in bark texture (structure) was significantly related to the growth index of height and diameter (Table 2).

In accordance with the data, trees of deep fissured cork phenotype (coarse bark) are considered as the most productive. At the age of 71, their average height is up to 30.8 m, and average diameter of 42.7 cm. Trees of middle fissured cork (transitional) are second to the first one in average inventory indices: height by 8 % and diameter by 20 %. Overall, however, it is also a very promising, fast-growing,

phenotype. Some of its individuals are among the highest in the plantation, reaching at the age of 71 38.5–39.5 m. in height. Both phenotypes have a small degree of tapering and a well-developed crown.

Trees of the shallow, fissured cork phenotype (plane bark) expressed significantly lower values of height (by 25 %) and diameter (by 42 %) in comparison to deep fissured cork (coarse bark) phenotype. They were characterized by higher values of variation coefficients. These plants formed the second layer of the stands.

The relationship between the *Pseudotsuga menziesii* phenotypes in bark structure and height and diameter of the trees was confirmed by the results of variance analysis (Table 3).

Table 2. Variation in growth traits of *Pseudotsuga menziesii* bark phenotypes.

Phenotype	Age, years	Height, m		Diameter, cm	
		M ±*m*	min – max	*M* ± *m*	min – max
SFR "Priluksky"					
Coarse bark	71	30.8 ± 0.7 a	14.8 – 39.8	42.7 ± 1.5 a	16.4 – 67.0
Transitional		28.5 ± 0.7 a	12.1 – 39.5	35.6 ± 1.1 b	14.3 – 64.4
Plane bark		23.2 ± 0.8 b	11.4 – 38.2	24.7 ± 1.0 c	13.4 – 57.6
SSI "Central Botanical Garden of NAS of Belarus"					
Coarse bark	73	24.5 ± 0.2 a	20.7 – 27.0	45.0 ± 1.0 a	32.9 – 60.1
Transitional		23.6 ± 0.4 a	21.7 – 25.6	43.9 ± 1.7 a	32.7 – 52.7
Plane bark		24.0 ± 0.3 a	18.4 – 26.6	39.0 ± 1.1 b	22.1 – 49.8

Note: *M* – mean value, ±*m* – error of the mean; Means followed by the same letter within a column don't differ significantly at $P < 0.05$.

Table 3. Analysis of variance for testing the relationship between bark structure phenotypes and growth and traits of *Pseudotsuga menziesii*

Growth variable	Dispersion	*SS*	*df*	*MS*	*F*	*p*-level
Height	variants	1352.60	1	1352.60	35.35	7.3×10^{-9}
	balance	12014.47	314	38.26		($p < 0,05$)
	total	13367.08				
Diameter	variants	10159.64	1	10159.64	88.52	1.1×10^{-18}
	balance	36038.85	314	114.77		($p < 0,05$)
	total	46198.49				

Legend: *SS* – sum of squares, *df* – degrees of freedom, *MS* – mean square, *F*-value, *p*-value.

The calculation of power of influence factor (η^2) on studied characteristics of a tree trunk showed that for the height it amounts to $\eta^2_H = 0.101$ and for the diameter – $\eta^2_D = 0.220$. The significance of the corresponding values was confirmed by the calculated values of criterion $\chi^2_H = 31.92$ and $\chi^2_D = 69.52$ ($p \leq 0.05$).

Phenotypic variability of morphological characters in *Pseudotsuga menziesii*, taken with its various economically valuable characteristics can be used for breeding purposes (Cruz-Nicolás et al. 2011). In particular, the bark type may be an additional indicator for plus tree selection.

Conclusion

Plantations of *Pseudotsuga menziesii* remain highly polymorphic when cultivated in conditions of the Republic of Belarus. The most informative and accessible are bark structure phenotypes, which include deep fissured cork (coarse bark), middle

fissured cork (transitional) and shallow fissured cork (plane bark). Each of the plants is characterized by highly individual phenotypic spectrum.

Phenotypes of *Pseudotsuga menziesii* in bark texture (structure) crust differ in productivity, which allows to conclude that two of them (deep fissured cork (coarse bark) and moderately fissured cork (transitional) are the most promising for the establishment of forest plantations. Type of bark can also be a used as a marker in plus tree selection.

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