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# Physiological Performance of Sweetgum (*Liquidambar stryraciflua* L.) and Norway Maple (*Acer platanoides* L.) Under Drought Condition in Urban Environment

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**Abstract:** Urban environments are stressful for the growth of trees, as they are affected by multiple and combined stressors from their surroundings. Moreover, the task of selecting and recommending convenient tree species for such conditions becomes more complex under the predicted climate change scenarios. Therefore, the present study was aimed at investigating the physiological performance of Sweetgum (*Liquidambar styraciflua* L.) and Norway maple (*Acer platanoides* L.) in an urban street site, under wet and drought conditions. Most of the observed gas exchange parameters were negatively affected by drought in both of the studied species. Furthermore, chlorophyll *a* fluorescence parameters were shown to be a good indicators of drought stress. The overall result of this study highlighted better physiological performance of Sweetgum, in comparation to Norway maple, under drought condition in urban environment. In accordance to that, it might be assumed that Sweetgum is a promising alternative to Norway maple in the urbanized area.

**Keywords:** *Acer platanoides* L., *Liquidambar styraciflua* L., leaf gas exchange, chlorophyll *a* fluorescence, drought.

## 1. Introduction

As 50%-75% of world’s population have been documented to live in cities in developed countries in the 21th century (Antrop, 2004), the importance of urban forestry has been widely recognized. Urban trees, as the most important elements of urban green areas, have a broad set of benefits to urban surroundings and its’residents (Wargo et al. 2002), i.e. reducing the urban heat-island effect (Douglas et al. 2012; Scholz et al. 2018), improving air quality (Paoletti et al. 2011; Baumgardner et al. 2012), providing shade (Akbari et al. 2001), etc. Indeed, urban trees create a “green infrastructure“, which makes the cities more livable for humans (Darling et al. 2017).

However, to establish a vital and long-lasting street alley of trees in an urbanized area, a wide range of diverse ecological, microclimatic, physiological, and aesthetic value has to be examined and recognized (Vogt et al. 2017). Namely, it has been well proven that urban trees are subjected to numerous and combined stress factors (Calfapietra et al. 2015). Furthermore, the issue to find and select suitable tree species with good adaptation potential to the growing conditions at urban sites becomes even more challenging and important under the predicted climate change (Roloff, 2018). Indeed, the effects of drought are predicted to be more severe in future, as the climate change scenarios predict long lasting and more severe drought periods, combined with heat waves. This phenomenon will become even more intense in urban paved areas, and the trees will suffocate even more, as drought was shown to negatively affect their lifespan (Dale et al. 2014). As the tree's vitality will be challenged in such conditions, it will also impact the ecosystem services they provide for citizens (Konarska et al. 2015).

In order to maintain the resilience of urban forests under climate change, high diversity of species is of key importance (Kevrešan and Stevanov, 2017; Sjöman et al. 2018; Vaštag et al. 2018). However, the strategic use of various tree species in urban areas is compromised by the limited knowledge about the adaptation ability of native and introduced species (Sjöman and Nielsen, 2010). Therefore, studying the selection of suitable tree species for sustainable management and the future planning of urban greenery are essential and should be the main tasks of urban forestry (Gillner et al. 2013; Swoczyna et al. 2014). Although introducing a new species to the urban landscape can negatively affect the distribution of native species, in the forthcoming climate changes, when implemented with caution and following scientific evidences, they can be helpful to fulfil the demanded benefits and ecosystem services of native trees (Konarska et al. 2015).

In accordance to that, the present study was aimed at: (1) evaluating the drought stress tolerance and adaptation potential of Norway maple (*Acer platanoides*L.) - a native species in South-Eastern Europe, and Sweetgum (*Liquidambar styraciflua* L.) – a recently introduced tree species to urban environments, (2) and to provide proposal for their suitable planting in urban areas. For this purpose, leaf gas exchange parameters were assessed in combination with parameters of chlorophyll *a* fluorescence, as they have been previously proven as a reliable and non-invasive method for evaluating the plants overall health status (Perez et al. 2014; Bucher et al. 2018; Vastag et al. 2019).

## 2. Materials and Methods

### *2.1. Experimental location and plant material*

The present study was conducted in Simeona Piščevića street (N 45°15', E 19°48), in Novi Sad, Serbia. At the studied site, 5 Norway maples (*Acer platanoides* L.) and 5 Sweetgums (*Liquidambar styraciflua* L.) were planted in a continuous row along the sidewalk, with a randomly assessed arrangement. The height of both species were approximately 12 m, and the planting space between the trees was 8 m.

In order to estimate the response to drought of both of the above-mentioned species, measurement of leaf gas exchange and chlorophyll *a* fluorescence were made during wet (16th of August 2019) and drought period (31th of August 2019). For this purpose, fully expanded leaves were chosen, with the same orientation. The measurements were made on 5 replications on 5 plants per a single species.

### *2.2. Meteorological characteristics*

The mean daily air temperatures and the total daily precipitations of the 2019 growing season (from 1th of May until the 4th of September 2019) were recorded at the nearby meteorological station, Rimski Šančevi (N 45°20', E19°51'; altitude 84 m a.s.l). Furthermore, the soil water potential (SWP) (MPa) was monitored with calibrated gypsum blocks (Delmhorst Inc., USA) at soil depth of 50 cm, by automatically recording every 30 minutes.

During the growing season of 2019 two severe drought periods were observed. The first one lasted 10 days (from 30th of July until 8th of August) and a second one, which started at the 26th of August and lasted even after the 4th of September 2019 (Figure 1).

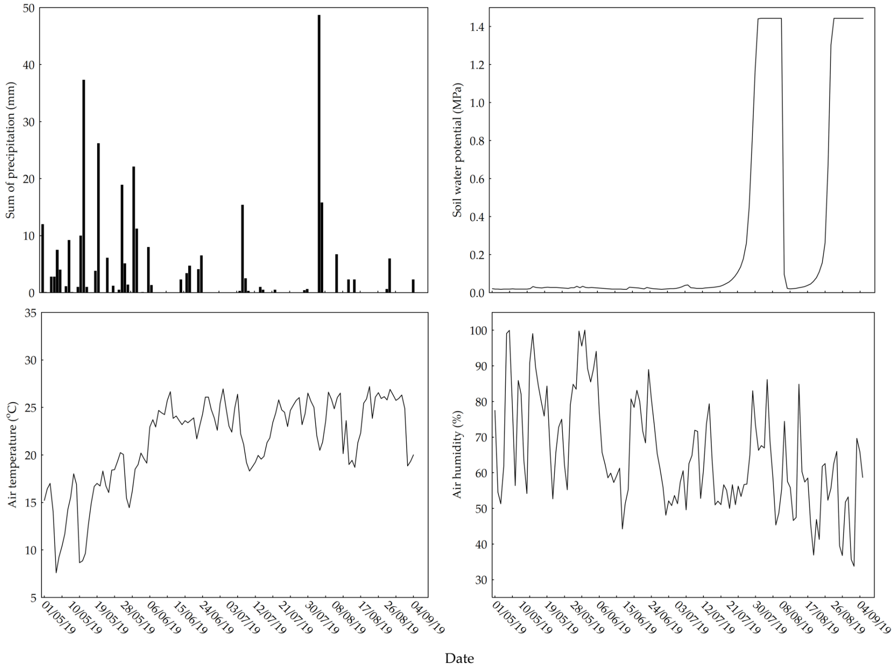

**Figure 1.** Mean daily air temperatures (°C), total daily precipitations (mm) and soil water potentials (MPa) during the period from 1th of May to 4rd of September 2019.

### *2.3. Assessment of leaf gas exchange*

The assessment of net photosynthesis (A [μmol/m$^2$/s]), rate of transpiration (E [mmol/m$^2$/s]), stomatal conductance (gs [mmol/m$^2$/s]) and substomatal concentration $CO_2$ (Ci [μmol/mol]) was performed with a CIRAS-3 portable photosynthesis system (Amesbury, MA, USA) in a timescale between 9:00 AM and 11:00 AM. The measurements were recorded under photosynthetic active radiation (PAR) of 1000 μmol m$^{-2}$ s$^{-1}$, while the humidity, temperature, and the concentration of $CO_2$ were measured at the studied site and varied in accordance to the ambiental conditions. Water use efficiency (WUE [μmol/m$^2$/s]) was derived as a ratio of A and E. Furthermore, intrinsic water-use efficiency (WUEi [μmol mol$^{-1}$]) was assessed as the ratio of A and gs (Flexas et al. 2013). After the assessment of leaf gas exchange, the same leaves were used for measurement of chlorophyll *a* fluorescence.

### *2.4. Assessment of chlorophyll a fluorescence*

Chlorophyll *a* fluorescence was assessed by a non-destructive method of the tree leaves at the studied site between 9:00 AM and 11:00 AM. The measurements were recorded with a PAM-

2500 portable chlorophyll fluorometer (Walz, Germany), by it's rapid light curve (RLC) function with increasing intensities of actinic illumination in nine steps from 144 to 2,443 μmol (photon) $m^{-2}$ $s^{-1}$. The illumination periods lasted 10 s and each of them were separated by a white saturating flash of ~3000 μmol $m^{-2}$ $s^{-1}$. The following primary fluorescence parameters were measured for calculation of the key fluorescence parameters (Table 1): Fo, Fo′- minimum fluorescence of dark and light adapted leaf, Fm and Fm′- maximum fluorescence of light and dark-adapted leaf and Ft- momentary fluorescence yield.

**Table 1.** The list of key fluorescence parameters used for estimation of photosynthetic activity of PSII.

| Formula | Nomenclature and basic physiological interpretation |
|---|---|
| Y(II)=Fm′-Ft/Fm′ | Effective photochemical quantum yield of PS II (Genty et al. 1989) |
| Y(NO)=Ft/Fm | Quantum yield of non-regulated heat dissipation and fluorescence emission (Genty et al. 1996) |
| NPQ= Fm/Fm′-1 | Stern-Volmer type of non-photochemical quenching (Schreiber et al. 1986 as formulated by van Kooten and Snel, 1990) |
| qN= 1- (Fm′-Fo′/ Fm-Fo) | Coefficient of non-photochemical fluorescence quenching (Bilger and Björkman, 1990) |
| qP = (Fm′-Ft)/(Fm′-Fo′) | Coefficient of photochemical quenching (Schreiber et al., 1986 as formulated by van Kooten and Snel, 1990) |
| qL = qP*(Fo′/Ft) | Coefficient of photochemical fluorescence quenching assuming interconnected PS II antennae (Kramer et al. 2004) |
| ETR = PAR · 0.84· 0.5.· | Electron transport rate (Xu et al. 2009) |

### *2.5. Assessing visual vitality and decorative value*

The urban tree visual vitality and decorative value has been assessed using the method of Anastasijević et al. (2007) on 31th of August 2019. For visual vitality the overall health status of tree was observed: the presence of mechanical, psychopathological or entomological damages. The decorative value was assessed by observing the stem straightness and quality of crown structure. For scoring of the mentioned qualitative parameters, the classification scale of 1 (poor health condition and low esthetic value) to 5 (excellent health condition and high esthetic value) was applied.

### *2.6. Statistical analysis*

Statistical analysis of data was performed using one-way ANOVA. When significant differences occurred between wet and drought period, comparison of means was applied by using Tukey's honestly significant difference (HSD) test. Bar graphs for leaf gas exchange parmaterers, visual vitality and decorative value were made using R 3.3.2. for Windows, while rapid light curves (RLC's) of chlorophyll *a* fluorescence parameters were constituted in Statistica 13 (TIBCO Software Inc., 2017).

## 3. Results

The results of the present study evidenced a statistically significant decrease of A, WUE and WUEi of Sweetgum and Norway maple during drought (Figure 2.). Furthermore, drought has affected Ci, as well, causing its increase in both of the above-mentioned species. The decrease of A was slightly higher in Sweetgum, reaching 76.1%, while in Norway maple was found to be 79.3%. However, A was higher in both observed periods, (in the wet period for 50.2% and in drought for 46.0%) in Sweetgum, in comparation to Norway maple. In terms of WUE, the same pattern was observed, having the highest values in both observed periods in Sweetgum (in wet period for 37.9% and drought for 17.8%), showing a faintly pronounced decline in this species (79.7%), compared to Norway maple (82.2%).

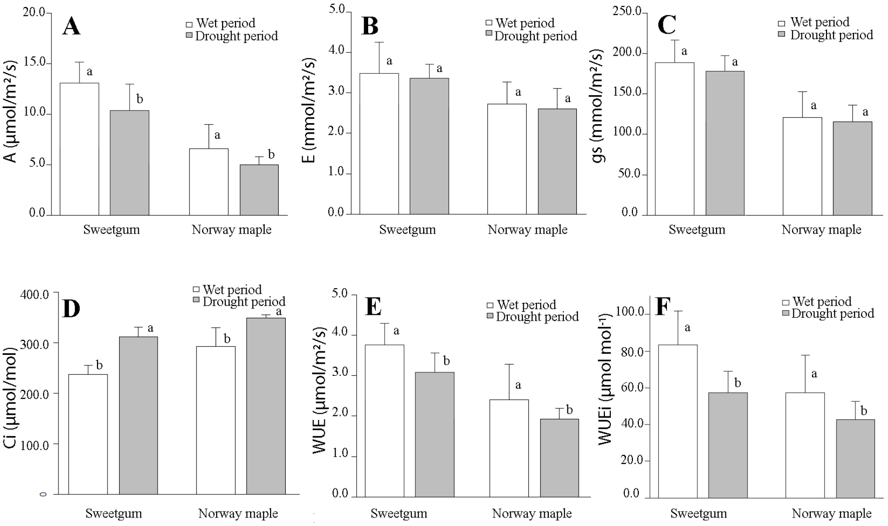

**Figure 2.** Leaf gas exchange parameters of Sweetgum (*L. styraciflua* L.) and Norway maple (*A. platanoides* L.) measured in wet and drought period. A - Net photosynthetic rate (A [µmol/m$^2$/s]); B - rate of transpiration (E [mmol/m$^2$/s]); C - stomatal conductance (gs [mmol/m$^2$/s]); D - substomatal concentration $CO_2$ (Ci [µmol/mol]); E – water use efficiency (WUE [µmol/m$^2$/s]); F - intrinsic water-use efficiency (WUEi [µmol mol$^{-1}$]) . The different small letters next to error bars indicate significant differences between the values (Tukey test; P ≤ 0.05).

Similar to A and WUE, WUEi showed to have the highest values for Sweetgum, in wet (for 31.1%) and dry (for 25.9%) periods, as well. As far as Ci values are concerned, the increase was a bit greater in Norway maple (31.5%) compared to Sweetgum (19.5%) during drought, and was higher in both measured periods for the first mentioned species. Furthermore, the absence of significant differences was detected for E and gs between two periods of measurements. Concerning chlorophyll *a* fluorescence, Sweetgum and Norway maple showed a very similar behavioral pattern, observable on the shape and ranks of the RLC's, under both of the studied periods. In addition, Fo', Y(NO), qP, qL decreased, while, Fm', Ft, Y(II), Y(NPQ), qN, NPQ and ETR were found to be increased along the RLC's under drought condition, in comparation to the wet period (Figure 3.). The biggest differences between wet and drought periods were observed in Ft, Y(NO), Fm'. On the other hand, a Fo', qN and qP differed to the smallest content between the two observed periods, in both species. The results of vitality and decorative value showed the same trend, with slightly higher values in Sweetgum (5.00), in comparation to Norway maple (4.80). However, the differences were found to be not statistically significant (Figure 4).

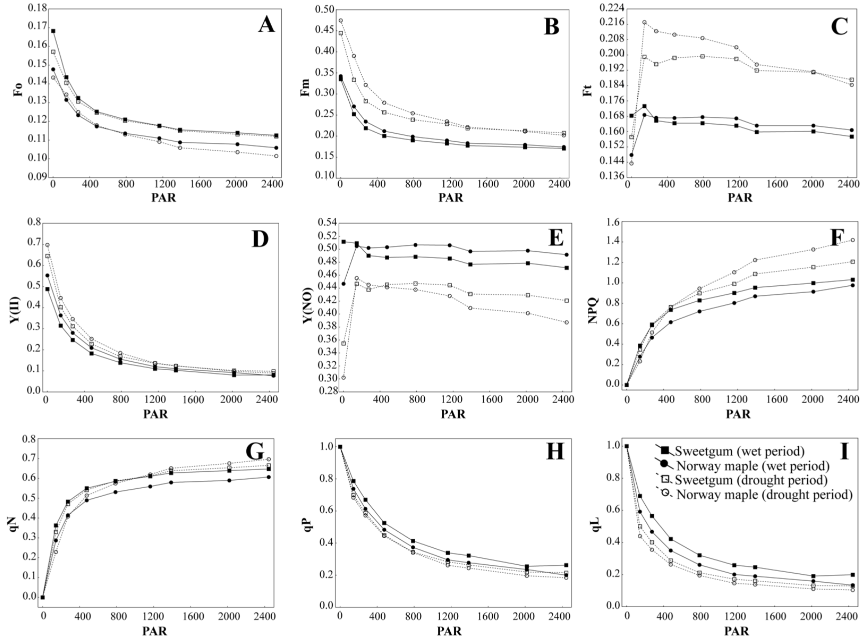

**Figure 3.** Chlorophyll *a* fluorescence parameters of Sweetgum (*L. styraciflua* L.) and Norway maple (*A. platanoides* L.) measured in wet and drought period. A - minimum fluorescence of light adapted leaf (Fo'); B - maximum fluorescence of light adapted leaf (Fm'); C - momentary fluorescence yield (Ft); D - Effective photochemical quantum yield of PS II (Y(II)); E - Quantum yield of non-regulated heat dissipation and fluorescence emission (Y(NO)); F - Quantum yield of light-induced non-photochemical fluorescence quenching (Y(NPQ)) G- Coefficient of non-photochemical fluorescence quenching (qN); H - Coefficient of photochemical quenching (qP); I - Coefficient of photochemical fluorescence quenching assuming interconnected PS II antennae (qL); J - Stern-Volmer type of non-photochemical quenching (NPQ); K - Electron transport rate (ETR).

Namely, stomatal closure has been identified as the main cause of reduction in A under mild to moderate drought conditions (Medrano et al. 2002), while under more pronounced and severe drought the non-stomatal limitations are responsible for its' diminish (Flexaset al. 2002; Flexas et al. 2006). Furthermore, the increase of Ci during drought period in comparation to wet, was also assumed to be the consequence of non-stomatal inhibition of photosynthesis (Yin et al. 2006; Bojović et al. 2017). Non-stomatal limitation of A could result from reduced mesophyll conductance, photochemical or enzymatic limitations (Galmés et al. 2007; Varone et al. 2012).

Concerning the leaf gas exchange parameters, the present study evidenced higher values of A, E, gs, WUE and WUEi coupled with the lower values of Ci in Sweetgum, during both measurement periods, in comparation to Norway maple, indicating its better performance under the observed urban environment. The lower adaptation potential of Norway maple in urban surroundings have been proven by many authors (Aasamaa and Sober, 2011; Forrai et al. 2012; Gillner et al. 2015). Indeed, observing the leaf gas exchange parameters of five common urban tree species Gillner et al. (2015) concluded that Norway maple cannot cope with drought in periods of high vapor pressure deficit as well as *Platanus* × *hispanica*, *Quercus rubra* or *Tilia platyphyllos*.

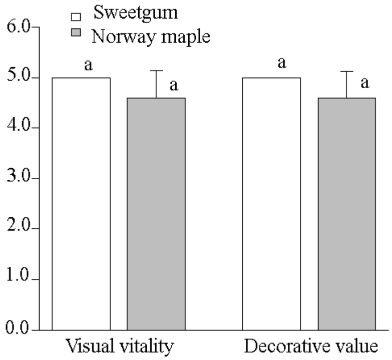

**Figure 4.** Visual vitality and decorative value of Sweetgum and Norway maple. The different small letters next to error bars indicate significant differences between the values (Tukey test; $P \leq 0.05$).

## 4. Discussion

The present study showed the adaptation potential and performance of mature Sweetgum and Norway maple trees, in an urban street site. Under severe drought condition a more pronounced decrease of A was observed in comparation to gs, for both of the studied species. Higher physiological performance of introduced species in comparation to native species, was noted by other authors, as well, presuming that it could be the result of lack of antagonists or diseases or their wider physiological amplitude and tolerance to respective local bio-climatic conditions (Meyer, 2016; Roloff, 2018). As far as the suitability of Sweetgum is concerned, to the best of our knowledge, this is the first study evaluating the physiological performance of this species in an urban environment. Concerning its tolerance to drought, some authors have claimed its moderate tolerance to drought (McCarter and Hughes, 1984), while according to others, it inhibits dry sites in the United States, which are often subjected to severe drought during the growing period (Dixon et al. 1965). However, observed by leaf gas exchange parameters, our study showed a better performance of Sweetgum in comparation to Norway maple during the drought conditions at the street site.

Concerning the physiological responses observed by the parameters of chlorophyll *a* fluorescence, both of the above mentioned-species exhibited quite similar behavioral pattern. Observing the different responses of the two studied species in two different periods, namely wet and drought, Fm′, Ft, Y(NO), NPQ and qL showed to be most affected, and therefore potentially could be used as good indicators of drought stress. In addition, the results of chlorophyll *a* fluorescence measurement showed a more pronounced increase of NPQ in Norway maple during the drought period, which suggest that this specie was more sensitive to the prevailing environmental conditions, in comparation to Sweetgum. Namely, many authors have addressed the elevated levels of NPQ parameter as one of the fastest, reversible employed protective mechanism of plants to cope with the stress induced changes of their surroundings (Lambrev et al. 2012; Nath et al. 2013). Indeed, a previous study showed that a decrease of A in plants, as in the case of the present study, can increase the need for photosystem II protection, even in mild drought stress (Cornic and Fresneau, 2002). Furthermore, investigating the drought tolerance of broadleaf street trees by applying chlorophyll *a* fluorescence technique Vaz Monteiro et al.(2016) observed that among the nine most commonly used street trees, Norway maple was the least tolerant, and exhibited the lowest tendency to recover after drought. On the other-hand, lower values of NPQ in Sweetgum indicate that photosystem PSII haven't experience any photochemical stress over the two of the studied periods (Schwartz and Zait, 2018). Furthermore, the lower values of qL and qP of Norway maple during both of the measured periods, are in accordance to this finding, suggesting a better performance of Sweetgum studied street site. However, to our surprise, Norway maple exhibited a slightly higher ETR values during both of the measured periods.

In terms of visual vitality and decorative characteristics, both of the species showed good state of health coupled with high ornamental values (Callow et al. 2018), with slightly better values for Sweetgum. Namely, Sweetgum has been noted as a desirable tree species in urban environments due to its straight bowl, pyramidal crown, and brilliant autumnal foliage (Bilan, 1974).

## 5. Conclusion

Drought has significantly affected most of the observed gas exchange parameters (A, Ci, WUE and WUEi) in both of the studied species. Concerning the parameters of chlorophyll *a* fluorescence, Fm, Ft, Y(NO), NPQ and qL were shown to be the most effective in detection of drought stress. The overall result of the present study evidenced higher leaf-gas exchange rates and better physiological performance of Sweetgum in comparation to Norway maple under drought studied street site. The significance of this study lies in the detection of appropriate species for urban environments under drought conditions.

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