論文題目：Molecular ecology of season/altitude-specific longevity and function of leaves of an evergreen perennial, *Arabidopsis halleri* subsp. *gemmifera*

（常緑多年草ハクサンハタザオにおける季節・標高特異的な葉の寿命と機能に関する分子生態学的研究）

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要約

Leaves are the central organ of photosynthetic production, but plants have evolved additional functions of leaves, such as storage, protection, and defense functions. Here, seasonal and altitudinal changes in leaf properties were studied in natural populations of an evergreen perennial Brassicaceae, *Arabidopsis halleri* subsp. *gemmifera* to elucidate adaptive functions of leaves. In this dissertation, two aspects of adaptation in leaf function were studied, i.e., seasonal changes of leaf and altitudinal differentiation of freezing tolerance.

In chapter 1, the previous studies on leaf functions in relation to seasonal and altitudinal adaptation were reviewed and summarized. In chapter 2, results of a three-year study on leaf-cohort and whole-plant foliage are presented. Leaf cohorts emerged during the growth season (GS) had short longevity and senesced successively, which resulted in high leaf turnover and a foliage structure with young leaves. Overwintering (OW) cohorts had extended longevity with synchronized senescence at reproduction, which resulted in the development of age-diverged foliage structure prior to reproduction. Modeling suggested that photoperiod rather than temperature primarily determined short and extended leaf longevities of GS and OW cohorts, respectively.

In chapter 3, the results of four sets of manipulative experiments (self-shading and sink-removal in GS and OW cohorts) are presented. Self-shading accelerated leaf senescence through upregulation of dark/stress-induced senescence genes specifically for GS cohorts, which caused desynchronized senescence within cohorts depending on light environments of individual leaves. Strong sink demand for reproduction accelerated leaf senescence of OW cohorts with upregulation of some phosphate-starvation response genes, which caused synchronized senescence within and between cohorts irrespective of leaf ages. We conclude that the two-layered control of individual leaf longevities optimizes resource acquisition and resource storage/translocation at the whole-plant level

in a seasonal environment.

In chapter 4, altitudinal differentiation in the freezing tolerance of leaves was analyzed using natural *A. halleri* populations occurring at different elevations on Mt. Ibuki. We conducted freezing experiments in which tolerance was evaluated by electorate leakage and quantum yield in photosystem II. Leaves of the semi-alpine ecotype showed significantly higher freezing tolerance than those of low-elevation ecotype both before and after acclimation. In the acclimation process, the low-elevation ecotype showed the maximum freezing tolerance after one week of acclimation and maintained it. On the other hand, freezing tolerance continued to increase over eight weeks in the semi-alpine ecotype. Post-flowering individuals showed lower freezing tolerance than plants at the vegetative stage for both altitudinal ecotypes. During the flowering season, translocation to reproductive organs is likely to cause a decrease in freezing tolerance of leaves. There was little difference in the gene expression involved in cold acclimation between the ecotypes.

In chapter 5, the altitudinal differentiation in cuticular wax of the leaf surface was studied. Then, the role of water-repellency of cauline leaves was experimentally studied. Using the altitudinal ecotypes at Mt. Ibuki, leaf cuticular wax was analyzed by comprehensive two-dimensional gas chromatography (GC)-mass spectrometry and GC-flame ionization detector. Young flowering buds wrapped by cauline leaves were exposed to freezing temperatures with or without water, and frost damage of the flower buds was compared between plants from semi-alpine and low-elevation habitats. Higher amounts of C29, C31, and C33 alkanes were observed in the cauline leaves of semi-alpine plants than those of low-elevation plants. In the freezing experiment, water application increased damage to flowering buds of low-elevation plants, and we detected less damage to flowering buds for semi-alpine plants. Altitudinal differentiation in the amounts of alkanes on the leaf surface occurred specifically in cauline leaves, and we found that the water repellency of these bud-wrapping leaves presumably minimized frost damage to flowering buds at high altitudes.

In conclusion, the importance of temperature regimes was shown in determining leaf properties through seasonal plasticity and local adaptation. Especially, in evergreen plants occurring temperate regions, properties of leaves during winter are likely to have critical adaptive significance.