学位論文内容の要旨

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学位論文題名

Influence of elevated CO_2 and ground-level O_3 on native deciduous trees in Japan

(北東アジアの落葉樹に対する地表付近のCO_2とオゾンの影響力)

The levels of ozone (O_3) and carbon dioxide (CO_2) are nowadays elevated throughout the Northern Hemisphere, and further elevation is projected for the future. Ozone and CO_2 are the major gases which may pose threat for vegetation, ecosystems, human welfare and finally the biosphere sustainability in the future. Therefore, a critical issue will be the reduction of their effects on plants. The expected depletion of the global phosphate resources may lead to increase in fine root production with a consequent increase of root-fungi symbiosis and mediation of CO_2 effects. However, mediation of O_3 effects through soil is not expected because O_3 is a strong oxidant which can also directly injure plant tissues. Although several substances have been studied as potential protectants of plants against O_3 injury, only ethylenediurea (EDU), a chemical compound, has been found to effectively protect plants against O_3 damage, via a currently unclear mode of action. In this study, I investigated the following two topics:

1. Long term effects of elevated atmospheric CO_2 levels on root traits of a community of native tree species and the role of soil as a driver of the CO_2 effects

Long-term effects of elevated CO_2 levels on belowground structure of trees growing in different soils remain hitherto unexplored. Saplings of a beech (*Fagus crenata*), an oak (*Quercus mongolica* var. *crispula*) and three birches (*Betula ermanii, B. maximowicziana* and *B. platyphylla* var. *japonica*) were grown in immature volcanic ash soil (VA: Vitric Andosols) or brown forest soil (BF: Dystric Cambisols). Volcanic ash is a nutrient poor soil, especially phosphorus poor, broadly distributed in northern Japan. The saplings were further exposed to ambient CO_2 (375-395 ppm) or elevated CO_2 (500 ppm), during daylight hours; each treatment was replicated three times. Beech was exposed to the treatments for eleven years, whereas the other species were exposed for four growing seasons. For both beech and the other species, elevated CO_2 caused a significant increase ($P<0.05$) in the total root production of saplings grown in VA but did not significantly affect ($P>0.05$) that of saplings grown in BF. It seems that impacts of elevated CO_2 levels expected in the future may vary among regions with different soils. Elevated CO_2 caused rhizo-morphogenesis through significant enhancement ($P<0.05$) of fine root production accompanied by an extensive foraging strategy of roots. These phenomena may have long-term implications in the biogeochemical cycles of ecosystems and the below ground biodiversity. The present study provides evidence showing that the soil is an important factor which affects the impacts of elevated

CO_2 on roots.

2. Effects of elevated tropospheric O_3 levels on willow (*Salix sachalinensis* F.Schmidt) and the use of ethylenediurea (EDU) as protectant against O_3 damage

The willow *Salix sachalinensis* is a fast growing species native to wide areas of Asia and Russian Far East. As a hygrophilous and heliophilous species, *S. sachalinensis* could be sensitive to elevated O_3 levels. However, elevated O_3 effects on this species have not been previously studied. A two-year integrated study was carried out to provide new insights on this issue. Current-year cuttings were grown in commercial potting medium, a mixture (1:1) of Akadama (well-weathered VA) and Kanuma (well-weathered pumice) soils – free from organic matter. Plants were exposed to ambient O_3 (≈29 ppb) or to elevated O_3 (≈66 ppb) levels, with three replicates per treatment, during daylight hours. In addition, the plants were treated with 200 ml soil drench containing 0, 200 or 400 mg EDU L^{-1} or with foliar spray at 0, 200 or 400 mg EDU L^{-1}, every nine days. Elevated O_3 injured *S. sachalinensis* plants as it was evidenced by significantly lower ($P<0.05$) number of leaves, average leaf size and dry matter, plant leaf area and dry matter of root, shoots, foliage, aboveground and the total. The impacts of elevated O_3 were moderate in magnitude and practically significant. EDU soil drench was ineffective in protecting the plants against elevated O_3 injury. However, EDU foliar spray efficiently protected the plants when applied at 200-400 mg L^{-1}. It is concluded that: (i) *S. sachalinensis* plants are sensitive to elevated O_3; (ii) EDU foliar spray is more effective in protecting against O_3 phytotoxicity in this fast-growing species than EDU soil drench.

Since EDU contains nitrogen (N), there is a speculation that EDU protects plants against O_3 injury via contributing with N to plants. To further test if EDU at high doses is phytotoxic and if it acts as a N source to this species, an additional open-field experiment was conducted. Willow plants, from the same source as the prior experiment, were exposed to ambient O_3 atmosphere and treated with soil drench of 0, 800 or 1600 mg EDU L^{-1}, every nine days, for approximately 2.5 months. These EDU concentrations are 0, 2 and 4 times the common concentration of 400 mg EDU L^{-1}, which effectively protected different plant species against O_3 injury. After examining about fifty response variables, among them N content in different plant organs, it was found that EDU was transferred up to the leaves and high doses significantly increased ($P<0.05$) the N content in leaves. EDU had no effect on the carbon contents in the plant and was not toxic to this fast-growing species even at the highest dose. Furthermore, based on soil N content, EDU did not persist in the soil which was free from organic matter and poor in N content. Based on estimations, EDU is not expected to act as N source when applied in the appropriate low doses and when the soil does not lack N, and it is unlike N level being responsible for the O_3 protection effect of EDU.

Based on the findings of both topics, I discuss specific responses of deciduous trees to the atmospheric conditions as whole-tree level. My findings may contribute to silviculture techniques for protection and conservation in the future changing environment.