博士（環境科学）　Edgard Alves Bontempo e Silva

学 位 論 文 題 名

A physiological and morphological field study of *Abies sachalinensis* and *Picea glehnii* juveniles of different size-classes

（トドマツとアカエゾマツの異なるサイズの幼木に関する生理学的及び形態学的野外研究）

学位論文内容の要旨

Abies sachalinensis (トドマツ) and *Picea glehnii* (アカエゾマツ) are major components of the forests of Hokkaido, Japan. Similar Spruce-Fir forests can be found in large portions of the northern hemisphere and will probably be impacted by global warming. A recent work suggests that reversals in competitive superiority at different developmental stages could be important to explain their coexistence. Such shifts in competitive advantage can be mechanistically understood by studying the corresponding physiological differences between distinct life stages. Nevertheless, no work has been done comparing juvenile trees at different developmental stages in the understory. Therefore, the objective of this study was to investigate the photosynthesis of shade-growing juveniles of these two species at two different size-classes, seedlings and saplings, in the field.

The study was carried out on a sub-boreal forest area in northwestern Hokkaido. The size-classes were defined based on the plants height in relation to the dwarf bamboo, *Sasa senanensis*, in the understory. We defined saplings as the juveniles of each species that surpassed considerably the height of the surrounding dwarf bamboo, and seedlings as those of shorter height than the dwarf bamboo undergrowth. In this study, photosynthetic pigments were qualified and quantified, to investigate differences on photosynthesis and photoadaptation between the studied species and size classes, as well as any possible variations in these characteristics that should happen throughout the growing season. Microclimate variables were measured to characterize the environment at plant level and its variation though the studied period. Height, basal stem diameter and lateral shoot extension were measured to characterize growth. Finally, maximum steady-state photosynthetic rate accompanied by chlorophyll fluorescence were measured in the late summer, to analyze photosynthetic performance and to characterize the condition of the photosynthetic apparatus.

This study showed that the photosynthetic capacity and the seasonal variation in the

content of photosynthetic pigments of *A. sachalinensis* and *P. glehnii* were different between saplings and seedlings. However, while some of these variables presented similar dynamics in each of the two studied species or in each of the two studied size-classes, others showed mixed results that suggest a complex interaction between the species and the size-class factors. Results showed that seedlings of both species had higher concentrations of de-epoxidated photoprotective xanthophylls than saplings even though subjected to similar light conditions. This suggests that seedlings of both species are more sensitive to abiotic stress than saplings and apparently take longer to recover from the winter photoinhibited state. The observed variations in the measured chlorophyll *a/b* ratio suggest that it, and consequently the antenna complex of both species, responds in a similar fashion to the observed monthly microclimatic variations. This study is the first, to the author's knowledge, to show supporting physiological evidence for a photoinhibition tendency at the onset of bud-break in these evergreen species, in the field. Furthermore, results show an inversion of photosynthetic performance and growth rate between saplings and seedlings of both species. Photosynthetic capacity and lateral shoot extension rate decreased from the seedling to the sapling stage in *A. sachalinensis* but the opposite was observed in *P. glehnii*. *Abies sachalinensis* had higher photosynthetic rates at the seedling stage but lower rates at the sapling stage than *P. glehnii*. Regardless of the dynamics observed within each species, *A. sachalinensis* had a higher lateral shoot extension rate than *P. glehnii* at both size-classes. Our physiological results support previous ecological observations that *A. sachalinensis* is a superior competitor to *P. glehnii* in the understory and it also shows that its competitive advantage is higher at the seedling stage than at the sapling stage.

学位論文審査の要旨

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The study was carried out in a sub-boreal forest in northern Hokkaido. The size-classes were defined based on the plant height in relation to the dwarf bamboo, *Sasa senanensis*, in the understory. The sapling was defined as the juvenile of each species that surpassed considerably the height of the surrounding dwarf bamboo, and the seedling as that of shorter height than the dwarf bamboo undergrowth. In this study, photosynthetic pigments were quantified to investigate differences in photosynthesis and photo-adaptation between the studied species and size classes, as well as any possible variations in these characteristics that should happen throughout the growing season. Microclimate variables were measured to characterize the environment at the plant level and its variation though the studied period. Height, basal stem diameter and lateral shoot extension were measured to characterize growth. Finally, maximum steady-state photosynthetic rate together with chlorophyll fluorescence were measured in the late summer to analyze photosynthetic performance and to characterize the condition of the photosynthetic apparatus.

This study showed that the photosynthetic capacity and the seasonal variation in the content of photosynthetic pigments of *A. sachalinensis* and *P. glehnii* were different between saplings and seedlings. However, while some of these variables presented similar dynamics in each of the two studied species or in each of the two studied size-classes, others showed mixed results that suggest a

complex interaction between the species and the size-class factors. The results of this study showed that seedlings of both species had higher concentrations of de-epoxidated photo-protective xanthophylls than saplings even though their light conditions were similar. This suggests that seedlings of both species are more sensitive to abiotic stress than saplings and apparently take longer to recover from the winter photo-inhibited state. The observed variations in the measured chlorophyll *a/b* ratio suggest that the antenna complex of both species responds in a similar fashion to the observed monthly microclimatic variations. This study is the first to show supporting physiological evidence for a photo-inhibition tendency at the onset of bud-break in these evergreen species in the field. Furthermore, the results show a reversal of photosynthetic performance and growth rate between saplings and seedlings of both species. Photosynthetic capacity and lateral shoot extension rate decreased from the seedling to the sapling stage in *A. sachalinensis* but these increased in *P. glehnii*. *Abies sachalinensis* had higher photosynthetic rates at the seedling stage but lower rates at the sapling stage than *P. glehnii*. Regardless of the dynamics observed within each species, *A. sachalinensis* had a higher lateral shoot extension rate than *P. glehnii* at both size-classes. The physiological results of this study support previous ecological observations that *A. sachalinensis* is a superior competitor to *P. glehnii* in the understory and also show that its competitive advantage is higher at the seedling stage than at the sapling stage.

The examination committee recognized that this study provides new insights into ecological phenomena in boreal forests from a physiological point of view and contributes to the development of ecological and environmental studies of boreal forests. The committee thereby concluded that the applicant is eligible for the degree of Doctor of Philosophy (Environmental Science).