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Response to O_3 and SO_2 for Five Mongolian Semi-arid Plant Species

By

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Summary

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Increasing air pollution level in Mongolia has caused great concerns in the stability of some of the semiarid grassland ecosystems. So far, there is no experimental datum available for assessing the effects of air pollutants on the native grass species in this region. In the present study, five Mongolian semiarid plant species (*Astragalus* spp., *Carex* spp., *Chamaeneriau angustifolium*, *Polygonum alopecuroides* and *Sanguisorba officinalis*) were exposed to either O_3 (0.05 ppm average, 0.1 ppm maximum) or SO_2 (0.1 ppm constant) for 4 weeks in controlled environment chambers. To investigate the growth responses of these species to the two air pollutants, growth parameters such as leaf number, leaf area, biomass and root/shoot ratio were measured at the final harvest. Different species showed different sensitivities to the two air pollutants. O_3 significantly reduced leaf number of *Carex* spp., biomass and root/shoot ratio of *Polygonum alopecuroides*, root/shoot ratio of *Sanguisorba officinalis*, but had no effect on other growth parameters of these species or all the growth parameters of the other species. SO_2 significantly reduced leaf number and biomass of *Carex* spp., and had no effects on other growth parameters for this species and all the growth parameters of the rest of the four species.

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Introduction

In the past decade, along with rapid industry development and motor vehicle number increase, atmospheric pollutants (such as SO_2, NO_2, O_3) concentrations have reached an alarming level in most of the developing countries in Southeast Asia (EMBERSON & al. 2001, ZHENG & SHIMIZU 2003). Air-pollution-caused forest declining and agriculture production reduction have been reported in many parts in this regions (EMBERSON & al. 2001, YANG & al. 2002, ZHENG & SHIMIZU 2003). Recently, a survey reported that the health of larch trees (*Larix sibirica*) around Mt. Bogdkhan near Ulaanbaatar (capital of Mongolia) had shown signs of declining (SASE & al. 2005). Air pollution, including exhaust emission from thermal power plants near Mt. Bogdkhan, was suspected as one of the possible causes (SASE & al. 2005).

Around Mt. Bogdkhan, there are some important grass species, including medicinal herb species, grown in this semiarid grassland (MINISTRY OF NATURE AND THE ENVIRONMENT 1998). Because of the semiarid climate condition and the infertile sandy soil, the ecosystem in this region is fragile. Any environmental stress could potentially put this ecosystem in further deteriorating situation. The increasing air pollution level in this region has caused great concerns in the stability of the semiarid grassland ecosystem. However, there is no datum which we are aware of regarding the responses of the native grass species to SO_2 and O_3 in this region.

The objective of the present study was to investigate the growth responses of five herbaceous species from semiarid Mongolia to SO_2 and O_3 in controlled environment chambers, in order to provide baseline data of species sensitivities to SO_2 and O_3 for assessing the potential effects of air pollution to the grassland in this region.

Material and Methods

Five Mongolian semiarid plant species (*Astragalus* spp., *Carex* spp., *Chamaeneriau angustifolium*, *Polygonum alopecuroides* and *Sanguisorba officinalis*) were studied for their responses to atmospheric O_3 and SO_2 in controlled environment chambers at the National Institute for Environmental Studies, Japan. Seeds were collected in a semiarid region around Mt. Bogdkhan, Mongolia. After brought to Japan, seeds were germinated in a medium with 70 % sand and 30 % artificial horticulture soil (Kureha Engeibaido, Kureha Chemical Industry Co. Ltd., Japan) under greenhouse conditions. Four-week-old plants were transplanted into pots (0.28 litre) containing the same growth medium as used for germination. Potted plants were grown in the same greenhouse and watered as needed with tap water. Sixteen plants of each species, after recovered from transplanting, were transferred to naturally-lighted environment-controlled growth chambers (S-203 A, Koito Ind., Japan; width × length × height: 2 m × 2 m × 2 m). In addition to the natural sun radiation, 4 fluorescence lamps (FLR40S, Panasonic Co., Japan) were used in each chamber to provide a 14-hour photoperiod. Air temperature and relative humidity in all the chambers were maintained at 25/15 °C (day/night) and 55/75 % RH (day/night), respectively, as shown in Fig. 1. Plants were watered once every 2 days using tap water in order to provide a nutrient and water limiting condition similar as in the field where these plants were growing. The overall environment conditions of each growth chamber were balanced similarly, and differences among chambers were less than 5 %.

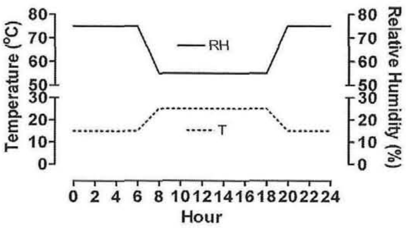

Fig. 1. Air temperature (T) and relative air humidity (RH) in all chambers during the experiment. 25 °C and 55 % RH (8:00-18:00); 15 °C and 75 % RH (20:00-6:00); transition (6:00-8:00, 18:00-20:00).

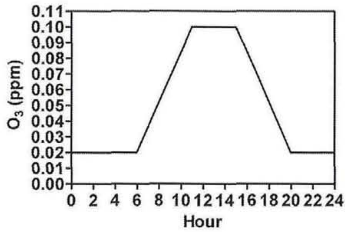

Fig. 2. O_3 diurnal pattern in the ozone-exposure chamber during the experiment. O_3 concentration: 0.02 ppm (20:00-6:00); 0.1 ppm (11:00-15:00); transition (6:00-11:00, 15:00-20:00).

There were three treatments such as control (CK), ozone (O_3) and sulfur dioxide (SO_2) exposures in the present experiment: CK, with charcoal-filtered ambient air containing no air pollutants; O_3 treatment, with a diurnal O_3 concentration as shown in Fig. 2 (0.05 ppm average); SO_2 treatment, with a SO_2 concentration as kept at 0.1 ppm constantly for day and night. O_3 concentration was monitored by photometric analyser (ML9810, Monitor Labs, USA) and SO_2 concentration was monitored by fluorescent analyser (ML9850, Monitor Labs, USA). Both gas concentrations in the respective chambers were controlled by the system with mass flow controllers (SFC-480, Hitachi Metals, Ltd., Japan).

Four weeks after gas exposure, plant visible injuries were examined by eyes and leaf number of each plant were counted. Then each plant was separated into leaf, stem and root. Leaf area was measured by LI-3100 area meter (LI-COR, Inc., Lincoln, NE, USA). All the plant tissues were oven dried at 80°C for more than 3 days and weighed separately. Root/shoot ratio was calculated by dividing the under-soil biomass by above-soil biomass.

The treatment means of all the growth parameters were compared by Tukey's multiple comparison. Software GraphPad Prism 4 (San Diego, California, USA) was used for the statistical analysis.

Results and Discussion

Astragalus spp.

No visible symptoms of O_3 and SO_2 injury or nutrient deficiency were observed throughout the experiment for leaves of *Astragalus* spp. under any of the treatments. Neither SO_2 nor O_3 had any significant effect ($P>0.05$) on leaf number, leaf area, plant biomass and root/shoot ratio (Fig. 3).

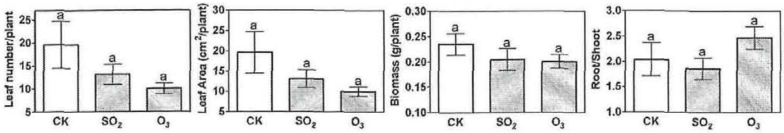

Fig. 3. Growth responses of *Astragalus* spp. to SO_2 and O_3. Data are means of 16 individuals ± standard error. Bars bear the same letter are not significantly different at 5 % level.

Carex spp.

No visible symptoms of O_3 and SO_2 injury or nutrient deficiency were observed throughout the experiment for leaves of *Carex* spp. under any of the treatments. Growth responses of *Carex* spp. are shown in Fig. 4. SO_2 and O_3 significantly reduced ($P<0.05$) plant leaf numbers by 23 % and 21 %, respectively. SO_2 also significantly reduced ($P<0.05$) plant biomass by 18 %. Leaf area and root/shoot ratio were not significantly affected ($P>0.05$) by either SO_2 or O_3.

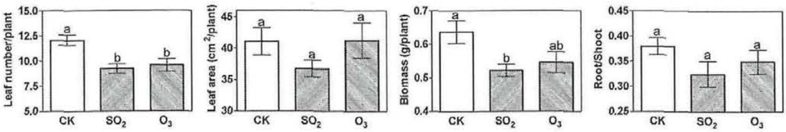

Fig. 4. Growth responses of *Carex* spp. to SO_2 and O_3. Data are means of 16 individuals ± standard error. Bars bear the same letter are not significantly different at 5 % level.

Chamaeneriau angustifolium

No visible symptoms of O_3 and SO_2 injury or nutrient deficiency were observed throughout the experiment for leaves of *Chamaeneriau angustifolium* under any of the treatments. Neither SO_2 nor O_3 had any significant effect ($P>0.05$) on leaf number, leaf area, plant biomass and root/shoot ratio (Fig. 5).

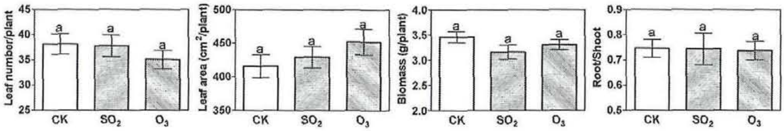

Fig. 5. Growth responses of *Chamaeneriau angustifolium* to SO_2 and O_3. Data are means of 16 individuals ± standard error. Bars bear the same letter are not significantly different at 5 % level.

Polygonum alopecuroides

No visible symptoms of O_3 and SO_2 injury or nutrient deficiency were observed throughout the experiment for leaves of *Polygonum alopecnuroides* under any of the treatments. Neither SO_2 nor O_3 had any significant effect ($P>0.05$) on leaf number and leaf area. However, O_3 significantly reduced ($P<0.05$) plant biomass and root/shoot ratio, while SO_2 did not have any significant effect (Fig. 6).

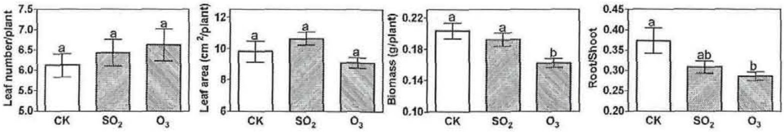

Fig. 6. Growth responses of *Polygonum alopecuroides* to SO_2 and O_3. Data are means of 16 individuals ± standard error. Bars bear the same letter are not significantly different at 5 % level.

Sanguisorba officinalis

No visible symptoms of O_3 and SO_2 injury or nutrient deficiency were observed throughout the experiment for leaves of *Sanguisorba officinalis* under any of the treatments. Neither SO_2 nor O_3 had any significant effect ($P>0.05$) on leaf number, leaf area and biomass. However, O_3 significantly reduced ($P<0.05$) plant root/shoot ratio, while SO_2 did not have any significant effect (Fig. 7).

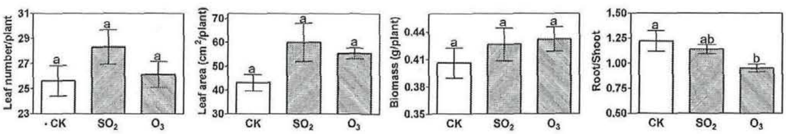

Fig. 7. Growth responses of *Sanguisorba officinalis* to SO_2 and O_3. Data are means of 16 individuals ± standard error. Bars bear the same letter are not significantly different at 5 % level.

As reported by SHIMIZU & al. 1993 and ZHENG & al. 1998, different plant species had different sensitivities to O_3 and SO_2. To O_3, *Carex* spp., *Polygonum alopecuroides* and *Sanguisorba officinalis* were more sensitive than *Astragalus* spp. and *Chamaeneriau angustifolium*; to SO_2, *Carex* spp. was more sensitive than the rest of the four species. WHO's ozone guideline in Europe for agriculture crops is 5.3 ppm h, and that for forests is 10 ppm h cumulative exposure over growing season; and the SO_2 guideline for agricultural crops is 0.03 ppm annual or winter mean (WHO 2000). Both O_3 and SO_2 concentrations used in the present study were much higher than the above guidelines. The cumulative O_3 concentration was 33.6 ppm h and the average SO_2 level was 0.1 ppm during the 4-week experiment. As we could not find any injurious symptoms and severe growth reduction during the experiment, these five Mongolian species might not be so sensitive to O_3 and SO_2, as compared with sensitive crop species. Plant sensitivity to air pollutant is negatively correlated with leaf stomatal conductance (ZHENG & al. 1998). It is normally assumed that leaf stomatal conductance of semiarid plant is low to conserve water under the water limiting environment. Then, lower stomatal conductance limits gaseous pollutants getting into the leaves through stomata.

Root/shoot ratio response of *Polygonum alopecuroides* and *Sanguisorba officinalis* confirmed the conclusion from previous studies (ANDERSEN & al. 1991, 1997, SHIMIZU & al. 1993) that O_3 could decrease allocation of carbon (photosynthates) to roots and decrease root biomass relative to shoot biomass.

SASE & al. 2005 showed that in this semiarid region in Mongolia, average concentrations of O_3 and SO_2 were around 0.03 ppm and 0.002 ppm, respectively, measured by passive samplers. Therefore, SO_2 may not be so serious threat now and in the near future. However, we should take notice of O_3, because an average of 0.05 ppm O_3 in the present study induced some eco-physiological changes on three semiarid species without any visible symptoms. Furthermore, in general, combination effects of several air pollutants are more harmful than a single pollutant (ZHENG & SHIMIZU 2003). Therefore, it is still wise to pay close attention to all the air pollutants levels and the responses of the native plant species to air pollution in the field in this region.

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