Bangladesh J. Bot. **45**(4): 791-796, 2016 (September), Supplementary

PHOTOSYNTHETIC CHARACTERISTICS, CARBON FIXATION AND OXYGEN RELEASE FUNCTIONS OF THREE LANDSCAPE TREES

ZHOULI LIU, WEI CHEN, XINGYUAN HE* AND SHUAI YU

Key Laboratory of Forest Ecology and Management, Institute of Applied Ecology, Chinese Academy of Sciences, Shenyang, Liaoning-110016, China

Key words: Photosynthesis, Carbon fixation, Oxygen release, Landscape tree

Abstract

The amount of carbon fixed per plant (CFC per plant) and oxygen released per plant (ORC per plant) for *Platanus acerifolia* were 1080.72 and 785.98 g/d, respectively. The highest contents in carbon fixation and oxygen release of *P. acerifolia* may indicate a good photosynthetic capacity compared to *S. japonica* and *Z. serrata*. However, the later two species of trees were found efficient related to the net photosynthetic rate (Pn) and leaf area index (LAI).

Introduction

Human activities are contributing to the global climate change by greenhouse gas emissions (Barcelos *et al.* 2014, Liu *et al.* 2015), and carbon dioxide (CO_2). They are most important greenhouse gases in the atmosphere (Bazzaz 1990, Tripathi and Agrawal 2012, Kumari and Agrawal 2014). The concentrations of CO_2 have continuously increased and reach 400 ppm on an average per day at Mauna Loa (Ward *et al.* 2015). Urban areas are directly or indirectly responsible for over 70% of atmospheric CO_2 emission (Briber *et al.* 2013, Velasco *et al.* 2013).

Landscape plants are an important part of urban ecosystem, which can reduce concentrations of atmospheric CO_2 by fixing it into carbohydrate in plant organs (Berg *et al.* 2010, Fuchs 2011). Carbon fixation is one of the dominant biochemical processes in the biosphere, which refers to the conversion process of inorganic carbon (CO_2) to organic compounds by plants (Geider *et al.* 2001, Berg 2011). All the major biological components of carbon fixation are derived from the photosynthetic process of plants (Körner *et al.* 2005). So far, several studies were carried out focusing the photosynthetic capacity of plants to adapt different environments (Calatayud *et al.* 2002, Reddy and Zhao 2005, Hamilton *et al.* 2008, Geissler *et al.* 2009, Danyagri and Dang 2013, Meng *et al.* 2014, Niu *et al.* 2014). However, less information is available on the photosynthetic characteristics and the functions of fixing carbon and releasing oxygen in landscape trees.

Three landscape trees, namely Chinese scholar tree (*Sophora japonica*, Fam. Fabaceae), Japanese zelkova (*Zelkova serrata,* Fam.: Ulmaceae) and London plane tree (*Platanus acerifolia*, Fam.: Plantanaceae) are dominant species of deciduous forest in northern China. These species have the important ecological and economical status in urban area. In the present study, the photosynthetic characteristics and the functions of fixing carbon and releasing oxygen in the three landscape trees were studied. By estimating the functions of fixing carbon and releasing oxygen by the three plants, we can determine the role of landscape trees in mitigating climate change and offsetting local CO_2 emissions. It would provide critical insights on future research of ecological function evaluation of landscape trees.

*Author for correspondence: <forestry83@hotmail.com>.

Materials and Methods

The authors studied the landscape trees at the England Stone Botanical Garden of the Dalian (38°53′N, 121°21′E). Dalian is a major seaport city in the north-east of China and has sub-provincial administrative status. The climate of Dalian is influenced by continental monsoon climate. The annual average temperature is 8.4 - 10.5°C, the annual precipitation averages 700 - 800 mm and the rainfall is heavy in the summer months.

The experiments were carried out in late May (Spring), late July (Summer) and early September (Autumn) of 2014. Leaf area of the plants was determined by Li-3000 leaf area meter (Li-COR, Lincoln, NE, USA). Gas exchange was measured by Li-6400 photosynthesis system (Li-COR Inc. Lincoln, NE, USA). Leaf temperature, light intensity and CO_2 concentration inside leaf chamber were kept constant. All the measurements were taken between 9:00 and 11:30 a.m. under natural conditions and the data were recorded 6 times. The contents of carbon fixation and oxygen release were calculated according to Farquhar *et al.* (2001) and Gregoriou *et al.* (2007).

The statistical analysis was carried out with one-way analysis of variance (SPSS17.0). Comparisons were performed by the LSD test. Data were presented as mean ± standard deviation.

Results and Discussion

Photosynthesis is important for plant growth and biomass production (Liu *et al.* 2013). The maximum net photosynthetic rate could be used to characterize the potential of light energy utilization in plants (Jia *et al.* 2015). As shown in Fig.1, the three landscape trees had the different maximum net photosynthetic rate (Pn). The Pn values of *S. japonica*, *Z. serrata* and *P. acerifolia*

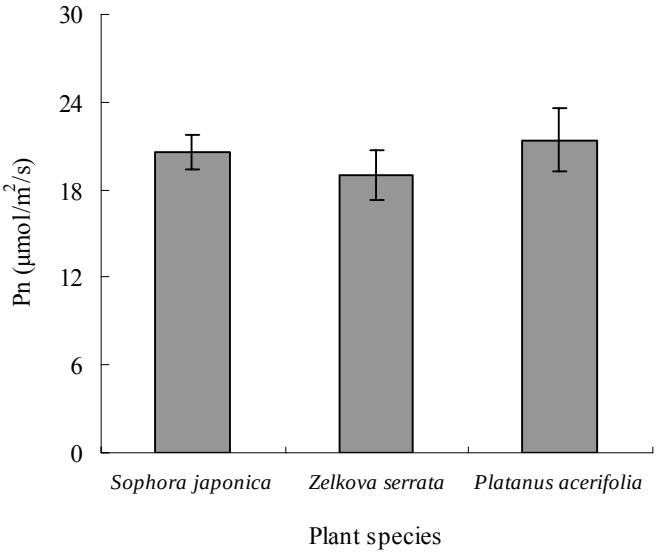

Fig.1. The maximum net photosynthetic rate of three landscape trees.

were 20.55, 18.98 and 21.40 μmol/m^2/s, respectively which indicated that the three landscape trees had all good potential of light energy utilization. There were not significant differences in Pn values of the three landscape trees ($p > 0.05$), and *P. acerifolia* showed a better potential of light energy utilization.

Leaf area index (LAI) is used to prove photosynthetic primary production and provide a reference for plant growth (Wilhelm *et al.* 2000, Breuer *et al.* 2003). As shown in Fig. 2, *S. japonica*, *Z. serrata* and *P. acerifolia* had different LAI values, and reached 2.57, 3.08 and 4.45, respectively which indicated that *P. acerifolia* had the highest LAI value. There is a significant difference in LAI value of *P. acerifolia* compared to *S. japonica* and *Z. serrata* ($p < 0.05$).

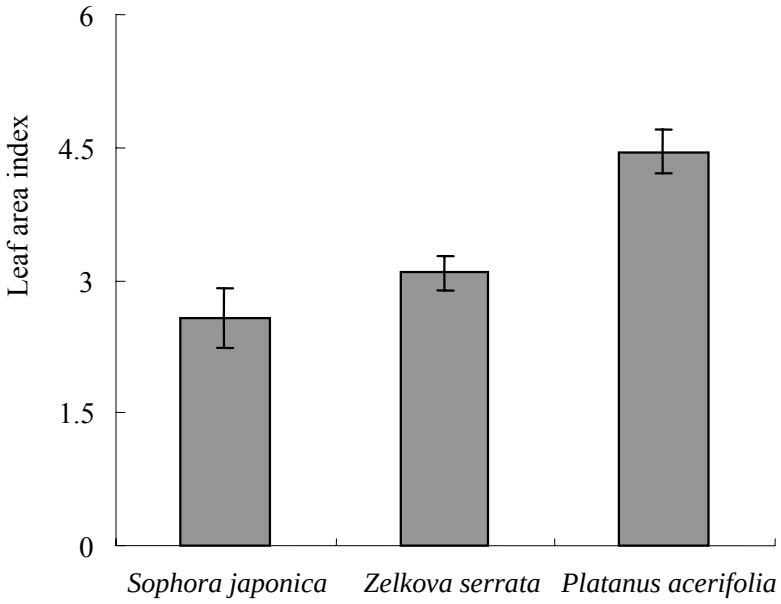

Fig. 2. Leaf area index (LAI) of three landscape trees.

The carbon fixation and oxygen release function is considered as an important indicator to evaluate photosynthesis capacity, which could provide a good reference for the ecological function of urban landscape trees (Herter *et al.* 2002). As shown in Fig. 3, carbon fixation and oxygen release function had similar trend of change. The function of fixing carbon and releasing oxygen in two plants (*Z. serrata* and *P. acerifolia*) increased significantly compared to *S. japonica*. The contents of carbon fixation per plant (CFC) and oxygen release contents per plant (ORC) of *P. acerifolia* all reached the highest (1080.72 and 785.98 g/d). The high contents in fixing carbon and releasing oxygen of *P. acerifolia* may indicate a good photosynthetic capacity, which is well related to the values of Pn and LAI (Figs 1 and 2). The present study is in conformity with that of Berg (2011). It is commonly considered that the plants with carbon fixation and oxygen release functions could exchange much more CO_2 and O_2 with the external environment, and make more solar energy converted into organic matter stored in plants.

In conclusion, in the present study, the highest contents in fixing carbon and releasing oxygen of *P. acerifolia* were shown compared to *S. japonica* and *Z. serrata*, which may indicate a good photosynthesis capacity, in good relation with the values of Pn and LAI. The present study could provide a good reference for the ecological function of urban landscape trees, which can increase canopy cover effectively and become an important storage site for CO_2 to cool urban heat islands and saves energy used for air conditioning and space heating. It is also confirmed that landscape

trees can provide much more social, economic and environmental benefits to urban greening construction and residents.

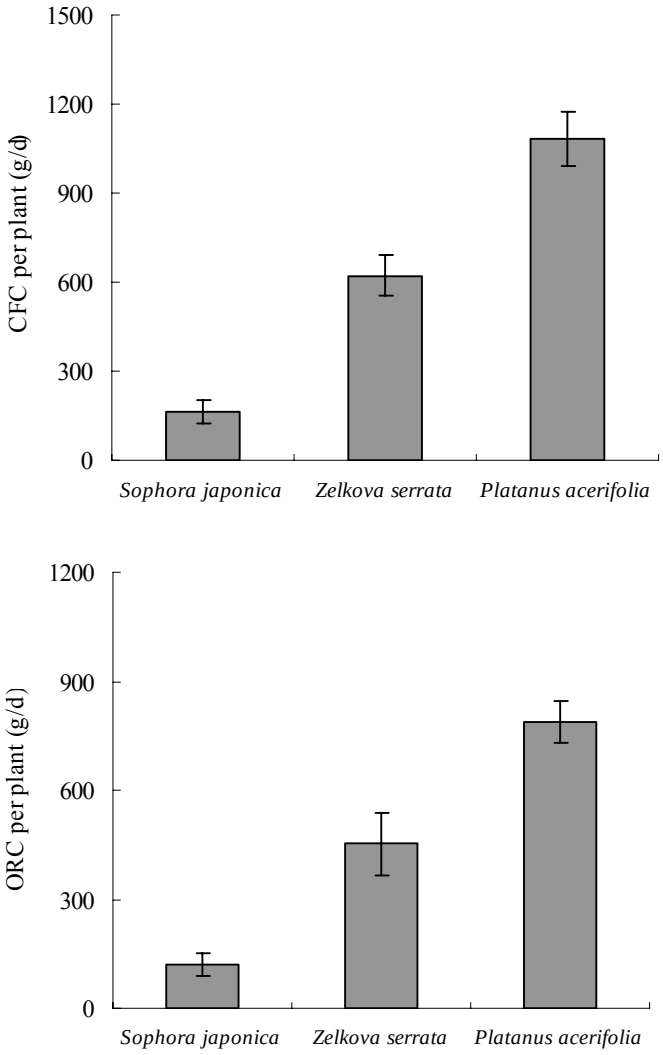

Fig. 3. Carbon fixation contents per plant and oxygen release contents per plant of three landscape trees.

Acknowledgements

This work was supported by the key project of Chinese Academy of Sciences (KFZD-SW-302-01), the National Natural Science Foundation of China (41301340), the National Science & Technology Pillar Program (2012BAC05B05) and the major National Science and Technology project "water pollution control and management" (2012ZX07202008) of China.

References

Barcelos e RJ, Schulz KG, Brownlee C, Sett S and Azevedo EB 2014. Effects of increasing seawater carbon dioxide concentrations on chain formation of the diatom *Asterionellopsis glacialis*. PLoS One **9**(3): e90749.

Bazzaz FA 1990. The response of natural ecosystems to rising global CO_2 levels. Annu. Rev. Ecol. Syst. **21**: 167-196.

Berg IA 2011. Ecological aspects of the distribution of different autotrophic CO_2 fixation pathways. Appl. Environ. Microbiol. **77** (6): 1925-1936.

Berg IA, Ramos-Vera WH, Petri A, Huber H and Fuchs G 2010. Study of the distribution of autotrophic CO_2 fixation cycles in Crenarchaeota. Microbiology **156**: 256-269.

Breuer L, Eckhardt K and Frede HG 2003. Plant parameter values for models in temperate climates. Ecol. Model **169**: 237-293.

Briber BM, Hutyra LR, Dunn A, Raciti SM and Munger JW 2013. Variations in atmospheric CO_2 mixing ratios across a Boston, MA urban to rural gradient. Land **2**(3): 304-327.

Calatayud A, Ramirez JW, Iglesias DJ and Barreno E 2002. Effects of ozone on photosynthetic CO_2 exchange, chlorophyll a fluorescence and antioxidant systems in lettuce leaves. Physiol. Plantarum **116**: 308-316.

Danyagri G and Dang QL 2013. Effects of elevated [CO_2] and low soil moisture on the physiological responses of mountain maple (*Acer spicatum* L.) seedlings to light. PLoS One 8(10): e76586.

Farquhar GD, von Caemmerer S and Berry JA 2001. Models of photosynthesis. Plant Physiol. **125**(1): 42-45.

Fuchs G 2011. Alternative pathways of carbon dioxide fixation: Insights into the early evolution of life. Annu. Rev. Microbiol. **65**: 631-658.

Geider RJ, Delucia EH, Falkowski P, Finzi A, Grime P, Grace J, Kana T, Roche JL, Long SP, Osborne BA, Platt T, Prentice IC, Raven JA, Schlesinger WH, Smetacek V, Stuart V, Sathyendranath S, Thomas RB, Vogelmann TC, Willians P and Woodward FI 2001. Primary productivity of planet earth: Biological determinants and physical constraints in terrestrial and aquatic habitats. Global Change Biol. **7**: 849-882.

Geissler N, Hussin S and Koyro HW 2009. Interactive effects of NaCl salinity and elevated atmospheric CO_2 concentration on growth, photosynthesis, water relations and chemical composition of the potential cash crop halophyte *Aster tripolium* L. Environ. Expt. Bot. **65**(2): 220-231.

Gregoriou K, Pontikis K and Vemmos S 2007. Effects of reduced irradiance on leaf morphology, photosynthetic capacity, and fruit yield in olive (*Olea europaea* L.). Photosynthetica **45**(2): 172-181.

Hamilton EW, Heckathorn SA, Joshi P, Wang D and Barua D 2008. Interactive effects of elevated CO_2 and growth temperature on the tolerance of photosynthesis to acute heat stress in C_3 and C_4 species. J. Integr. Plant Biol. **50**(11): 1375-1387.

Herter S, Fuchs G, Bacher A and Eisenreich W 2002. A bicyclic autotrophic CO_2 fixation pathway in *Chloroflexus aurantiacus*. J. Biol. Chem. **277**(23): 20277-20283.

Jia L, Liu ZL, Chen W, Ye Y, Yu S and He XY 2015. Hormesis effects induced by cadmium on growth and photosynthetic performance in a hyperaccumulator, *Lonicera japonica* Thunb. J. Plant Growth Regul. **34**: 13-21.

Körner C, Asshoff R, Bignucolo O, Hattenschwiler S, Keel SG, Pelaez-riedl S, Pepin S, Siegwolf RTW and Zotz G 2005. Carbon flux and growth in mature deciduous forest trees exposed to elevated CO_2. Science **309**: 1360-1362.

Kumari S and Agrawal M 2014. Growth, yield and quality attributes of a tropical potato variety (*Solanum tuberosum* L. cv Kufri chandramukhi) under ambient and elevated carbon dioxide and ozone and their interactions. Ecotox. Environ. Safe. **101**: 146-156.

Liu ZL, Chen W, Fu W, He XY, Fu SL and Lu T 2015. Effects of elevated CO_2 and O_3 on leaf area, gas exchange and starch contents in Chinese pine (*Pinus tabulaeformis*) in northern China. Bangladesh J. Bot. **44**(5): 917-923.

Liu ZL, He XY, Chen W, Jia L, Huang YQ, Zhang Y and Yu S 2013. Cadmium-induced physiological response in *Lonicera japonica* Thunb. Clean-Soil Air Water **41**(5): 478-484.

Meng F, Zhang J, Yao F and Hao C 2014. Interactive effects of elevated CO_2 concentration and irrigation on photosynthetic parameters and yield of maize in north-east China. PLoS One **9**(5): e98318.

Niu J, Feng Z, Zhang W, Zhao P and Wang X 2014. Non-stomatal limitation to photosynthesis in *Cinnamomum camphora* seedings exposed to elevated O_3. PLoS One **9**(6): e98572.

Reddy KR and Zhao D 2005. Interactive effects of elevated CO_2 and potassium deficiency on photosynthesis, growth, and biomass partitioning of cotton. Field Crop Res. **94**(2): 201-213.

Tripathi R and Agrawal SB 2012. Effects of ambient and elevated level of ozone on *Brassica campestris* L. with special reference to yield and oil quality parameters. Ecotox. Environ. Safe. **85**: 1-12.

Velasco E, Roth M, Tan SH, Quak M, Nabarro SDA and Norford L 2013. The role of vegetation in the CO_2 flux from a tropical urban neighbourhood. Atmos. Chem. Phys. **13**: 10185-10202.

Ward HC, Kotthaus S, Grimmond CSB, Bjorkegren A, Wilkinson M, Morrison WTJ, Evans JG, Morison JIL and Iamarino M 2015. Effects of urban density on carbon dioxide exchanges: Observations of dense urban, suburban and woodland areas of southern England. Environ. Pollut. **198**: 186-200.

Wilhelm WW, Ruwe K and Schlemmer MR 2000. Comparisons of three leaf area index meters in a corn canopy. Crop Sci. **40**: 1179-1183.

(Manuscript received on 29 April, 2016; revised on 27 June, 2016)