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in

Leone V. (ed.), Lovreglio R. (ed.).
Proceedings of the international workshop MEDPINE 3: conservation, regeneration and restoration of Mediterranean pines and their ecosystems

Bari : CIHEAM
Options Méditerranéennes : Série A. Séminaires Méditerranéens; n. 75

2007
pages 73-77

NUTRIENT DYNAMICS DURING DECOMPOSITION OF FOUR DIFFERENT PINE LITTERS

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Abstract

The dynamics of N, K, Mg, Mn, Fe and Cu was investigated during litter decomposition, at Mount Vesuvius, of four different pine species (Pinus pinea L., P. laricio Poiret, P. sylvestris L., and P. nigra Arn.). Initial chemical composition of the brown needle litters differed among species. The data presented suggest that nutrient dynamics in studied litters is mainly regulated by the initial nutrient content. P. nigra, the litter richest in N, released the nutrient during decomposition; in contrast the other litters with a lower initial concentration accumulated N. K was accumulated in the late phase only by P. sylvestris that had the lowest initial K concentration. Mg was accumulated by all litters. Mn was accumulated in P. nigra and in P. pinea, the litters poorest in Mn, and released in P. sylvestris and P. laricio. Fe and Cu were accumulated in all litters independently of the initial concentration.

INTRODUCTION

Litter decomposition is a key process for nutrient cycling. It is controlled by climate, decomposer microorganisms and litter quality i.e. litter chemical composition [1]. Decomposition process is mainly affected by litter macro- and micro-nutrients concentration and by the amount of complex substances such as chitin, cellulose, hemicellulose and lignin, that are particularly recalcitrant to enzymatic degradation [2]. The early stages of decomposition are positively influenced by high concentrations of macronutrients, such as N, while in the late stages lignin is the main regulation factor; particularly, high concentrations of lignin may inhibit the degradation process [3].

Different patterns of nutrient concentration changes have been observed during litter decomposition mainly depending on the initial litter chemical composition [4]. Some nutrients may be readily leached from the litter and their amount decreases at a rate greater than that of litter mass loss. Other nutrients are released at a rate proportional to that of litter mass loss so that an increase of their concentration is observed; other nutrients are retained within or even imported into the decomposing litter resulting in the increase of both concentration and amount during litter decay.

The aim of this research was to compare the dynamics of N, K, Mg, Mn, Fe and Cu during the decomposition of four pine litters (*Pinus pinea* L., *P. laricio* Poiret, *P. sylvestris* L and *P. nigra* Arn.) differing in chemical composition.

STUDY AREA

Decomposition of *Pinus pinea* L., *P. laricio* Poiret, and *P. sylvestris* L were investigated in a Stone pine forest located at Terzigno on the southeastern slope of Mount Vesuvius at 250 m a.s.l.; decomposition of *P. nigra* Arn. was studied in a Black pine forest located at Atrio del Cavallo on the northeastern slope of Mount Vesuvius at 800 m a.s.l. At both sites pine had been planted on pyroclastic material of the last Vesuvius eruption in 1944. Some soil characteristics for the two experimental sites are showed in table 1.

Climate in the area is characterised by warm and dry summers and wet winters. Based on long-term observations (1926-1950), in the weather station Osservatorio Vesuviano, 612 m a.s.l., annual mean temperature is 13.2℃ and annual mean precipitation is 960 mm. Since the year 2002 a weather station

(Gran Cono) is active on the Vesuvius crater at 1000 m a.s.l.; annual mean temperature is there 14.2℃ (with 10.1 and 18.9℃ respectively in the coldest and in the warmest months) and rainfall 910mm.

Table 1. Some soil characteristics for the experimental sites (0-5 cm depth).

Site	pH	Organic matter (%)	C/N
Terzigno	6.0	6.1 ±0.4	24.6 ±1.8
Atrio del Cavallo	4.2	3.1 ±0.8	8.9 ±0.3

MATERIAL AND METHODS

Brown needles of *P. pinea*, *P. laricio* and *P. sylvestris* were sampled at abscission by shaking tree branches. The needle litter of *P. laricio* was sampled at a Corsican pine stand (50-80 years old) in Golia (1300 m a.s.l. on Sila Mountains, Calabria, South-Italy); needles of *P. sylvestris* were sampled at a Scots pine stand (130 years old) in Jädraås (185 m a.s.l., East Central Sweden);

After air-drying, needles of the three species of pine were incubated in bottom less containers (100x100 cm, 5 cm height) in the Stone pine forest, where the *P. pinea* needles had been collected. Needle samples were collected from the containers every 2-3 months for about 3 years (for more details see Virzo De Santo et al., 2002, [5]).

Decomposition of *P. nigra* was studied by a direct field method [6]. The whole organic profile was collected, in 8 replicates, by a box (20x20 cm). Four needle layers were recognised based on morphological criteria and the linear weight was used to assess decomposition [7].

For chemical analyses each type of pine litter was dried at 75℃ and pulverised by a Fritsch pulverisette (type 00.502) with an agate pocket and ball mill. Nitrogen content was determined by combustion with an Elemental Analyser (NA 1500, Carlo Erba). K, Mg, Mn, Fe and Cu concentrations were determined by a SpectrAA-20 Atomic Absorption spectrometer (Varian) after digestion of the samples in a mixture of nitric (65%) and hydrofluoric (50%) acid (v:v=2:1) in a Digestore Milestone MLS1200.

RESULTS AND DISCUSSION

Initial chemical composition of the brown needle litters differed between species (Table 2). Litter of *P. pinea* was the richest in lignin, K and Mg and the poorest in Fe as compared with the other pine litters (Table 2). *P. nigra* needles had the highest concentrations of N and Fe and were poorest in lignin, Mn and Cu (Table 2). The litter poorest in N, K and Mg was that of *P. sylvestris;* however it was the richest in Mn (Table 2).

Table 2. Initial chemical composition of needle litters.

Litter type	Lignin (mg/g)	N (mg/g)	K (mg/g)	Mg (mg/g)	Mn (mg/g)	Fe (mg/g)	Cu (µg/g)
P. pinea L.	369	5.1	4.8	2.7	0.06	0.2	1.9
P. laricio P.	276	4.7	2.4	1.3	0.6	0.3	1.8
P. sylvestris L.	266	4.0	0.5	0.4	1.2	0.3	2.5
P. nigra Arn.	223	23.9	2.3	1.5	0.03	2.9	1.4

Nutrient dynamics are showed at each stage of decomposition as percent of the initial value of the element (absolute amount). For *P. nigra,* the deepest litter layer was not considered in the elemental

analyses because of difficulty to separate decomposing material from soil. The correlation between absolute amounts of element and mass loss was evaluated by the Pearson correlation coefficient.

The pattern of decomposition (Fig. 1) was well described by an asymptotic model in *P. nigra*, the litter richest in nitrogen; in contrast *P. pinea*, *P. laricio*, *P. sylvestris*, that were poorer in nitrogen, showed an exponential model of decomposition [4].

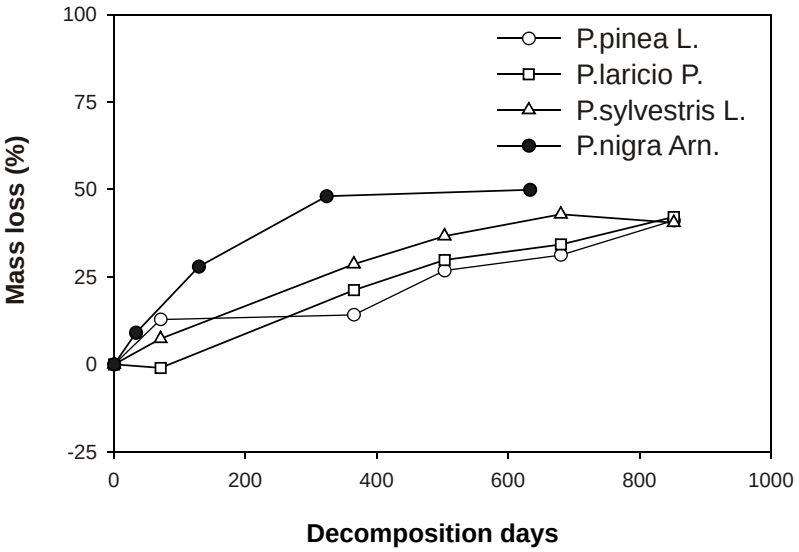

Fig. 1. Mass loss of needle litters of *P. pinea* L., *P. laricio* P., *P. sylvestris* L. and *P. nigra* Arn.

During decomposition of *P. pinea*, *P. laricio* and *P. sylvestris* the absolute amount of N (Fig. 2) increased. In *P. nigra* litter N content increased during the early 34 days of decomposition and was released thereafter, reaching about 60% of the initial value at 633 days.

N is a nutrient that strongly controls the growth of microorganisms [4]; it was immobilized in the litters with low initial concentration, and released in *P. nigra* that had an initial N content 5 times higher than the other litters. N amount was positively correlated ($P<0.05$) to mass loss in *P. sylvestris*, the litter with the lowest N concentration and negatively correlated to mass loss in *P. nigra* the litter with the highest N content.

K is a very mobile element and a proportion of total may be leached very soon after litter fall. According to Laskowski et al. (1995) [8] K dynamics is characterized by two phases: the initial phase in which a rapid K release occurs and the late phase in which K is slowly accumulated. The studied pine litters show a pattern consistent with the model of Laskowski et al. [8] and K dynamics (Fig.2) appears to be controlled by the initial litter concentration. Thus *P. sylvestris* litter, with a low initial content, increased the absolute amount of K during decomposition and the absolute amount was positively correlated to mass loss ($P<0.05$).

Mg (Fig.2) was released from the litter of *P. pinea, P. laricio* and *P. sylvestris* in the early phase of decomposition although more slowly than for K; in the later phase an increase of Mg amount was observed in all three litters. In *P. nigra* Mg was accumulated since the beginning of the decomposition process. The highest increases of Mg absolute amount were observed in *P. sylvestris* and *P. nigra*. The microbial immobilization of Mg is evidenced by the positive correlation ($P<0.05$) with mass loss found in all litters.

Mn is essential for lignin degrading enzymes [9]. Mn dynamics (Fig.2) showed different patterns in the four litter types depending on the initial concentration. *P. laricio* and *P. sylvestris* needles had high initial Mn concentrations and released Mn during decomposition, while *P. nigra* and *P. pinea* needles, with low initial content, accumulated Mn. Mn accumulation in *P. nigra* started in the very early phase of decomposition leading to Mn amount ca 5 fold higher in the far decomposed litter as compared to freshly fallen litter. Soil pH in the *P. nigra* forest had lower values than in the *P. pinea* forest; the mobility of Mn increases at low pH values, however at low Mn concentration in litter the microbial population is able to import the nutrient in the decomposing litter-microbes complex as indicated by the positive correlation

observed in *P. nigra* litter between Mn and mass loss (P<0.001). A negative correlation was found between Mn and mass loss in *P. laricio* (P<0.01) and *P. sylvestris* (P<0.05) litters that released the nutrient.

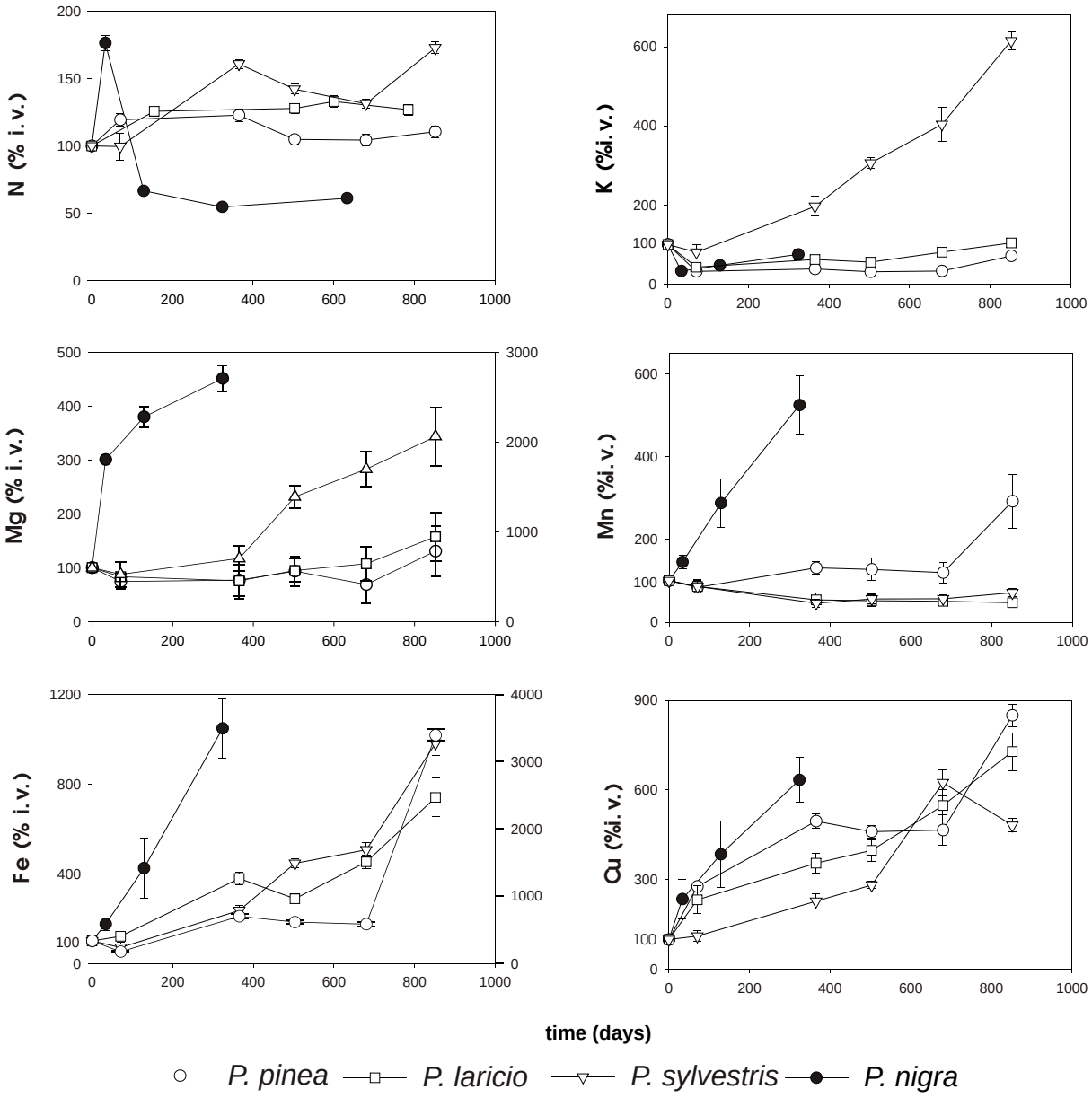

Fig. 2. Changes in absolute amounts of N, K, Mg, Mn, Fe and Cu during decomposition of *P. nigra*, *P. pinea*, *P. laricio* and *P. sylvestris*. In Mg sub-graph values for *P. nigra* litter are on the left axis. In Fe sub-graph values for *P. nigra* and *P. pinea* litters are on the left axis.

Fe and Cu are micro-nutrients/heavy metals. They may be immobilized during decomposition and even imported from the soil through the fungal mycelium. Besides their ions may form stable complexes with humic compounds [10]. The absolute amounts of Fe and Cu increased in all four litter types (Fig.2), especially in *P. nigra* needles. Absolute amounts of Fe and Cu and accumulated mass loss were significantly and positively correlated (P<0.05) in all litters.

The data presented in this study suggest that nutrient dynamics in the four different pine litters is mainly regulated by the initial content with immobilization or release respectively for poor and rich litters during decomposition. However the initial litter concentration does not explain the accumulation of Mg and Fe in decomposing *P. nigra* needles.

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