Fol. Bot. Misc., 9: 127-136 Barcelona 1993

LITTERFALL IN TWO PYRENEAN STANDS OF *PINUS SYLVESTRIS* L. UNDER DIFFERENT ENVIRONMENTAL CONDITIONS[1]

Juli G. PAUSAS[2]

ABSTRACT

Litterfall was studied at two Scots pine (*Pinus sylvestris* L.) stands (Ps1 and Ps2) in the eastern Pyrenees (NE of the Iberian Peninsula). The stands were close together and the climate and the geological substrate were similar. Microenvironmental conditions (aspect, soil depth and stoniness), however, were different. Thus, water availability and sapwood area of Ps1 were lower than Ps2. In contrast, needle production was higher in Ps1. Climatic conditions during the year of study, and also demography of the needles were studied in an attempt to explain the different litterfall pattern.

Key words: Climate, forest production, litterfall, *Pinus sylvestris*, Scots pine, topography.

RESUM

Caiguda de fullaraca en dues parcel·les de *Pinus sylvestris* L. dels Pirineus situades en diferents condicions ambientals.

S'ha realitzat un seguiment de la caiguda de fullaraca en dues parcel·les (Ps1 i Ps2) de bosc natural de pi roig (*Pinus sylvestris* L.) als Pirineus orientals. Les dues parcel·les estan situades molt properes entre sí i presenten unes condicions macroclimàtiques així com el substrat geològic molt similars. En canvi, les característiques microclimàtiques relacionades amb la retenció hídrica del sòl (exposició, profunditat i pedregositat del sòl, etc.) són diferents. La parcel·la Ps1 està situada en condicions més xèriques i presenta superfície d'albeca més petita que Ps2. La parcel·la Ps1 correspon també a la parcel·la on s'observa una producció de fullaraca més elevada. S'estudien les condicions climàtiques de l'any de mostreig, així com la demografia de les acícules dels arbres per tal d'explicar les diferències en la producció de fullaraca.

1. Introduction

Litterfall is a key mechanism in nutrient cycling (BINKLEY, 1986). There

1. This work was partially supported by *La Caixa de Pensions de Barcelona* and by the DGICYT (project PB90-0059).

2. Departament de Biologia Vegetal. Universitat de Barcelona. Av. Diagonal, 645. 08028 Barcelona.

is a positive correlation between site quality and sapwood area and also leaf area (WARING *et al.*, 1980). A similar relationship for litter production has been reported (BRAY & GORHAM, 1964; ALBREKTSON, 1988). However, this regularity is not always evident and the effect of water deficit on canopy dynamics and biomass production still requires further consideration (LINDER *et al.*, 1987).

This paper is limited to a study of one year's litterfall in two stands of Scots pine (*Pinus sylvestris* L.) and to the analysis of the differences in needle litterfall.

2. Methods

2.1. Sampling

The study area is located in the montane zone of the Vall de Tosses, eastern Pyrenees (NE of the Iberian Peninsula), about 125 km north of Barcelona. This area is mainly dominated by natural *Pinus sylvestris* forest in the mid-slopes, and by deciduous forest in the gullies.

Two stands of mature *Pinus sylvestris* forest under different aspect of the same valley were selected to represent two different hydric conditions. Thus, stand Ps1 was located on the south slope at 1540 m a.s.l. and Ps2 on the north slope at 1380 m a.s.l., both in mid-slope. These experimental plots were close together (less than 1 km in a straight line) and the bedrock type was schists in both plots. Based on the thermal gradient estimated in the study area (XERCAINS, 1981), the altitudinal difference between the plots gives a difference in mean annual temperature of about 0.88°C. We assume that this difference is much lower than the temperature effect produced by the difference in aspect. This led us to consider that the two stands were in approximately the same macroenvironmental conditions but in different microenvironments. No recent human disturbance was evident in the stands.

Litterfall was collected using 5 randomly located litter traps (NEWBOULD, 1967) with an area of 0.5 m^2 each. The traps were emptied monthly for one year (from March 1990 to February 1991).

Tree density, basal area and sapwood area were measured in each stand. The sampling methods and treatment of forest structure are described in detail in PAUSAS & FONS (1992). Soil depth was estimate by driving a 1 meter nail at 10 systematically placed points. Four volumetric samples from the top 10 cm of the soil were collected in each stand.

In order to determinate the age structure of the needles, eight branches from different trees were collected in each stand in August 1991. The branches were selected from the upper half and in different orientations of the crown to avoid the effect of the different incoming radiation.

2.2. Laboratory methods and analysis

The litter trapped was air dried. The components separated were needles, cones, twig, bark and male flowers. The miscellaneous remaining included minor items such as bracts, insects, animal droppings, lichens and small number of leaves from others trees (*Abies alba* and *Ilex aquifolium*).

Each litter component for each trap of the two plots was weighed. A composite sample for each component was dried at 60°C to constant weight to allow us to express the litterfall as dry-weight. Statistical comparison of needle litterfall between the plots was performed by least-significant-difference test (LSD).

The needles of the branches collected after the period of the litterfall studied were sorted for ages and counted. Thus, the percentage number of the remaining needles in the tree for each age (age structure) was estimated. The cumulative percentage of needles over time was fitted using a logarithmic regression. This function was used because we assume that the probability of death for a needle increase with its age (Harper, 1989).

The volumetric soil samples were sieved and the stoniness was calculated as the mean of the percentage of stones (fraction bigger than 2 mm) in the 4 soil samples.

Climatic conditions (precipitation and temperature) of the year of the study were compared with the average climatic conditions of 22 years on the basis of data from the meteorological station at La Molina (1704 m a.s.l.). This station is only 6-7 km from the study sites.

3. Results

Stand characteristics for Ps1 and Ps2 are shown in table 1. Ps1 is the stand with the highest slope, the highest stoniness and the lowest soil depth. Ps1 also shows less tree basal area and less tree density than Ps2. Total sapwood area as well as sapwood area in relation to tree density are lower in Ps1 than in Ps2. Pausas & Fons (1992) found less biomass, production and growth in Ps1 than in Ps2. They also reported higher specific leaf weight ($mg \cdot cm^{-2}$) in Ps1 than in Ps2. From these results, the assumption that Ps1 is under drier conditions than Ps2 is valid.

The annual pattern of flower and needle litterfall is shown in figure 1. The needle litterfall showed a clear concentration in the period September-October. During this peak phase needle litterfall was 58.8% in Ps1 and 64.4% in Ps2 of the total annual needle litterfall. Flower production also showed a clear peak phase in June-July, in which 61% (Ps1) and 88% (Ps2) of the total annual production was collected. The miscellaneous fraction of the litter also showed a summer concentration since the main component

Table 1. General characteristics of the two stands studied.

	Ps1	Ps2
Altitude (m)	1540	1380
Aspect	SSE	N
Soil:		
slope (°)	32	28
depth[a] (cm)	68.3	97.8
stoniness[b] (%)	60.7	46.5
Forest structure:		
density ($trees \cdot ha^{-1}$)	592	854
basal area ($m^2 \cdot ha^{-1}$)	31.6	53.4
($m^2 \cdot tree$)	0.053	0.063
sapwood area ($m^2 \cdot ha^{-1}$)	14.68	27.97
($m^2 \cdot tree$)	0.025	0.033

[a] means are different at $p<0.01$ level
[b] means are not significantly different

Table 2. Mean litterfall ($kg \cdot ha^{-1}$ in dry-weight) and coefficients of variation (cv) in the two stands studied (Ps1 and Ps2). For each litter fracion, the second row indicates the percentage of total litterfall.

	Ps1		Ps2		signif.[a]
	mean	cv	mean	cv	
Needles	2771.9	8.8	1015.4	9.9	**
	59.9		44.9		
Twigs	451.0	30.3	262.5	32.9	ns
	9.7		11.6		
Bark	650.6	21.9	373.0	13.7	**
	14.1		16.5		
Flowers	363.6	24.7	311.9	14.5	ns
	7.9		13.8		
Cones	158.4	44.3	171.3	35.2	ns
	3.4		7.6		
Miscellaneous	233.3	12.6	128.6	13.3	**
	5.0		5.7		
Total	4628.7	9.1	2262.8	11.8	**

[a] **, means are significantly different at $p<0.01$ level
ns, means are not significantly different

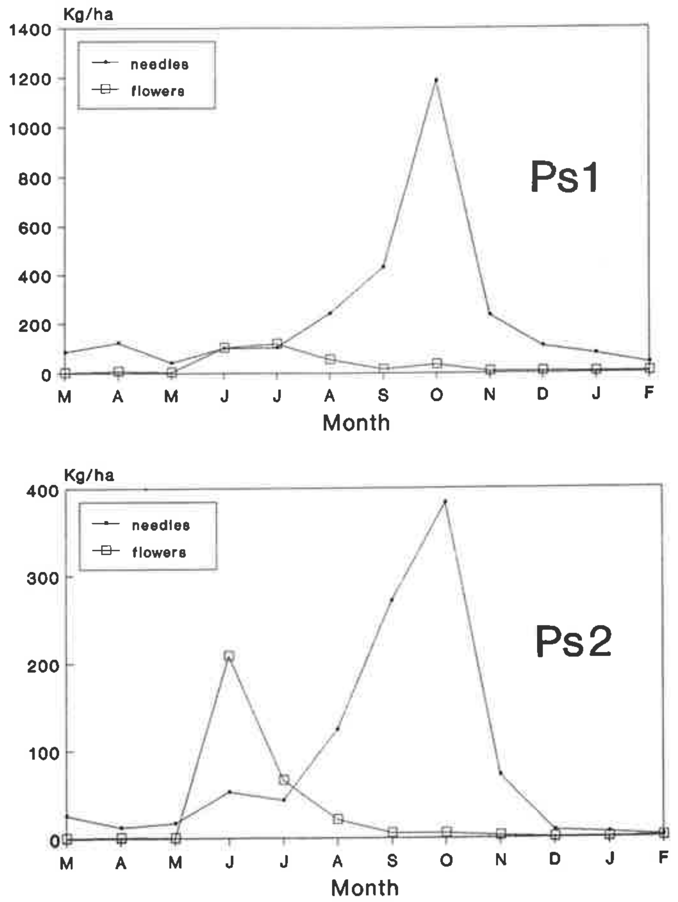

Figure 1. Monthly variation of flower and needle litterfall in kg·ha^{-1} of dry-weight.

of this fraction are bracts of the buds. A non-clear seasonallity was found for bark, cones and twigs.

The mean annual litterfall for each fraction as well as for the total litterfall is presented in table 2 and figure 2. There is large difference in needle litterfall between the two stands. Ps1 showed 2.7 times more needle litterfall than Ps2. The needle fraction corresponds to 60% of the total litterfall in Ps1 and to 45% in Ps2. The bark fraction is also larger in Ps1 than in Ps2.

The age struture of the needles after the litterfall sampled period is shown in figure 3. The maximum observed life-span of a needle was 5 years. An unexpected, strong decrease (more pronounced in Ps1) in the number of needle was found for the 1-year-old needles. These needles were born at the beginning of the litterfall sampled period. To estimate the expected

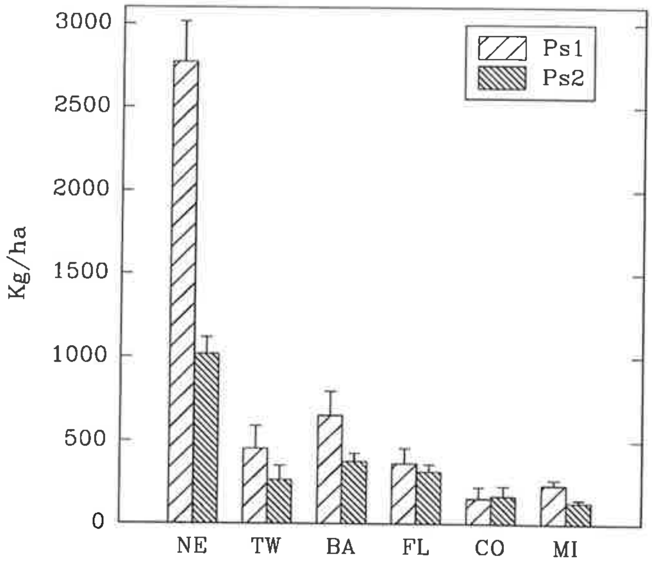

Figure 2. Comparison of mean litterfall (kg·ha^{-1} of dry-weight) of the different litter fractions in the stands studied (Ps1 and Ps2). NE: needles; TW: twigs; BA: bark; FL: flowers; CO: cones; MI: miscellaneous. Vertical lines indicate the standard deviation.

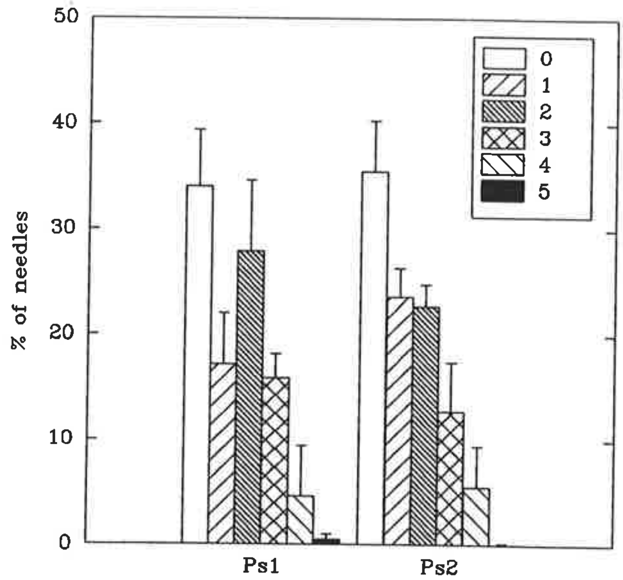

Figure 3. Age structure of needles in the stands sampled (on August 1991) as a percentage of the number of needles for each age (0 = needles of the current year, 1 = 1-year-old needles, 2 = 2-year-old needles, etc.). Vertical lines indicate the standard deviation.

values of the 1-year-old needles, regression analysis was performed using the remaining points (Figure 4). We conclude that the stand Ps1 had 17% fewer 1-year-old needles than what would be expected from regression. The difference for Ps2 was about 10%.

Comparing the climatic conditions between the sampled year (1990) and the period of the 22 years the study (Table 3 and figure 5) we conclude that 1990 was a dry year. In addition, the mean monthly temperature during 1990 was higher in all months than for the mean of the 22 years. The difference between the mean annual precipitation in 22 years and the precipitation in 1990 was more than 300 mm.

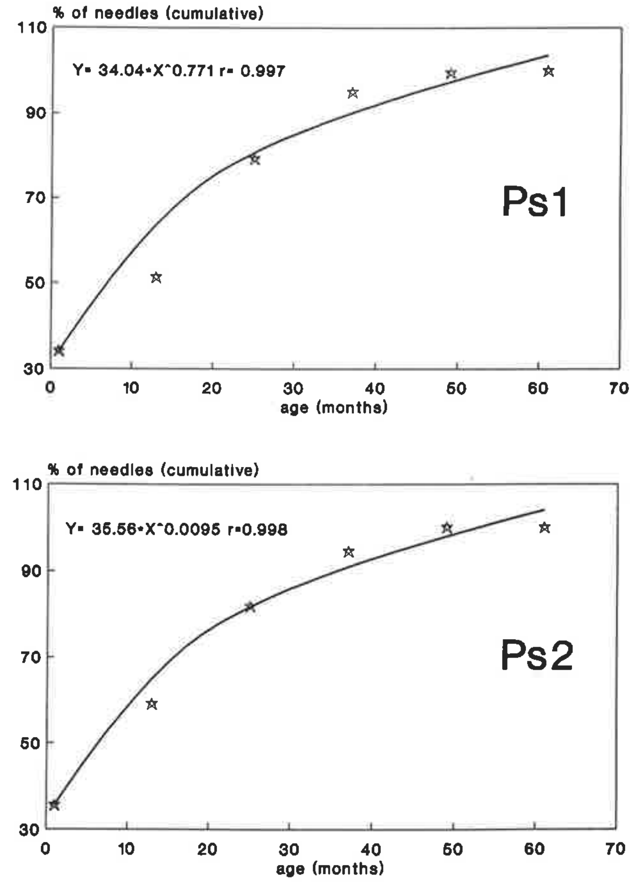

Figure 4. Logarithmic regression analysis between the cumulative percentage of the number of needles and the age of the needles. The fit was performed without taking into account the data for 1-year-old needles.

Table 3. Precipitation and temperature in the sampled year (1990), and the mean of 22 years (data source: meteorological station at La Molina).

	year 1990	mean of 22 years
Precipitation (mm)	960	1281
Precipitation > 100 mm (months)	4	8
Mean temperature (°C)	7.1	5.4

4. Discussion

In the context of the Iberian *Pinus sylvestris* forests, the amount of needle litterfall in Ps1 is close to the needle litterfall reported for central Pyrenees (Alvera, 1973: 2 Mg·ha^{-1}·yr^{-1}) and Iberian Range (Carceller *et al.*, 1989: 2.1 Mg·ha^{-1}·yr^{-1}), but far from the stands studied in the Central Range of Spain (Santa Regina & Gallardo, 1985: 4.1 Mg·ha^{-1}·yr^{-1}). Stand Ps2 showed lower needle litterfall than these studies.

The variation coefficient between the different traps for total litterfall and for the needle fraction was low (8-12%) and the estimation is acceptable (Table 2). However, the estimation of twigs and cones may be subject to a large error and no further analysis was carried out for these fractions. A larger number of traps should be used to estimate the production of these fractions with accuracy.

The stand Ps1 clearly showed less water availability and sapwood area than Ps1, and is thus the stand with less site quality. However, Ps1 is also

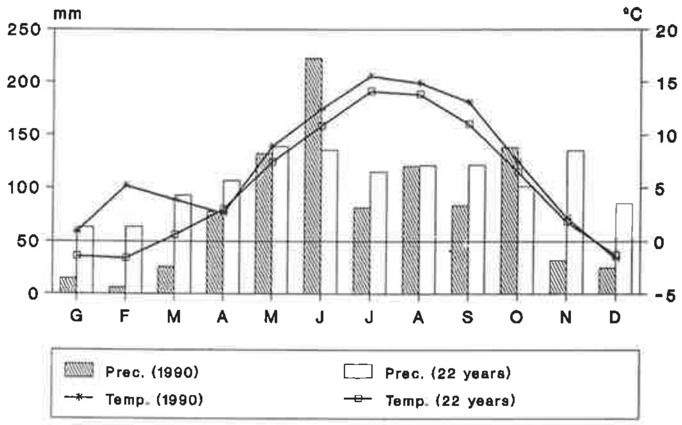

Figure 5. Comparison of monthly precipitation and monthly temperature between 1990 (litterfall sampled year) and mean monthly from 22 years. Data from meteorological station at La Molina.

the stand with the largest litterfall. These can be explained by the climatic conditions of the sampled year. The dryness of 1990 (figure 5, table 3) led to a water stress for the trees. Thus, the stand with low site quality (Ps1) was not able to hold its current foliar biomass and an increase in mortality rate of young needles was found. Consequently, litterfall increased significantly. The stand with better site quality was able to resist the water stress and the litterfall pattern was less modified. LINDER *et al.* (1987) also found an increase in litterfall in non-irrigated plots of *Pinus radiata* compared to irrigated ones, due to a water stress in a dry year. GHOLZ *et al.* (1985) also reported an increase in litterfall in *Pinus elliotii* under drier conditions.

5. Conclusion

A dry year can significantly modify the pattern of litterfall and lead to an increase in the amount of litterfall in the stands with low site quality. Thus, the use of litterfall to estimate forest production should be treated with caution.

Acknowledgements

I am grateful to Marcel Sicart (Colònies Cadí, Cortariu) and Tere Sauras for the help provided in the sampling, and to Núria and to my brother Jordi for the collaboration on the separation of the litterfall into fractions. Valuable comments on the manuscript were made by Ramon Vallejo and two anonymous referees.

References

ALBREKTSON, A. 1988 – Needle litterfall in stands of *Pinus sylvestris* L. in relation to site quality, stand age and latitude. *Scand, J. For, Res.*, 3: 333-342.

ALVERA, B. 1973 – Estudios en bosques de coníferas del Pirineo Central. Serie A: Pinar con acebo de San Juan de la Peña: 1) Producción de hojarasca. *Pirineos*, 109: 17-29.

BINKLEY, D. 1986 – *Forest Nutrition Management.* John Wiley & Son, New York.

BRAY, J.R. & GORHAN, E. 1964 – Litter production in forests of the world. *Advances in Ecological Research* 2: 101-157. Academic Press. London.

CARCELLER, F., SANTA CECILIA, M.A. & VALLEJO, V.R. 1989 – Introducción al ciclo de la materia orgánica en cinco ecosistemas forestales del Moncayo. *Turiaso*, 9: 361-372.

GHOLZ, H.L., PERRY, C.S., CROPPER, W.P. & HENDRY, L.C. 1985 – Litterfall, decomposition and nitrogen and phosphorus dynamics in a chronosequence of slash pine (*Pinus elliotii*) plantations. *Forest Sci.*, 31: 463-478.

HARPER, J.L. 1989 – The value of a leaf. *Oecologia*, 80: 53-58.

LINDER, S., BENSON, M. L., MYERS, B. J. & RAISON, R. J. 1987 – Canopy dynamics and growth of *Pinus radiata*. I. Effects of irrigation and fertilization during a drought. *Can. J. For. Res.*17: 1157-1165.

NEWBOULD, P. J. 1967 – *Methods for estimating the primary production of forests*. Blackwell Scientific Publications. Oxford. IBP, 2, 62 pp.

PAUSAS, J. G. & FONS, J. 1992 – Estructura i creixement d'algunes pinedes en diferents situacions topogràfiques. *Fol. Bot. Misc.*, 8: 199-213.

SANTA REGINA, I. & GALLARDO, J. F. 1985 – Producción de hojarasca en tres bosques de la Sierra de Béjar (Salamanca). *Mediterránea (Ser. Biol.)*, 8: 89-101.

WARING, R. H., THIES, W. G. & MUSCATO, D. 1980 – Stem growth per unit of leaf area: a measure of tree vigor. *For. Sci.*, 26: 112-117.

XERCAVINS, A. 1981 – *Los climas de montaña media y alta en el Pirineo oriental. Análisis de las precipitaciones*. Ph. D. Thesis, Universitat de Barcelona (unpublished).

Rebut: maig de 1992