Root biomass and carbon storage in oriental spruce and beech stands in Artvin, Turkey.

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Abstract

In this study, influence of slope position (south-facing vs. north-facing), species type and sampling time on fine(0-2 mm), small (2-5 mm) and coarse (5-10 mm) root biomass and carbon storage of oriental spruce (*Picea orientalis*) and oriental beech (*Fagus orientalis*) were investigated. Mean total root biomass of oriental spruce was 20160 kg ha^{-1} in south-facing slopes and 17140 kg ha^{-1} in north-facing slopes. Mean total belowground C storage of oriental spruce was 7861 kg ha^{-1} in south-facing slopes and 6840 kg ha^{-1} in north-facing slopes. Similarly, biomass and C storage of oriental beech were 17190 and 6690 kg ha^{-1} in south-facing slopes, and 13260 and 5200 kg ha^{-1} in north-facing slopes, respectively. Oriental spruce had significantly higher fine root biomass than did oriental beech in south-facing slopes. Fine root biomass was significantly higher in fall than in spring in south-facing slopes.

Introduction

Biomass studies are essential in determining the distribution and flow of materials in forest ecosystems, and necessary to understand the dynamics of these systems (Santantonio et al., 1977). Both above- and belowground biomass studies provide information that is essential in the management of forest ecosystems.

Most researchers limit their biomass work with aboveground biomass due to difficulties to study belowground biomass. However, much of the competition among plants takes place underground. In contrast to aboveground competition which primarily involves a single resource, light, plants compete for a broad range of soil resources, including water and at least 20 essential mineral nutrients that differ in molecular size, valence, oxidation state, and mobility within the soil. Belowground competition often reduces plant performance more than does aboveground competition (Casper and Jackson, 1997).

Fine roots represent an important component of root biomass. Production and turnover of fine roots can account for over 40% of total dry-matter production by forest ecosystems (Keyes and Grier, 1981). In addition, fine roots are the major sources of soil organic matter in most ecosystems due to their rapid turnover rate. Kelly et al. (1996) found that reduced root biomass accounted for up to 90% of the variation in soil organic matter across spatial gradients in shortgrass steppe.

Oriental spruce (*Picea orientalis* L.) and oriental beech (*Fagus orientalis* Lipsky.) are two main timber species of northern Turkey. Oriental spruce and oriental beech cover 1% and 3.26% of country’s forest area, respectively (Saracoglu, 1998). There are no studies related to root biomass of oriental spruce and oriental beech in Turkey. Most of the studies related both species focused on soil properties and aboveground timber production (Saracoglu 1998).

The objectives of this study were to quantify and compare fine (0-2 mm), small (2-5 mm) and coarse (5-10 mm) root biomass and carbon storage of oriental spruce and oriental beech growing on south-facing and north-facing slopes during two year period.

Our second objective was to determine influence of slope position (north-facing vs. south-facing) and sampling time on fine, small and coarse root biomass and carbon storage of both species in the same sites.

Materials and Methods

This study was conducted in adjacent stands of oriental spruce and oriental beech in Artvin, Turkey. Both stands had similar ecological conditions with 40-60% slopes and well-drained inceptisol soils of sandy-loam texture. Elevations of sampling plots ranged from 1350 to 1600 m from sea level. Mean annual temperature and precipitation of the study area were 7.9 °C and 1165 mm, respectively.

Root biomass was measured in 20 x 20 m sampling plots in the Fall of 2001 and 2002 (October), and in the Spring of 2003 (May)(n=8 plots per species, n=4 of them in south-facing and n=4 of them in north-facing slopes). Sequential coring was used to determine fine (0-2 mm), small (2-5 mm) and coarse root (5-10 mm) biomass (Joslin and Henderson, 1987; Tufekcioglu et al., 1999). Six soil cores of 6.4 cm diameter were removed from each sampling plot from the surface 0-30 cm of soil. Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Roots were sorted into diameter classes of 0-2 mm (fine root), 2-5 mm (small root) and 5-10 mm (coarse root) root classes. The roots from each size category were oven-dried at 65 °C for 24 h, weighed and ground to pass through 1 mm mesh size sieves. Ground samples were analyzed for carbon using dichromate-oxidation method (Kalra and Maynard, 1991).

Statistical comparisons were made using the SPSS program. We used ANOVA to compare fine, small and coarse root biomass, sampling times and slope positions ($P<0.05$).

Results and Discussion

Fine root biomass differed between species types. Oriental spruce had higher fine root biomass than did oriental beech both in south-facing and north-facing slopes, but these differences were significant in north-facing slopes at $P<0.05$ level and roughly significant in south-facing slopes at $P<0.1$ level. Fine root biomass values of oriental spruce ranged from 3520 kg ha^{-1} in north-facing slopes to 15010 kg ha^{-1} in south-facing slopes (Fig. 1A) and fine root biomass values of oriental beech ranged from 4110 kg ha^{-1} in north-facing slopes to 14520 kg ha^{-1} in south-facing slopes (Fig. 2A). Small and coarse root biomass of oriental spruce and beech were not significantly different.

Fine root biomass of oriental spruce varied significantly with slope positions. South-facing slopes had significantly higher fine root biomass than did north-facing slopes in both 2001 and 2002 ($P=0.04$). Small and coarse root biomass of oriental spruce were greater in north-facing slopes but these differences were not significant. Fine root biomass of oriental beech was significantly greater in south-facing slopes than in north-facing slopes in 2002 but not in 2001. Both small and coarse root biomass of oriental beech didn't vary significantly between south-facing and north-facing slopes.

Fine root biomass varied with sampling time. Fine root biomass was significantly higher in fall than in spring in south-facing slopes. North-facing slopes also had higher fine root biomass in the fall than in the spring but these differences were not significant.

Small and coarse root biomass did not differ significantly between fall and spring (Fig. 1A & 2A).

Mean carbon concentrations of oriental spruce were 36.91% in fine roots, 41.51% in small roots and 42.72% in coarse roots. Mean carbon concentrations of oriental beech were 34.47% in fine roots, 43.1% in small roots and 44.54% in coarse roots. Mean carbon concentrations in fine roots of oriental spruce were significantly higher than of oriental beech. However, small and coarse roots of oriental spruce had significantly lower mean carbon concentrations than did small and coarse roots of oriental beech ($P=0.04$).

Carbon storage varied with slope positions, species types and sampling times. Fine root C storage of spruce varied significantly with slope positions. South-facing slopes had significantly higher fine root C storage than did north-facing slopes both in 2001 and 2002 ($P<0.05$). Small and coarse root biomass carbon storage of spruce were greater in north-facing slopes than in south-facing slopes but these differences were not significant. Fine root biomass carbon storage of oriental beech was significantly greater in south-facing slopes than in north-facing slopes in 2002 but not in 2001. South-facing slopes had significantly higher fine root carbon storage in the fall than in the spring. Both small and coarse root biomass C storage of oriental beech didn't vary significantly between south-facing and north-facing slopes.

Mean total root biomass of oriental spruce was 20160 kg ha^{-1} in south-facing slopes and 17140 kg ha^{-1} in north-facing slopes. Mean total belowground carbon storage of oriental spruce was 7861 kg ha^{-1} in south-facing slopes and 6840 kg ha^{-1} in north-facing slopes. Similarly, total biomass and carbon storage of oriental beech were 17190 and 6690 kg ha^{-1} in south-facing slopes, 13260 and 5200 kg ha^{-1} in north-facing slopes, respectively.

We observed higher root biomass values in the south-facing sites than in the north-facing sites. Similar results found by Hendrick and Pregitzer (1993) in two sugar maple (*Acer saccharum* Marsh.) stands, one in north-facing slope and the other one in south-facing slope. They observed mean fine root biomass values of 7901 and 9530 kg ha^{-1} at the south-facing site, 6913 and 7967 kg ha^{-1} at north-facing site for April and October, respectively. Higher root biomass values in south-facing slopes could be due to higher evaporation, higher transpiration and lower soil moisture values in these slopes compared to north-facing slopes. In this study, maximum fine root biomass values were observed in the Fall. This is consistent with findings of Keyes and Grier (1981), Hendrick and Pregitzer (1993) and Joslin and Henderson (1987).

Mean fine root biomass values for beech and spruce in the present study were comparable with the results of other researchers. Fahey and Hughes (1994) reported that mean fine root biomass of 6470 kg ha^{-1} for June and 7010 kg ha^{-1} for October in a north-facing hardwood forest dominated by sugar maple, American beech and yellow birch. Vogt et al. (1987) comparing 13 stands with different ages, young stands had the highest biomass compared to old stands. McQuen (1968) found that fine root biomass decreased with the increasing stand age in *Pinus sylvestris* stands. These studies found fine root biomass values that were close to our findings in oriental beech stands.

The mean fine root biomass values for oriental spruce were higher than that of the values quoted for *Picea abies* (European spruce) (Vogt et al., 1996). Lower mean annual temperatures of Europe compared to Turkey could be the reason for this. Vogt et al.

(1996) reported a significant positive correlation between mean annual temperatures and fine root biomass ($r=0.61$, $P<0.001$).

Fine root biomass of oriental spruce was significantly higher than that of oriental beech. We did not find any literature specifically comparing fine root biomass of oriental spruce with oriental beech. However, examination of mean fine root biomass values of Norway spruce and European beech from the current literature revealed that beech generally has less fine root biomass than does spruce (DeAngelis et al., 1981; Vogt et al., 1996).

Fine roots are important carbon sinks of the world forest and grass ecosystems. Jackson et al. (1997) reported that global fine root carbon is more than 5% of all the carbon contained in the atmosphere. Assuming conservatively that fine roots turn over once per year, they represent 33% of global annual net primary productivity. Our results indicate that oriental spruce allocated more carbon into belowground biomass than did oriental beech and; there was more carbon stored in belowground biomass in south-facing slopes than in north-facing slopes. Therefore, giving priority to oriental spruce in plantations could diminish atmospheric carbon load and enhance soil quality better than could oriental beech.

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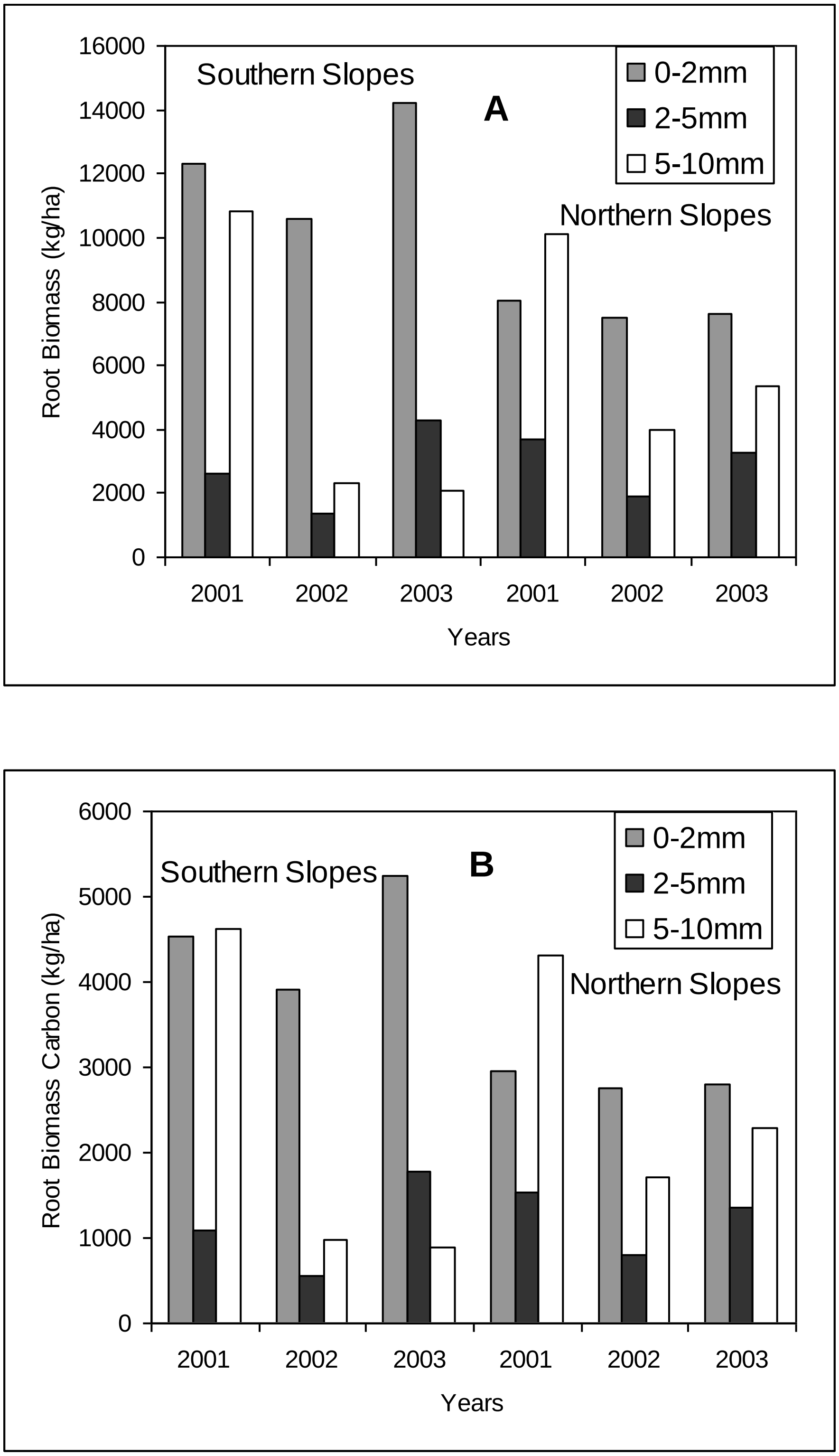

Fig. 1. Root biomass (A) and carbon (B) of oriental spruce in Artvin/Turkey.

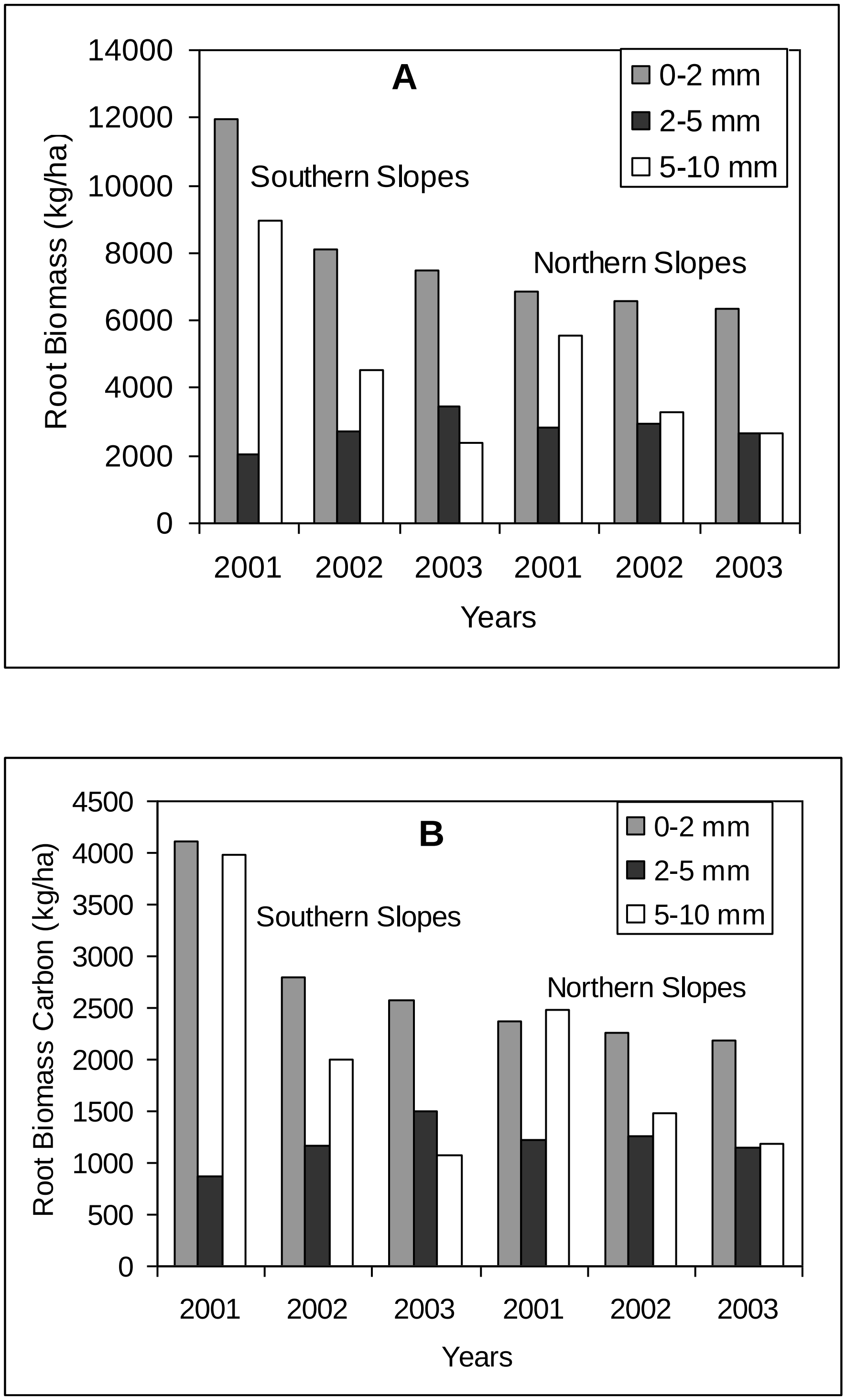

Fig. 2. Root biomass (A) and carbon (B) of oriental beech in Artvin/Turkey.