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学位論文題名

Influence of elevated CO₂ and ground-level O₃ on native deciduous trees in Japan
(北東アジアの落葉樹に対する地表付近の CO₂ とオゾンの影響力)

The levels of ozone (O₃) and carbon dioxide (CO₂) are nowadays elevated throughout the Northern Hemisphere, and further elevation is projected for the future. Ozone and CO₂ 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 CO₂ effects. However, mediation of O₃ effects through soil is not expected because O₃ is a strong oxidant which can also directly injure plant tissues. Although several substances have been studied as potential protectants of plants against O₃ injury, only ethylenediurea (EDU), a chemical compound, has been found to effectively protect plants against O₃ damage, via a currently unclear mode of action. In this study, I investigated the following two topics:

1. Long term effects of elevated atmospheric CO₂ levels on root traits of a community of native tree species and the role of soil as a driver of the CO₂ effects

Long-term effects of elevated CO₂ 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 CO₂ (375-395 ppm) or elevated CO₂ (500 ppm); 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 CO₂ 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 CO₂ levels expected in the future may vary among regions with different soils. Elevated CO₂ caused rhizo-morphogenesis through significant enhancement ($P<0.05$) of fine root production accompanied by an extensive foraging strategy of roots. My findings provide the soil is an important factor which affects the impacts of elevated CO₂ on roots.

2. Effects of elevated tropospheric O₃ levels on willow (*Salix sachalinensis* F.Schmidt) and the use of ethylenediurea (EDU) as protectant against O₃ damage

The willow is a fast growing species native to Asia and Russian Far East. As light demanding species, this willow could be sensitive to elevated O₃ levels. A two-year integrated study was carried out to provide new insights on this issue. Current-year cuttings were grown in potting medium, a mixture (1:1) of well-weathered VA and well-weathered pumice soils – free from organic matter. Plants were exposed to ambient O₃ (≈ 29 ppb) or to elevated O₃ (≈ 66 ppb) levels, with three replicates per treatment, during daylight hours. 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 O₃ 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 O₃ were moderate in magnitude and practically significant. EDU soil drench was ineffective in protecting the plants against elevated O₃ injury. However, EDU foliar spray efficiently protected the plants when applied at 200-400 mg L⁻¹. It is concluded that: (i) The willow sensitive to elevated O₃; (ii) EDU foliar spray is more effective in protecting against O₃ phytotoxicity in this species than EDU soil drench.

Since EDU contains nitrogen (N), there is a speculation that EDU protects plants against O₃ 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 O₃ 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 O₃ 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 O₃ 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.

Therefore, we acknowledge that the author is qualified to be granted the Degree of Doctor of Philosophy in Agriculture from Hokkaido University.