Jour. Korean For. Soc. Vol. 95, No. 2, pp. 216~219 (2006)

JOURNAL OF KOREAN FOREST SOCIETY

Visual and Physiological Characteristic Changes of Five Tree Species Exposed to SO_2

Ki-Won Kwon[1], Jeong-Ho Choi[2], Su-Young Woo[3], Jae-Cheon Lee[4] and Jeong Ho Lee[5]

[1]*Department of Environmental Forest Resources, Chungnam National University, Daejeon 305-764, Korea*
[2]*Forest Practice Research Center, Korea Forest Research Institute, Pocheon 487-821, Korea*
[3]*Department of Environmental Horticulture, University of Seoul, Seoul 130-743, Korea*
[4]*Department of Forest Genetic Resources, Korea Forest Research Institute, Suwon 441-350, Korea*
[5]*National Arbortetum, Pocheon 487-821, Korea*

Abstract : After long exposure to low-density SO_2, the five tree species showed different changes in their visible damage: *Ailanthus altissima* showed no visible damage; *Acanthopanax sessiliflorus*, *Populus alba ×Populus glandulosa*, and *Platanus orientalis* showed typical damage of yellow spots on their leaves; and *Liriodendron tulipifera* showed serious damage on the end of leaf tip. The photosynthesis rate of *Liriodendron tulipifera* and *Acanthopanax sessiliflorus* was usually lower than the control group: *Ailanthus altissima*, *Populus alba ×Populus glandulosa*, and *Platanus orientalis* showed no difference from the control group, while *Acanthopanax sessiliflorus* and *Liriodendron tulipifera* showed large changes. In regard to the light compensation points, *Ailanthus altissima* showed similar values, *Populus alba×Populus glandulosa* and *Platanus orientalis* exposed to SO_2, showed 3 to 5 $\mu mol \cdot m^{-2} \cdot s^{-1}$ higher values than the control group, and *Acanthopanax sessiliflorus* and *Liriodendron tulipifera* exposed to SO_2 showed approximately twice higher light compensation points.

Key words **:** *visible damage, net photosynthesis, compensation, SO_2*

Introduction

Recently, rapid industrialization and urbanization have caused excessive use of fossil fuel, which drastically increased and widely expanded discharged pollutants resulting in serious environmental issues. Air pollutants generally cause direct pollution through acidification of the ecological systems of soil and water, and then indirect one through various physiological reactions (Bache, 1980; Freedman, 1989). They thus negatively affect the growth of plants. In particular, they disturb photosynthesis, carbon decomposition, use of water content, activation of chlorophyll and enzyme, and opening and closing of air channels. They disturb, in result, the physiology of plants, suppress their growth, and make them wither to death (Fox and Mickler, 1996; Olson and Dubey, 1990; Skärby, *et al*, 1987; Woo *et al.*, 2003 a, b). SO_2 is one of direct air pollutants, which is a colorless irritating non-inflammable gas that dissolves well in water. It is discharged mainly from combustion of sulfur-containing charcoal and petroleum, metal smelting, and other industrial processes. SO_2, like nitrogen oxides, is one of main root causes of acid rain, which in turn acidifies soil, lakes, rivers, etc (Winner, 1994). If plants absorb SO_2, it is usually accumulated as sulfate or sulfite, which show toxicity and disturb the internal metabolism (Agrawal and Deepak, 2003; Reich *et al.*, 1983). To recover the metabolism, the plant produces additional energy by increasing its respiration and reducing its growth. The absorbed SO_2 ultimately disturbs the photosynthesis that is closely related to the growth of plants (Agrawal and Verma, 1997; Darrall, 1989). This study compared the visual and physiological characteristics of five species of trees exposed to SO_2, to find the damage types. It thus intends to provide basic information for growth and selection of pollution-resistant plants.

Materials and Methods

1. Plant Materials

Five tree species were used in this study; *Ailanthus altissima*, *Acanthopanax sessiliflorus*, *Liriodendron tulipifera*, *Platanus orientalis*, and *Populus alba×Populus glandulosa*. The seeds were collected at seed orchard in Suwon, the Korea Forest Research Institute (KFRI),

*Corresponding author
E-mail: uptake@hanmail.net

Breeding Station. These seeds were stored at 4°C in a refrigerator until sowing. Two weeks after germination, they were placed in the greenhouse at 70% relative humidity. *Populus alba* × *Populus glandulosa*, the test material was prepared by cutting its branches early March, storing them at 4°C, and then planting them in pots early April. Each cuttings were dipped into a rooting hormone (Indole-3-butyric-acid), and then cultivated into saplings in 0.5 liter pots which contained peatmoss, vermiculite and soil in a 1:1:1 ratio. Pots were watered daily and NPK fertilizer (15-16-17) was used twice per week. The temperature in the greenhouse was between 23 and 25°C during the experimental period. The relative humidity was 70% at seedling height. This study was conducted in Expermental Unit, Breeding Station in the Korea Forest Research Institute. All of the seedlings in this study were two years old.

2. SO_2 Exposure

We established an appropriate environmental system in a chamber, exposed the trees to 300 ppb SO_2, 8 hours a day for 20 days (Figure 1). SO_2 concerations were monitored with a SO_2 analyzer. The monitor was re-calibrated daily before SO_2 fumigation. After plants leaf showed a visible damage, the SO_2 exposure was stopped and then the plants were placed in the clean to measure phothsynthesis and compared the results with the control group.

3. Net Photosynthesis Measurement

Light-saturated net photosynthesis (An) was measured on fully expanded, mature leaf number 4 counted from each shoot apex on every individual in the treatments. Net photosynthesis was measured with a broad-leaf cuvette of the Li-cor 6400 Potable Photosynthesis System (Li-cor Inc., USA), the leaf was sealed and CO_2 concentration was allowed to be maintained at ambient levels. Air flow through the analyzer was adjusted to maintain leaf cuvette relative humidity near ambiebt level (70±10%) during measurement. The average cuvette temperature was maintained at 25°C For photosynthesis capacity, this study measured the light-photosynthesis curve by adjusting the light intensity from 0 to 2,000 μmol m^{-2} s^{-1} with a photosynthesis analyzer (Woo *et al.*, 2003). Net Photosynthesis was calculated as :

$$A_n = \frac{u_e(c_e - c_c)}{100s} = c_c E$$

An; Net Photosynthesis (μmol CO_2 m^{-2} s^{-1}), u_e; mole flow rate of air entering the leaf chamber (μmol s^{-1}), c_e; mole fraction of CO_2 in the leaf chamber (μmol CO_2 mol^{-1} air), c_c; mole fraction of CO_2 entering in the leaf chamber (μmol CO_2 mol^{-1} air), s; leaf area (cm^2), E; transpiration (mmol H_2O $m^{-2}s^{-1}$)

This study also performed a regression analysis and obtained photosynthesis curves using SigmaPlot(SPSS Inc.) to estimate precise light-photosynthesis curves and light compensation points.

$$y = ax / (b + x)$$

A light compensation point is obtained when y = 0 in the equation above.

Results and Discussion

Photosynthesis capacity is a good standard to deter-

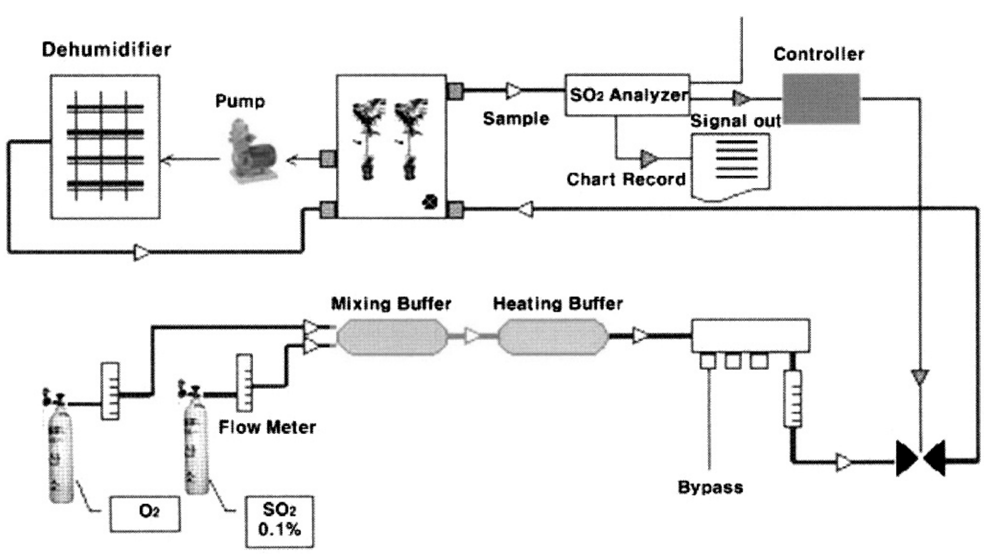
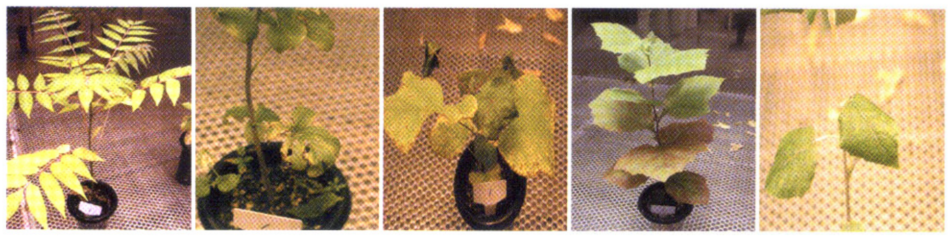


Figure 1. Schematic diagram of the SO_2 exposure for the measurement of visual and physiological characteristics in five tree species.



Ailanthus altissima | *Acanthopanax sessiliflorus* | *Liriodendron tulipifera* | *Platanus orientalis* | *Populus alba* × *Populus glandulosa*

Figure 2. Visible damage of 5 tree species after SO_2 fumigation for 20 days.

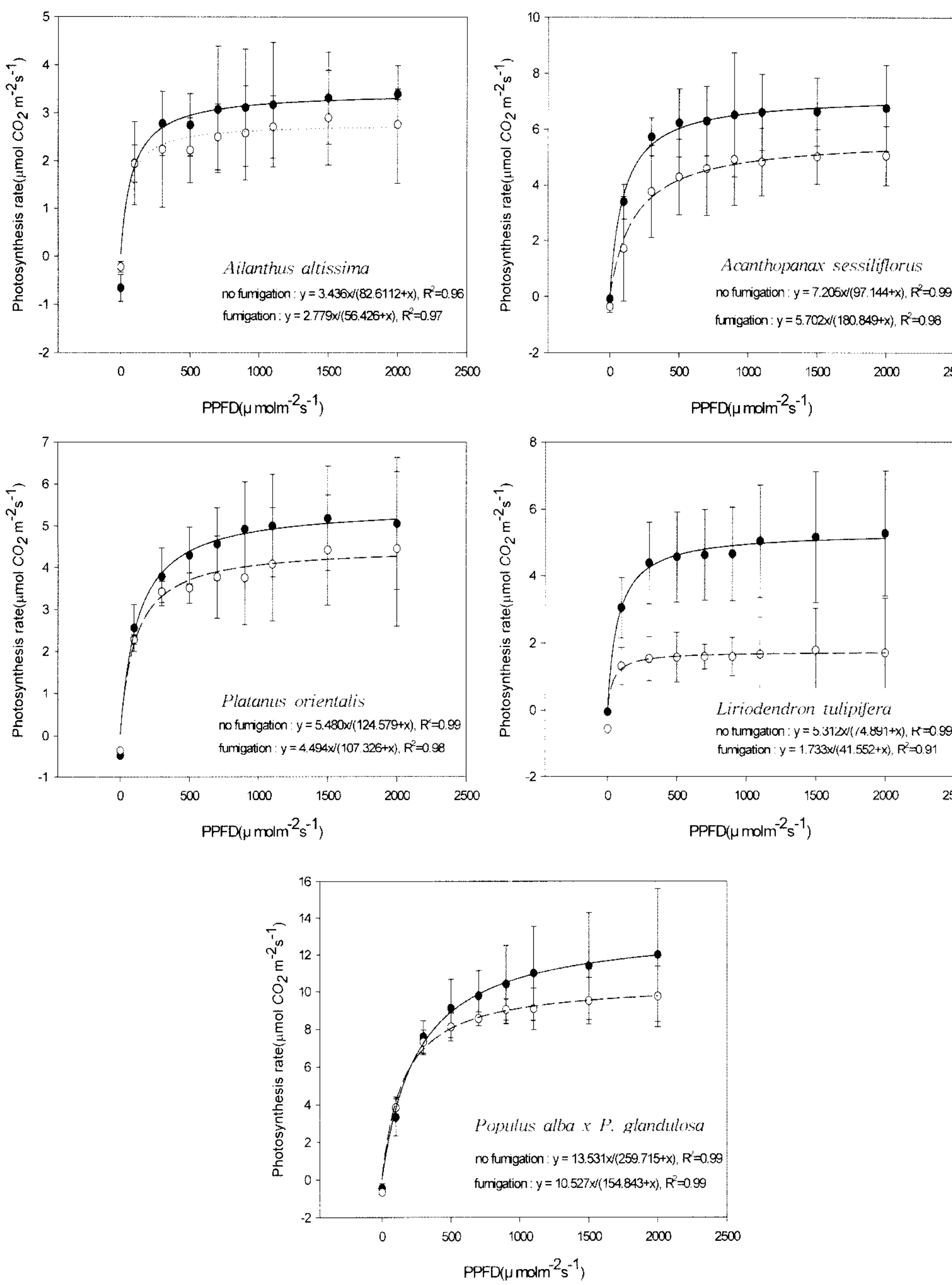


Figure 3. Light response curves in net photosynthesis of five tree seedlings fumigated with SO_2. Bars indicate standard deviation. PPFD means Phothsynthetic Photon Flux Density; control(●), and SO_2 fumigation for 20 days (○).

mine how much plants are damaged by air pollution. This study exposed the trees to low-density SO_2 for 20 days.

In regard to the visible damage, *Ailanthus altissima* showed no visible damage even after SO_2 exposure and *Populus*

Table 1. Estimated values of light compensation point in the five deciduous tree seedlings fumigated with SO_2. ($\mu mol \cdot m^{-2} \cdot s^{-1}$)

Treatment	*Ailanthus altissima*	*Acanthopanax sessiliflorus*	*Liriodendron tulipifera*	*Populus alba* × *P. glandulosa*	*Platanus orientalis*
Control	34.0±6.5	38.0±8.5	57.0±10.3	16.0±4.2	28.0±8.5
Damage	32.0±4.4	16.0±5.2	17.0± 4.3	21.0±6.9	31.0±3.5

alba×*Populus glandulosa* showed yellow spots on its leaves. For *Acanthopanax sessiliflorus*, the leaves contracted as the yellow spots worsened on their front ends. *Platanus orientalis* showed damage between the main vein and the later ones on the leaves. *Liriodendron tulipifera*, in particular, showed the most serious damage that started at the end and edge of the leaves and expanded widely and uniformly (Figure 2).

In regard to the photosynthesis rate, the five species of trees showed lower rate after SO_2 exposure: *Ailanthus altissima*, *Populus alba*×*Populus glandulosa*, and *Platanus orientalis* showed little difference from the control group; *Acanthopanax sessiliflorus* showed much lower rate; and *Liriodendron tulipifera*, in particular, showed less than half of the control group's rate. *Liriodendron tulipifera*, in result, showed remarkable changes both in its visible damage and photosynthesis rate (Figure 3). SO_2 stress decreased the photosynthesis in many other plants species (Reich *et al*, 1983, Woo *et al.*, 2003 a, b).

The result to be consequently overall, *Ailanthus altissima* was to resistant species against SO_2 pollution. In contrast, *Acanthopanax sessiliflorus* and *Liriodendron tulipifera* had significiant reduction in photosynthesis following expoure and showed visible damage.

Table 1 compares the light compensation points of SO_2-exposed trees and the control group.

As shown in the table, *Ailanthus altissima* showed little difference between the two groups, while, for *Populus alba*×*Populus glandulosa* and *Platanus orientalis*, the points of exposed leaves were higher than those of the control group by 3 to 5 $\mu mol \cdot m^{-2} \cdot s^{-1}$. For *Acanthopanax sessiliflorus* and *Liriodendron tulipifera*, however, the points of the exposed leaves were higher by 22 to 40 $\mu mol \cdot m^{-2} \cdot s^{-1}$ than those of the control group, which means exposed leaves showed more than twice higher light compensation points than the control group. Many changes in a plant physiology and growth, such as those caused by SO_2, are the results of biological compensatory responses to an environmental stress (Winner, 1994. Woo *et al*, 2003 a, b).

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(Received February 21, 2006; Accepted March 8, 2006)