



Title	Physiological and stoichiometry study on foliar nutrients and defensive characteristics of representative deciduous broad-leaved tree species in northern Japan under environmental changes [an abstract of dissertation and a summary of dissertation review]
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## 学位論文内容の要旨

博士の専攻分野名称：博士（農学）

氏名：Cong SHI

### 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)

### Introduction

The global environment has been dramatically changing due to human activities, especially elevated atmospheric carbon dioxide (CO<sub>2</sub>), ozone (O<sub>3</sub>), and nitrogen (N) as a precursor for O<sub>3</sub>. Atmospheric CO<sub>2</sub> has been globally increasing and promotes plant growth via photosynthetic enhancement for an extent. At the same time, ground-level O<sub>3</sub>, as one of the serious environmental stresses for plants, has also been continuously increasing in Asia. As O<sub>3</sub> has strong oxidative characteristics, O<sub>3</sub> via stomata penetrating plants and induces morphological and chemical changes in leaves. This 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.

Representatives of deciduous broad-leaved tree species native to the northern forests of Japan, such as, 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 considered to be the essential components. Specific O<sub>3</sub> sensitivity have been estimated by former experiments with potted plants in open top chambers for the beech, birch and oak, which have different shoot developmental patterns as determinate, indeterminate and semi-determinate, respectively.

Therefore, my research concerning the physiological and stoichiometry study on these trees will be of help for their adaption investigation to environmental changes and will be utilized on developing appropriate strategies of afforestation in the future. 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.

Firstly, I investigated the physiological effects of elevated CO<sub>2</sub> (eCO<sub>2</sub>) and/or elevated O<sub>3</sub> (eO<sub>3</sub>) on leaf nutrient status of oak species. I chose two oak (*Qm* and *Qs*) species as the Japanese representative of *Quercus* species that more tolerant to O<sub>3</sub>. Secondly, I examined the stoichiometry of foliar element concentrations and retranslocation of three species to eO<sub>3</sub> under three different soils (brown forest: B, volcanic ash: V, and serpentine: S) over one or two growing seasons and I also discussed on the plausible understanding of physiological functions. Finally, I studied foliar defensive characteristics of three species in responses to eO<sub>3</sub> under two soil conditions (B and V) in relation to protection capacity of the species against biological stresses via eO<sub>3</sub>.

### 1. Foliar nutrients chemical composition of oak species to elevated CO<sub>2</sub> and elevated O<sub>3</sub>

Oaks are regarded as O<sub>3</sub> stress tolerant species among 18 woody plants tested in Japan while *Qm* is considered to be more tolerant to O<sub>3</sub> compared to *Qs*. At eCO<sub>2</sub>, stomatal conductance is low, which results in suppression of O<sub>3</sub> absorption via stomata. As eCO<sub>2</sub> may have combined effects with eO<sub>3</sub> on growth and photosynthetic capabilities of the two oak species grown under B soil, I investigated foliar nutrients composition (P, N, K, Mg, Mn, Ca) as well as the foliar carbohydrates (starch and sugar) amount of 2-year-old oak seedlings (*Qm* and *Qs*) exposed to eCO<sub>2</sub> and/or eO<sub>3</sub>

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<sub>3</sub> on two oaks. I also found that *Qs* may have a higher ability of recovering from O<sub>3</sub> damages and likely become more tolerant to eO<sub>3</sub> than *Qm* under eCO<sub>2</sub> independent of sugar and starch concentration.

## **2. Foliar element concentrations, the retranslocation and seasonal changes of three species to elevated O<sub>3</sub> under three different soils**

This study was divided into two sections. 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<sub>3</sub> 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<sub>3</sub> enrichment system under 3 soil types (B, V and S).

For the first section (chapter 3), I focused on the net retranslocation of foliar nutrients (major elements: N, P, K, minor elements: Ca, Fe, Mg, Mn, and non-essential element: Al) to discuss potential effects of eO<sub>3</sub> on seedlings in relation to different soil conditions via retranslocation traits. I also found that the retranslocation rate of P was increased by eO<sub>3</sub> 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<sub>3</sub> and soil in *Fc*. I could not detect molybdenum because of too small value.

For the second section (chapter 4), in addition to foliar elements studied above, I added foliar Ni and Cr as an additional minor essential and non-essential element, respectively. This was to further estimate the effects of eO<sub>3</sub> alone and together with different soil conditions on seasonal changes and physiological understanding of stoichiometry of the foliar elements of three species. Relationships among the foliar elements within each species were also investigated. I found that *Fc*, with a determinate shoot growth pattern, was relatively more sensitive to O<sub>3</sub> stress on foliar contents, meanwhile *Qm* was possibly susceptible to O<sub>3</sub> concerning dynamics of immobile elements. Soil nutrients had distinct impacts on retranslocation rate of K, Fe, and P. Principal component analysis revealed that Mn and K can become indicators in assessing O<sub>3</sub> 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<sub>3</sub> under two different soils**

Plants defend themselves against herbivores by employing mainly physical and chemical defense mechanisms. As leaf defense depends on the strong influence of both genotype and environmental conditions, I investigated the leaf chemical defense traits by analyzing the C/N ratio and amount of defensive compounds (lignin, secondary metabolites production: total phenolics and condensed tannin) in response to eO<sub>3</sub> under B and V soils for *Bp*, *Fc* and *Qm* species as components of Fagaceae. In this study, foliar defensive traits were affected by eO<sub>3</sub> for *Bp*; N and C/N were influenced by soils but defensive chemicals were by eO<sub>3</sub> for *Fc*; *Qm* as a tolerant species, it was able to survive under various environment changes.

In conclusion, my results provide the 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<sub>3</sub> tolerant species, after making comparisons among species, it can be susceptible to O<sub>3</sub> 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.