BRIEF COMMUNICATION

Physiological and biochemical responses of roadside trees grown under different urban environmental conditions in Seoul

H.N. YOU[*], S.Y. WOO[*,+], and C.R. PARK[**]

Department of Environmental Horticulture, University of Seoul, Seoul 02504, Republic of Korea[*]
Division of Forest Ecology, National Institute of Forest Science, Seoul 02455, Republic of Korea[**]

Abstract

The present study revealed that *Ginkgo biloba* and *Platanus occidentalis*, the most abundant roadside trees in Seoul, grown under polluted environmental conditions, displayed lower contents of total chlorophyll (Chl), carotenoids (Car), and ascorbic acid (AsA) compared to the trees grown under clean conditions. The reduction in Chl, Car, and AsA contents was 59, 53, and 50%, respectively, in *G. biloba*, contrary to 26, 23, and 24%, respectively, in *P. occidentalis*. Furthermore, relative ion leakage and leaf temperature was higher in the trees grown under polluted conditions than in those grown under clean conditions. The increase in relative ion leakage and leaf temperature was 58 and 3% for *G. biloba* and 17 and 4% for *P. occidentalis*, respectively. Our results, therefore, highlighted the negative impact of urban environmental pollution on the physiological and biochemical parameters in roadside trees.

Additional key words: antioxidant; pigments; transpiration; urban air pollution; urban forest.

Environmental pollution is a serious problem in urban areas caused by the accumulation of pollution sources and increased traffic volume owing to the concentration of population in metropolis (Fenger 2009). Reducing pollution is a global necessity. Roadside trees are very important in reducing urban environmental pollution, because they help diminish air pollutants, such as particulate matter (PM10 and PM2.5), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and carbon monoxide (CO). They can also improve human health and life quality (Nowak *et al*. 2006). Environmental pollution directly affects the roadside trees, negatively affecting the plant growth and human health, as well (Baek and Woo 2010). The present study was conducted to investigate the physiological responses of *Ginkgo biloba* and *Platanus occidentalis* grown under two different urban environmental conditions in Seoul, Korea, with an aim of supporting urban forest management. The two selected roadside species are the most abundant trees in Korea. Clean and polluted sites were selected on the basis of the air pollutant concentrations and a traffic volume. We chose a university campus as the clean site and the roadside area of a six-lane road with congested traffic as the polluted site, based on the concentrations of PM10, PM2.5, NO_2, SO_2, and CO observed by NIER (2013). The concentrations of different air pollutants at the clean site and the polluted site were as follows:

Pollutant	Clean site [campus]	Polluted site [roadside]
PM10 [μg m^{-3}]	43	51
PM2.5 [μg m^{-3}]	22	30
NO_2 [μg g^{-1}]	0.034	0.048
SO_2 [μg g^{-1}]	0.005	0.006
CO [μg g^{-1}]	0.5	0.6

The study, carried out in June and October, evaluated five parameters: total chlorophyll (Chl), carotenoid (Car), ascorbic acid (AsA) content, relative ion leakage, and

Received 15 September 2014, *accepted* 30 October 2015, *published as online-first* 11 November 2015.
[+]Corresponding author; tel:+82-2-6490-2691, e-mail: wsy@uos.ac.kr
Abbreviations: AsA – ascorbic acid; Car – carotenoid; Chl – chlorophyll; DTT – dithiothreitol; FM – fresh mass; NEM – N-ethylmaleimide; PM10 – particulate matter with aerodynamic diameters ≤ 10 μm; PM2.5 – particulate matter with aerodynamic diameters ≤ 2.5 μm; ROS – reactive oxygen species; TCA – trichloroacetic acid.
Acknowledgement: This paper was supported by research project (No.: FE0100-2010-03-2014, Title: Management Discipline and Quantification of Biotope at Human-disturbed and Urbanized Green Areas and Forests) of Korea Forest Research Institute.

leaf temperature. Chl and Car were extracted from 0.1 g of leaf fresh mass (FM) using 80% acetone. Absorptions were measured with spectrophotometer (*Epoch Microplate*, *Bio-Tek*, USA), and the Chl and Car contents were calculated by the method of Arnon (1949). For measuring AsA, the supernatant was mixed with 10 mM dithiothreitol (DTT), 0.2 M sodium phosphate buffer (pH 7.4), and incubated at 42°C for 15 min. After the incubation, 0.5% N-ethylmaleimide (NEM) was blended in the mixture, followed by the addition of 10% trichloroacetic acid (TCA), 42% H_3PO_4, 4% 2,2'-dipyridyl, and 3% $FeCl_3$. The samples were incubated at 42°C for 40 min and then absorbance at 525 nm was measured (Kampfenkel *et al*. 1995) with a spectrophotometer (*Epoch Microplate*, *Bio-Tek*, USA). Leaf temperature was monitored by thermal imaging infrared camera (*IM2300*, *FLIR Systems Inc*., USA) and electrolyte leakage was measured using electrical conductivity meter (*MC226*, *Mettler Toledo*, England). Statistical analysis of the data was performed using the statistical package for social science, *SPSS 21.0* (*SPSS*, Chicago, USA). Significant differences between the means were compared by the *t*-test ($p<0.05$).

According to the results, total Chl contents in *G. biloba* and *P. occidentalis* grown at the polluted site were lower than the contents in the trees grown at the clean site. Especially, the total Chl contents in *G. biloba* were significantly lower at the polluted site compared to the contents in trees grown at the clean site in both June and October (Fig. 1*A*). The total Chl contents in *P. occidentalis* showed significant difference between the two sites in October as compared to that in June (Fig. 1*B*). As Chl plays an important role as a photoreceptor, photosynthetic capacity can be affected by Chl contents. In our study, the two roadside species grown at the polluted site showed the low total Chl contents, which could lead to the low photosynthetic rate. Car contents also showed a pattern similar to that observed for total Chl, with a significantly lower Car contents in *G. biloba* at the polluted site in both June and October (Fig. 1*C*). In the case of *P. occidentalis*, the difference was, however, significant only in October (Fig.1*D*). Reactive oxygen species (ROS) are produced during the plant metabolic processes such as photosynthesis. Theoretically, Chl is the main pigment of photoreceptors and Car plays a role in photoprotection of photosynthetic apparatus. When

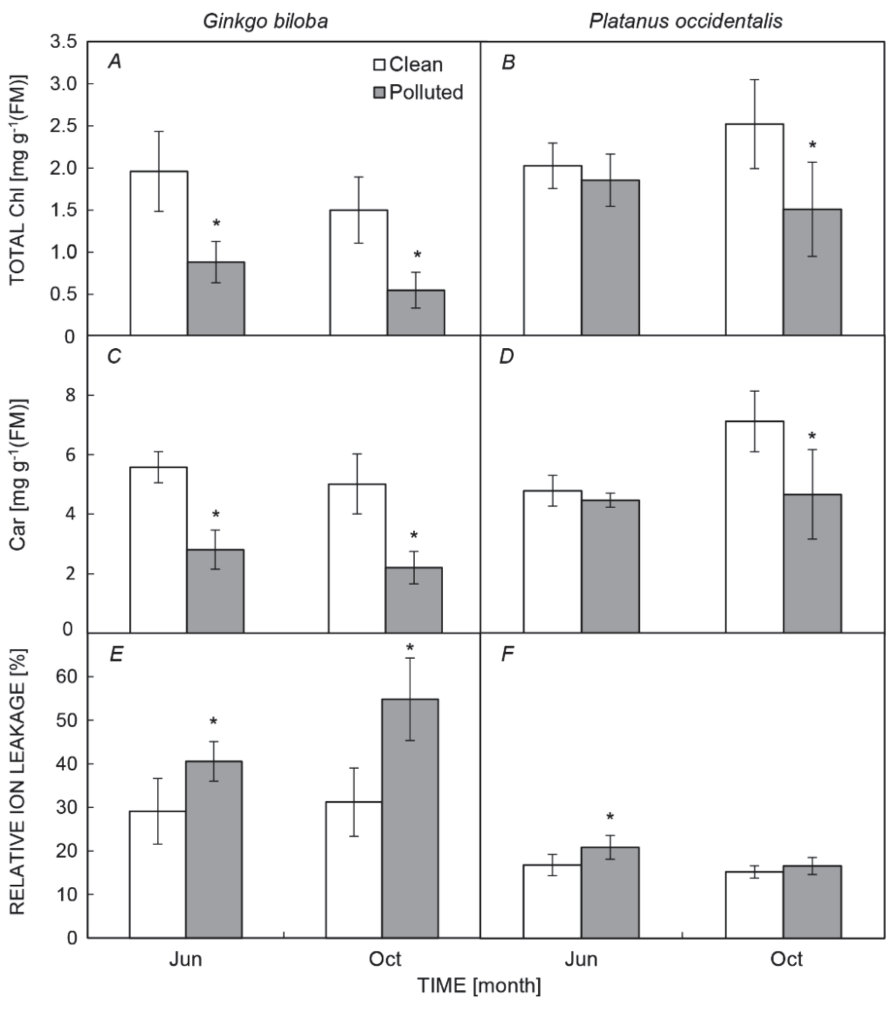

Fig. 1. Total chlorophyll content (*A*,*B*), carotenoid content (*C*,*D*), and relative ion leakage (*E*,*F*) of *Ginkgo biloba* and *Platanus occidentalis* grown at the clean and polluted site. Statistically significant differences between the two sites are marked as * at $p<0.05$.

photoreceptors operate improperly for transmitting of light energy, oxygen molecules generate ROS by reacting with excited energy (Asada 1999). ROS have the potential to cause oxidative damage to plant cells; overproduction of ROS has negative effects on DNA and cellular metabolism in plants (Melhorn *et al*. 1990). Thus, an excessive increase in the amount of ROS in plant cells, under environmental stress, leads to considerable cell damage. Car can scavenge ROS formed within the chloroplast. Therefore, a low Car content indicates the reduced capacity to cope with the toxic effects of ROS and cell damage. In our study, the Car contents in the two roadside species grown at the polluted site were lower than the contents in those grown at the clean site. Similar results were obtained by Joshi and Swami (2009), who reported that the Car contents of *Shorea robusta* decreased at roadsides in urban areas.

The difference in the values of relative ion leakage was found between the trees from both sites. Relative ion leakage indirectly represents the level of cell membrane damage. Recently, it has been reported that ROS is one of the most noxious stressors to induce electrolyte leakage, which in turn is considered to be related to K^+ efflux from the plant cells (Campos *et al*. 2003, Demidchik *et al*. 2014). Ion leakage in the two roadside species grown at the polluted site was considerably higher than that in the trees grown at the clean site (Fig. 1*E*,*F*). However, in the case of *P. occidentalis* the difference was significant only in June (Fig. 1*F*). Change in leaf temperatures caused by plant transpiration is an indirect method for measuring the physiological activity of plants. According to our observations, *G. biloba* displayed significantly different leaf temperatures at the two sites in October. At the polluted site, leaf temperatures were 33.3 and 23.3°C in June and October, respectively, whereas at the clean site leaf temperatures were 33.3 and 21.3°C in June and October, respectively. Similarly, leaf temperatures of *P. occidentalis* grown at the polluted site were significantly higher than those of *P. occidentalis* grown at the clean site, both in June and October. At the polluted site, leaf temperatures were 34.0 and 22.2°C in June and October, respectively, whereas at the clean site leaf temperatures were 33.0 and 20.9°C in June and October, respectively. The higher leaf temperatures of the two roadside species grown at the polluted site suggest that they exhibited lower transpiration rates than those grown at the clean site.

Plants possess intricate antioxidant systems in order to overcome oxidative stress. AsA is one of the most important plant antioxidants. Thus, high AsA contents in a plant suggest that the plant possesses strong antioxidant capacity. The present study revealed that the AsA contents of *G biloba* grown at the polluted site calculated per g of FM (June: 289 µg, October: 14 µg) were significantly lower than the contents of those grown at the clean site (June: 550 µg, October: 52 µg), in both June and October ($p<0.05$). Likewise, the AsA contents of *P. occidentalis* grown at the polluted site (June: 243 µg, October: 40 µg) were lower than the contents of those grown at the clean site (June: 245 µg, October: 126 µg); more pronounced difference was detected during October ($p<0.05$).

Based on our results, we concluded that the physiological and biochemical activities of *G. biloba* and *P. occidentalis* were affected by different urban environmental conditions, especially by air pollution.

References

Arnon D.I.: Copper enzymes in isolated chloroplasts. Polyphenol oxidase in *Beta vulgaris*. – Plant Physiol. **24**: 1-15, 1949.

Asada K.: The water-water cycle in chloroplast: Scavenging of active oxygens and dissipation of excess photons. – Annu. Rev. Plant Phys. **50**: 601-639, 1999.

Baek S.G., Woo S.Y.: Physiological and biochemical responses of two tree species in urban areas to different air pollution levels. – Photosynthetica **48**: 23-29, 2010.

Campos P.S., Quartin V., Ramalho J.C. *et al*.: Electrolyte leakage and lipid degradation account for cold sensitivity in leaves of *Coffea* sp. plants. – Plant Physiol. **160**: 283-292, 2003.

Demidchik V., Straltsova D., Medvedev S.S. *et al*.: Stress induced electrolyte leakage: the role of K^+-permeable channels and involvement in programmed cell death and metabolic adjustment. – J. Exp. Bot. **65**: 1259-1270, 2014.

Fenger J.: Air pollution in the last 50 years – From local to global. – Atmos. Environ. **43**: 13-22, 2009.

Joshi P.C., Swami A.: Air pollution induced changes in the photosynthetic pigments of selected plant species. – J. Environ. Biol. **30**: 295-298, 2009.

Joshi P.C., Swami A.: Air pollution induced changes in the photosynthetic pigments of selected plant species. – J. Environ. Biol. **30**: 295-298, 2009.

Kampfenkel K., Van Montagu M., Inze D.: Extraction and determination of ascorbate and dehydroascrobate from plant tissue. – Anal. Biochem. **225**:165-167, 1995.

Melhorn H., Tabner J.M., Wellburn A.R.: Electron spin resonance evidence for deformation of free radicals in plants exposed to ozone. – Physiol. Plantarum **79**: 377-383, 1990.

NIER (National Institute of Environmental Research): Annual Report of Air Quality in Korea. Pp. 3-284. Ministry of Environment, Seoul 2013.

Nowak D.J., Crane D.E., Stevens J.C.: Air pollution removal by urban trees and shrubs in the United States. – Urban For. Urban Gree. **4**: 115-123, 2006.