Plant and Soil 102, 223–227 (1987)

PLSO 6845

Nutrient concentrations in litterfall from some western conifers with special reference to calcium

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Received 20 April 1986. Revised February 1987

Key words: calcium, cupressaceae, leaf litter, litterfall, nutrients, pinaceae, taxodiaceae

Abstract

Foliar litterfall nutrient concentrations were analysed for selected members of Taxodiaceae and Cupressaceae families and *Pseudotsuga menziesii* for two arboreta in western Oregon and Washington. Nutrient results between arboreta show similar concentrations with the exception of magnesium, which may be the result of historical land use. Nutrient concentrations between species vary considerably. *Pseudotsuga menziesii* is particularly distinctive from the Cupressaceae and Taxodiaceae by retaining large amounts of phosphorus and potassium. Taxodiaceae is distinctive by high concentration of Mg while Cupressaceae retains calcium, especially *Chamaecyparis nootkatensis*. Results suggest that all members of Taxodiaceae and Cupressaceae retain considerably more Ca than Pinaceae in foliar litter.

Introduction

Conifer leaf litters differ considerably in their nutrient content. Variation of nutrient concentrations in litter in Pacific Northwest coniferous forests has been attributed to temperature and micro-habitat, age of the stand, species composition, substrate quality, leaching of nutrients by throughflow in senescent foliage, mycorrhizal fungi association and the ability to internally redistribute nutrients within foliage and woody tissue prior to abscission (Daubenmire, 1953; Fogel and Cromack, 1977; Krumlik, 1974; Krumlik, 1979; Sollins *et al.*, 1980; Tarrant and Issac, 1951; Tiedman *et al.*, 1980).

Although a relatively immobile cation, calcium varies in concentration in conifer litter among family members and appears to be high in certain families. Percentage of Ca in the foliar litter of *Thuja plicata* (Donn ex D. Don), family Cupressaceae, is higher than in species of Pinaceae (Alban, 1967; Beaton *et al.*, 1965; Gessel *et al.*, 1973; Ovington, 1958; Tarrant and Issac, 1951). Ca was the main exchangeable cation in bark and leaf humus under *Sequoiadendron giganteum* [(Lindl.) Buchholz], family Taxodeaceae, and its foliar Ca concentration was considerably higher than Pinaceae tested (Zinke and Crocker, 1962). *Cupressus pygmaea* [(Lemmon) Sarg.], family Cupuressaceae, and redwood *Sequoia sempervirens* [(D. Don) Endl.], contained considerably more Ca in foliar litter than did *Pinus Contorta* var. *bolanderi* [(Parl.) Vasey] or *Pinus muricata* (D. Don) (Westman, 1978). Similarly, Ca content of living tissues varies among coniferous families but is consistently higher in Cupressaceae and Taxodiaceae members than in Pinaceae (Ovington, 1958; Zobel and Liu, 1979). These results appear to reflect differences asociated with family characteristics. However, they could also reflect site or microsite differences. Because of the consistency of these reported results we wondered if all species within the Taxodiaceae and Cupressaceae accumulate more Ca than Pinaceae growing on the same sites.

In this paper we compare nutrient concentrations, with an emphasis on calcium, of foliar litterfall from all members of the Taxodiaceae and Cupressaceae in western North America (with the exception of *Juniperus* and *Cupressus* species in the Cupressaceae) grown in two arboreta in the Pacific Northwest. Nutrient availability should have been equally accessible for each species within each arboretum.

Materials and methods

Sites of foliage collection

Peavy Arboretum is in the foothills east of the Oregon Coast Range near Corvallis, Oregon. Most trees were planted between 1930 and 1940. Soils in the arboretum are deep and well-drained, formed in colluvium weathered from Siletz River volcanic basalt. Soil pH is around 5.6 for the first 16 centimeters and 5.1 at 30 centimeters in depth. Soil texture is silty clay loam (Jorgenson-McCadden, 1983).

Wind River Arboretum is on the Wind River Experimental Forest, Gifford Pinchot National Forest, in the western Cascades of Washington. Tree planting occurred between 1912 and 1925. Soils are deep, coarse sandy loams. The arboretum has a 10-percent slope, and is on an alluvial bench. The soils are fairly porus, have no hardpan subsoil, and dry rapidly (Silen and Woike, 1959).

Collection of litter

Foliar samples were collected from *Sequoiadendron giganteum* and *Sequoia sempervirens*, family taxodiaceae; and Taxodiaceae; and *Chamaecyparis nootkatensis* (D. Don), *C. Lawsoniana* [(A. Murr.) Parl.], *Calocedrus decurrens* [(Torr.) Florin], and *Thuja plicata*, family Cupressaceae; and *Pseudotsuga menziesii* [(Mirb.) Franco], family Pinaceae.

Collections at each arboretum were made in early to mid-October (period of peak foliar abscission for most western conifers) from four different trees from each of the above mentioned species. A large plastic sheet was placed beneath each tree and the branches shaken to dislodge dead foliage. All material other than discolored foliage (*i.e.*, green foliage, twigs, bits of bark or resin, cones, lichens, *etc.*) was carefully discarded. Our aim to obtain samples representative of litter when it first reaches the ground. Nutrient concentrations in newly fallen foliage are rapidly altered through leaching and microbial colonization.

Processing and chemical analysis of leaf litter

Samples were oven-dried for 48 hours at 50 degrees Celsius and ground to pass a 30-mesh Wiley Mill. The standard tissue Kjeldahl digestion procedure was used for nitrogen and phosphorus with concentrations determined by a Scientific Instuments CFA 200 autoanalyser. Elemental analysis for potassium, magnesium and calcium was performed using a nitric perchloric acid digestion, and the solutions analyzed by atomic absorption spectrometry.

Results

Elemental concentrations in leaf litter

On a species by nutrient comparison there is little difference between the two arboreta, except for the element magnesium. The greater Mg concentrations at Peavy Arboretum may be partially explained by the use of dolomitic limestone as a soil amendment when the arboretum was a nursery site.

Table 1 gives combined litterfall nutrient concentrations for species tested at Peavy and Wind River Arboreta. Calcium concentrations are significantly higher for all Taxodeaceae and Cupressaceae species than for *Pseudotsuga menziesii.* Phosphorous (mean P concentration 147% greater than the mean of other species) and potassium concentrations are significantly higher for *P. menziesii* than for all other species with the exception of K for *Calocedrus decurrens*.

In order to explain the disparate patterns of nutrient concentrations, data were analyzed with two multivariate statistical procedures: principal component and discriminant analyses. Using the principal component scores instead of the actual elemental concentrations in the analyses reduced the dimensionality in the problem without significant loss of information. The large accumulation of phosphorus for *Pseudotsuga menziesii* is the distin-

Table 1. Nutrient concentrations (expressed as percent oven dry weight) and significance in concentration by species. Numbers followed by a lower case letter denote significantly different values between indicated species for a particular nutrient ($P \leqslant 0.05$ Duncan's multiple range test)

Species		N		P		K		Ca		Mg	
		$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD	$\bar{X}$	SD
Sequoia sempervirens	(a)	0.457	0.116	0.054	0.014	0.217	0.061	2.231*g*	0.508	0.244	0.135
Sequoiadendron giganteum	(b)	0.460	0.109	0.085*a*	0.025	0.246	0.119	2.358*g*	0.756	0.399*ce*	0.277
Thuja plicata	(c)	0.504	0.193	0.077*a*	0.025	0.329	0.110	2.580*g*	0.541	0.159	0.105
Chamaecyparis nootkatensis	(d)	0.606*ab*	0.084	0.064	0.014	0.245	0.091	3.480*abcefg*	0.456	0.250	0.135
Chamaecyparis lawsoniana	(e)	0.565	0.125	0.065	0.021	0.232	0.085	2.376*g*	1.105	0.167	0.029
Calocedrus decurrens	(f)	0.612*ab*	0.074	0.084*a*	0.022	0.486*abcde*	0.148	2.325*g*	0.431	0.325	0.160
Pseudotsuga menziesii	(g)	0.636*abc*	0.084	0.229*abcdef*	0.044	0.560*abcde*	0.159	1.107	0.739	0.205	0.102

ctive variable separating Pinaceae from Cupressaceae and Taxodeaceae. This result may be an artifact of *P. menziesii* rather than the Pinaceae family. *P. menziesii* appears to have higher P concentrations than other Pinaceae species in the Northwest (Table 2). The high concentrations of potassium for *Calocedrus decurrens* and calcium for *Chamaecyparis nootkatensis*, and higher concentrations of magnesium for the two sequoia species separate Cupressaceae members from Taxodiaceae.

We next used a stepwise discriminant analysis which optimally separated the data into families along discriminant functions axes (Fig. 1). The excellent discrimination displayed is a function of distinctive nutrient concentrations, especially for discriminating *Pseudotsuga menziesii* from the Cupressaceae and Taxodiaceae. *Chamaecyparis lawsoniana* was the only species that could not be correctly classified at least 62% of the time.

Discussion

Factors relating to calcium differences

The calcium concentrations in our study concur with other Northwest studies (Table 2). These high Ca concentrations may be related to seveal factors.

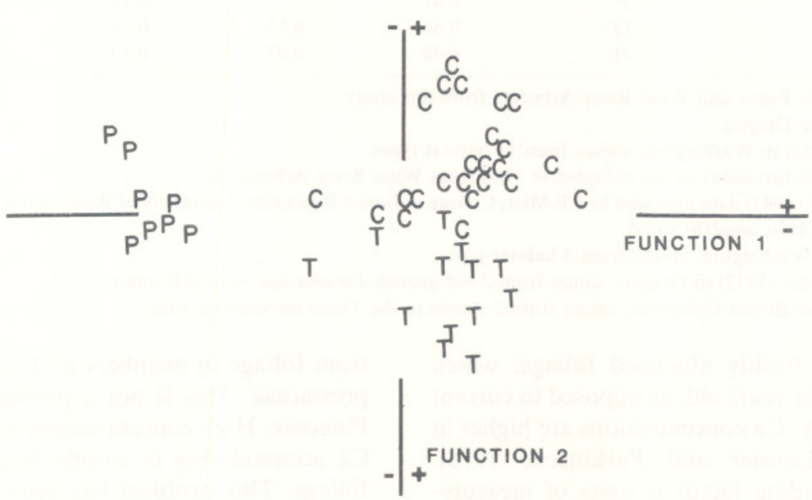

Fig. 1. Family members plotted along discriminant axes. P = Pinaceae, T = Taxodiaceae, and C = Cupressaceae.

Table 2. Litterfall nutrient levels in percent oven dry weight reported for northwestern coniferous species

Species	Foot-note	N	P	K	Ca	Mg
Calocedurus decurrens	D	0.94	0.09	0.63	1.57	–
	A	0.60	0.08	0.47	2.29	0.30
Chamaecyparis lawsoniana	D	0.86	0.11	0.64	1.55	–
	A	0.56	0.07	0.23	2.38	0.17
Chamaecyparis nootkatensis	D	0.99	0.15	0.43	2.68	–
	A	0.61	0.06	0.24	3.48	0.25
Thuja plicata	B	0.62	0.09	0.36	2.24	0.04
	C	0.40	0.50	0.29	2.00	–
	D	1.02	0.14	0.57	1.55	–
	E	0.43	–	0.20	1.66	0.08
	A	0.50	0.08	0.33	2.58	0.16
Sequoiadendron giganteum	C	0.81	0.11	0.46	1.36	–
	A	0.46	0.08	0.25	2.36	0.40
Sequoia sempervirens	A	0.46	0.05	0.22	2.23	0.24
Abies amabilis	E	1.02	0.12	0.53	0.53	0.11
	H	1.25	0.12	0.24	0.92	0.06
Abies grandis	C	0.58	0.09	0.33	2.45	–
Abies lasiocarpa	C	0.61	0.10	0.26	1.24	–
Larix occidentalis	C	0.43	0.21	0.35	0.49	–
Picea engelmannii	C	0.54	0.08	0.26	1.29	–
Picea sitchensis	B	1.16	0.10	0.24	0.48	0.09
Pinus albacaulis	C	0.50	0.07	0.18	0.28	–
Pinus contorta var. *contorta*	B	1.98	0.08	0.43	0.55	0.08
	C	0.59	0.04	0.20	0.64	–
Pinus monticola	B	0.76	0.12	0.30	0.62	–
	C	0.54	0.07	0.22	0.74	–
Pinus ponderosa	B	0.51	0.07	0.35	0.42	0.07
	C	0.57	0.09	0.31	0.43	–
Pseudotsuga menzisii	B	0.86	0.15	0.15	0.94	0.03
	C	0.60	0.13	0.49	1.57	–
	D	1.18	0.19	0.64	0.59	–
	G	0.54	0.11	0.14	1.63	0.09
	A	0.64	0.23	0.56	1.46	0.20
Tsuga heterophylla	B	0.77	0.11	0.19	0.59	0.06
	C	0.45	0.17	0.35	0.60	–
	F	0.41	–	0.18	0.62	0.11
Tsuga mertensiana	G	0.56	0.12	0.14	1.38	0.08
	H	0.48	0.07	0.10	0.56	0.09

A Average values of Peavy and Wind River Arboreta from this study.
B Tarrant, (1951) in Oregon.
C Daubenmire (1953) in Washington, values from 11 habitat types.
D Franklin (unpublished data) values collected in 1966 from Wind River Arboretum.
E Gessel and Klock (1981) data provided by CE Mier, College of Forest Resources, University of Washington, in Washington, values from an old-growth *Abies amabilis* stand.
F Alban (1967) in Washington, values from 3 habitat types.
G Abee and Lavender (1972) in Oregon, values from 2 old-growth *Pseudotsuga menziesii* stands.
H Krumlik (1979) in British Columbia, values from 2 stands in the *Tsuga mertensiana* zone.

Our study used freshly abscissed foliage, which may be one to four years old, as opposed to current year's foliage only. Ca concentrations are higher in older foliage (Lousier and Parkinson, 1978). Another confounding factor is units of measurement. It is difficult to separate woody branchlets from foliage in members of Taxodiaceae and Cupressaceae. This is not a problem in members of Pinaceae. High concentrations may be the result of Ca accumulating in woody branchlets as well as foliage. This problem has been recognized in the literature but no studies to date have dealt with it

(Radwan and Harrington, 1986; Zobel and Liu, 1979).

Differences in calcium concentrations may be related to family genetic characterisitics and not just site or microsite. Most species exhibit strong intra-family affiliation. We recognize our study results used only one member of the Pinaceae. However, other Pinaceae members show similar concentration patterns (Table 2).

Since calcium is a relatively immobile element, redistribution is primarily through litterfall and decay. A high level of exchangeable Ca can act as a soil buffer. Maintaining a pH favorable to increasing bacterial populations facilitates decomposition. Consequently, the litter of Taxodiaceaae and Cupressaceae may contribute to soils richer in bases and generally more favorable to biological productivity. This could have broad scale silicultural implications.

Acknowledgements

The authors thank Jerry Franklin for encouraging us to gather this data and for his initial nutrient values from Wind River Arboretum. We also thank Jerry Franklin, Don Zobel, Pam Matson, Kermit Cromack and two ananymous reviewers for their comments. This study was partially funded by a National Science Foundation grant DEB 80-12162 for Long Term Ecological Research (LTER).

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