Hydraulic adaptation for tree height growth in tall tree species

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Forest ecosystems, one of the major elements of the mountainous area, are characterized by its complicated three-dimensional structure which is 95% occupied by canopy where cannot be reached from the ground, compared to grasslands, deserts and rocky areas (Lowman and Rinker 2004). Various life activities such as photosynthesis, transpiration, breeding, and interaction with various organisms are performed on the canopy. Canopy researches have been progressed rapidly by the development of methods for accessing treetop in recent years (Nakanishi et al. 2018).

The question of why trees can grow up so tall is simple but its discussion has continued for a long time among ecophysiological studies. Among some factors related to tree height growth being pointed out, a main factor is considered that the limitation of water transport from root to leaves at the far end (e.g. Ryan et al. 2006). While this is the beginning of theoretical research, it has not been directly measured how much actual leaves are affected by the water transport limitation in tall trees. Therefore, we accessed to crown for 100 m tall of *Sequoia sempervirens* and 50 m tall *Cryptomeria japonica* by tree climbing, and directly evaluated water relations characteristics of leaves at various heights. As a result, although the supposed influence by water limitation was not observed, the high water capacitance of treetop leaf was revealed. This results suggested that the high water capacitance of treetop leaf would compensate for the physical water transport limit at treetop (Ishii et al. 2014).

How can treetop leaves perform high water capacity? To investigate a relationship between leaf anatomy and water relations, leaves of 50 m tall C. japonica were freeze by liquid nitrogen in situ of crown before dawn and at midday, then took it back to the laboratory and sectioned with cryo-SEM for observations. As a result, it was revealed that the transfusion tissue specific to the gymnosperm, which is located between the vascular bundle and the mesophyll, reversibly stored water and shrink like a sponge. At the treetop, large number of transfusion cells contributed to maintain the physiological function by the tissue structure giving priority to the water limit compensation, and as a result, maximum tree height could be regulated by tradeoff of the resource allocation with photosynthetic structure (Azuma et al. 2016).

To elucidate the mechanism of water retention within leaves focusing on the physicochemical properties, infrared spectroscopy is conducted. By applying it to leaf cross-sections in combination with a microscope, it is possible to quantify and visualize the distribution of water and sugars which were difficult to evaluate by an anatomical method alone. Although water is treated as one kind in the present plant physiology, in actual, physicochemical studies are known that various water components exists due to a difference in hydrogen bonding. In this study, working hypothesis that water with short hydrogen bonding component could be retained to polysaccharides within leaves was discussed. (Azuma et al. 2017).

These results suggest the one of a mechanism for tree height growth in tall conifer species with a new insight that “adaptation” to the water transport limit at treetop. To elucidate the actual ecophysiological characteristics in such huge trees, more comprehensive understanding from multiple perspectives would be necessary.

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