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# GROWTH AND PHYSIOLOGICAL PERFORMANCE OF YOUNG URBAN TREES OF EIGHT TAXA IN WARSAW

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Unfavourable urban environmental conditions prove to be detrimental for street trees. Many species used in urban plantations are not able to cope with environmental stresses. The aim of the study was to evaluate the usefulness of 8 tree species/cultivars for urban street plantings. The assessment of tree growth was done based on trunk girth and crown volume increment measurements. Physiological performance of trees was evaluated using chlorophyll *a* fluorescence technique. Three of 8 taxa, *Gleditsia triacanthos, Platanus* × *hispanica* 'Acerifolia' and *Pyrus calleryana* 'Chanticleer', revealed sufficient tolerance to urban and street-side environments. On the contrary, *Acer campestre, Tilia cordata* 'Greenspire', *Tilia* × *europaea* 'Pallida', *Quercus rubra* and *Ginkgo biloba* trees did not stand those conditions and thus, should not be planted in extremely harmful street-side environments.

**Keywords:** chlorophyll fluorescence, urban plantings, street trees, species selection

## Introduction

The short lifespan of urban trees impedes maintenance of urban forest resources and results in worsening of urban microclimate and usually, in European cities only few species predominate (Pauleit et al., 2002). Many of used species, especially the indigenous ones, are susceptible to harsh urban environmental conditions (Borowski, 2008; Borowski and Pstrągowska, 2010). Therefore, the proper tree species selection for urban plantings is needed to be studied, including introduced species, focussing on climate adaptation properties and environmental stress tolerance (Sæbø et al., 2003; Borowski and Latocha, 2006). In preceding years several species and cultivars, which were never or seldom used before as street trees, were planted in Warsaw. However, their tolerance to urban environments in climatic conditions of Warsaw was assessed mostly on the basis of literature review. The proper tree species should be able to continue tree growth and crown development despite abiotic stress factors like water deficit, soil compaction, road-side salinity etc. Therefore the evaluation of growth parameters *in situ* is an important constituent to determinate species value for urban plantings (Borowski, 2008). Environmental factors should not disturb physiological stability of planted trees, which leads to gradual weakening of the specimens (Kalaji and Pietkiewicz, 1993). Photosynthesis mechanisms are generally susceptible to numerous stress factors (Kalaji et al., 2012), additionally they are responsible for production of carbohydrates, which are necessary as an energy source for next-year growth as well as for any recovery processess. Thus the evaluation of photosynthetic apparatus efficiency is an important indicator of tree physiological state (Kalaji et al., 2012). The maximum quantum yield of photosystem II ($F_V/F_M$) is a commonly used parameter for the evaluation of photosynthetic apparatus state. Bach et al. (2007) noticed that in lime trees slightly and strongly affected by soil salinity in a city avenue $F_V/F_M$ values were below 0.78 and 0.68, respectively, while in control trees exceeded 0.80. Measurements of $F_V/F_M$ values under stress allowed Percival et al. (2006) to distinguish drought-tolerant and drought-susceptible species and cultivars of *Fraxinus*. In young containerised trees of drought-tolerant species $F_V/F_M$ values did not diminish despite 2-week cessation of watering, whilst in young trees of drought-susceptible species/cultivars $F_V/F_M$ values decreased up to 60% of the initial value of 0.77–0.8.

This investigation was conducted in cooperation with the Environment Protection Department of the Capital City of Warsaw. The aim of the study was to examine growth and physiological performance of young newly planted trees of 8 selected tree species and cultivars in order to evaluate their usefulness in urban plantings.

## Materials and methods

Young trees of 8 species and cultivars, *Acer campestre* L., *Ginkgo biloba* L., *Gleditsia triacanthos* L., *Platanus* × *hispanica* Mill. ex Münchh. 'Acerifolia', *Pyrus calleryana* Decne 'Chanticleer', *Tilia cordata* Mill. 'Greenspire', *Tilia* × *europaea* L. 'Pallida' and *Quercus rubra* L., planted during

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2003–2005 in Warsaw along streets (except 15 trees of *A. campestre* planted in autumn 2006), were selected for the experiment. Trees were divided into two groups: trees in close proximity to a road (1–3.5 m) (B-trees) and away from a road (minimum 8 m) (A-trees). A-trees were planted in wide lawns, B-trees grew in lawn strips along streets or in planting pits with an area of 2 to 4 m$^2$, surrounded by pavement surface. All the trees were planted by contractors of the Metropolitan Authority of Parks, Greenery and Cleaning, Warsaw (ZOM) according to ZOM's procedures.

The climatic data were obtained from Department of Meteorology and Climatology WULS-SGGW, Warsaw, Poland. Soil samples at 0–20 cm depth from tree surroundings were taken for electrical conductivity measurement using a CX-551 multifunction meter (ELMETRON Sp.j., Zabrze, Poland) in order to determine soil salinity. Soil compaction was examined using a portable Eijkelkamp penetrometer (Eijkelkamp Agrisearch Equipment, Giesbeek, The Netherlands).

Tree trunk circumference at 1.3 m above the soil surface was measured at the end of winter in 2006, 2007 and 2008. A photographic method described by Borowski et al. (2005) was used to obtain tree crown volume increment in each year.

Measurements of chlorophyll a fluorescence were performed on 5 trees selected randomly in one A-site and one B-site for each species. Three (on 16–19$^{th}$ June 2008) or six mature leaves (on 5–6$^{th}$ August and 4–5$^{th}$ September) were selected in each tree crown. A Handy PEA chlorophyll fluorimeter (Hansatech Instruments Ltd., King's Lynn, Norfolk, UK) was used for maximum quantum yield of photosystem II ($F_V/F_M$) measurement.

Student's two-sample *t*-test was performed to compare roadside trees and reference trees within each species using STATISTICA 8.0 software (StatSoft, Inc., Tulsa, OK, USA).

## Results and disscussion

The winter preceding 2006 was very cold with the minimum -27 °C on the 24$^{th}$ of January and the winter 2006/2007 was mild. The late spring and the beginning of summer in 2006 were very dry (Fig. 1). However, in May precipitation slightly exceeded evapotranspiration and was sufficiently abundant in August 2006. The precipitation in 2007 reached 124% of twenty-year mean precipitation (1981–2000).

In most locations penetration resistance in soils surrounding newly planted trees was 2–3.5 MPa. However, in some sites it exceeded 4 MPa (*G. triacanthos* and *Q. rubra* A-trees), 5 MPa (*T. cordata* both A- and B-trees and *T.* × *europaea* A-trees), 6 MPa (*G. triacanthos* and *Q. rubra* B-trees) or 7 MPa (in *G. biloba* B-trees).

Soil salinity measured conductometrically in July 2008 in B-sites was 1.0–2.0 mS cm$^{-1}$ except *A. campestre* (0.79 mS cm$^{-1}$). In A-sites EC did not exceed 0.8 mS cm$^{-1}$.

In 2006 16.2% of total 444 young trees died. Many trees suffered and partially lost their branches due to drying. Died branches were lopped in July. Although the trees developed new shoots, in some species tree crowns diminished on average 14–80%. In 2007 most of the stressed trees recovered their crown volumes, except *T.* × *europaea* and *A. campestre* B-trees (Fig. 2). *T.* × *europaea* B-trees were not able to continue their growth.

Comparing the trunk circumference increment in every species between A- and B-trees the examination showed higher increment in both *Tilia* species in A-trees. The proximity to roads did not restrict the trunk circumference increment in *A. campestre, Q. rubra, G. triacanthos* and *P. calleryana* (Table 1).

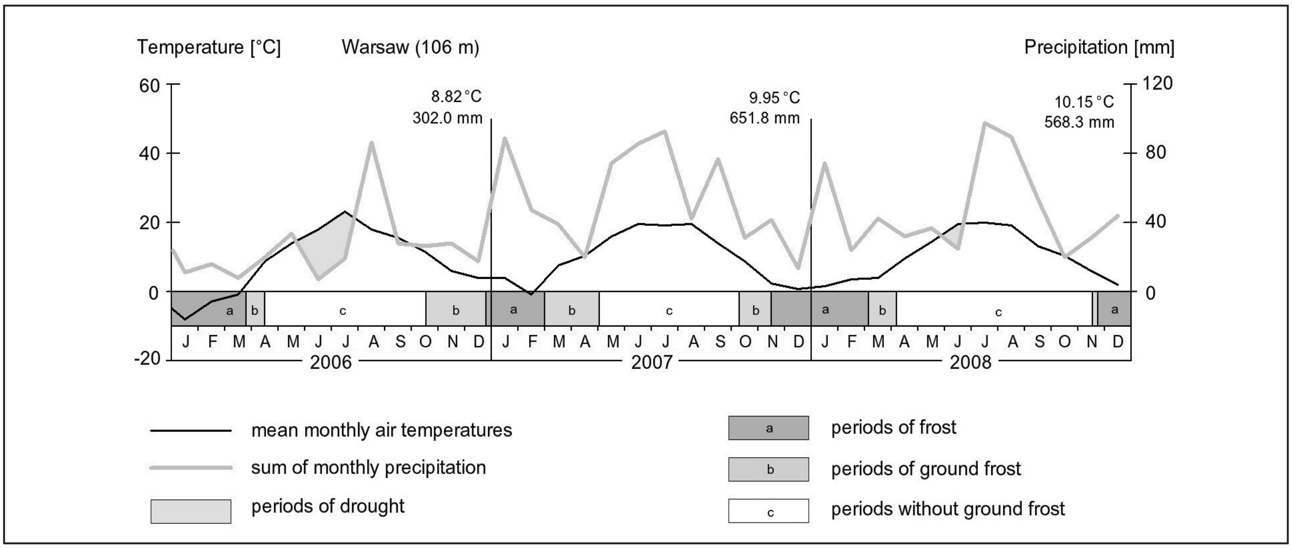


**Figure 1** Gaussen-Walther climatic diagram of 2006, 2007 and 2008
Data source from Department of Meteorology and Climatology WULS-SGGW

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**Table 1** Comparison of trunk circumference increment in % between trees planted away from roads (A) and in close proximity to roads (B). Significantly higher means (at $p$ <0.05) are highlighted in bold

| Species | Year | A | | B | | *p* | N | |
|---|---|---|---|---|---|---|---|---|
| | | Mean | SE | Mean | SE | | A | B |
| *Tilia cordata* 'Greenspire' | 2006 | **4.43** | 0.30 | 1.64 | 0.19 | **0.000** | 30 | 26 |
| | 2007 | **4.85** | 0.37 | 1.95 | 0.18 | **0.000** | 29 | 26 |
| *Tilia* × *europaea* 'Pallida' | 2006 | **4.45** | 0.36 | 0.93 | 0.14 | **0.000** | 30 | 12 |
| | 2007 | **2.97** | 0.28 | 2.14 | 0.20 | **0.019** | 30 | 32 |
| *Acer campestre* | 2006 | – | – | – | – | – | – | – |
| | 2007 | 3.22 | 0.21 | **5.36** | 0.86 | **0.024** | 15 | 24 |
| *Quercus rubra* | 2006 | 0.63 | 0.15 | **5.37** | 1.22 | **0.001** | 25 | 23 |
| | 2007 | 0.78 | 0.19 | **6.02** | 1.43 | **0.001** | 25 | 23 |
| *Gleditsia triacanthos* | 2006 | 4.86 | 0.45 | **8.81** | 1.09 | **0.002** | 23 | 21 |
| | 2007 | 6.32 | 0.63 | **10.42** | 1.15 | **0.004** | 23 | 21 |
| *Pyrus calleryana* 'Chanticleer' | 2006 | 4.64 | 0.45 | **7.36** | 0.94 | **0.018** | 16 | 13 |
| | 2007 | 3.88 | 0.65 | **12.24** | 1.42 | **0.000** | 16 | 13 |
| *Platanus* × *hispanica* 'Acerifolia' | 2006 | **17.53** | 2.52 | 8.34 | 2.45 | **0.035** | 23 | 10 |
| | 2007 | 19.03 | 1.64 | 18.27 | 1.17 | 0.724 | 23 | 18 |
| *Ginkgo biloba* | 2006 | 1.05 | 0.18 | 1.48 | 0.29 | 0.210 | 29 | 42 |
| | 2007 | 1.96 | 0.36 | **6.18** | 1.29 | **0.003** | 29 | 42 |

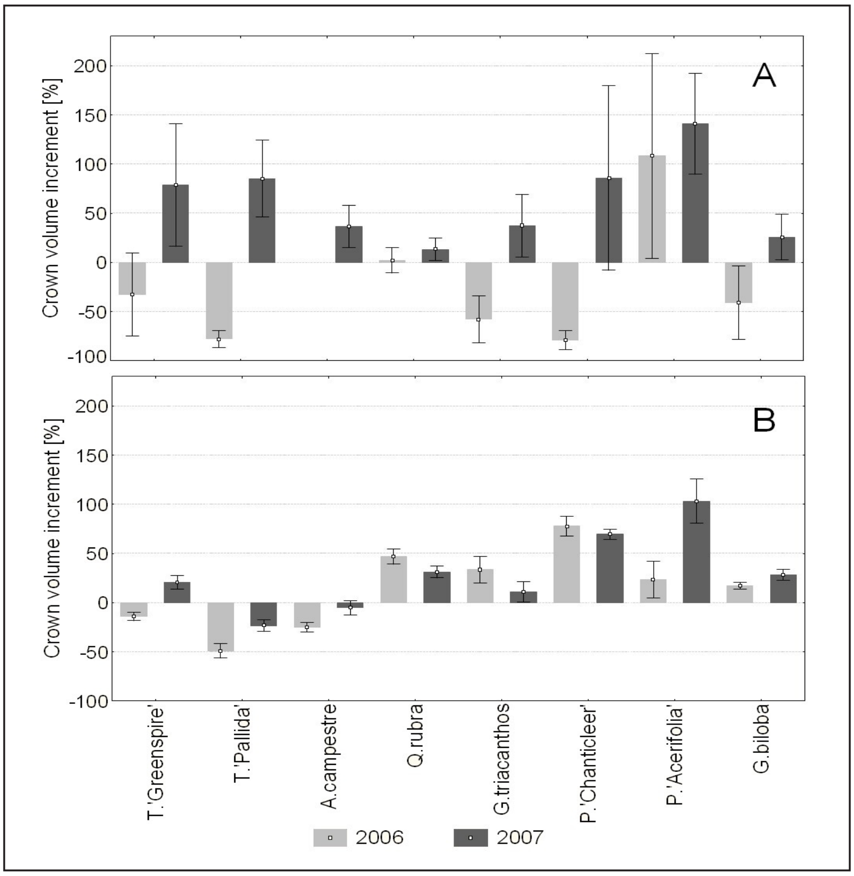


**Figure 2** Crown volume increment in 2006 and 2007; means and SE. A-trees planted away from roads, B-trees planted in close proximity to roads

In most species the performance of photosynthetic apparatus, expressed by $F_V/F_M$ ratio, was not different between A- and B-trees (Fig. 3). Only in *G. biloba* the $F_V/F_M$ ratio in B-trees revealed the poor performance during the whole growing season. In *T. cordata* a marked decrease in $F_V/F_M$ occurred in the end of the growing season. Road-side trees of *A. campestre* revealed good condition of PSII until September, while in A-trees the PSII condition weakened. The highest values of $F_V/F_M$ were noted in *G. triacanthos*, *P.* × *hispanica* and *P. calleryana* inspite of the location.

Newly planted trees in cities are subjected to numerous stress factors. Although basic maintenance is carried out, i.e. the trees are watered and pruned, there are some environmental factors which seem to be out of city arborists' control. Soil compaction of the street surroundings is the consequence of road building technology. It occures both in old streets and in new ones, however its magnitude is not the same in different sites, it depends also on local soil properties (Alberty, 1984). The values of 3–4 MPa are considered

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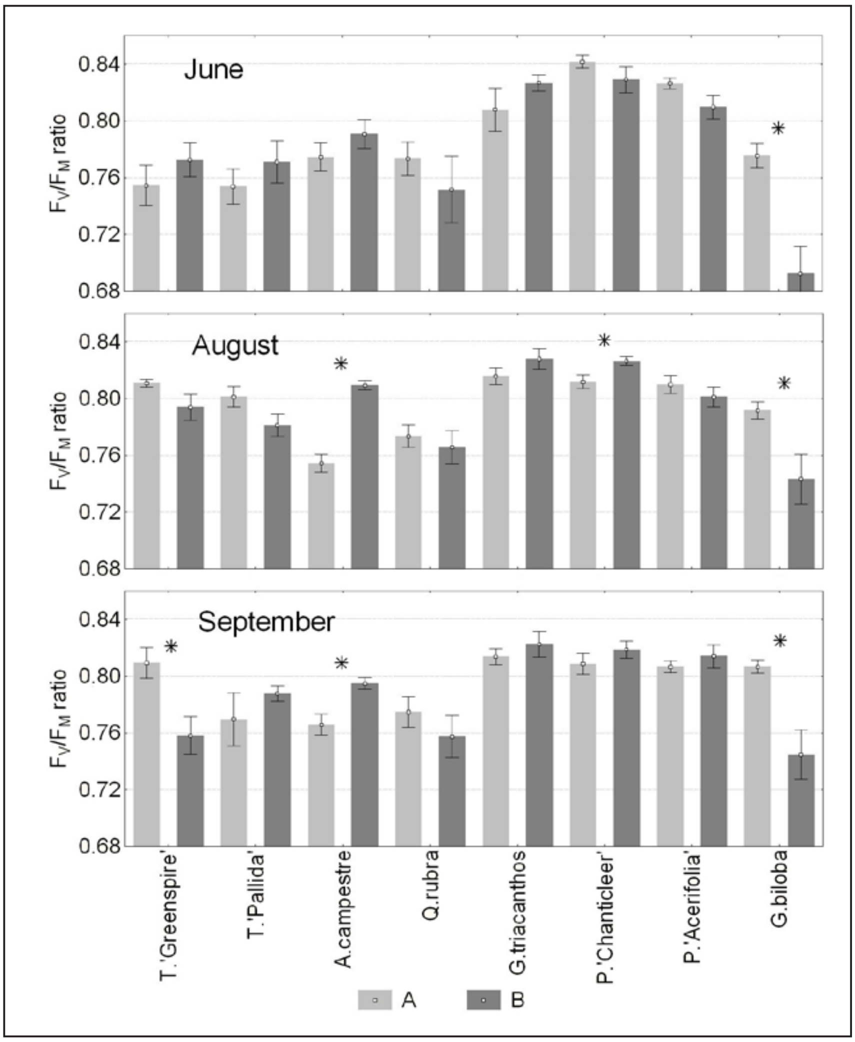


**Figure 3** Maximum quantum yield of PSII ($F_V/F_M$) in trees planted away (A) and in close proximity to roads (B) in 2008; means and SE

to be detrimental for root growth, although some species are able to continue it at the values exceeding 3–4 MPa (Sinnet et al., 2008).

We expected that the close proximity to roads would affect tree growth and physiological performance due to higher soil salinity. The EC values measured in July were not much higher than in the sites of the greater distance to a road. However, Cekstere et al. (2008) noted that before spring precipitation mean concentrations of $Na^+$ and $Cl^-$ ions in road-side soils were twice or threefold higher than in July and contrary, leaf concentrations of $Na^+$ and $Cl^-$ ions increased in the months following the spring development of leaves. It might be the reason of poor physiological performance in road-side trees in *T. cordata* and *G. biloba.*

The climatic conditions seem to be the most important factor affecting the young trees. The precipitation in May 2006 was not very high and in June and July was extremaly low. This resulted in shrivelling of young leaves and branches. Trees obtaining insufficient watering partially lost their crowns. According to Bühler et al. (2006) road-side trees need about 640 L of water apart from precipitation. In our research the applied amount of watering, *i.e.* 20 L per week in dry period (maximum 10 weeks) supported only approximately 200 L of additional water supply during the growing season. Treder (2000) noted that in newly established orchards the proper irrigation determined growth and yielding in the following years due to successful root development, crucial for future nutrition of the whole organism. In our examination the period of effective root forming in the trees planted in 2005 was too short to develop sufficient root system. Trees planted in former years continued their growth. The climatic conditions in 2007 were more favorable to the young trees and trees of some species recovered. Only *T.* × *europaea* and *A. campestre* road-side trees were not able to continue the growth. Presumably the drought stress in the previous year preceded the threshold of their tolerance. The poor growth of trunk volume in both *Tilia* road-side trees in both 2006 and 2007 indicates that these species can hardly cope in road-side environments (Borowski and Pstrągowska, 2010).

$F_V/F_M$ parameter is considered to be the universal physiological parameter for every photosynthetising material with the optimal values of around 0.83 (Maxwell and Johnson, 2000; Kalaji et al., 2012). Our examination revealed the clear division into the "best performers" and the "week performers". Three introduced species *G. triacanthos, P.* × *hispanica* and *P. calleryana* reached $F_V/F_M$ values approximate to optimum regardless of the location and date. The high values of soil compaction did not disturb physiological performance in *G. triacanthos. Likewise,* in *T. cordata* and *T.* × *europaea* trees planted away from a road the higher $F_V/F_M$ values indicate that the both *Tilia* species are able to adjust their physiological performance to unfavourable soil compaction provided that the trees obtain sufficient watering. The road-side locations are subjected to increased soil salinity which diminishes access to the soil water and results in harmful ions accumulation (Cekstere et al. 2008). The latest leads to leaf structure injuries and disturbances

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of photosynthetic performance (Kalaji and Pietkiewicz, 1993; Percival et al., 2003). The worst values in *G. biloba* were probably the result of synergic influence of soil salinity, water scarcity and extremal soil compaction. The soil compaction was presumably the reason of either poor growth and worse physiological performance of *Q. rubra* trees.

## Conclusions

On the basis of the results the folllowing conclusions can be made:

1. In harsh urban environments tree species differ both in growth intensity and physiological vitality.
2. Close proximity to roads leads to diminishing of both *Tilia* species growth.
3. Road-side conditions and high soil compaction may affect negatively the physiological performance of *Ginkgo biloba*.
4. *Acer campestre* is able to adapt to severe environmental conditions, keeping photosynthetic apparatus in good condition, however in extremely harsh environments the development of tree crown may be restricted.
5. Close proximity to a road does not limit the growth of *Gleditsia triacanthos, Platanus* × *hispanica* 'Acerifolia', *Pyrus calleryana* 'Chanticleer' and *Quercus rubra*, however high soil compaction in conjunction with summer drought may influence negatively the photosynthetic apparatus efficiency in *Quercus rubra*.
6. For newly planted trees water availability has the crucial meaning, other stresses like soil compaction or soil salinity also play a significant role.
7. Taking into consideration the three factors influencing young trees, the species/cultivars *Gleditsia triacanthos, Platanus* × *hispanica* 'Acerifolia' and *Pyrus calleryana* 'Chanticleer' are sufficiently tolerant to be cultivated in urban environments. *Acer campestre, Tilia cordata* 'Greenspire', *Tilia* × *europaea* 'Pallida', *Quercus rubra* and *Ginkgo biloba* trees should not be planted in extremely harmful conditions.

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