Effects of Traffic Volume on Photosynthetic Function and Water Use Efficiency of Tall Street Trees in Kyoto City

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Introduction

Urban trees play an important role in improving the urban environment by providing shade through their canopy, cooling effects through transpiration, capturing air pollutants, and absorbing carbon dioxide.

However, because street trees are planted in urban areas, they are susceptible to the air pollution caused by exhaust gases. The stress caused by air pollution is known to reduce physiological functions such as photosynthesis, which may prevent street trees from fulfilling their required role.

In this study, we focused on the environmental stress caused by air pollution and investigated the effect of different traffic levels on the photosynthetic function of tall street trees by measuring the photosynthetic function and stable carbon isotope ratios of three street tree species at four sites with different traffic levels in Kyoto City. Since traffic volume and air pollution levels are strongly related, we used traffic volume as an indicator to measure air pollution in Kyoto City.

Materials and methods

1. Tree species

Three species were used: ginkgo (*Ginkgo bioloba* L.), Japanese maple (*Acer buergerianum* Miq.), and Someiyoshino cherry (*Prunus×yedoensis* Matsum.). These are all deciduous tall trees. The top three most commonly planted tall trees in Japan and in Kyoto were selected for the study.

2.Study site

The four study sites were chosen to be near an air monitoring stations that was set up by the Kyoto city government, which constantly measures the concentration of air pollutants. he four study sites were selected to provide as much variability as possible in 12-hour vehicle traffic volumes on adjacent roads.

3.Photosynthesis measurements using the Li-6400 XT

The collected leaves were used to generate an A-Ci curve using a photosynthesis measurement system (Li-6400 XT, Li-Cor, USA). The maximum carboxylation rate (V_{cmax}) and the electron transport rate (J) of the thylakoid membrane were determined from the A-Ci curves.

Since the average CO_2 concentration in the environment where trees are actually planted is about 400 μ mol mol^{-1}, the photosynthetic rate (A) at a CO_2 concentration of 400 μmol mol^{-1} of CO_2 was calculated as A_{400}, and the stomatal conductance (g_s) at 400 μmol mol^{-1} was also determined. The water use efficiency (WUE) was calculated as A_{400}/g_s.

4.Stable carbon isotope ratio measurement of leaves

The dried leaves were powdered and sealed in tin foil at 1.0 ±0.05 mg each. The stable carbon isotope ratios (delta-^{13}C) were measured using a CN-IRMS mass spectrometer at the Research Institute for Humanity and Nature. Working standards CERKU-03 and CERKU-07 (03:Glycine, 07:STARCH-C4) were used for the correction of delta-^{13}C.

Results

The photosynthetic rate of *G. biloba* was lower at high traffic sites and higher at low traffic sites. For *P. yedoensis*, the photosynthetic rate was lower at the site that had second highest traffic volume, compared to the other three sites. For *A. buergerianum*, stomatal conductance decreased with increasing traffic volumes, but the maximum carboxylation rate increased, and as a result, there was no difference in photosynthetic rate between sites. Water use efficiency tended to increase with traffic volume in *P. yedoensis,* but did not correlate with traffic volume in *G. biloba* and *A. buergerianum*.

Discussion

Different air pollution levels had different effects on photosynthetic function in different tree species. High air pollution levels imposed negative impact on the photosynthetic rate for *G. biloba*, and it imposed positive impact on the water use efficiency for *P. yedoensis*. The photosynthetic rate of *P. yedoensis* was higher than that of the other two tree species at all study sites, and it may have a sensitive response to stress because its water use efficiency increased with the increase in traffic volumes. These results suggest that the leaves of *P. yedoensis* effectively absorbed CO_2 as a street tree in the year 2020.

Keywords: Stable carbon isotope ratio, Environmental stress, Photosynthesis

