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THE UPTAKE OF SO_2 AND NO_2 BY PLANTS

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ABSTRACT

Foliar removal of sulfur dioxide and nitrogen dioxide was measured in a closed exposure system. The purpose was to identify local plant species capable of removing appreciable amounts of these gases from the air. Seedlings of twenty-one plants were exposed to known concentrations of the pollutant. The difference in pollutant concentration before and after exposure period was taken as the amount absorbed by the plant.

INTRODUCTION

The physiological processes of photosynthesis and respiration involved an exchanged of carbon dioxide and oxygen between the atmosphere and plants through their stomates. The stomatal pores provide the channels for the escape of water from the plant in transpiration as well as for the diffusion of other gased into the plant. The latter mechanism is significant in relation to the air pollution problem confronting cities and industrial centers. If plants can absorb air pollutants, then they can help cleanse the air of undesirable substances.

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Foliar absorption of gaseous pollutants by plants has been reported in several studies (1-4). Lists compiled with respect to relative susceptibilities of plants to air pollutants are also available (5-7). However, except for a local investigation focusing on the toxic levels of SO_2 (sulfur dioxide) in rice and how the gas affects the growth and yield of rice plants (8), the available information refers to vegetation and environmental conditions markedly different from those in the Philippines.

The work reported here was an attempt to investigate the foliar removal of SO_2 and NO_2 (nitrogen dioxide) from the air. The purpose was to identify local plants capable of removing appreciable amounts of these pollutants from the atmosphere.

EXPERIMENTAL SECTION

Materials

Seedlings of twenty-one plant species* (Table 1) were potted in a 2 to 1 mixture of garden soil and sawdust. Soil analysis showed that nutrients were present in sufficient amounts. The potted seedlings were kept in the University of the Philippines Natural Science Research Center (UPNSRC) plant house in Diliman until needed for the chamber exposure. Average day temperature in the plant house was 30° C, night temperature, 26 °C; relative humidity was 72 percent.

Exposure to SO_2

Experiments were conducted during the midmorning

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* These plants were shown in another aspect of the "Uptake" project as able to grow well and remain healthy for four months in Makati, Ermita, Quiapo, and Cubao.

Table 1. The plant species used in the study of SO_2 and NO_2 uptake.

Common Name	Scientific Name	Family
Antsoan dilau	*Cassia spectabilis* DC.	Leguminosae
Caballero	*Caesalpinea pulcherrima* (L.) Sw.	Leguminosae
Ipil-ipil	*Leucaena leucocephala* (Lam.) Dewit.	Leguminosae
Moluccan sau	*Albizia falcataria* (L.) Fosb.	Leguminosae
Lumbang (candle nut tree)	*Aleurites moluccana* (L.) Willd.	Euphorbiaceae
Picara	*Excoecaria cochinchinensis* Lour.	Euphorbiaceae
San Francisco	*Codiaeum variegatum* (L.) Blume	Euphorbiaceae
Zigzag plant	*Pedilanthus tithymaloides* (L.) Poit.	Euphorbiaceae
Adelfa	*Nerium indicum* Mill.	Apocynaceae
Campanilla	*Thevetia peruviana* (Pers.) Merr.	Apocynaceae
Chichirica	*Catharanthus roseus* (L.) G. Don.	Apocynaceae
Large yellow bell	*Allamanda cathartica* L.	Apocynaceae
Molave	*Vitex parviflora* Juss.	Verbenaceae
Yemane	*Gmelina arborea* L.	Verbenaceae
Bougainvillea	*Bougainvillea spectabilis* Willd.	Nyctaginaceae
Bunga	*Areca catechu* L.	Palmae
African tulip	*Spathodea campanulata* Beauv.	Bignoniaceae
Bandera Española	*Canna indica* L.	Cannaceae
Creeping daisy	*Wedelia trilobata* (L.) Hitchc.	Compositae
Mayana	*Coleus blumei* Benth.	Labiatae
Pandan (edible)	*Pandanus odoratissimus* L.	Pandanaceae

to early afternoon period under natural sunlight. On overcast days, additional illumination was provided by a 40 watt Grolux cool beam lamp. Prior to exposure, the potted plants were watered and the pots individually wrapped in plastic bags. Each plant was then covered with a plastic sheet and placed in a 1.7 cubic meter Plexiglas exposure chamber (E) equipped with an air circulation system (Figure 1).

Ambient air was pulled through a charcoal filter (D) into the chamber at the rate of 15 liters per minute by adjusting the air compressor (C), flowmeters (B_2 and B_3) and the rotary pump (J). SO_2 gas was introduced at an appropriate flowrate by controlling the flowmeter (B_1) from the gas tank (A) until the desired concentration (0.10 to 0.18 ppm) was reached. The wet test meter (I) was removed from the setup during the introduction of SO_2 into the chamber.

The SO_2-air mixture was allowed to equilibrate for one hour during which three determinations of SO_2 concentration were made. SO_2 concentration was measured spectrophotometrically according to the method of West and Gaeke (9). Chamber air samples for spectrophotometric analysis were pulled by a diaphragm pump (J) into an absorbing solution contained in the bubbler (G). Actual sample volume was measured by use of the wet test meter (I). SO_2 concentration was also determined by the gas chromatographic method of Stevens and co-workers (10). Air samples were introduced directly from the exposure chamber into the sample loop of the chromatograph.

The plant was uncovered and exposed to SO_2 for three hours. Other exposure conditions were: temperature, 25 to 40°C; relative humidity, 35 to 91 percent; wind speed, 2 meters per second. Air samples were collected and analyzed spectrophotometrically and by gas chromatograph every hour. The difference between the initial and the final SO_2 concentration was taken to be the amount of SO_2 absorbed by the plant. The total leaf area of the seedling was

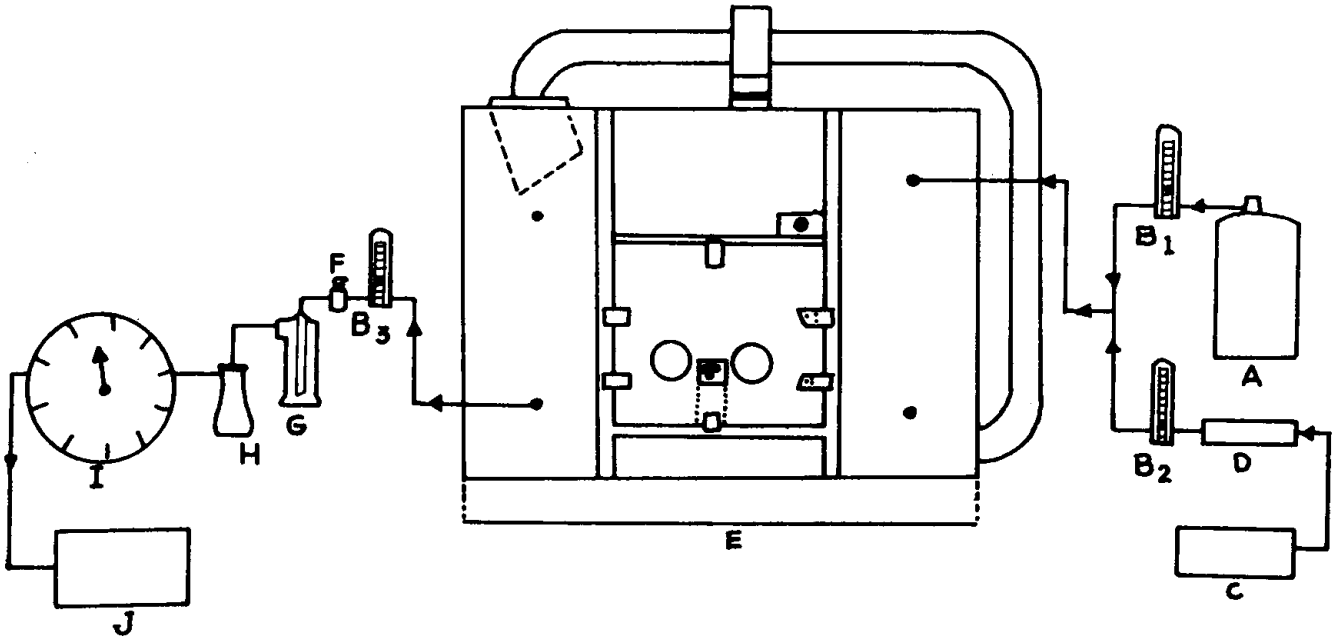

Figure 1. Diagram of the system used to measure SO_2 uptake. A - SO_2 tank; B_1, B_2, B_3 - air compressor; D - charcoal filter; E - chamber; F - threeway valve; G - bubbler; H - trap; I - wet test meter; J - pump (air or diaphragm).

determined. Plants were examined for any visible injury immediately after exposure and up to three or four days thereafter.

Exposure to NO_2

The absorption of NO_2 was determined as in the preceding procedure except that a vaporizer was used for introducing NO_2 (0.11 to 0.20 ppm) into the chamber and gas concentration measured by the Griess-Saltzman method (11).

Leaf blades of the exposed plants were sectioned before, immediately after, one day after, and three days after exposure. The thin sections were individually suspended in distilled water: 95% ethanol: glycerin (1:1:1) and mounted on slides, the cover slips sealed with nail polish. The slides were examined microscopically under 45 x magnification.

RESULTS AND DISCUSSION

The seedlings that were exposed for three hours to SO_2 (0.10 to 0.18 ppm) in a specially designed chamber did not show any symptoms of foliar injury.

The species tested absorbed SO_2 gas at varying rates rates (Table 2). *Ipil-ipil*, *picara*, Moluccan *sau*, *yemane* and *pandan* appeared to be more effective in reducing the pollutant concentration in the chamber than *bougainvillea*, *Bandera Española*, *bunga lumbang* and *San Francisco*.

The sixteen plants that were exposed to NO_2 (0.11 to 0.20 ppm) likewise exhibited no visible foliar injury symptoms. *Ipil-ipil*, yellow bell, *chichirica*, Moluccan *sau* and *lumbang* appeared to be better NO_2 absorbers than *bunga*, *molave*, *campanilla*, *bougainvillea* and zigzag plant (Table 3).

As evident in the absence of any changes in the chloroplasts, palisade and mesophyll cells, *ipil-ipil*, Moluccan *sau*, *molave*, *bougainvillea*, creeping daisy and *San Francisco* appeared not to have been injured by exposure

Table 2. The sorption of SO_2 by plants.

Plant Species	Initial SO_2 Concentration, ppm	Uptake Rate* ug m^{-2} s^{-1}
Ipil-ipil	0.14	2.77
Picara	0.10	1.22
Moluccan sau	0.16	1.13
Yemane	0.13	1.06
Pandan	0.15	1.00
Chichirica	0.17	0.89
Caballero	0.13	0.86
African tulip	0.14	0.84
Zigzag plant	0.15	0.83
Mayana	0.15	0.82
Antsoan dilau	0.12	0.75
Molave	0.18	0.70
Creeping daisy	0.13	0.67
Adelfa	0.16	0.57
Yellow bell	0.17	0.52
Campanilla	0.15	0.49
Bougainvillea	0.14	0.44
Bandera Española	0.11	0.19
Bunga	0.11	0.19
Lumbang	0.16	0.15
San Francisco	0.13	0.15

*Values given are the mean uptake of two of three seedlings. Exposure time: 3 hours.

Table 3. The sorption of NO_2 plants.

Plant Species	Initial NO_2 Concentration, ppm	Uptake Rate,* ug m^{-2} s^{-1}
Ipil-ipil	0.11	0.33
Yellow bell	0.17	0.25
Chichirica	0.14	0.24
Moluccan sau	0.14	0.24
Lumbang	0.15	0.22
African tulip	0.13	0.19
Bandera Española	0.11	0.19
Yemane	0.16	0.17
Pandan	0.14	0.17
San Francisco	0.20	0.17
Antsoan, dilau	0.11	0.15
Bunga	0.14	0.14
Molave	0.19	0.13
Campanilla	0.12	0.10
Bougainvillea	0.12	0.08
Zigzag plant	0.11	0.03

*Values given are the main uptake of two or three seedlings. Exposure time: 3 hours.

to SO_2. Similarly, *ipil-ipil* and *San Francisco* withstood exposure to NO_2 at the concentrations indicated above.

Examination of plant tissues injured by exposure to high SO_2 concentrations (golden shower, *Cassia fistula* L., at 2.1 ppm and yellow shower, *Cassia fructicosa* Mill., at 0.69 ppm) revealed colllapsed mesophyll cells and changes in the shape of chloroplasts. Similar results were obtained with *ipil-ipil* tissues that have been exposed to 0.33 ppm NO_2. In one instance, the leaves of *molave* turned brown a day after exposure to $>$ 2 ppm SO_2. Under the microscope, however, only the epidermal layer appeared discolored and the mesophyll cells showed no change. The observations suggest that the stomates must have closed during exposure, preventing contact of SO_2 with the internal cells.

The response of plants to air pollutants depends on the concentration of the pollutant, the length of exposure, the plant environment (temperature, light, humidity, wind speed, soil moisture, mineral nutrition) and the stage of plant development (12). Uptake is favored by the difference between pollutant concentration in the air and in the plant cells, and is limited by aerodynamic, stomatal and mesophyllic resistances (13). Enclosing the plant in a chamber, such as was done in this study, subjects it to abnormal conditions which affect its behavior, including the sorption of gases. In addition, the plants used were one to two year old seedlings whose responses may not be directly related to their responses when mature.

The results presented here, therefore, are limited by our choice of plants and may be correct only under the special circumstances prevailing during exposure. They should be viewed as first-order estimates of the SO_2 and NO_2 absorbing capacities of the tested plants. However, the uptake rates observed, though approximations, compare well with values reported by other investigators (Table 4). It would seem that, on the whole, the uptake of SO_2 does not vary greatly with plant species.

Table 4. The uptake of SO_2 by nontropical plants.

Plant	Pollutant Concentration, ppm	Uptake Rate, ug m^{-2} s^{-1}	Reference
Alfalfa	0.02	0.15	1
Azalea	0.2	1.3	3
White ash	0.2	1.2	3
Firethorn	0.2	1.7	3
White birch	0.2	1.9	3
Barley seedling	0.02	0.05	4

Studies on pollutant gas uptake by vegetation provide the basis for assessing the effectiveness of green belts in the abatement of air pollution. There is a need, therefore, for the accurate determination of pollutant uptake rates under field conditions, possibly by the use of ecophysiological methods (14).

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