Recent advances in woody plant: Preface to a special issue in Plant Root

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We are pleased to publish "Recent Advances in Woody Plant," a special issue of the Sixth International Symposium on Physiological Processes in Roots of Woody Plants. The topics of studies on roots of woody plants are diverse, ranging from gene expression and physiological processes to processes at the ecosystem level. At any scale of study, we—root researchers—are interested in root traits, which contribute to plant functions, although studies at different scales may have different objectives depending on their focus, such as survival, growth, reproduction or harvest of individual plants, production, decomposition, soil formation, and retarding or driving succession through material cycling of ecosystems. This special issue contains four studies on roots of trees in Japan, on different themes and scales: the mechanisms of stress tolerance to excessive heavy metal soil (Okimura et al. 2015), anatomical and morphological differentiation within a root system (Tawa and Takeda 2015), root biomass distribution patterns under competition (Hishi et al. 2015), and response of tree organs to long-term N saturation (Nagakura et al. 2015).

Root function under stress is often important for existence in toxic soil conditions (Larcher 2003). High amounts of heavy metals, such as Nickel (Ni), in the soil are often the main stress factors, even if these heavy metals are essential micronutrients. *Thujopsis dolabrata* var. *hondai* is a commercially important tree species in Japan that produces secondary metabolites of many types, and these compounds prevent infection from pathogens. In addition, *T. dolabrata* var. *hondai* is naturally distributed in serpentine soils with high Ni content. Okimura et al. (2015) showed that catechin production in the roots of *T. dolabrata* var. *hondai*, which exists naturally in serpentine soil with high Ni concentration, increased in high Ni concentration soil as compared to those in other soil conditions, suggesting that the roots of *T. dolabrata* var. *hondai* detoxify by chelating the catechin–Ni complexes in plant cells.

Presence of a sustainable system of acquiring soil resources, owing to tree longevity, is the main difference in roots between woody plants and other grasses or crop plants. The high ability of absorption of soil resources by the root system benefits plant growth; however, there is a trade-off between absorptivity and longevity in tree root systems. Heterorhizy, which is the functional differentiation within roots in physiological activities and in turnover (Hishi 2007), is an effective mechanism enabling root systems of trees to have both high absorptivity and long longevity. Tawa and Takeda (2015) determined that root anatomical and morphological traits, such as diameter size, branching order and protoxylem groups related to primary and secondary root development in *Cryptomeria japonica*, which is the major plantation tree species in Japan. They found that diameter categorization was the most reliable determinant in *C. japonica*. This study indicated that measuring only the diameter would provide us with plenty of information on functional hierarchy in physiological and anatomical traits, or in turnover within fine root systems.

Belowground competition is an important process in both individual plants and plant communities (Schenk 2006). Belowground competition for soil resources is often stronger than aboveground compe-

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tition, even between overstory trees and understory vegetation (Riegel et al. 1995). Understory vegetation is generally considered an inferior competitor to overstory tree species in relation only to aboveground light competition. In addition, previous studies have used only overstory tree species to evaluate ecosystem material cycling, ignoring the understory because of its small C and N sinks. Hishi et al. (2015) found asymmetric competition, showing Japanese dwarf bamboo, *Sasa nipponica*, could be a superior competitor to overstory trees under low nutrient conditions in larch plantations and deciduous broadleaf forests. Furthermore, this study suggested that the ecosystem functions of understory vegetation should not be ignored.

Long-term effect of N deposition on plant growth or on net primary production under global climate change is an important topic to be considered in forest ecology. In Japan, anthropogenic N saturation in forest ecosystems has recently been reported (Chiwa et al. 2015). Long-term studies, especially in tree species, are important for slow turnover organs, such as stems, which are the main C sinks in forest ecosystems because stem growth with low turnover rate may not respond to transient N addition. Nagakura et al. (2015) showed that N deposition treatment over 7 years increased N concentrations of needles and fine roots, but did not affect trunk biomass of *C. japonica*. Leaf N concentration is considered to increase photosynthesis and benefit individual plants. However, this study showed that increase in leaf N did not imply a higher C input, and that the plant did not act as a C sink. This is contrary to other previous studies, which showed increased stem increment (Miller and Miller 1976). The response to fertilization is different among tree species (Magill et al. 2004), and therefore, the finding that long-term N addition did not increase tree stem growth in *C. japonica* is important. In addition, they showed that the other macronutrients decreased with increasing amount of added N, suggesting that other nutrients or water also limit stem growth under N saturation. This study proved that accurate evaluation requires a long-term study of tree species. In future studies, long-term investigations based on stoichiometry would be required to fully understand the mechanisms of increasing C sinks in Japanese plantation ecosystems.

As mentioned above, roots of tree species have different growth mechanisms under different soil conditions, with respect to stresses, competition, and nutrient deposition. Furthermore, the root strategies that increase the fitness of individual trees contribute to long-term ecosystem material cycling. We hope that many readers are interested in studies on roots of woody species and on forest ecosystems with long lifespans, so as to fully understand the concept of sustainable environment.

References

Chiwa M, Saito T, Haga H, Kato H, Otsuki K, Onda Y 2015 A nitrogen-saturated plantation of *Cryptomeria japonica* and *Chamaecyparis obtusa* in Japan is a large nonpoint nitrogen source. J Environ. Quality. 44: 1225-1232.

Hishi T 2007 Heterogeneity of individual roots within the fine root architecture: causal links between physiological and ecosystem functions. J. For. Res. 12: 126-133.

Hishi T, Tashiro N, Maeda Y, Urakawa R, Shibata H 2015 Spatial patterns of fine root biomass and performances of understory dwarf bamboo and trees along with the gradient of soil N availability in broad-leaved natural forests and larch plantation. Plant Root 9: 85-94.

Larcher W. 2003 Excess of Heavy Metals. In: Physiological Plant Ecology. Fourth Edition. Springer, Berlin, pp. 428-436.

MagillAH, Aber JD, Currie WS, Nadelhoffer KJ, Martin ME, McDowell WH, Melillo JM, Steudler P 2004 Ecosystem response to 15 years of chronic nitrogen additions at the Harvard Forest LTER, Massachusetts, USA. For. Ecol. Manage. 196: 7-28.

Miller HG, Miller JD 1976 Effect of nitrogen supply on net primary production in Corsican pine. J. Appl. Ecol. 13: 249-256.

Nagakura J, Akama A, Shigenaga H, Mizoguchi T, Yamanaka T, Tanaka-Oda A, Tange T 2015 Changes in the carbon and nutrient status of *Cryptomeria japonica* needles and fine roots following 7 years of nitrogen addition. Plant Root 9: 95-102.

Okimura S, Yamaji K, Hitsuma G, Mori S 2015 Catechin production in roots of *Thujopsis dolobrata* var. *hondai* in soils on Mt. Hayachine with high Ni concentrations. Plant Root 9: 70-78.

Riegel GM, Miller RF, Krueger WC 1995 The effects of aboveground and belowground competition on understory species composision in a *Pinus ponderosa* forest. For. Sci. 41: 864-889.

Schenk HJ 2006 Root competition: beyond resource depletion. J. Ecol. 94: 725-739

Tawa Y, Takeda H 2015 Which is the best indicator for distinguishing between fine roots with primary and secondary development in *Cryptomeria japonica* D. Don: Diameter, branching order, or protoxylem groups? Plant Root 9: 79-84.