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Litterfall, organic matter and soil properties of forest ecosystems in Northern Portugal
Chute de litière, matière organique et propriétés du sol d'écosystèmes forestiers dans le Portugal du Sud

<u>MARTINS Afonso</u> (1), **MADEIRA Manuel** (2), **FONSECA Felícia** (3), **RAIMUNDO Fernando** (1)

(1) UTAD, Dep. Edafologia, 5001 Vila Real, Portugal
(2) ISA, Dep. Ciências do Ambiente, Tapada da Ajuda, 1399 Lisboa, Portugal
(3) ESAB, 5300 Bragança, Portugal

Introduction

Above litter production has been considered to be an important pathway of carbon and nutrient circulation in forest ecosystems (Vogt *et al*., 1986). The high variation in forest floor mass within similar climatic zones may be due to variation in litter quality and different availabilities of nutrients. The amount and quality of litterfall in similar environmental conditions, are dependent on the forest tree species. The species influence the amount and turnover of organic matter of the organic layers as well as the quantity of nutrients release and soil characteristics. In this context, a study is being carried out to investigate the differences of *P pinaster* Ait., *P nigra* Arnold, *Pseudotsuga menziesii* Mirb., var. Franco and *C sativa* Mill. stands, with respect to the amount and nutrient concentration of litterfall and organic layers, decomposition and nutrient dynamics of needle or leaf litterfall, and characteristics of mineral soil layers. The first two-year results are shown and discussed in the present paper.

Materials and methods

The study was located in the *Serra da Padrela* area, Northern Portugal (41^{o} 30' 38''N, 7^{o} 36' 43''W, at an altitude of 900 m). The annual mean temperature and precipitation are 11.3^{o}and 1381 mm respectively (INMG, 1978). The soils are Humic Cambisols (FAO-UNESCO, 1988) derived from granites.

The stands under study were installed in 1938 in similar topographic conditions. The tree density was respectively 988, 475, 313 and 1438 tree ha^{-1} in *P. pinaster* (*PP*), *P. nigra* (*PN*), *P. menziesii* (*PM*) and *C. sativa* (*CS*) stands. The size of the studied plots was 85 x 85 m. The plots had a sparse understory dominated by *Calluna vulgaris*, *Chamaespartium tridentatum* and *Ulex europaeus*.

Litterfall was estimated monthly for two years (from August 95 to August 97), from the catch of litter in ten circular litter traps with 1 m^2 of area, located at random in each studied plots of each stand. The forest floor sample units were the litter (L) layer and the humus (F and H) layers. All live plant material was not considered as part of the forest floor. The litter and humus layers were sampled (15 replicates) within a square frame with 0,70 x 0,70 m placed at the soil surface. Soil mineral layers (0-10 cm and 10-25 cm) were sampled, (15 replicates) with a soil corer.

Litterfall was separated into needles or leaves, cones or burs, bark, branches and inflorescences and weighed individually. Decomposition of needle or leaf litterfall was estimated by weight loss of samples in litterbags placed in the field. Litterbags (size 25 x 10 cm) were of nylon mesh with mesh size 1 mm, for *PP*, *PN* and *CS* and mesh size of 0.25 mm for *PM*. Every 3-4 months 15 litterbags of each type of litter were removed from each stand, dried at 65 ^{o}C and weighed individually. Annual decay constant (k) was calculated according to Olson (1963).

The mass of litterfall, litter and humus layers were quantified as dry mass (65^{o}C). The samples of each litter component from each stand and at each date, were mixed to obtain one composite sample. In the case of litter and humus layers five composite samples were obtained for each stand. Each time the litterbags were sampled, each litter type was pooled into a composite sample. The organic samples were ground for analysis of N and mineral nutrients (P, K, Ca, Mg and S) in a laboratory mill to a particle size < 1mm. The mineral nutrients were determined after ashing (6 h at 450^{o} C) and taken up in HCl. Carbon was considered to be 50% of the ash-free dry organic mass. The samples of mineral layers were analysed following standard methods.

Results and discussion

The annual amount of litterfall in *P. nigra* stand (6.97 ± 1.82t ha^{-1}) was significantly higher (P<0.01) than in *P. pinaster* (4.08±1.26t ha^{-1}),.*P. menziesii* (3.96 ± 0.64t ha^{-1}) and *C. sativa* (2.79 ± 0.64t ha^{-1}) stands. The differences with respect to leaf or needle litter were less pronounced. The amount of components other than leaves or needles in litterfall were significantly higher (P<0.01) in *P. nigra* stand (3.18 ± 1.48t ha^{-1}) than in the others (0.63 - 1.29t ha^{-1}) (Table 1). Such a difference was mostly related to the higher amount of cones quantified in the former. The estimated litterfall amounts are similar to those from *P. pinaster* and *P. radiata* stands located in Southern Portugal (Berg *et al*., 1993; Cortez, 1996) with an annual mean precipitation of 600 - 700 mm. Additionally, these quantities fall within the range found for similar latitude (Vogt *et al*. 1986).

Table 1 - Annual total litterfall (TL), leaf (or needle) litterfall (LL) and other components litterfall (OL) in *PP*, *PN*, *PM* and *CS* stands. The values are average ± standard deviation (n=10).

Litterfall	PP	PN	PM	CS
	t ha^{-1}			
TL	4.08 ±1.26	6.97 ±1.82	3.96 ±0.64	2.79 ±0.64
LL	2.79 ±0.50	3.79 ±0.52	3.26 ±0.41	2.16 ±0.32
OL	1.29 ±0.96	3.18 ±1.48	0.70 ±0.31	0.63 ±0.41

Preliminary results indicate that the annual amounts of K, Ca and Mg delivered to the soil through litterfall did not show marked differences among stands. The amount of N was highest (31.3 kg ha^{-1}) for *P. menziesii* stand whereas that of P and S was highest respectively, in the *P. menziesii* and *P. nigra* stands (Table 2).

Table 2 - Annual amounts of nutrients (kg ha^{-1}) delivered to the soil through litterfall in *PP*, *PN*, *PM* and *CS* stands.

Stand	N	P	K	Ca	Mg	S
			kg ha^{-1}			
PP	19.4	0.9	5.8	16.5	4.8	1.6
PN	26.9	1.9	5.9	12.8	3.8	3.2
PM	31.3	2.3	9.4	12.0	3.6	2.9
CS	20.9	1.8	6.6	8.7	6.0	1.0

The needle litter of *P. pinaster* and *P. nigra* had lower N and P concentrations than that of the other species (Table 3). The lignin content did not show substantial difference (246 - 297mg g^{-1}) among leaf and needle litters. The leaf litter of *C. sativa* and the needle litter of *P. menziesii* had much lower C/N ratio (53 - 61) and lignin/N ratio (30-32) than other needle litters (Azevedo, 1997). Differences in litter quality strongly influenced the annual decay rate of studied litters. In fact, litter of *C. sativa* and *P. menziesii* showed an higher decay rate (0.35-0.55) than those of *P. pinaster* and *P. nigra* (0.18-0.19). Amounts of N and P released from needle or leaf litter during the first year of decomposition closely followed the pattern of weight loss (Table 3); therefore they correlate well with the annual decomposition rates calculated for the studied litters.

Table 3 - Initial content of N, P and lignin, values of C/N and lignin/N ratios and decay rate of needle of *PP*, *PN*, *PM* and leaf litter of *CS*; also shown annual decay rates and remaining weight, N and P of the litters after one year of decomposition.

Stand	N	P	Lignin Klasson	C/N	Lignin/N	Decay rate	Remaining N	Remaining P	Remaining weight
	mg g^{-1}						%		
PP	3.9	0.26	272	128	69	0.18	92.4	93.7	81.7
PN	4.6	0.35	272	109	59	0.19	90.1	85.0	84.7
PM	9.4	0.65	297	53	32	0.35	77.6	76.0	70.3
CS	8.2	0.75	246	61	30	0.55	61.6	48.0	56.9

The mass of the forest floor (L, F and H layers) was significantly higher in *P. nigra* (59.3 ±18.4t ha^{-1}) than in the other stands ($P<0.01$). The *C. sativa* stand had the lowest mass (16.6 ±3.1t ha^{-1}) (Table 4). The highest and lowest amounts of forest floor mass occurred in the stands which also showed the highest and lowest annual litterfall mass. Forest floor mass of *P. pinaster* stand is much lower than data obtained for a *P. pinaster* stand (60 years old) in a Southern Portugal area with lower precipitation (Cortez, 1996). But forest floor mass of *P. nigra* stand is similar to that estimated in the latter.

The amount of forest floor organic matter in the studied stands may be mostly conditioned on the annual litterfall. This explains why the amount of organic matter in the *P. nigra* stand was much higher than in the others. However, such a difference is enhanced by the low decomposition rate shown by the *P. nigra* needle litter. In fact, the ratio between the litterfall mass of *P. nigra* and that of *C. sativa* was about 2.5, whereas the ratio between the respective organic mass in the forest floor reached 3.6. Consequently, the mean residence time of organic matter in the forest floor, determined as the quotient between the forest floor mass and the mass of annual litterfall, is lower in *C. sativa* stand than in that of *P.nigra*. In spite of the low decomposition rate shown by the needle litter of *P. pinaster*, there was no evidence of higher relative accumulation of organic matter in this stand in respect to that of *C. sativa*. Such a result suggests a possible anthropic perturbance in the former.

Table 4 - Amounts of dry mass (t ha^{-1}) in ash-free basis and nutrients (kg ha^{-1}) corresponding to the forest floor (FF) in *PP*, *PN*, *PM* and *CS* stands (n=15). For FF the values are average ± standard deviation.

Stand	FF	N	P	K	Ca	Mg	S
	t ha^{-1}			kg ha^{-1}			
PP	23.5± 8.0	267	8.9	19.8	72.1	117.3	36.7
PN	59.3±18.4	577	43.3	96.4	128.3	219.1	73.0
PM	33.1±10.9	492	38.9	40.7	191.9	320.1	67.0
CS	16.6±3.1	343	8.8	35.8	108.4	145.1	37.6

Nitrogen was the nutrient accumulated in highest amounts in the forest floor of the studied stands. Nitrogen accumulation is a result of increase of N concentration from the L litter layer to the H humus layer (Table 5). However, such a trend was less pronounced in the *P. menziesii* and particularly in the *C. sativa* stands than in *P. nigra* stand. In fact, the mean residence time of N was 15.7-16.4 years in the former two, whereas in the latter reached 21.5 years. This N turnover rate correlates well with the N release dynamics from decomposing litters (Table 3). Differences of N turnover rate in the forest floor may be ascribed to differences in N concentration which was higher in *C. sativa* stand than in the others.

Table 5 - Nutrient concentrations and C/N ratio values of the L, F & H layers, and pH of the H layer in *PP*, *PN*, *PM* and *CS* stands.

Stand	Litter layer	N	P	K	Ca	Mg	S	C/N	pH H_2O
				mg g^{-1}					
PP	L	5.7	0.4	0.3	1.2	1.0	0.7	88	-
	F	13.2	0.5	1.1	1.8	2.9	1.9	38	-
	H	12.0	0.3	0.8	5.9	10.5	1.6	42	3.8
PN	L	5.0	0.5	0.8	1.1	0.4	0.3	100	-
	F	10.7	0.7	2.5	1.5	1.0	1.4	47	-
	H	14.5	1.1	1.2	4.8	13.0	2.2	34	3.5
PM	L	8.6	0.6	0.6	1.0	1.6	0.8	58	-
	F	17.8	1.0	1.3	4.3	6.6	2.5	28	-
	H	19.2	1.0	2.0	14.6	25.3	3.0	26	4.7
CS	L	13.4	0.5	1.1	2.0	1.2	1.0	37	-
	F	21.8	0.6	1.8	4.2	3.8	2.2	23	-
	H	22.8	0.5	3.2	12.1	19.5	3.0	22	4.1

High amounts of P only occurred in the forest floor of *P. nigra* and *P. menziesii* stands. The increase in phosphorous concentration from the L to the H layer observed in these stands indicates a selective immobilisation of P within the forest floor. In contrast, P was not selectively immobilised in the forest floor of *C.sativa*, suggesting a fast recirculation into the above tree mass. This behaviour is confirmed by the low P mean residence time (4.9 years) in the forest floor of *C. sativa*, as compared to that for *P. menziesii* (16.9 years) and *P. nigra* (22.7 years), and correlates well with the differences in P releasing rate during the early stage of litter decomposition (Table 3).

The humus H layer showed pH values in pine stands lower than those in *P. menziesii* and *C. sativa*. This is stressed by the higher concentration of bases in the latter than in the former. The C/bases (Ca+Mg+K) molecular ratio was 153-168 for the pine stands and only 73 for the others.

Table 6 - Soil properties corresponding to the 0-10 and 10-25 cm soil layers in *PP*, *PN*, *PM* and *CS* stands.

Stand	Depth	C	N	pH	Exchangeable bases				Exc.	BSP	Ext. P
	cm	g kg^{-1}		H_2O	Ca	Mg	K	Na	acidity	%	mg kg^{-1}
					cmol$_c$ kg^{-1}						
PP	0-10	21	1.5	4.9	0.13	0.17	0.26	0.08	2.10	15.8	9.18
	10-25	14	1.1	4.9	0.15	0.12	0.15	0.07	1.82	7.0	3.06
PN	0-10	41	2.9	4.7	0.21	0.14	0.29	0.04	6.07	6.3	3.93
	10-25	32	2.0	4.7	0.12	0.09	0.20	0.06	5.35	3.6	1.75
PM	0-10	33	2.9	5.3	3.30	1.08	0.66	0.11	1.67	32.9	0.00
	10-25	29	2.7	4.8	0.18	0.26	0.24	0.09	3.05	6.3	0.87
CS	0-10	38	3.4	5.0	0.36	0.58	0.29	0.06	3.57	8.5	3.50
	10-25	35	3.0	4.9	0.14	0.13	0.16	0.07	2.88	4.5	1.75

Differences among stands with respect to mineral soil characteristics were found in the 0-10 cm layer only (Table 6). The highest carbon concentration in this layer was measured in the *P. nigra* stand whereas that of nitrogen occurred in the *C. sativa* stand.

Therefore, the latter showed lower C/N ratio values than the others, as was also observed for the H humus layer. The values of pH and concentration of exchangeable Ca, Mg and k (and base saturation percentage) were highest in *P. menziesii* stand, which also had the highest concentration of these base cations in the H humus layer. In contrast, the pH values and the concentration of Ca and Mg were lowest in *P. nigra* and *P. pinaster* stands. Therefore, the differences in the top soil layer among stands correlates well with those found for the H humus layer.

Stands of *P. nigra* produced high amounts of low quality litterfall leading to low turnover rates of organic matter, N and P in the forest floor, and decreasing soil pH values and lowering the soil base status, as compared to *C. sativa*. In contrast, *P. menziesii*, with higher organic matter, N and P turnover rates than those estimated *for P. nigra*, strongly improved the soil base status relatively to *C. sativa*. In spite of the possible anthropic perturbance in *P. pinaster* stand, available data suggest a behaviour similar to that of *P. nigra*.

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