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NITROGEN, LIGNIN, CELLULOSE AND ADSS DYNAMICS DURING DECOMPOSITION OF *PINUS NIGRA* Arn. NEEDLES ASSESSED BY DIRECT FIELD MEASUREMENTS

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Abstract

In a P. nigra Arn. forest, implanted on volcanic lapillus of the last eruption of the Vesuvius (1944), litter mass loss and the dynamics of nitrogen and organic-chemical constituents was studied without enclosing the needles in litter-bags. The vertical distribution of fungi within the different litter layers was also examined. The dynamics of needle litter decomposition showed a rapid mass-loss phase followed by a slow mass-loss phase; the accumulated mass loss reached an asymptotic level at about 50% of the initial mass. During decomposition nitrogen was released since the early stage. As much as 72% of the original mass of lignin, and 60% and 20% of the original mass of ADSS and cellulose, respectively, were found in the far decomposed litter. The amount of total and live fungal mycelium was similar in L_A (light-brown needles) and L_B (dark-brown needles) and increased in L_C (brown-black needles) and L_D (black needles) layers.

INTRODUCTION

In forest ecosystems decomposition of leaf litter is an important process controlling nutrient cycling and the accumulation of organic matter in the soil. Mediterranean type ecosystems are characterized by hot dry summers and mild wet winters. The temporal asynchrony of favourable temperature and moisture conditions may influence the rate of litter production and of litter decomposition [1] affecting the size and the quality of carbon reservoir within the soil. These effects are sharpened in coniferous and sclerophyllous forests and shrublands with species bearing leaves rich in recalcitrant components.

The aim of this study was to assess the accumulation of organic matter in the soil of a *P. nigra* Arn. forest ecosystem. In the second half of the last century this species has been widely used in Italy for reforestation and afforestation [2]. We studied the mass loss, and the dynamics of N and organic constituents of litter without enclosing the needles in litter-bags. Virzo De Santo et al., [3] showed that confining litter in bags as compared to direct measurements, increases the moisture content with significant discrepancies between decomposition values obtained with the two different methods. A further aim of this work was to examine the vertical distribution of fungi within litter layers and the relationships with litter mass loss and litter organic constituents.

STUDY AREA

The study site was a 45 years old *Pinus nigra* Arn. forest located on a slope in the area called Atrio del Cavallo (40°49' N 14°23'E) at 800 m above sea level in the Vesuvius National Park (Naples, South-Italy). The climate is Mediterranean with mean annual precipitation of 910 mm (almost half falling from October to January) and mean annual temperature of 14.2°C; mean temperature are 10.1°C and 18.9°C for the coldest months (January-February) and the warmest months (June-August) respectively. The climatic data are based on 3 years (2002-2004) observations at Gran Cono Meteorological Station, about 1000 m above sea level. The forest is a primary implant on volcanic lapillus of the last eruption of the volcano in 1944. The very shallow soil (1-5 cm) is a Lepti-Vitric Andosol [4], according to FAO (1998) classification [5], with a pH 4.16±0.18.

MATERIAL AND METHODS

The decomposition process was studied by a direct field method. The litter mass loss was determined sorting the needles on the basis of the morphological criteria described by Kendrick [6] and Gourbière[7].

Four needle litter compartments were singled out: surface layer (L_A) with needles light-brown in colour and still intact; L_B layer with dark-brown and fragmented needles; L_C layer with very fragmented brown-black needles; L_D layer with black needles broken in very small pieces.

Table 1. Soil nutrient content

N	K	Fe	Mg mg g^{-1}	Na	Mn	Zn	Cu µ g g^{-1}
5,97 ± 1.08	0.16± 0.05	0.10 ± 0.003	66.70 ± 0.92	79.44 ± 0.03	12.90 ± 0.05	11.24 ± 3.50	4.80 ± 0.20

Table 2. Soil biological characteristics

Respiration µg CO_2 g^{-1} h^{-1}	Microbial Biomass mg C-CO_2 g^{-1}	qCO_2 µg C-CO_2 mg C mic^{-1}	Catabolic evenness
34.81 ± 0.86	2.04 ± 0.02	4.70 ± 0.30	13.10 ± 0.94

The initial needle-weight (L_0) was determined in the litter-fall (2002-2003) collected, in 10 litter traps (Ø: 1m^2) placed randomly in the pine forest. The ground litter sampling was made in eight replicates on June 29-2004 with a box 20x20x20 cm including organic soil. The decomposition time for mass loss was calculated with the method of Kurz et al. [8]. The litter mass loss was measured comparing the mass of one meter of decomposing litter to that of one meter of newly-shed litter (L_0). The litter residence time was determined in the 4 layers on the basis of the annual litterfall, the layer mass and the layer mass loss. Element contents were determined on soil and litter by atomic absorption spectrometry (Spectraa 220FS Varian). C and N concentrations were determined by combustion in an Elemental Analyser (Flash 112 Series EA). The analyses of ADSS (Acid detergent soluble substances), lignin and cellulose were made using the method of Goring and Van Soest [9]. Soil was analysed for microbial catabolic evenness, microbial biomass C, metabolic quotient and basal respiration after Degens et al. [10] and for live and total fungal mycelium according to Sundman & Sivelä [11] and Olson [12].

The correlation between: N, ADSS, lignin, cellulose, total and live fungal mycelium and the mass loss, N and total and live fungal mycelium, were evaluated by the Spearman Rank Order correlation coefficient.

RESULTS AND DISCUSSION

Nutrient content and biological characteristics are shown in Table 1 and Table 2 respectively.

Table 3 shows the concentration of organic components.

Table 3. Initial Nitrogen and organic fraction in the litter of *Pinus nigra*. The values are means of 8 measurements ± standard error

ADSS	Cellulose mg g^{-1}	Lignin	N
459.47 ± 6.61	316.91 ± 3.08	223.62 ± 7.50	23.80 ± 1.85

Nitrogen content is very high as compared to values commonly found in pine needle litter; the initial concentration of lignin was 223.62 mg g^{-1}; this value is similar to that found in other pine litters [13].

The needle mass loss plotted against the estimated decomposition time, shows a pattern that is best described by the model used to present the data reported in Fig. 1: Y= Ymax (1-exp (-K*x).

The dynamic of needle litter decomposition (Fig. 1) shows two phases: an initial rapid mass loss of about 30-35 % occurring in the first 200 days followed by a slow mass-loss phase. Litter mass loss reached an asymptotic level of 45-50% of the initial mass. Such decomposition pattern is consistent with the model described by Berg and McClaugherty [13].

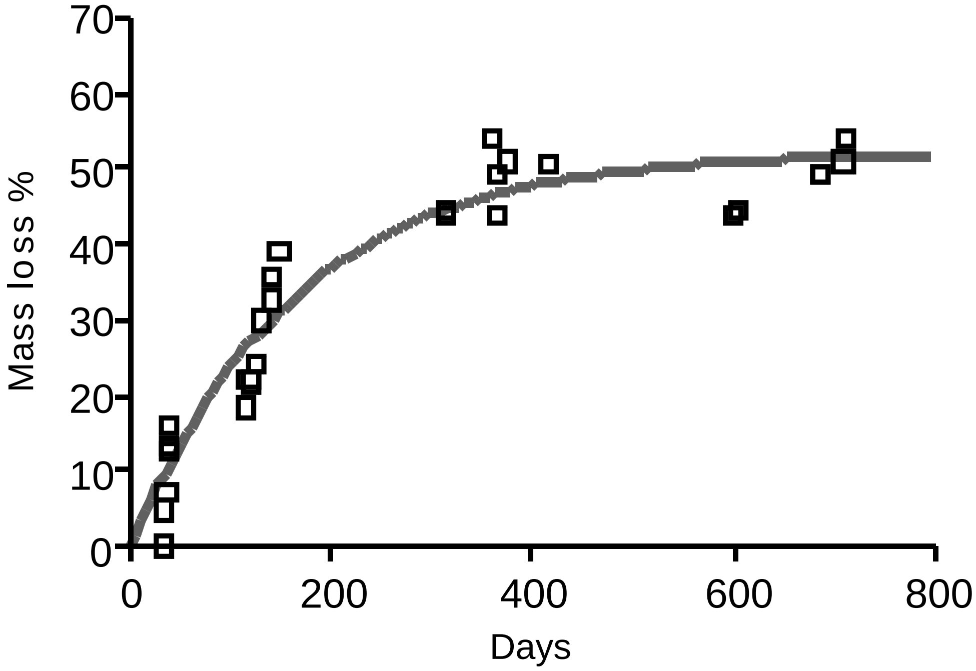

Fig. 1. Mass loss of the needle litter of *P. nigra* Arn

Figure 2 shows the changes in concentration and absolute amount of N, lignin, cellulose, and acid-detergent soluble substances (ADSS) during decomposition. After an initial increase the absolute amount of N decreased, indicating the occurrence of N mineralization since the early stage of decomposition.

Also the absolute amount of lignin increased during the very early stage of decomposition; thereafter lignin mass decreased slowly and 72% of the original mass remained after 633 days of decomposition.

Cellulose absolute amount decreased during decomposition and 20% of the original mass was measured at the end of the decomposition period. ADSS decreased rapidly in the early stage and then decreased slowly to 63% of the initial value.

Figure 3 shows the vertical distribution of total and live fungal mycelium within the litter layers. The amount of both total and live fungal mycelium was similar in L_A and L_B layers and increased in L_C and L_D layers. The concentration of total and live mycelium was significantly (P<0,05) and positively correlated to mass loss and litter water content and negatively correlated to cellulose content (P< 0,05).

Litter mass loss was significantly (P<0,05) and negatively correlated to concentration of N, lignin, cellulose and ADSS. Concentration of lignin was significantly (P<0,05) and positively correlated to concentration of N.

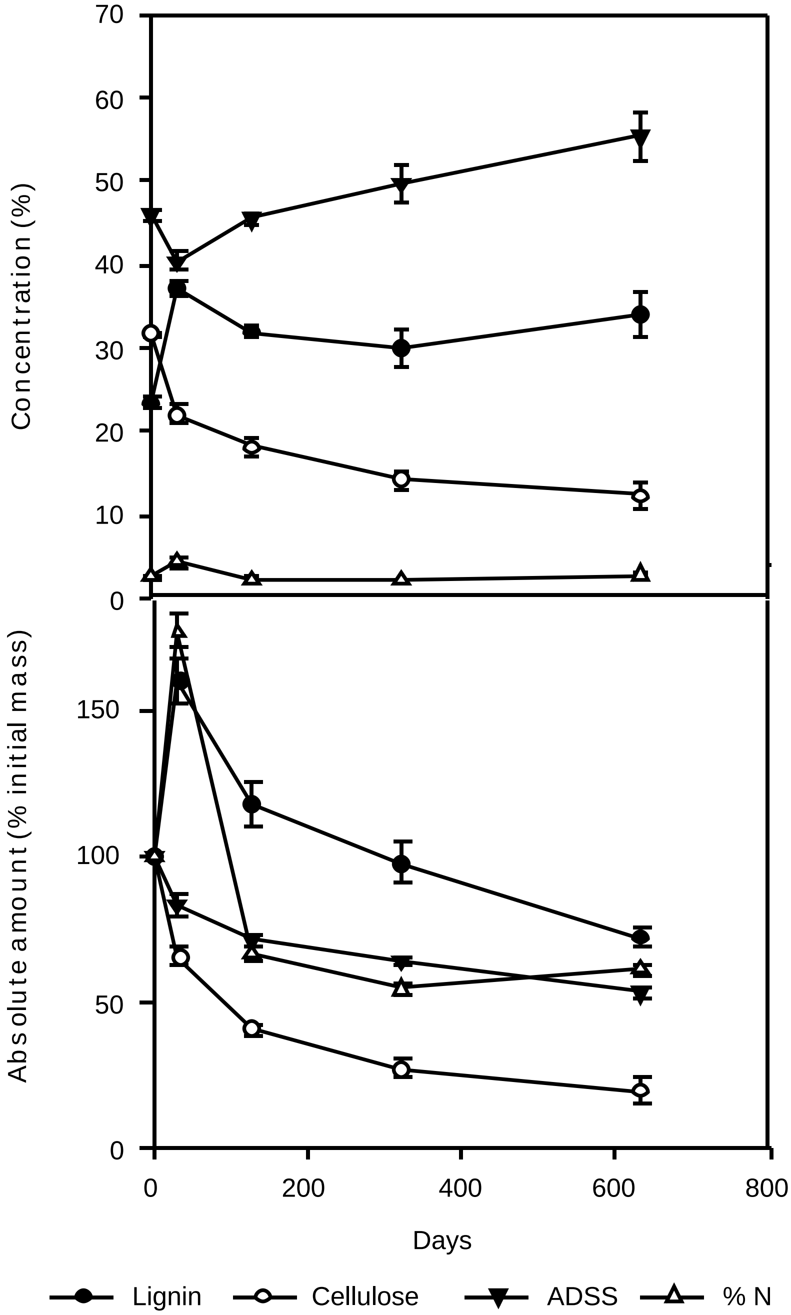

Fig. 2. Changes in concentration and absolute amounts of N, lignin, cellulose, and Acid-Detergent Soluble Substances (ADSS) during decomposition.

CONCLUSION

The observed dynamics of decomposition shows that an asymptotic level is reached at about 50% of the initial needle-litter mass; this results in a large accumulation of organic matter in the forest soil developing from the volcanic lapillus. The recalcitrancy of the *Pinus nigra* needle litter is, at least partially, due to the slow decomposition of the lignin fraction the amount of which at the asymptotic level is as high as 72% of the initial mass; also the remaining ADSS fraction is high, i.e. 63% of the initial mass. In contrast cellulose is decomposed much more quickly than ADSS and lignin, probably due to the high N content of *P. nigra* Arn., as reported by Carriero et al. [14] who found that cellulose decay is enhanced by N addition. The positive and significant correlation of live and total fungal mycelium with cellulose concentration and soil water content, indicates that under moist conditions cellulose is an important energy source regulating the hyphal growth in the litter and litter decay rate.

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