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MINERAL ELEMENT CONCENTRATIONS OF FOUR SUBALPINE TREES AND SHRUBS AT ARTHUR'S PASS, SOUTH ISLAND, NEW ZEALAND

Summary: Samples of one and two seasons old foliage, leaf litter, shoots, bark, and wood of *Hoheria glabrata, Olearia ilicifolia, Senecio bennettii,* and *Dracophyllum traversii* were analysed for nitrogen, phosphorus, potassium, and calcium. Total mineral element concentration was 9.14% in leaves of the deciduous *H. glabrata* and ranged from 3.94% to 1.93% in one season old evergreen foliage of S. *bennettii* and *D. traversii,* respectively. On average, 60-70% of foliar N, P, and K were withdrawn before leaf fall, but Ca content increased by some 100% and 200%, respectively, in leaf litter of *O. ilicifolia* and *S. bennettii.* Results are discussed in relation to the species' ecological status and browse resistance.

Keywords: Mineral element concentration; subalpine scrub; browse resistance; Arthur's Pass National Park.

Introduction

Information on mineral element concentrations of plant tissues is a prerequisite for the quantitative study and modelling of biogeochemical cycles such as nutrient returns in litterfall (e.g., Levett, Adams and Walker, 1985) and also contributes to the understanding of the ecological status of a particular species, e.g., habitat preferences, soil fertility requirements, role during succession, and susceptibility to browsing. Relevant information on New Zealand woody plants is generally scarce, however. While some economically important trees have been investigated in this respect (e.g., Miller, 1963; Nordmeyer, 1980), data for small trees and shrubs are almost lacking (Lee and Johnson, 1984; Lee, 1988). Such information is important for ecosystem studies and conservation of woody vegetation in the upper montane and subalpine regions of New Zealand.

This study presents data for the major mineral elements nitrogen, phosphorus, potassium, and calcium in various tissues of four subalpine trees and shrubs from Arthur's Pass.

Study area

Samples were collected in various associations of subalpine low forest and scrub at Pegleg Flat, near the summit of Arthur's Pass (42 ∞54'S, 171∞34'E, 835 m a.s.l.) (Fig. 1). The soils of this alpine region are developed on upper Triassic sandstones, siltstones, and mudstones (Cave, 1987) and are moderately to strongly podzolised. The local climate is cool and superhumid with a mean annual temperature of 7.4 ∞C (February 12.5∞C, July 2.4∞C) and an estimated mean annual precipitation of 5370 mm (Haase, 1986a). The vegetation of the study area has been described elsewhere (Haase, 1986a).

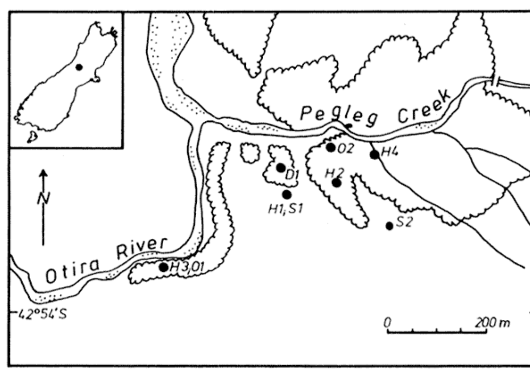

Figure 1: *Location map of the study area and sampling sites at Pegleg Flat.*

Methods

Four of the locally common woody species, the deciduous *Hoheria glabrata*,* and the evergreen *Olearia ilicifolia, Senecio bennettii,* and *Dracophyllum traversii,* were studied. The autecology of these species has been described in a series of papers (Haase, 1986b, c, d, 1987). The sampling sites ranged from 830-910 m in elevation, except for one *S. bennettii* stand at approximately 1000 m.

Samples of one and two seasons old foliage, leaf litter, young shoots, bark, and wood were collected in late February to late April, 1983 and 1984. The age of *D. traversii* foliage is less well defined; samples were distinguished as growing (1-3 seasons old) and mature (3-6 seasons old) leaves (Haase, 1986b). Sampling was most extensive for *O. ilicifolia* and *S. bennettii,* where

*Nomenclature follows Allan (1961).

five apparently healthy shoots were harvested from 5-10 shrubs at two sampling sites each (Fig. 1). Up to five *H. glabrata* trees at four individual sites and three *D. traversii* trees from one site were sampled. Recently shed leaves were collected from the ground beneath the sample trees. Old layers of the papery bark of *Olearia, Senecio,* and *Dracophyllum* were sampled from the tree trunks and increment cores were used as wood samples. .

The samples were oven dried at 105 °C, milled, and analysed for nitrogen, phosphorus, potassium, and calcium. For the three evergreen species, foliage samples of individual trees were analysed separately. The foliage of *H. glabrata* and all other samples of individual sampling sites were pooled and two replicates of the mixed samples were analysed. Nitrogen content of 0.1 g aliquots was determined with the microkjeldahl method after digestion in 5 ml concentrated sulphuric acid. For determination of P, K, and Ca, 1 g aliquots of plant material were heated with 3 ml 30% magnesium nitrate solution and then transferred into a muffle furnace and ashed at 550°C for 3 hours. The ash was dissolved in 5 ml 2N hydrochloric acid, filtered, and diluted to 100 ml. Potassium and calcium were determined with a flame photometer and phosphorus was determined colometrically (Chen *et al.,* 1956).

Results and discussion

Hoheria glabrata contains considerably higher concentrations of N, P, K, and Ca in any of the analysed tissues than the three evergreen species (Table 1). Element concentrations are similar in *Olearia ilicifolia* and *Senecio bennettii* except for slightly higher foliage concentrations of S. *bennettii*. Mineral element concentrations of *Dracophyllum traversii* (except wood) are considerably lower than the respective concentrations of the two former species. Total mineral element concentrations in one season old foliage range from 9.14% in the deciduous *H. glabrata* to 1.93% in *D. traversii*. Total mineral element concentrations are lowest in bark and wood of *D. traversii* (0.58%) and in the wood of *O. jlicifolia* (0.62%) and S. *bennettii* (0.61%).

One season old apical shoots of *H. glabrata* contain slightly higher concentrations of P and K, twice the amount of N, and four times as much Ca as those of *O. ilicifolia* and S. *bennettii*. Shoots of *D. traversii* were not sampled because of the basically different morphology (Haase, 1986b). The papery bark of the three evergreen species contains low nitrogen and very low phosphorus and potassium

Table 1: *Mineral element concentrations (% dry weight) in different tissues of four subalpine woody species. Functional leaves were harvested at the end of their first (Foliage 1) and second growing season (Foliage 2). Data are means of all samples or replicates; the standard deviation (s.d.) is only calculated for n≥4 samples/replicates.*

	Hoheria	Olearia	Senecio	Draco-phyllum
Nitrogen				
Foliage 1	2.66±0.23	1.39±0.06	1.51±0.11	0.89
Foliage 2	-	1.03±0.05	1.03±0.10	0.78
Leaf litter	1.03	0.67±0.06	0.44±0.04	0.37
Shoot	1.88±0.21	0.91±0.06	0.90±0.10	-
Bark	-	0.60	0.57	0.35
Wood	0.46	0.30±0.04	0.25	0.27
Phosphorus				
Foliage 1	0.23±0.04	0.14±0.02	0.22±0.05	0.06
Foliage 2	-	0.08±0.01	0.13±0.03	0.05
Leaf litter	0.10±0.02	0.04±0.01	0.06±0.01	0.02
Shoot	0.22±0.04	0.18±0.05	0.16±0.04	-
Bark	-	0.05	0.02	0.01
Wood	0.07	0.03	0.02	0.01
Potassium				
Foliage 1	2.15±0.23	1.24±0.14	1.63±0.17	0.27
Foliage 2	-	0.77±0.14	1.03±0.29	0.20
Leaf litter	0.70±0.29	0.43±0.21	0.65±0.05	0.09
Shoot	1.45±0.18	1.38±0.22	1.27±0.29	-
Bark	-	0.04	0.08	0.01
Wood	0.39	0.15	0.20	0.12
Calcium				
Foliage 1	4.10±0.83	0.60±0.07	0.58±0.13	0.71
Foliage 2	-	1.16±0.18	1.68±0.23	0.86
Leaf litter	5.09±0.79	1.34±0.17	1.81±0.07	1.04
Shoot	1.62±0.31	0.49±0.07	0.40±0.06	-
Bark	-	0.75	1.12	0.21
Wood	0.68	0.14	0.14	0.18
Total				
Foliage 1	9.14	3.37	3.94	1.93
Foliage 2	-	3.04	3.87	1.89
Leaf litter	6.92	2.48	2.96	1.52
Shoot	5.17	2.96	2.73	-
Bark	-	1.44	1.79	0.58
Wood	1.60	0.62	0.61	0.58

concentrations, but, except in *D. traversii,* comparatively high calcium contents. Wood contents of N and Ca are lower, but K concentrations are much higher than in bark samples.

Mineral element concentrations in different tissues are mostly poorly correlated; exceptions are the total mineral element ($r=0.9997$; $P<0.01$) and potassium ($r=0.9805$; $P<0.02$) concentrations between first season leaves and litter, and the Ca concentrations between second season foliage and litter ($r=0.9997$; $P<0.02$) and first season foliage and wood (r=0.9992; P<0.01). Correlation between any two elements in the same tissue is always poor. Over all four species and six tissues, N is least (0.25-2.66%) and K most variable (0.01-2.15%).

The above average mineral element concentrations in *H. glabrata* are related to its deciduous habit and particular ecological habitat. *H. glabrata* preferentially occupies disturbed sites, e.g., recent river terraces, slip scars, and talus fans, which are normally characterised by high soil fertility. *O. ilicifolia* is associated with *H. glabrata* but is more prominent in river terrace stands. *S. bennettii* is an almost ubiquitous shrub in the undergrowth of various low forest associations and also the dominant species in successional scrub and scrub above timberline (Haase, 1986a, c). *D. traversii* occupies the opposite end of a soil fertility gradient and this is also reflected by the comparatively low mineral element concentrations of its tissues.

Foliar contents of N, P, and K become successively lower with increasing leaf age (Table 1). This decrease is mainly a result of re-distribution of mineral nutrients into new growth and reproductive organs (e.g., Smith, 1962), but some of the loss may be due to leaching. In *Olearia* and *Senecio,* most of the initial leaf P and K is already lost in second season foliage, whereas 50-55% of the total N loss is withdrawn before leaf fall. Withdrawal before shedding is even more pronounced in N, P, and K contents of *D. traversii* foliage. This, together with a higher leaf age, is probably an adaptation which serves as nutrient conservation on poor soils. The decrease in foliar N, P, and K is accompanied by rising Ca concentrations, mainly during the second season, which increase by some 100% and 200%, respectively, in litter of *O. ilicifolia* and S. *bennettii.* The Ca accumulation is of a lower order in litter of *H. glabrata* (24%) and *D. traversii* (47%). Calcium is relatively immobile and its accumulation in old foliage (and bark) is mostly the result of precipitation by secondary metabolites, e.g., as Ca-oxalate (Larcher, 1976).

Table 2 gives foliar concentrations of N, P, K, and Ca in two sample stands of *O. ilicifolia* and *S. bennettii*. The difference between stands is often only 0.01 % of the dry weight, which is equivalent to less than 1 % variation for nitrogen and potassium contents, but approximately 10% for phosphorus. Inter-stand variation is thus much smaller than differences between individual sample trees/shrubs (indicated by the standard deviation). However, inter-stand variation is mostly >0.05% of the dry weight in second season foliage *(Senecio* N, K, Ca; *Olearia* K,

Table 2: *Inter-stand variation of foliar element concentrations in two different stands of* Olearia ilicifolia *and* Senecio bennettii.

	Nitrogen	Phosphorus	Potassium	Calcium
Olearia 1				
Fol. 1	1.40 ± 0.05	0.13 ± 0.01	1.23 ± 0.10	0.60 ± 0.03
Fol. 2	1.05 ± 0.05	0.08 ± 0.01	0.68 ± 0.08	1.01 ± 0.09
Olearia 2				
Fol. 1	1.39 ± 0.07	0.14 ± 0.03	1.24 ± 0.11	0.59 ± 0.10
Fol. 2	1.01 ± 0.05	0.09 ± 0.01	0.87 ± 0.11	1.30 ± 0.11
Senecio 1				
Fol. 1	1.49 ± 0.06	0.22 ± 0.05	1.53 ± 0.15	0.60 ± 0.16
Fol. 2	0.95 ± 0.07	0.13 ± 0.03	0.84 ± 0.21	1.80 ± 0.22
Senecio 2				
Fol. 1	1.54 ± 0.15	0.21 ± 0.04	1.76 ± 0.08	0.56 ± 0.08
Fol. 2	1.12 ± 0.05	0.14 ± 0.04	1.29 ± 0.14	1.53 ± 0.15

Ca). Between shrub variability (s.d.) in *S. bennettii* is generally larger than in *O. ilicifolia.*

Only two published studies describe the mineral element concentrations of New Zealand shrubs and small trees (Lee and Johnson, 1984; Lee, 1988). The data of Lee (1988) from six woody plants on Auckland Island can be readily compared with the results of the present study since both source areas are climatically roughly equivalent (e.g., Meurk, 1984). Lee (1988) analysed only foliage and bark samples (and the senescent leaves of two species), but additionally determined magnesium, sulphur, and sodium. The bark types samples by Lee are different from the papery bark of *O. ilicifolia, S. bennettii,* and *D. traversii,* however. Total concentrations of N, P, K, and Ca in functional foliage ranged from 2.26% in *Dracophyllum longifolium* to 3.39% in *Coprosma foetidissima* and are comparable to those of the three evergreen species investigated in the present study. The much higher concentration (4.88%) in *Olearia lyallii,* a near-shore plant, was mainly due to a high (2.39%) potassium content (Lee, 1988). Foliar concentrations of single elements are comparable between the evergreen species analysed in both studies, except for the high potassium content in *O. lyallii,* but calcium concentrations were considerably higher (average of 68%) in Auckland Island plants. This may be related primarily to he higher Ca content of the local parent rock (Pliocene basalt) compared with the mostly arenaceous sediments ("greywacke") in the study area.

Wardle and Hayward (1970) calculated a susceptibility rating of understorey species in the Taramakau catchment for browsing by deer and chamois. *H. glabrata* (0.25) and *S. bennettii* (0.24) were grouped into an "extinction class" of species which were relatively rare in the 30-180 cm tier compared with the abundance of taller plants. *O. ilicifolia* (1.02) and *D. traversii* (1.07) were classified as "animal tolerant" species. In *H. glabrata* and *S. bennettii,* the susceptibility to browsing is correlated with higher foliar mineral element concentrations (particularly P and K) in functional foliage. Browse resistance of *O. ilicifolia* is probably mostly a result of its spinous leaves which also possess aromatic compounds (musk smell), whereas *D. traversii* foliage contains comparatively low concentrations of N, P, and K and thus has a lower nutritive value. Leaf element concentrations are therefore not always directly proportional to potential browsing pressure, since particular leaf morphology and/or chemical compounds can serve as a deterrent to browsing animals.

Acknowledgements

The analytical data presented in this study were obtained during research for a Ph.D. thesis at the Department of Plant and Microbial Sciences, University of Canterbury. Permission for vegetation sampling was granted by the Arthur's Pass National Park Board, now Department of Conservation.

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