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The chemical composition of poplar wood in relation to the species and age of trees

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Abstract: *The chemical composition of poplar wood in relation to the species and age of trees.* The contents of the following substances: mineral substances, extractives, cellulose, lignin, holocellulose, in wood from fast-growing poplar species (*Populus deltoides* x *maximowiczii* and *Populus trichocarpa* Torr and A.Gray) aged 2.5, 3, 5 and 7 years were compared to the contents of the abovementioned substances in *Populus nigra* L. and *Populus alba* L. wood, aged about 30. According to other publications, the cellulose and lignin contents increase in parallel with the tree's age. On the other hand, the comparison of cellulose content in poplar wood showed that its content did not depend from the species of tree, age and growth environment. Whereas, the content of extractives in poplar wood was dependent from the species of tree, age and growth environment. The lignin content increased slightly as a tree age, but its content in 7-year-old wood was already similar to the level to be found in the wood at the age of about 30 years. About 30-year-old wood of *P. nigra* and *P. alba* contained less holocellulose as compared to its contents in *P. deltoides* x *maximowiczii* and *P. trichocarpa* wood, regardless of its age.

Keywords*:* poplar wood, mineral substances, extractives, cellulose, lignin, holocellulose

INTRODUCTION

The percentage of particular components in the structure of wood tissue depends on species of tree, environmental conditions of its growth, their determination method and other factors. According to species, also age of tree, among others, has an impact on chemical composition of wood. This impact is especially visible in coniferous species, while it varies among the deciduous ones.

Poplar (*Populus*) belongs to the Salicaceae family. About 30 of the fastest-growing (in our climate) tree species, form the *Populus* genus. The poplar wood is light, very soft, easily cleavable, glueable, easily accepts dyes and impregnants; in humid environment it is very prone to fungi-induced decomposition. The poplar wood is highly appreciated in cellulose and paper industry and is often used for food packaging in form of wood wool.

The particularly often used species are these fast-growing, such as *Populus deltoides* x *maximowiczii* or *Populus trichocarpa* Torr and A. Gray hybrides. These poplars have been investigated as regards the use of its biomass as an renewable energy sources, including raw material for bioethanol production (Antczak et al. 2016, Antczak et al. 2018, Antczak et al. 2019, Sannigrahi et al. 2010). During the abovementioned research, the lignocellulose biomass has been obtained from the 1, 2, 3, 5 and 7-year-old trees.

According to Prosiński and Surmiński (Prosiński, 1984), the contents of mineral substances, extractives and pentosans are higher in 1-year-old *Salix acutifolia* shoots by 30%, 31% and by 13% as compared to 3-year-old willow wood, while the contents of cellulose and lignin are lower by 10% and 15% respectively. On the other hand, the wood of 2-year-old sharp-leaf willow shoots contains 35% less mineral substances as compared to 1-year-old shoots and 8% as compared to 3-year-old shoots. Also, the wood of 2-year-old shoots contains 30% less extractives as compared to 1-year-old shoots and 3% less as compared to 3-

year-old shoots. The contents of cellulose and lignin in wood increase gradually in parallel with the *S. acutifolia* shoots' age, while pentosans content decreases (Prosiński 1984).

According to data provided by Waliszewska and Wiśniewska (2005), cellulose content in shrub willows depends on species. The wood of 1-year-old swedish willow (variety Orn. Valne) and *Salix americana* x *viminalis* are characterized by a higher cellulose content determined with the use of Seifert method by about 15% as compared to its content in basket willow wood and by 10% as compared to *S. americana* wood. Whereas, *S. viminalis* wood is characterised by 35% higher lignin content as compared to its content in *S. americana* x *viminalis* wood and by 13% as compared to *S. americana* and *S. viminalis* x *acutifolia* wood. The wood of 1-year-old *S. viminalis* shoots has also about 25% lower cellulose content as compared to 27-year-old *Salix caprea* L. in bottom part and by 17% lower at DBH (Diameter of Breast Height) (Waliszewska and Wiśniewska 2005, Waliszewska and Prądzyński 2005). The wood of 1-year-old *S. americana*, *S. viminalis* x *acutifolia* shoots has a comparable lignin content as compared to the wood in bottom part and at the DBH of 27-year-old *S. caprea*. On the other hand, the wood of 1-year-old *S. americana* x *viminalis* has 20% lower lignin content, and the wood of *S. viminalis x caprea* has 15% lower lignin content as compared to the 27-year-old *S. caprea*.

According to the data provided, the contents of particular components depends on the species and age of a tree. It is therefore purposeful to compare the chemical composition of fast-growing *P.deltoides* x *maximowiczii* and *P. trichocarpa* varieties with the wood of about 30-year-old black poplar and white poplar wood.

MATERIAL AND METHODS

The chemical composition of 2.5, 3, 5 and 7-year-old *Populus deltoides* x *maximowiczii* and *Populus trichocarpa* wood was compared to that of 30-year-old *Populus nigra* and *Populus alba* wood. The 2.5, 3, 5 and 7-year-old poplars were harvested from the experimental field of the Department of Genetics, Breeding and Biotechnology of Plants, Faculty of Horticulture and Landscape Architecture in Wolica and black poplar and white poplar from the areas of Wielkopolskie and Pomorskie voivodships.

Extractives in the *P. deltoides* x *maximowiczii* and *P. trichocarpa* were determined with the use of chloroform-ethanol mixture (93:7 w/w) and in the 30-year-old *Populus alba* and *Populus nigra* wood with the use of benzene-ethanol mixture (1:1 w/w). Cellulose was determined by Kürschner-Hoffer method according to Krutul (2002), lignin by Tappi method according to PN-92/P-50092 standard, and holocellulose by Tappi method according to Kaćik and Solar (1999) and Krutul (2002).

RESULTS AND DISCUSSION

The data concerning the wood components content of *P. deltoides* x *maximowiczii* and *P. trichocarpa* in 2.5, 3, 5 and 7-year-old wood and about 30-year-old *P. nigra* and *P. alba* wood are shown in Fig. 1-5.

According to the data shown in Fig. 1, mineral substances content in 7-year-old wood of *P. deltoides x maximowiczii* was about 40% lower than in 2.5, 3, 5-year-old wood, where the mineral substances content was the same. Also, mineral substances contents in the 7-year-old *P. deltoides* x *maximowiczii* wood was about 30% lower as compared to 30-year-old *P. nigra* wood, but 30% lower as compared to 30-year-old *P. alba* wood. Content of mineral substances in 7-year-old wood of *P. trichocarpa* was about 40% lower than in 2.5 and 5-year-old wood and over two times higher as compared to 3-year-old wood, while mineral substances content in 7-year-old wood of *P. trichocarpa* was similar to the contents of mineral substances in 30-year-old *P. alba* wood and two times lower than in *P. nigra* wood.

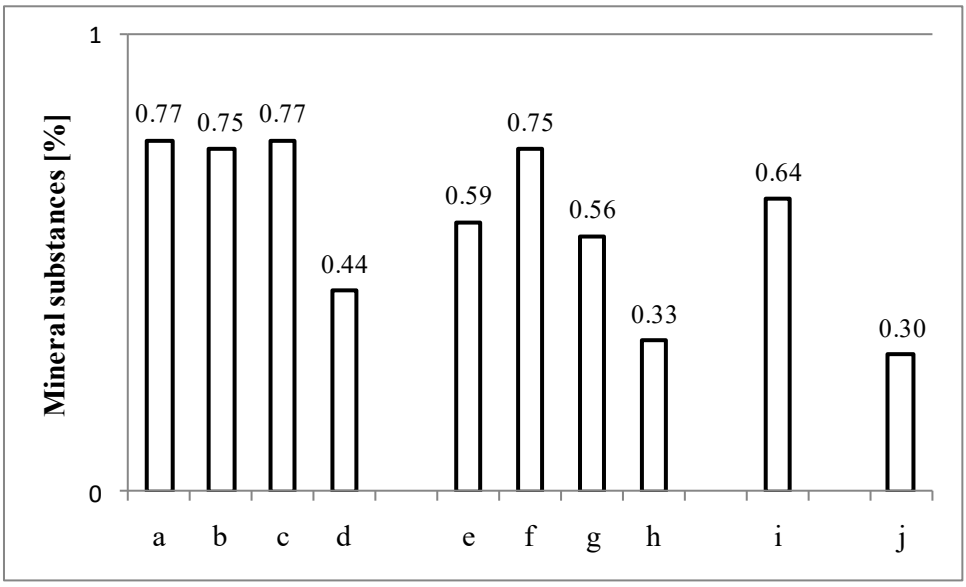

Figure 1. Mineral substances content in poplar wood: a – *Populus deltoides* x *maximowiczii*, 2.5-year-old; b – *P. deltoides* x *maximowiczii*, 3-year-old; c – *P. deltoides* x *maximowiczii*, 5-year-old; d – *P. deltoides* x *maximowiczii*, 7-year-old; e – *Populus trichocarpa* Torr and A. Gray, 2.5-year-old; f – *P. trichocarpa*, 3-year-old; g – *P. trichocarpa*, 5-year-old; h – *P. trichocarpa*, 7-year-old; i – *Populus nigra* L., about 30-year-old; j – *Populus alba* L., about 30-year-old.

The *P. trichocarpa* 2.5, 5, 7-year-old wood had lower mineral substances content as compared to *P. deltoides x maximowiczii* wood, while 3-year-old *P. trichocarpa* wood contained similar percentage of mineral substances as compared to *P. deltoides* x *maximowiczii* 2.5, 3, 5-year-old wood, as well as to 30-year-old *P. nigra* wood and amounts to 0.75% according to Bowersox et al. (1979) data, the content of mineral substnances in poplar hybrids' wood was 0.8%, which meant that 7-year-old *P. deltoides x maximowiczii* and *P. trichocarpa* wood contained two times less mineral substances. On the other hand, 2.5, 3 and 5-year-old *P. deltoides x maximowiczii* wood and 3-year-old *P. trichocarpa* contained similar percentage of the abovementioned substances to the present in the wood of poplar hybrids grown in the center of Pennsylvania.

As a summary, we can state that the wood of 7-year-old *P. deltoides* x *maximowiczii* and *P. trichocarpa* contained less mineral substances as compared to their contents in 2.5, 3 and 5-year-old wood and similar percentage to wood in 30-year-old *P. alba* (Fig. 1).

According to the data shown in Fig. 2, the content of extractives, where the chloroform-ethanol mixture (93:7 w/w) was used as a solvent, reached the levels between of 2.5% to 2% in *P. deltoides* x *maximowiczii* wood and 1.7% to 1.5% in *P. trichocarpa* wood.

In the about 30-year-old white poplar wood the content of extractives, where benzene-ethanol mixture (1:1 w/w) was used as a solvent, reached the levels of 5.7% and 1.8% in black poplar wood. According to data provided by Drożdżek (2011), the content of extractives in the about 30-year-old white poplar, where chloroform-ethanol mixture (93:7 w/w) was used as a solvent, reached the level of 3.3%. It can be stated, that about 30-year-old *P. alba* wood contained from 2 to 3 times less extractives as compared to their content in *P. deltoides* x *maximowiczii*, *P. trichocarpa* and *P. nigra* wood. According to Sannigrahi et al. (2010), it can be stated, that the extractives content in *Populus tremuloides* determined with the use of benzene-ethanol mixture, was 24%, 1.4% in *P. deltoides* and 2.7% in *P. trichocarpa* wood.

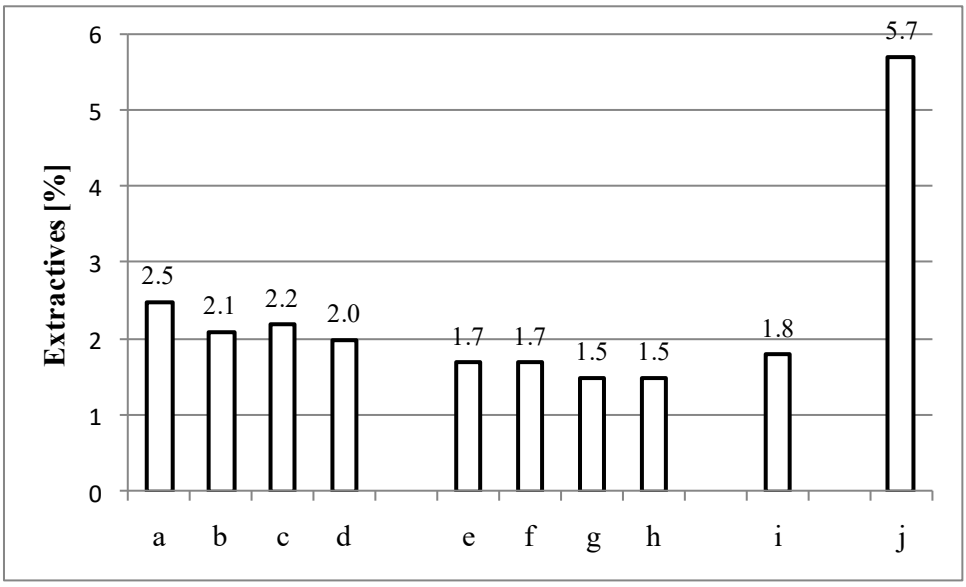

Figure 2. Extractives content in poplar wood: a – *Populus deltoides* x *maximowiczii*, 2.5-year-old; b – *P. deltoides* x *maximowiczii*, 3-year-old; c – *P. deltoides* x *maximowiczii*, 5-year-old; d – *P. deltoides* x *maximowiczii*, 7-year-old; e – *Populus trichocarpa* Torr and A. Gray, 2.5-year-old; f – *P. trichocarpa*, 3-year-old; g – *P. trichocarpa*, 5-year-old; h – *P. trichocarpa*, 7-year-old; i – *Populus nigra* L., about 30-year-old; j – *Populus alba* L., about 30-year-old.

According to data shown in Fig. 2, the wood of studied *P. deltoides* x *maximowiczii* poplar hybrids contained between 28% and 40% more extractives as compared to their contents in *P. deltoides* wood from poplars grown in North America. On the other hand, the studied *P. trichocarpa* wood contained 37% to 44% less extractives as compared to their contents in *P. trichocarpa* wood from North America (Sannigrahi et al. 2010).

On the basis of the data provided we may state that the extractives contents in the wood of studied poplar hybrids depends on the environment in which they grow, as well as on their variety.

Cellulose is a basic wood component, which determines its physical and mechanical properties. On the basis of the data shown in Fig. 3, we can state that the cellulose content in the poplar hybrids' wood in question as compared to its content in about 30-year-old *P. nigra* and *P. alba* wood was changing only within the range of 0.5% to 1.7%. A higher (by about 4%) cellulose content can be found in 5-year-old *P. deltoides* x *maximowiczii* and *P. trichocarpa* wood as compared to its content in 7-year-old *P. deltoides* x *maximowiczii* wood, whereas other differences are within the limits of determination error.

On the other hand, as a tree gets older, according to Prosiński (1984), the content of cellulose and lignin increases. For example, cellulose content in 9-year-old wood of alders was 39.6% and in 7-year-old – 45.5%. In the wood of 70-year-old alder, there was 13% more cellulose than in 9-year-old alder. Also, in the wood of 1-year-old *Salix acutifolia*, the cellulose content determined by Kürschner-Hoffer method amounted to 47.24% and in the wood of 3-year-old shoots to 54.76%.

In the studied *P. deltoides* x *maximowiczii* and *P. trichocarpa* as well as in about 30-year-old *P. alba* and *P. nigra* no interdependence between cellulose contents and tree's age were found.

According to the data presented in Fig. 4, *P. deltoides x maximowiczii* 7-year-old wood contained 9%, 12% and 8% more lignin respectively as compared to its contents in 2.5 3 and 5-year-old wood. The *P. trichocarpa* wood contained similar amounts of lignin, irrespectively from its age: from 19.9% in 2.5-year-old tree to 20.3% in 7-year-old tree (Fig.

4). The lignin content in about 30-year-old white poplar was 21.3% and was similar to its content in 7-year-old *P. deltoides* x *maximowiczii* wood (21.8%).

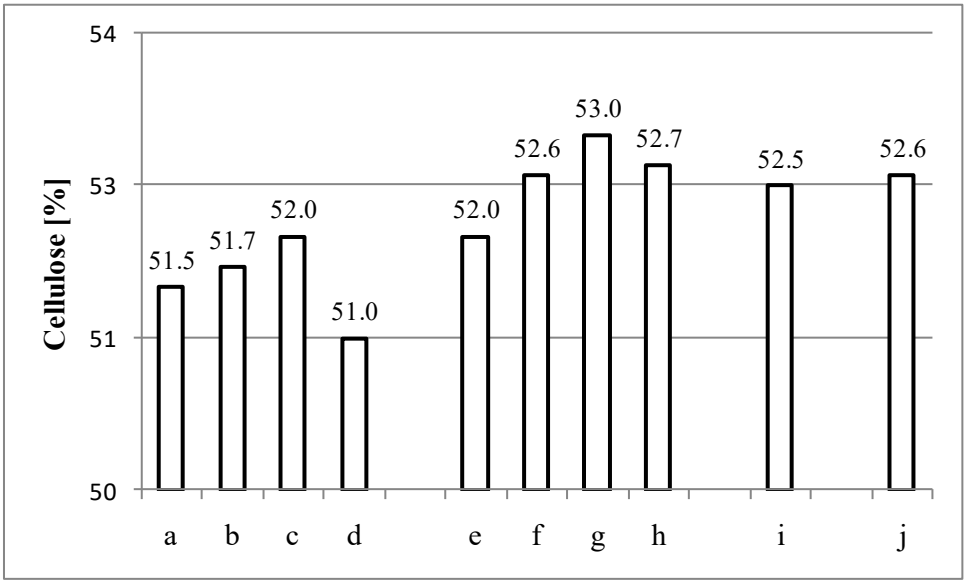

Figure 3. Cellulose content in poplar wood: a – *Populus deltoides* x *maximowiczii*, 2.5-year-old; b – *P. deltoides* x *maximowiczii*, 3-year-old; c – *P. deltoides* x *maximowiczii*, 5-year-old; d – *P. deltoides* x *maximowiczii*, 7-year-old; e – *Populus trichocarpa* Torr and A. Gray, 2.5-year-old; f – *P. trichocarpa*, 3-year-old; g – *P. trichocarpa*, 5-year-old; h – *P. trichocarpa*, 7-year-old; i – *Populus nigra* L., about 30-year-old; j – *Populus alba* L., about 30-year-old.

On the other hand, according to data obtained by Komorow (Prosiński 1984) 43-year-old poplar wood contained 20% and 9% more lignin respectively, as compared to its content in 17-year-old and 22-year-old poplar wood.

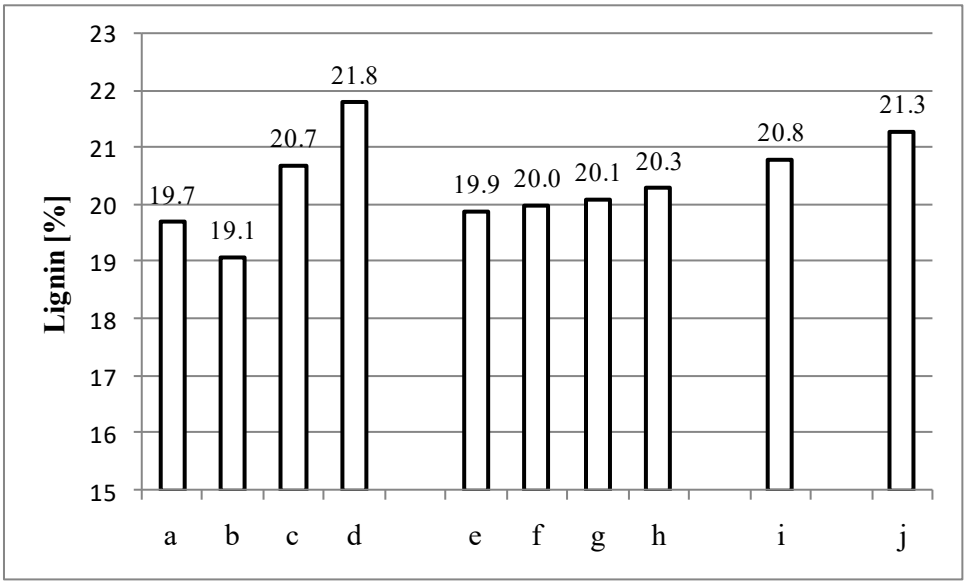

Figure 4. Lignin content in poplar wood: a – *Populus deltoides* x *maximowiczii*, 2.5-year-old; b – *P. deltoides* x *maximowiczii,* 3-year-old; c – *P. deltoides* x *maximowiczii*, 5-year-old; d – *P. deltoides* x *maximowiczii*, 7-year-old; e – *Populus trichocarpa* Torr and A. Gray, 2.5-year-old; f – *P. trichocarpa*, 3-year-old; g – *P. trichocarpa*, 5-year-old; h – *P. trichocarpa*, 7-year-old; i – *Populus nigra* L., about 30-year-old; j – *Populus alba* L., about 30-year-old.

The *P. trichocarpa* wood contained slightly higher percentage of holocellulose (from 2% to 4%) as compared to its content in *P. deltoides x maximowiczii* wood and higher, from 9% to 12% as compared to the *P. alba* and *P. nigra* respectively (Fig. 5).

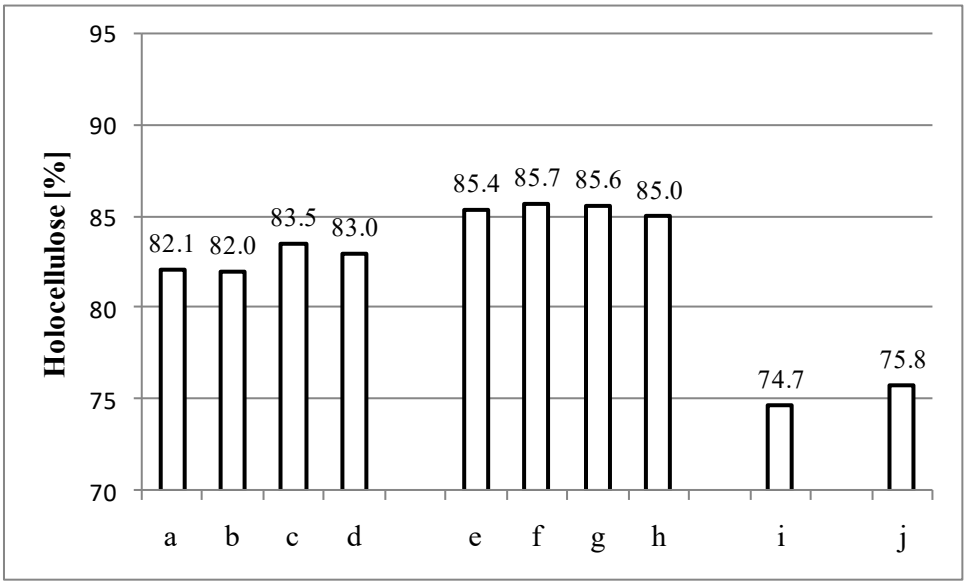

Figure 5. Holocellulose content in poplar wood: a – *Populus deltoides* x *maximowiczii*, 2.5-year-old; b – *P. deltoides* x *maximowiczii*, 3-year-old; c – *P. deltoides* x *maximowiczii*, 5-year-old; d – *P. deltoides* x *maximowiczii*, 7-year-old; e – *Populus trichocarpa* Torr and A. Gray, 2.5-year-old; f – *P. trichocarpa*, 3-year-old; g – *P. trichocarpa*, 5-year-old; h – *P. trichocarpa*, 7-year-old; i – *Populus nigra* L., about 30-year-old; j – *Populus alba* L., about 30-year-old.

It can be assumed that 30-year-old wood of the *P. alba* and *P. nigra* contained less holocellulose as compared to *P. deltoides* x *maximowiczii* and *P. trichocarpa*, regardless of their age.

CONCLUSIONS

The comparison between the chemical wood composition of *Populus deltoides* x *masimowiczii* and *Populus trichocarpa* 2.5, 3, 5 and 7-year-old and 30-year-old wood from *Populus nigra* and *Populus alba* showed that:

- the wood of 7-year-old *P. deltoides* x *maximowiczii* and *P. trichocarpa* contained less mineral substances as compared to their contents in 2.5, 3 and 5-year-old wood and similar percentage to wood in 30-year-old *P. alba*,
- the extractives content in poplar wood depended from its variety and growth environment,
- the cellulose content in poplar wood did not depend from its age, variety and growth environment,
- the lignin content in poplar wood increased slightly in parallel with age of trees, and 7-year-old *P. deltoides* x *maximowiczii* wood had a higher lignin content as compared to *P. trichocarpa* wood and was similar to the lignin content in 30-year-old *P. alba* wood,
- 30-year-old *P. nigra* and *P. alba* wood had a lower holocellulose content as compared to its contents in wood of *P. deltoides* x *maximowiczii* and *P. trichocarpa*, regardless of their age.

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Streszczenie: *Skład chemiczny drewna topoli w zależności od gatunku i wieku drzewa.* Porównano zawartość substancji mineralnych, ekstrakcyjnych, celulozy, ligniny, hemiceluloz w 2,5-letnim, 3-letnim, 5-letnim, 7-letnim drewnie szybko-rosnących gatunków topoli (*Populus deltoides* x *maximowiczii* i *Populus trichocarpa* Torr and A.Gray) z zawartością tych substancji w drewnie około 30-letnim topoli czarnej (*Populus nigra* L.) i topoli białej (*Populus alba* L.). Z danych literaturowych wynika, że wraz ze wzrostem wieku drzewa zwiększa się w nim zawartość celulozy i ligniny. Natomiast z porównania danych zawartości celulozy w drewnie topoli otrzymanych w tej pracy, okazało się, że zawartość celulozy nie zależała od gatunku, wieku i środowiska wzrostu drzewa. Z kolei zawartość substancji ekstrakcyjnych w drewnie topoli była zależna od gatunku, wieku i środowiska wzrostu drzewa. Zawartość ligniny nieznacznie zwiększała się w drewnie topól wraz z ich wiekiem, ale już w drewnie 7-letnim jej zawartość była zbliżona do zawartości w drewnie około 30-letnim. Drewno około 30-letnie topoli czarnej i białej charakteryzowało się mniejszą zawartością holocelulozy w odniesieniu do jej zawartości w drewnie *P. deltoides* x *maximowiczii* i *P. trichocarpa*, niezależnie od ich wieku.

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