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ECOPHYSIOLOGICAL PROPERTIES OF WHITE AND CANADIAN POPLAR IN HABITATS WITH VARIOUS WATER REGIMES

Abstract: In this paper are presented the analyzes of some morphometric properties, leaves area stomata density and the intensity of leaves transpiration of white poplar, *Populus alba* L. and canadian poplar, *Populus x canadensis* Moench 'I 214' in populations at (1) flooded (wet) and (2) unflooded (dry) habitats on the Ada Ciganlija river island during the growing season. Six trees of each species from both habitats were selected, with similar height, age and physiological condition. The morphometric analysis of the analysed poplar species show that the type of habitat did not influence tree height and trunk as well as the leaves area. However, crown width and trunk diameter were greater in the wetter habitat. It was found that the intensity of transpiration of *Populus x canadensis* 'I 214' trees had higher average values (0,73 $gH_2Odm^{-2}h^{-1}$) than white poplar (0,68 $gH_2Odm^{-2}h^{-1}$). Transpiration of both taxa was more intensive on the drier than on the flooded habitats. By analyzing the number and size of stomata on leaves of the investigated *Populus x canadensis* 'I 214' trees, it was found that stomata are more numerous but of smaller size on the leaves from drier habitats. It could be concluded that both species could have impact on microclimate conditions by increasing air moisture content and decreasing air temperature but Canadian comparing to white poplar, slightly greater.

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Increasing air temperature is a consequence of evident global climate change. Through transpiration plants reduce summer air temperature indirectly, by increasing its relative humidity.

Key words: transpiration, stomata, leaf area, *Populus alba*, *Populus x canadensis* 'I 214', microclimate

ЕКОФИЗИОЛОШКА СВОЈСТВА БЕЛЕ И КАНАДСКЕ ТОПОЛЕ НА СТАНИШТИМА СА РАЗЛИЧИТИМ РЕЖИМОМ ВОДЕ

Извод: Овај рад анализира интензитет транспирације листова, густину стома и нека морфометријска својства беле тополе (*Populus alba* L.) и канадске тополе (*Populus x canadensis* Moench 'I 214' у популацијама на стаништима (1) влажно (плављено) и (2) суво (неплављено) на Ади Циганлији током вегетације. Издвојено је по шест стабала сваког таксона на оба станишта, сличне висине, старости и физиолошке виталности. Морфометријска анализа оба таксона топола показала је да тип станишта није утицао на укупну висину стабала и дебла као и на површину листа, док су ширина круне и пречник дебла били већи на влажнијем станишту. Утврђено је да је интензитет транспирације канадске тополе имао веће просечне вредности (0,73 g $H_2Odm^{-2}h^{-1}$) него код беле тополе (0,68 g$H_2Odm^{-2}h^{-1}$). Транспирација оба таксона била је интензивнија на сувљем него на влажнијем, више плављеном станишту. Анализом броја стома на испитиваним листовима канадске тополе, утврђено је да су стоме бројније на листовима индивидуа са сувљег станишта с тим што је уочено да су мањих димензија.

Могло би се закључити да оба истраживана таксона потенцијално могу имати знатан утицај на микроклиматске услове повећањем влажности и смањењем температуре ваздуха, с тим што нешто већи утицај имају стабла канадске тополе. Повећање температуре ваздуха је последица присутних глобалних климатских промена. Утицај вегетације на микроклиму, нарочито у урбаним срединама, значајан је чинилац у ублажавању последица овог загревања.

Кључне речи: транспирација, стоме, лисна површина, *Populus alba, Populus x canadensis* 'I 214', микроклима

1. INTRODUCTION

Predictions of future changes in climate are uncertain, but it is very likely that global warming will be accelerated by continued and increasing emissions of CO_2. Widespread changes in extreme temperatures have been observed over the last 50 years. Cold days, cold nights and frost have become less frequent, while hot days, hot nights, and heat waves have become more frequent.

Policy makers are seriously concerned with the fact that human-induced climate change is causing increasing risks of floods and droughts, and they need to be able to identify areas where these will occur. The risk of landslides and fires is also influenced by the type of vegetation present in any particular area (IPCC, 2007). Increases in atmospheric carbon dioxide influence higher photosynthetic rates and increased plant water-use efficiency (Nobel, 2005). Some authors (Wullschleger and Norby 2001, Wullschleger *et al.* 2002) warn that this could have very bad consequences on stand-level water relations.

The influence of vegetation on microclimate, especially in urban areas, is avery important factor in alleviating the consequences of this warming. The most important physiological plant process, transpiration, is a major consumer of solar energy on the Earth. Plants through transpiration mitigate summer air temperature indirectly, by increasing its relative humidity. If it is known that the surface of leaves of woody plants can be an average of several tens of times larger than the area of land on which they grow, it is clear that the air in the surrounding area has higher moisture content than the areas with no vegetation. A single isolated tree can lose 200-400 liters of water per day. For every kg of tree dry matter production several hundred kilograms of water are necessary (Kozlowski and Pallardy, 1997) .

Transpiration is the process of releasing the water from living plants and can be conducted through open stoma, cuticle, and periderm lenticels. The driving force behind this process is lower water potential of plants in relation to land and higher water potential in relation to the atmosphere. Plants use this gradient to transport water from the soil through the plant and then pay to the atmosphere without their own energy consumption. Plants have an efficient system for regulating the water regime that is strongly influenced by external factors, especially the intensity of solar radiation. Specifically, photosynthesis uses only 0.5-2% of energy that reaches the leaves, and 96-97% is spent on the process of transpiration and heat transfer depending on the type and structure of leaves.

Stomata density varies according to plant age and is directly influenced by environmental conditions. However, such characteristic was positively related to CO_2 assimilation (Abrams *et al.*, 1994), due to the positive relation between stomata density, gas exchanges (Araus, 1986) and greater stomata conductance (Boardman, 1977).

Stomata are among the most important physiological features of the body of a tree (Gravano *et al.*, 2003). Their characteristics can help determine the nature of physiological processes, water regime and photosynthesis in a specific plant. Plants with more stomata per unit area have more transpiration intensity and photosynthetic production. Generally, a tree with few stomata per unit of leaf surface tends to have large stomata. Kozlowski and Pallardy (1997) reported the variations in the stomata size and frequency among species and genotypes. *Populus maximowiczii* A.Henry x *P. nigra* L, *Acer negundo* L. and *A. saccharium* L. had many small stomata and *Populus deltoides* W.Bartram, *P. nigra* L., and *Ginkgo biloba* L. had few but large ones.

Populus alba L. inhabits a habitat rich in moisture and light, most commonly by rivers, lakes and canals. It is tolerant to slightly acidic or salty soils. It has a very rapid growth and can reach a height of 40 *m* and a crown width of 12–15 *m*. Formed leaves are simple and dimorphic, on the long shoots they are ovoid and lobular (3-5 lobes) whereas thez are ovate on short shoots. The length of the leaves is from 4 - 7 *cm*, and on the edges they are coarse and blunt toothed. The underside of the leaf is covered with white hair and the face is dark green, which makes it an effective ornamental tree.

Populus x canadensis ‘I 214’ was developed by crossing European and American black poplars. The trunk is quite right, well established and growing in whorls. It usually has better technical characteristics than the parents and it is therefore cultivated. The crown of the poplar is narrow and half-pyramidal. The leaves are dark green, slightly leathery and glossy, serrated. It is favorable for planting in urban areas because of its resistance to harmful gases. The best-known varieties and clones are : ‘Serotina’, ‘Robusta’, ‘Regenerata’, ‘Marilandica’, ‘I 214’, and ‘I 154’.

Trees of Canadian and white poplar are very numerous in the area of Ada Ciganlija river island. The share of white poplar is 57,8%, while clone I 214 participates with 18.2% in the total covered surface *(Posebne osnove gazdovanja šumama za G.J. „Ada Ciganlija”*, 2004.

This paper analyzes the intensity of leaves transpiration, leaves area and stomata density of *Populus alba* and *Populus x canadensis* ‘I 214’ in populations of (1) flooded (wet) and (2) unflooded (dry) habitats on the river island Ada Ciganlija in the Belgrade area during the growing season 2011. This kind of investigation can be useful in future plans of tree planting because poplars are the most efficient in water absorbing and they influence the air temperature and microclimate conditions.

2. STUDY SITE, MATERIAL AND METHODS

2.1. Environmental conditions and vegetation

The Sava River undoubtedly had the most influence on the emergence and evolution of the Ada Ciganlija lake island: the regime change and the annual flooding of the level of maximum and minimum water level is a crucial influence on the properties of geological materials and profiles, the origin and evolution of ground and relief formations, the maintenance of specific micro-climate and the evolution, structure and properties of vegetation.

The geological structure of the soil are powerful tertiary layers of clay which are deposited in Quaternary sand, gravel, and their different mixtures are shifting toward approaching the surface of the muddy sands, loess and clay. Soil type is in a wide range of very wet alluvial pararendzine and its transition to clay soils over moderately moist alluvial pararendzine.

The area is characterized by temperate continental climate with the mean temperature in the three summer months that is higher than 20ºC, mean duration of the frost-free period is from 180 to 215 days, average rainfall is 691 *mm*, the minimum is in February and September, a maximum in May and in June, while during the growing season (March-September) 434 mm falls, which is 60% of annual precipitation. (*Posebne osnove gazdovanja šumama za G.J. Ada Ciganlija*, 2004).

The natural vegetation of Ada Ciganlija is quite diverse. At the lowest positions occurs the *Saliceto Populetum* Raj. community, which is close to the shore of the river, providing the stability of the surface compared to the negative effects of flooding. At a higher altitude there are communities *Populetum nigrae* Knapp. Community *Populetum albo – nigrae* Slav. covers the most areas where there are populations of gray poplar trees. A significant part of the depression is in habitats with elm and ash. The dominant species is the white poplar, which participates with 57.8% of the total volume. It builds pure and mixed populations. A significant portion of these stands is of good quality, high productivity and secondary health conditions. Populations of white poplar trees are about 62 years old. The volumetric representation, the Canadian poplar clone I 214 with 18.3% of the total volume management unit, elm with 6.1%, ash 7.9% and oak 3.5%. Other species, such as white willow, silver linden, aspen, birch, white ash, maple tree, and the tree of heaven are present together with 16.4% (*Posebne osnove gazdovanja šumama za G.J. Ada Ciganlija,* 2004).

2.2. Plant material

Leaf samples were collected from twelve poplar trees of both poplar species, approximate age, height, diameter and physiological vitality, three times during the growing season (May, June, and September). Tree height was measured by laser altimeter Tru Pulse and trunk diameter by millimeter diameter.

Out of six white poplar trees and six Canadian poplar clones I-214, three are on the moister habitat, often subject to flooding, while the other three are located in a more dry and drain position. The leaves that were used for this survey were taken from the lower third of the crown and from north side position. The research was carried out during the vegetative growth period when leaves were completely developed.

2.3. Transpiration intensity, leaf area and stomata density determination

The transpiration intensity, mass transpired water per unit leaf area per unit time ($gH_2Odm^{-2}h^{-1}$) was determined in the laboratory by the gravimetric method. Samples of cut off leaf tops were immersed in water with paraffin on the surface to prevent evaporation. Leaf area was determined by the gravimetric method. Transpiration intensity was calculated and expressed in $g\ H_2Odm^{-2}h^{-1}$.

Stomata density was analyzed on the upper side (abaxial epidermis) and lower side (adaxial epidermis) of the leaf in six selected trees of Canadian poplar from both sites (dry and wet). The analysis was done on the fully developed, vital leaves. Samples of epidermal tissue were taken from the middle part of the plant and the middle part of leave blade near the main vein. Three samples of every leaf were taken for making permanent preparations. Determination of the number of stomata per mm^2 was estimated using light microscopy with ocular scale and stage micrometer scale. The mean value of these three calculations was considered mean value for a plant and mean value for 6 plants, as a mean value for a population.

2.4. Statistics

All data were processed in the statistical analysis of data STATGRAPHIC. The conclusions were made on the basis of the analysis of variance (ANOVA) and LSD test was used to determine significant differences among the mean values of the treatments ($p<0.05$).

3. RESULTS

3.1. Poplar trees morphometric analysis

Table 1. White and Canadian poplar trees morphometric properties mean values on wet and dry sites on Ada Ciganlija

Табела 1. Морфометријска својства беле и еурамеричке тополе на влажном и сувом станишту Аде Циганлије (средње вредности)

Tree species /site type Врста / тип станишта	**Total tree height (*m*) Висина стабла (*m*)**	**SE**	**Trunk height clear of branches (*m*) Висина дебла без грана (*m*)**	**SE**	**Trunk diameter at breast height (*m*) Пречник стабла на прсној висини (*m*)**	**SE**	**Crown width (*m*) Ширина круне (*m*)**	**SE**
White poplar – wet site Бела топола – влажно ст.	15.67 b	±0.882	4.50 a	±0.289	2.83 a	±0.203	16.17 a	±0.328
White poplar – dry site Бела топола – суво ст.	16.33 b	±0.667	4.67 a	±0.333	1.73 b	±0.233	13.27 c	±0.393
Canadian poplar – wet site Канадска топола -влажно ст.	18.00 ab	±1.527	5.33 a	±0.333	2.93 a	±0.329	15.67 a	±0.333
Canadian poplar – dry site Канадска топола -суво ст.	19.67 a	±0.333	4.33 a	±0.333	2.43 ab	±0.120	14.57 b	±0.233

Legend / Легенда: Means followed by same letters are not significantly different at $p<0.05$ / Средње вредности означене истим словима се сигнификантно не разликују на нивоу $p<0.05$

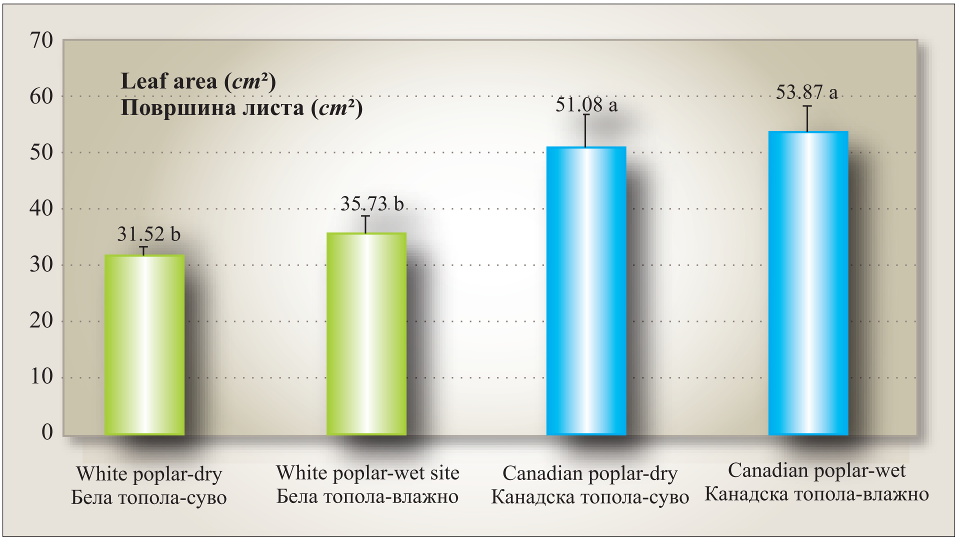

Diagram 1. White poplar and Canadian poplar leaf area mean values on wet and dry site on Ada Ciganlija. Means followed by the same letters are not significantly different at $p<0.05$

Графикон 1. Површина листа беле и канадске тополе (cm ^{2}) на влажном и сувом станишту на Ади Циганлији (средње вредности). Средње вредности означене истим словима се сигнификантно не разликују на нивоу $p<0.05$

The analysis of white poplar and Canadian poplar trees in both habitats indicates that trees in the dry habitat are higher (16.33 *m*; 19.67 *m*, respectively), but not at a significant level. The larger diameter at breast height was noticed in both poplar species in wet sites (2.83 *m*; 2.93 *m*, respectively), but a significantly lower value was found in white poplar in the dry site (1.73 *m*). Trunk height clear of branches did not show significant differences between the species in both sites. Crown width was greater in the wet site for both species (Table 1). Crown heigt was calculated as the total tree height - trunk height clear of branches. The presence of rot was observed on the open trunk and thicker branches of the most of trees as well as phytopathological disease and entomological damage. There are some dry branches in lower parts of the crowns. The presence of semi-parasite plant *Viscum album* L was also noticeable.

3.2. Leaf area

Data on Graph 1. show that site type does not significantly influence the leaf area in both poplar species. White poplar trees have lower value (average on both sites 33,62 cm^2) than Canadian poplar trees (average on both sites 52.47 cm^2) .

3.3. Transpiration intensity

The intensity of transpiration in Canadian poplar on the wet habitat was from 0.28 to 1.20, while on dry habitat from 0.52 to 1.93 in $gH_2Odm^{-2}h^{-1}$. The intensity of transpiration in white poplar on the wet habitat ranges from 0.15 to 1 g $H_2Odm^{-2}h^{-1}$ and on the dry habitat from 0.50 to 1.96 g$H_2Odm^{-2}h^{-1}$ (Graph. 2).

It can be concluded that the average values of transpiration intensity in Canadian poplar and white poplar trees on dry sites were significantly ($p<0.05$) higher (0.96; 0.93 g $H_2Odm^{-2}h^{-1}$, respectively) than in the wet habitat (0.50; 0.43 g $H_2Odm^{-2}h^{-1}$, respectively).

The average intensity of transpiration in Canadian poplar is higher than in the white poplar, but not statistically significant. The lowest transpiration rates were found in white poplar in the wet site (0.43 g $H_2Odm^{-2}h^{-1}$) (Graph. 2).

3.4. Stomata density in Canadian poplar

Table 2 shows the number of stomata on the upper and lower leaf epidermis in the Canadian poplar tree from two habitats. It a significantly ($p<0.05$) higher number of stomata was observed in the dry site (52; 42.67) than in the wet site (40.33; 27).

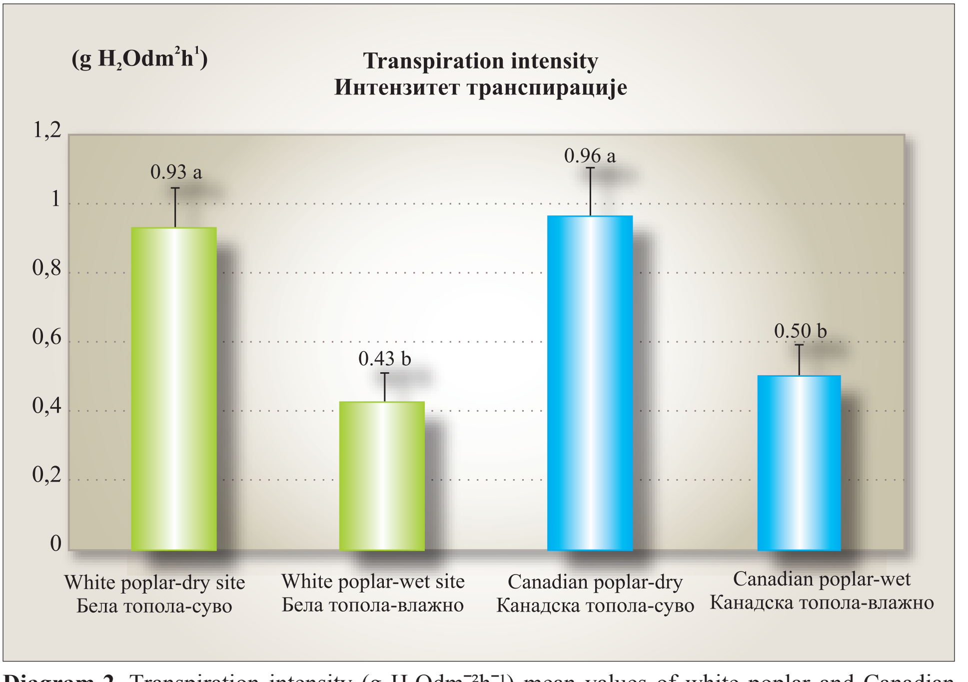

Diagram 2. Transpiration intensity (g $H_2Odm^{-2}h^{-1}$) mean values of white poplar and Canadian poplar in wet and dry sites on the Ada Ciganlija locality. Means followed by the same letters are not significantly different at $p<0.05$

Графикон 2. Интензитет транспирације беле и канадске тополе (g $H_2Odm^{-2}h^{-1}$) на влажном и сувом станишту на Ади Циганлији (средње вредности). Вредности означене истим словима се сигнификантно не разликују на нивоу $p<0.05$

Table 2. Trees stomata density mean values in the wet and dry sites on Ada Ciganlija
Табела 2. Густина стома канадске тополе на влажном и сувом станишту Аде Циганлије (средње вредности)

Tree species /site type Врста / тип станишта	**Stomata density - upper epidermis: No. of stomata per mm^2 Густина стома – горњи епидермис: број стома на mm^2**	**SE**	**Stomata density - lower epidermis: No. of stomata per mm^2 Густина стома – доњи епидермис: број стома на mm^2**	**SE**
Canadian poplar – wet site Канадска топола -влажно станиш.	52.00 a	±7.572	42.67 a	±4.055
Canadian poplar – dry site Канадска топола -суво станиште	40.33 b	±1.453	27.00 b	±4.041

Legend / Легенда: Means followed by same letters are not significantly different at $p<0.05$ / Средње вредности означене истим словима се сигнификантно не разликују на нивоу $p<0.05$

4. DISCUSSION

Morphometric parameters (Table 1) show that Canadian poplar trees have a higher volume of crown (average height 14.01 *m* and width 15.12 *m*) than *Populus alba* (average height 11.47 *m* and width 14.72 *m*).

Leaf area and transpiration influence on higher photosynthetic efficiency and biomass production (Djukić et Djunisijević, 2002).

According to the comparative analysis of the intensity of transpiration of Canadian and white poplar in both sites, it can be concluded that the values of transpiration intensity of Canadian poplar are higher than the values of white poplar but not at a significant level. The reason for the higher transpiration intensity of Canadian poplar might be a greater leaf area, longer leaf petal, great stomata density and absence of trichoma on leaves.

In our research, the leaf area in both poplar species did not differ significantly in the dry and wet sites, which means that the environmental factors did not influence the leaf area significantly. White poplar trees have lower values of leaves area than Canadian poplar trees.

Leaf area index and stomata conductance determine the canopy conductance. However, in high radiation shorter plants and trees with large leaves are less well coupled to the atmosphere because aerodynamic conductance is small. In these communities, if transpiration did not continue at an adequate rate, high radiation loads would quickly overheat the foliage, unless the amount of radiation intercepted can be reduced by wilting or leaf curling (Beerling *et al.* 2001). Leaf area and transpiration can be increased by irrigation and fertilization. It was reported that in *Populus deltoids*

W.Bartram trees irrigation and fertilization increased the transpiration by 66% and 90%, respectively and also the leaf area index from an average 1.16 in control stands to 1.45 (Samuelson *et al*., 2007).

Stomata analysis can help a better understanding of physiological processes, water regime and photosynthesis. The number, size, shape and arrangement of stomata are influenced by environmental factors such as the humidity of habitats, mineral nutrition, temperature, light, and other. Stomata are significant because they represent the openings through which the plant receives carbon dioxide, which is necessary for carrying out the process of photosynthesis, releases water and oxygen (Djukic *et al.* 2011). Thus, the analysis of stomata of beech on Mt. Kopaonik determined that when the stoma are at a higher altitude, the more arid habitats are smaller and higher density than those in the forest community at a lower altitude (Djukic et Djunisijević, 2002).

Stomata density varies according to plant age and is directly influenced by environmental conditions (Justo, 2005). However, such characteristic was positively related to CO_2 assimilation (Abrams *et al.,* 1994), due to the positive relation between stomata density and gas exchanges (Araus, 1986) and greater stomata conductance (Boardman, 1977).

On the basis of the footprints of stomata on the leaves of Canadian poplar, it was found that trees in the wet habitat have lower stomata density than in the dry site. This confirms data that the trees in drier positions transpire more, because stomata sizes are greater and also these trees probably have much more developed root systems. The role of roots proved to be crucial for the intensity of transpiration. It is assumed that the roots of poplars in the wet habitat are probably less developed due to large amounts of water in the shallow zones of the soil (Pallardy, 2007). Poplars in the drier habitat develop a stronger and deeper root in order to provide sufficient moisture from deeper soil layers. The larger the root in relation to leaf area, transpiration intensity is increased (Pallardy, 2007).

Various types of vegetation and their differences in sun energy use, aerodynamic conductance and water use efficiency interact with the local climate and mitigate the negative consequences.

This research could contribute to the identification of physiological principles that can be applied to attributes of local vegetation.

The results emphasize the need for further investigation which is significant for poplar selection under the conditions of the changed climate and water regimen in the soil.

5. CONCLUSION

The morphometric analysis of both poplar tree taxa species has shown that the type of habitat did not influence the tree and trunk heights and the leaves area. However, crown width and trunk diameter were greater in the wet habitat.

The transpiration of both species was more intensive in the drier than in the flooded habitat. By analyzing the number and size of stomata on the leaves of the investigated Canadian poplar trees, it was observed that stomata are more numerous but of smaller size on the leaves from drier habitats.

It was found that the intensity of transpiration of Canadian poplar trees had higher, but not significantly higher, average values (0,730 $gH_2Odm^{-2}h^{-1}$) than white poplar (0,385 $gH_2Odm^{-2}h^{-1}$).

It can be concluded that Canadian poplar and white poplar, may have an impact on microclimate conditions by absorbing ground water and increasing air moisture content. Canadian poplar can be recommended for air temperature reduction because of higher crown volume, greater leaf area, longer leaf petal, great stomata density and greater transpiration intensity in both sites.

The results emphasize the need for further investigation which is significant for poplar selection under the conditions of changed water regimen in the soil.

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ЕКОФИЗИОЛОШКА СВОЈСТВА БЕЛЕ И КАНАДСКЕ ТОПОЛЕ НА СТАНИШТИМА СА РАЗЛИЧИТИМ РЕЖИМОМ ВОДЕ

Резиме

Најважнији физиолошки процес у биљкама, транспирација, је велики потрошач сунчеве енергије на Земљи. Кроз одавање воде из својих органа биљке смањују летњу температуру ваздуха индиректно, повећавајући релативну влажност ваздуха. Познато је да укупна површина листова дрвенастих биљака може бити неколико десетина пута већа од површине земљишта на коме се оне развијају и да могу да излуче неколико десетина па и стотина литара воде у току једног дана, стога је јасно да ваздух који их окружује има већи садржај влаге од области без вегетације. У раду се анализирају морфометријска својства стабала, величина листова, интензитет транспирације и густина стома листова беле тополе (*Populus alba* L.) и канадске тополе (*Populus x canadensis* Moench ‘I 214’) у популацијама са различитим водним режимом станишта и то: (1) плављено (влажно) и (2) неплављено (суво) на речном острву Ада Циганлија током вегетационог периода. Издвојено је шест стабала сваког таксона на оба станишта, сличне висине, старости и физиолошке виталности. Морфометријска анализа оба таксона топола показала је да тип станишта није значајно утицаона на укупну висину стабла и дебла као и на површину листова док су ширина круне и пречник дебла били већи на влажном станишту.

Утврђено је да је интензитет транспирације канадске тополе имао нешто веће просечне вредности (0, 73 $gH_2Odm^{-2}h^{-1}$) него код беле тополе (0, 68 $gH_2Odm^{-2}h^{-1}$). Транспирација оба таксона тополе била је интензивнија на сувом него на влажном станишту. Анализом броја стома на испитиваним листовима канадске тополе, утврђено је да су стоме бројније на листовима индивидуа са сувог станишта. Уочено је да су оне мањих димензија од оних на влажном станишту.

Могло би се закључити да обе тополе могу имати утицај на микроклиматске услове, тј. смањење температуре ваздуха повећањем садржаја влаге ваздуха с тим што би нешто већи утицај имала стабла *Populus x canadensis* 'I 214' и то због већег обима круне, веће површине листа, дуже дршке листа, веће густине стома, већег интензитета транспирације на оба типа станишта.

Повећање температуре ваздуха је важна манифестација присутних глобалних климатских промена. Утицај вегетације на микроклиму, нарочито у урбаним срединама, значајан је чинилац у ублажавању последица овог загревања. Свакако треба указати на потребу за даљим истраживањима која би била значајна за избор најпогоднијих таксона топола као и других лишћарских врста дрвећа и жбуња у условима измењеног режима воде у земљишту.