論文内容の要旨

論文題目　Optimal resource allocation patterns regulated at the individual plant level in response to multiple environmental factors
(複合的環境要因に応じた植物個体レベルの最適資源分配)

氏名　杉浦大輔

Plants plastically regulate resource allocation patterns and show various physiological and morphological traits in response to multiple environmental factors, such as availabilities of light, soil nitrogen, and water. In this thesis, I investigated actual resources and biomass allocation patterns for plants in response to these factors and criteria which determine the allocation patterns theoretically and experimentally. Further, a mechanism which regulated these allocation patterns was discussed.

In Chapter 1, it was investigated that whether changes in morphological and physiological traits of plants such as leaf to root ratio (L/R), leaf nitrogen content per area (N_{area}), and leaf mass per area (LMA), in response to light and nitrogen availabilities were optimal biomass allocation which maximizes whole-plant relative growth rate (RGR). Here, I developed a biomass allocation model based on previous studies to predict optimal L/R and N_{area}. In the model, net assimilation rate (NAR) was determined by light-photosynthesis curve, light availability measured during experiments, and leaf temperature affecting the photosynthesis and leaf dark respiration rate in high and low-light environments. Two pioneer trees, Mulberry (*Morus bombycis*) and trident maple (*Acer buergerianum*), were grown in various light and nitrogen availabilities in an experimental garden and used for parameterizing and testing the model predictions. They were grouped into four treatment groups (relative photosynthetic photon flux density, RPPFD 100% or 10% × nitrogen-rich or nitrogen-poor conditions) and grown in an experimental garden for 60 to 100 days. The model predicted that optimal L/R is higher and N_{area} is lower in low-light than high-light environments when compared in the same soil nitrogen availability. Observed L/R and N_{area} of the two pioneer trees were close to the predicted optimums. From the model predictions and pot experiments, I conclude that the pioneer trees, Mulberry and trident maple, regulated L/R and N_{area} to maximize RGR in response to nitrogen and light availability.

In Chapter 2, I tested whether saplings of devil maple (*Acer diabolicum*) produce fine root, which absorb water, more than enough to meet water demand for photosynthesis in leaves. If that's the case, stomatal conductance (*Gs*) and photosynthetic rate (*A*) would be affected little even if fine root biomass was decreased to some extent. Therefore, effects of decreasing fine root biomass on *Gs* and *A* were evaluated by simulation models and laboratory experiments using saplings of devil maple grown in high- and low-light environments. *A*-*Gs* relationships, hydraulic conductance of each organ were determined and used for the simulations. In the laboratory experiments, *Gs* of each sapling was measured with stepwise decrease in fine root biomass in a growth chamber where light intensity, temperature, and relative humidity were regulated at constant. The model predicted that *Gs* and consequently *A* decreased little even if fine root biomass was decreased to some extent. Furthermore, results of laboratory experiments were almost consistent with the model simulations. In conclusion, it was suggested that fine root biomass to leaf biomass was more than enough to meet the water demand for maintaining maximum photosynthetic rate for saplings of devil maple in high- and low-light environments.

Chapter 3 aimed to clarify allocation patterns of nitrogen and carbohydrate for trees under heterogeneous light environments using saplings of devil maple which had Y-shaped two branches. Saplings of Y-shaped devil maple were transplanted to pots in the experimental field and grown in following light treatment from 2009 to 2011. To create simplest heterogeneous light environments within the individual saplings, one branch was in 100% RPPFD (HL-branch) and the other branch was in 10%RPPFD (HS-branch) for HLS saplings. For comparison, both branches were in 100%RPPFD (L-branch) and 10%RPPFD (S-branch) for WL and WS saplings, respectively. Leaf nitrogen content per area (N_{area}) and stem volume of each branch were measured throughout growth period. In addition, net assimilated glucose (NAG) was estimated by a photosynthesis model, where relationships between photosynthesis parameters and N_{area} and actual meteorological datasets were considered, for each growth period. Throughout the growth period, concentrative allocation of nitrogen to HL-branch and suppressive allocation of nitrogen to HS-branch were observed for HLS saplings when compared with L-branch for WL and S-branch for WS saplings. It was also shown that there were highly-correlated relationships between branch stem growth and NAG. As a result, growth of HL-branch with highest N_{area} was largest and that of HS-branch with lowest N_{area} was smallest. It was also shown that allocation patterns of current photosynthate between branch growth and root growth was determined by local light environments, and not affected by light environments of the other branch. As a whole**,** whole-plant growth was increased by these resource allocation patterns for HLS saplings in heterogeneous light environments. These results suggest that tree canopy would be developed through such resource allocation patterns also in natural heterogeneous light environments.

Finally, in the section of general discussion, a mechanism regulating biomass allocation in response to changes in external and internal environmental factors was discussed. I particularly focused on allocation between shoot and root, and consequent L/R and N_{area}, and a probable model was designed by theoretical approach. It was suggested that plants need to recognize light availability and net assimilation rate in leaves, specific nitrogen absorption rate in roots, and current amount of leaves and roots or L/R. It was simulated that L/R could be optimized in response to changes in external and internal environments if these information were recognized and integrated per unit leaf area basis and transmitted to shoot apical meristem.