Fine root seasonal pattern and turnover. A case study of beech stand (*Fagus sylvatica* L.) in Southern Alps, Italy

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ABSTRACT

Root turnover is a critical process of ecosystem’s nutrient dynamics and carbon sequestration. It is also an important sink for primary productivity of plants. By using the root coring technique, we estimated fine root (d < 2mm) seasonal pattern and turnover rate for 1 yr growing season. The experimental site was located in a beech forest stand of Lombardy Southern Alps. Samples were collected at three soil dephts, each 10 cm tick. Live and dead roots were separated. The results show that mean Annual Fine Root Mass was 2.2 t ha^{-1} (1.53 t ha^{-1} biomass and 0.68 t ha^{-1} necromass) and its seasonal pattern was bimodal. Moreover, fine roots were up to 60% located in the uppermost soil layer (10-20 cm). Finally, the overall turnover rate was 1.07 yr^{-1} and increased with soil depth.

KEYWORDS: Root seasonal pattern, Turnover rate, *Fagus sylvatica* L.

INTRODUCTION

An understanding of ecosystems’ responses to simultaneous increase of atmospheric CO_2 and temperature is necessary to predict how ecosystems will respond in the future to further variations of CO_2 and temperature. Fine roots represent a small proportion of total plant biomass neverthless they also represent the most dynamic component of the root systems of woody plants. Fine-root turnover is a critical component of ecosystem’s nutrient dynamics and carbon sequestration and is also an important sink for plant primary productivity (Norby and Jackson, 2000). It is estimated to account for as much as 33% of global annual net primary production (NPP) (Jackson *et al.*, 1997). Hence, fine root dynamics is a major determinant into the ability of an ecosystem to sequester atmospheric C. Basic data on root processes has been acquired for different forest ecosystems, but still little information exists about fine root dynamics in Mediterranean ecosystems and beech forests. In order to increase our understanding of the fine root turnover in beech forest (*Fagus sylvatica* L.) of the Lombardy Prealps we have measured both fine –root biomass and turnover.

MATERIALS AND METHODS

The study area was located in the catchments of Telo stream in the Lombardy Alps (Intelvi Valley, Como province, NW Italy) approximately from 1000 m to 1250 m above sea level. This area is characterised by subcontinental climate, with mean annual precipitation of 1300 mm, occurring in two main periods (April-May and September-October) and a mean annual temperature of 11-13°C. Soil type is a leptosol 40-50 cm depth, generally frozen from late October to April. Sampling plots were placed in three coetaneous stands with different types of forest management. The core sampling method (Vogt and Persson, 1991) was used during the 2008 growing season at different soil depth. In each stand, four permanent 10 m^2 plots were set.

Two soil cores (8 cm diameter x 30 cm deep) were randomly collected in each plot. The sampling occurred within a period of 20 to 40 days. The soil cores were separated into three soil layers; 0-10 cm, 10-20 cm and 20-30 cm depths from soil surface. Minimal distance between the plots was 15 m and each plot was considerate as independent replicate. Samples were taken when the soil was free of snow cover and completely unfrozen (May-October). We collected a total of 168 cores by 7 collecting dates. Each sample were washed automatically in a filtering bags (300 µm mesh) that was built-in a plastics cylinder (6 mm mesh). Depending on their colour, texture and shape, live and dead fine roots were classified (Vogt and Persson, 1991). The roots freed from soil were scanned at resolution of 400 dpi. Successively they were oven dried and weighted. Fine roots images were analyzed by WinRhizo v. 2003b (Regent Instruments Inc., Quebec) in order to obtain morphological data (length and diameter). Value of root production was obtained using a method that assumes rapid fine root turnover. Therefore even monthly sampling might miss some dynamics of fine root vitality (McClaugherty and Aber, 1982). In this model, all the variations both in live (L) and dead (D) standing crop, between sampling dates, were included in calculation of production. Hence, the calculation of root Production (P) was obtained by the sum of the increments (δ) between two consecutive sampling dates as shown in the following equations n°1:

a) $\delta L > 0$ e $\delta D > 0 \rightarrow P = \delta L + \delta D$;
b) $\delta L > 0$ e $\delta D < 0 \rightarrow P = \delta L$; (1)
c) $\delta L < 0$ e $\delta D > 0 \rightarrow P = \delta V + \delta M$ o $P = 0$ (in the case of P negative value);
d) $\delta L < 0$ e $\delta D < 0 \rightarrow P = 0$.

Rates of biomass and necromass turnover were calculated as annual root production divided by mean standing biomass or necromass (Dalman and Kuchera, 1965).

RESULTS

During the vegetative season the value of th Live Fine Root Mass (LFRM) and Dead Fine Root Mass (DFRM) showed a bimodal pattern with two peaks (Figure 1). The highest values were found in the uppermost soil layer (0-10 cm) where it could be found almost 60% of LFRM and 57% of DFRM. LFRM in the uppermost layer (0-10 cm) presented a peak in July (99,07 ± 12.63 SE g m^{-2}) and a small decrease (4,76%) at the beginning of August. In deeper layers the LFRM fall was much more steep and accounted for 27% in 10-20 cm depth and 57% in the 20-30 cm depth. Moreover, in the two deeper layers the second peak of LFRM occurred in September whereas in the first soil layer LFRM value continued to increase up to last sampling date (October). DFRM in the uppermost soil layer showed two main peaks one in August (52.27 ± 6.98 SE g m^{-2}) and the other in October (30.25 ± 6.44 SE g m^{-2}) which were slightly shifted in time in respect to LFRM. In the two deeper layers the DFRM did not show a variation during the vegetative season.

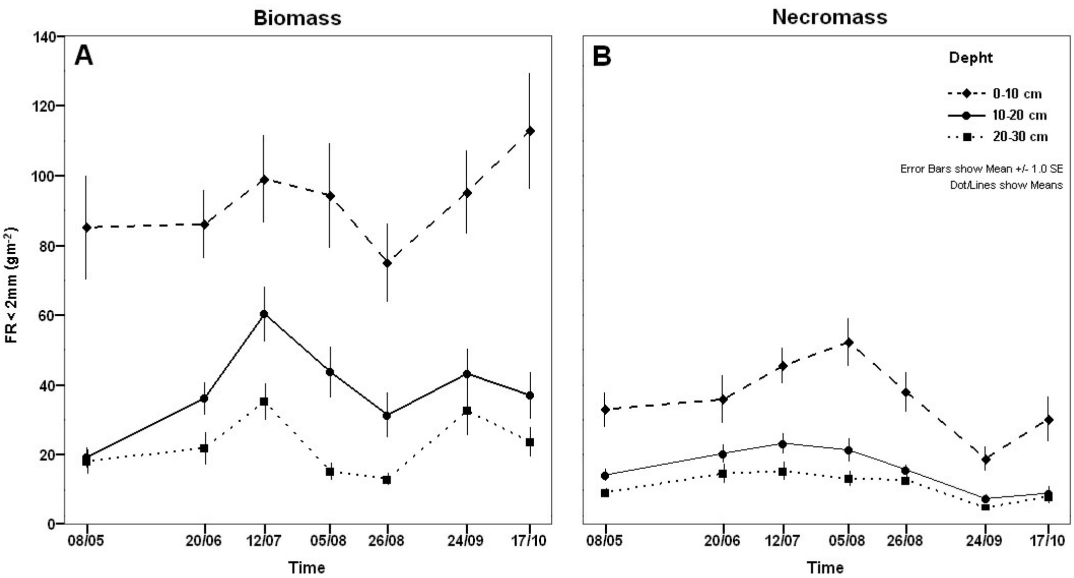

Figure 1. Seasonal pattern at three soil depths of LFRM (A) and DFRM (B)

A cumulative mean value for LFRM and DFRM referring to all vegetative season is shown in Table 1. The turnove rate (FRTR) resulted to be 1.04 yr^{-1} and the Total Fine Root Mass (TFRM) refering to the live plus dead roots was 2.2 t ha^{-1} (Table 1). The FRTR increased along the soil profile from 0.83 yr^{-1} to 2 yr^{-1}.

Table 1. Turnover rate, annual Biomass and Necromass at three different soil depths. Values are means of 168 measurements.

Soil depth (cm)	Turnover rate (yr^{-1})	Biomass (gr/m^2)	±SE	Necromass (gr/m^2)	±SE
0-10	0,83	92,73	5.09	36,36	2.33
10-20	1,63	38,98	2.57	16,05	1.04
20-30	2,01	22,87	1.78	11,22	0.84
0-30	1,04	153.49	6.78	68.65	3.87

DISCUSSION

This study indicate that TFRM in a beech forest ranges between a maximum of 3.35 ton ha^{-1} to a minimum of 1.66 ton ha^{-1}. This range of TFRM may depend on local climate and/or site conditions differences, the age of stands (Idol, 2000). Furthermore, we cannot exclude the effect of different type of forest managements and/or tree density that we observe in that type of forest. However, the mean value of TFRM (2.1 ton ha^{-1}) is similar the ones reported in literature for temperate deciduous forests (Jackson *et al.*, 1997). The LFRM is approximately double of DFRM and this agrees with the suggestion made by Persson (2007), which indicates a high live/dead ratio as a condition for a healthy root system with a high rate of soil penetration (e.g. an efficient uptake function). The fine roots soil distribution suggests that almost 60% of LFRM and 57 % of DFRM is located in the uppermost soil layer (0-10 cm). Also in this case our findings are similar to those observed by other authors in the same climatic and soil conditions (Jackson *et al.*, 1997). Many studies demonstrate the occurrence of significant temporal changes in fine root biomass within the growing season (Makkonen and Helmisaari, 1998). In this study we find variation of biomass during the vegetative season for both live and dead fine roots with two peaks. Our patterns are similar to those reported for temperate deciduous trees which start growth in early spring with a maximum in June or July (Vogt *et al.*, 1998) and then slow growth thereafter. Probably the decrease of growth during the summer could be due to lower rainfall and/or soil warming (Hendrick and Pregitzer, 1997). Therefore our data confirm the presence of a complex bimodal pattern in root mortality when temperate forests are considered (Matamala *et al.*, 2003). We find the highest decay values in deeper soil layer with the two DFRM peaks being shifted in time when compared to LFRM as one would aspect when death and decomposition is the cause of LFRM fall. Gaudinski (2001) and Hendrick (1993) find that root population is younger in the deeper soil layers and this agrees with our data which show that FRTR increase with the soil depth. One interpretation could be the presence of specific nutrient conditions which could affect fine root life-span. FRTR in forest ecosystems is strongly influenced by local conditions such as temperature mean annual rainfall or soil types. In our study the FRTR is about 1.04 yr^{-1} a value similar to those found in temperate broadleaved ecosystems (Gill and Jackson 2000) and in the north-Europe beech stands (Bakker *et al*., 2008)

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