学位論文審査の要旨

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学位論文題名

Physiological and stoichiometry study on foliar nutrients and defensive characteristics of representative deciduous broad-leaved tree species in northern Japan under environmental changes

（変動環境における北日本の落葉広葉樹の葉成分と防御特性に関する生理的・化学量論的研究）

This thesis consists of total 164 pages including 14 Figures, 17 Tables, and 6 chapters, with 3 references.

Introduction

Global environment has been dramatically changing due to human activities, especially elevated atmospheric carbon dioxide (CO_2), ozone (O_3), and nitrogen (N) as a precursor for O_3. Atmospheric CO_2 has been globally increasing and promotes plant growth via photosynthetic enhancement for an extent. At the same time, ground-level O_3 has also been continuously increasing especially in Asia. Elevated O_3 can accelerate foliar senescence and negatively affect the vigor and health of forests. Moreover, soil conditions (e.g. nutrient availability) also affect the physiological function of both nutrient retranslocation and plant defense.

As representatives of deciduous broad-leaved tree species native to northern Japan, Japanese white birch (*Bp*: *Betula platyphylla* var. *japonica* Hara), Siebold's beech (*Fc*: *Fagus crenata* Blume), Mizunara oak (*Qm*: *Quercus mongolica* Fisch. ex Ledeb. var. *crispula* (Blume) Ohashi) and Konara oak (*Qs*: *Quercus serrata* Murray) are applied to this study. Specific O_3 sensitivity has been estimated in sequence of beech, birch and oak, with determinate, indeterminate and semi-determinate shoot growth pattern, respectively.

To assess the responses of the above species on various environmental changes, three researches have been carried out with a free-air enrichment system to simulate forest ecosystems.

1. Foliar nutrients composition of oak species to elevated O_3 accompanied with elevated CO_2

Oaks are regarded as O_3 stress tolerant species among 18 woody plants tested in Japan while *Qm* is considered to be more tolerant to O_3 compared to *Qs*. At eCO_2, stomatal conductance is low, which results in suppression of O_3 absorption via stomata. As eCO_2 may have combined effects with eO_3 on growth and photosynthetic capabilities of the two oak species, I investigated foliar nutrients composition (Ca, K, K, Mg, Mn, N, P) as well as the foliar carbohydrates (starch and sugar) amount of 2-year-old oak seedlings (*Qm* and *Qs*) exposed to eCO_2 and/or eO_3 with a free-air enrichment system. From the results of element concentration, it was found that N and Mg may have the potential to be

major indicators in assessing the effects of O_3 on two oaks. I also found that *Qs* may have a higher ability of recovering from O_3 damages and likely become more tolerant to eO_3 than *Qm* under eCO_2 independent of sugar and starch concentration.

2. Foliar element concentrations, the retranslocation and seasonal changes of three species to elevated O_3 under three different soils

This study consists with two chapters (Chapter 3 and 4). Retranslocation is the amount of an element that is depleted from aged plant components and is provided for new growth. As leaf senescence is usually accelerated at eO_3 and leaf shedding is also influenced by soil nutrient availability (and acidification), 2 year-old (as of 2014) seedlings of *Bp*, *Fc*, and *Qm* were planted in a free-air O_3 enrichment system under three different soil types (brown forest: B, volcanic ash: V, and serpentine: S).

In chapter 3, I focused on the net retranslocation of foliar elements (N, P, K, Ca, Fe, Mg, Mn and Al) to discuss potential effects of eO_3 on seedlings in relation to different soil conditions via retranslocation traits. I also found that the retranslocation rate of P was increased by eO_3 in *Bp* and by soil treatment in *Qm*; but constant across treatments in *Fc*. Retranslocation of N was affected by soil in *Qm*. Retranslocation of other elements was most sensitive to both eO_3 and soil in *Fc*.

In chapter 4, in addition to above elements, I added foliar Ni and Cr to further estimate the effects of eO_3 alone and together with different soils over two growing seasons. I investigated on physiological understanding of stoichiometry of foliar elements as well as relationships among the foliar elements within each species. I found *Fc* with a determinate shoot growth pattern, was relatively more sensitive to O_3 stress on foliar contents, but *Qm* was possibly susceptible to eO_3 concerning dynamics of immobile elements. Principal component analysis revealed that K and Mn can become indicators in assessing O_3 and soil effects in both short and long term growth monitoring of these tree species.

3. Foliar defense characteristics of three species to elevated O_3 under two different soils

As leaf defense depends on both genotype and environmental conditions, I investigated the leaf chemical defense traits by analyzing the C/N ratio and amount of defensive compounds (lignin, total phenolics and condensed tannin) in response to eO_3 under B and V soils for *Bp*, *Fc* and *Qm* species. In this study, foliar defensive traits were affected by eO_3 for *Bp*; N and C/N were influenced by soils but defensive chemicals were by eO_3 for *Fc*; *Qm* as a tolerant species, was able to survive under various environmental changes.

In conclusion, my results provide evidences that physiological explanation on stoichiometry of foliar elements and their dynamic variation as well as foliar defensive traits are varied upon environmental changes for each species and they are also species specific. Although *Qm* is regarded as an O_3 tolerant species, after making comparisons among species, it can be susceptible to O_3 concerning dynamics of immobile elements. My findings are essential in further comprehension to nutrient ecophysiological mechanism in the nutrient dynamics of cool-temperate forests of Japan and will be of help for the investigation of species adaption to environmental changes, which will be utilized on developing appropriate strategies of afforestation in the future.

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