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# Fine root biomass and morphology of *Pinus densiflora* under different conditions of aboveground growth

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ABSTRACT

The fine root (diameter ≤2.0 mm) biomass and morphology of Japanese red pines (*Pinus densiflora*) grown under different aboveground conditions (i.e., high and low competitive environments) were investigated in a pine–cypress mixed forest. All *P. densiflora* subject trees were approximately 40 years old, and the aboveground condition (i.e., size) of red pines appeared to be influenced by the surrounding Japanese cypress (*Chamaecyparis obtusa*). Smaller pines exhibited lower fine root biomasses, shorter root lengths, and lower root tip densities, but longer specific root lengths and higher specific root tip densities relative to larger ones. These results suggest that *P. densiflora* may adjust the morphological traits of fine roots at different biomass allocation to fine roots in relation to aboveground conditions.
KEYWORDS: Fine roots, Japanese red pine, Root biomass, Root morphology, Aboveground growth

## 1. INTRODUCTIONS

Plants can acclimate to various environmental conditions by altering energy allocation to organs or the morphological traits of fine roots and leaves. These responses allow plants to optimize primary production and nutrient uptake for maximizing growth rates under resource limits. While some of these plant acclimations have been well investigated, the morphological plasticity in belowground organs, particularly fine roots that function in the uptake of water and nutrients, has received less attention. Previous studies examined whether fine root architecture varied with interspecific competition for nutrients and/or light. These studies often used seedlings or saplings as the experimental trees because their environmental conditions were easy to manipulate. However, few studies have examined the effects of environmental variation on adult trees. Therefore, we examined whether adult trees show strategies similar to those observed in juvenile trees. In this study, we compared the fine root biomass and morphology of small pines (those experiencing an intense competitive environment by cypress) with those of large ones (those experiencing a weaker competitive environment by cypress) of the same age in a pine–cypress mixed forest.

## 2. METHODS

### 2.1. Site description

The study was conducted in Japanese red pine stand (mixed with Japanese cypress) at Ooe Research Forest of Kyoto Prefectural University in central Japan (34º59' N, 135º38' E, ~240 m a.s.l.). The canopy layer of the forest is composed of pines planted about 40 years ago after clear-cutting and cypresses invading from surrounding stands. Individual pines not adjoining other pines within 3 m were selected as subject trees. We divided the aboveground growth conditions into two groups (Large and Small) by measuring the widths of growth rings from the past three years. Large and small trees did not differ in mean height, but DBH, crown area and crown ratio

were higher and H/DBH was lower in large relative to small trees. Because all pines were of the same age and the basal area of cypress was larger around small pines than around large ones, cypress appeared to have been causing the declines in the growth of adjacent small individuals.

### 2.2. Sampling methods

The soil-core sampling method was used to collect fine roots. Soil samples were collected using a metal auger (inside diameter of 4.65 cm and depth of 30 cm). Eight soil cores were taken from points 0.5 and 1 m from each tree in four radial directions. The eight cores were pooled as one sample for each tree in the analysis. Every soil sample was separated into $A_0$ layer and three sub-samples of mineral soil (depth of 0-10 cm, 10-20 cm and 20 cm under). Living fine roots were carefully separated from the soil by gentle washing in tap water.

### 2.3. Evaluation of fine root attributes

The morphological traits of pine roots, such as root length and number of root tips, were analyzed using the digital image analysis system WINRhizo 2005c (Regents Instruments Inc., Quebec, Canada). After scanning, all root fragments were dried for 48 h at 90ºC and weighed. Based on these values, the following morphological indices were calculated: root tip density (number of root tips per soil volume), specific root length (SRL: the ratio of root length to root mass) and specific root tip density (SRT: the ratio of the number of root tips to root mass). SRL and SRT are used as indicators of efficiency of resource acquisition to root cost. For cypress samples, the dry weight of fine roots was measured.

## 3. RESULTS AND DISCUSSIONS

### 3.1. Fine root biomass

The fine root biomass of pine was higher in large (mean = 78.7 g $m^{-2}$) relative to small (mean = 4.3 g $m^{-2}$) trees. Vertical distribution of fine root biomass of pine was the highest at the top layer ($A_0$), and declined exponentially with increasing soil depth in large tree, while specific tendency was not seen in small one. The fine root biomass of cypress did not significantly differ between large (mean = 322.6 g $m^{-2}$) and small (mean = 343.2 g $m^{-2}$) pine trees. Vertical distributions of fine root biomass of cypress in both large and small trees also decreased with increased soil depth, similar to one of pine fine roots in large tree. Because cypress trees exhibited the same level of fine root biomass in both large and small trees, the observed differences in pine growth may have been caused primarily by aboveground competition for light and less by belowground competition. Pine trees suppressed by aboveground competition may be carbon-limited, perhaps causing trees to reduce allocation to belowground organs and weaken also in belowground as it is difficult for small pines to spread fine roots in the nutrient-rich top layer.

### 3.2. Fine root morphology

The average fine root length and tip density in pine were also higher in large relative to small trees. However, the fine roots of small pine exhibited higher SRL and SRT relative to large ones, suggesting that roots achieve high absorption with low costs. The fine roots in small pine may alter their individual morphology to compensate for lower biomass. These results correspond to the results of previous studies with juvenile trees. We indicated that, similar to saplings of previous studies, adult pines also altered their fine root morphology when suppressed by other species.