Foliar nitrogen dynamics in co-existing evergreen and deciduous species in an oak forest

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Abstract. Changes in foliar nitrogen was observed monthly in an Oak forest where evergreen and deciduous species were existing, together in pairs, at a distance of one and half meter. Nitrogen concentration during bud-break was significantly higher ($P<0.05$) for deciduous species compared to evergreen species (7.3% for deciduous and 6.4% for evergreen). Nitrogen concentration at senesced stage was significantly higher for evergreen species, compared to deciduous species (2.6% vs. 1.8%). However, at mature stage this difference was significant only for overstory tree pair. Retranslocation of nitrogen mass at senesced leaf stage was higher in deciduous species than evergreen species (61.9% vs. 20.8%) indicating that inspite of extracting nutrients from the same microsite both the types of species have different nutrient conserving strategy.

Introduction

Nutrients withdrawn from leaves during senescence are stored in perennial parts and are available for reuse for new leaf growth. Relationships between nutrients and leaf life span and leaf form are of great ecological importance. For example, evergreenness has often been associated with nutrient-deficient habitats (Monk 1966, Chapin 1980, Chabot and Hicks 1982). Differences in the fractions of leaf nutrient mass that are retranslocated during senescence have been analyzed in relation to leaf life span, especially deciduous vs. evergreen (Negi and Singh 1992), site fertility (Florence and Chueng 1974, Van Cleve and Vireck 1981, Chapin and Tryon 1983) and concentration of nutrients in green leaves (Lowry and Avard 1965, Morrison 1974, Chapin and Kedrowski 1983).

In the studies that compared evergreen and deciduous species so far, the individuals occupied different locations and sites and thus might have different soil nutrient levels, rendering comparisons less valid. In the present study, the individuals (saplings) of each pair of deciduous and evergreen species were rooted within 2m and therefore effect of difference in soil nutrients on plants was minimal, and thus comparisons were more valid.

This study on the individuals rooted immediately adjacent to each other was made to (i) find out how evergreen and deciduous species occupying similar soil conditions differ with regard to leaf nutrient concentration and proportional retranslocation of leaf nutrient mass and (ii) to analyze the role of other factors such as nutrient concentration in green leaves in influencing nutrient retranslocation. Since the evergreen species of the present study had a leaf life span of about one year they renewed their foliage annually as did the deciduous species. Thus compared to evergreens with several years of leaf life span, the evergreens of the present study were more similar to deciduous species. In evergreens with more than one year leaf life span nutrient retranslocation pattern differs across the leaves of different ages (Singh *et al.* 1984).

Study site

Presence of sufficient numbers of saplings of evergreen and deciduous species immediately adjacent to each other was the main criterion for site selection. The study site, an Oak forest *(Quercus floribunda)* Lindle. ex. A. cam. was located at hill slope 2,025 to 2,150m in elevations between 29°7"N lat, and 79°15"E long. in Naini Tal district of Kumaun Himalaya. The total tree basal cover, was smaller than generally found in this type of Oak forest, some trees were uprooted subsequent a landslide about 20 years ago. *Q. floribunda* Lindle ex. A. Cam. (tilonj oak) was the dominant species with 39.2 $m^2 ha^{-1}$ basal cover (Tripathi *et al.* 1991).

Litsea umbrosa Nees, an evergreen species, prepondered in the subcanopy. *Populus ciliata* Wall. and *Fraxinus micrantha* Lingelsh both early successional trees were the common deciduous associates in the overstory. Among shrub, *Sarcococca hookeriana* Baill. (evergreen) and *Rhamnus virgata* Roxb. (deciduous) were common. *S. hookeriana* is a common member of *Q. floribunda* forest community in the region, while the deciduous shrub grows in exposed sites within the oak zone of Central Himalaya (Troup 1921).

There are three main seasons: cold and relatively dry winters (December to February), hot and dry early summer or late spring (April to mid June), and a hot and humid late summer (mid June to September). Of the annual rainfall of 2,272mm, 78% occurs during late summer. The daily mean relative humidity is generally higher than 50%. Snowfall is frequent during winters.

The total nitrogen concentration in the surface (up

to 10cm) soil was 0.13%, phosphorus 0.008%, potassium 0.02% (extractable) and organic carbon 1.41%. Nutrient analysis was done following standard methods given in Misra (1968). The differences among microsites were not significant (Joshi *et. al.* 1991).

Material and methods

The species investigated were in pair of deciduous and evergreen as following: Pair I - *Quercus floribunda* Lindle ex A. Cam., an evergreen tree and *Fraxinus micrantha* Lingelsh, a deciduous tree, both canopy tree species; Pair II - *Populus ciliata* Wall. a deciduous canopy tree and *Litsea umbrosa* Nees, an evergreen undercanopy tree; and Pair III - *Sarcococca hookeriana* Baill, an evergreen shrub and *Rhamnus virgata*, a deciduous shrub. Observations were made on saplings of similar sizes in the case of trees, while for shrubs adult individuals were selected. The two co-existing individuals of different forms were rooted within 2m distance.

There were five replicates of each species pair. On each of five individuals of species 100 vegetative buds (100x5 individuals = 500 buds per species) were marked at the time of first and major bud break in March-April. Buds were dispersed in all parts of crown of individuals. From the marked population of buds, one hundred leaves (20 leaves from each of the five individuals of a species from all crown positions) were collected at monthly intervals. The leaves were handled with plastic gloves and placed in air tight polyethylene bags and brought to the laboratory. These leaves were ovendried till constant weight at 80°C, weighed in an electric balance to determine dry weight of individual leaf and were then ground and stored in air tight polyethylene bags. The ground material was digested by taking 500mg composite sample in 10ml concentrated H_2SO_4 using 5g catalyst mixture (potassium sulphate and cupric sulphate in the ratio of 9:1) in a quick digestion unit. The total nitrogen was determined by Kjel Auto-Analyzer based on microkjeldohl technique (Peach and Tracey 1956, Misra 1968). The nitrogen mass of leaves was computed as the products obtained by multiplying dry weight of leaves with their nitrogen concentration. Retranslocation of nitrogen from abscised leaves to perennial plant parts was calculated following Ralhan and Singh (1987) as follows:

$$\frac{\text{Nitrogen mass in leaf at steady state} - \text{Nitrogen mass in abscised leaf}}{\text{Nitrogen mass in leaf at steady state}} \times 100$$

In this computation additions due to the foliar absorption (Kannan 1986) and loss through leaching (Pathak and Singh 1984) were not considered. Since the rainfall is negligible during leaf senescence, and the loss of nutrients due to leaching has been found to be less than 1% of the nitrogen retranslocation in the Central Himalayan woody species (Ralhan and Singh 1987).

Results

Nitrogen concentration

Nitrogen concentration in all the species was maximum soon after the bud-break and then tended to decline with the aging of the leaf. First, as a consequence of the addition of structural tissue and cell elongation and then as a consequence of leaf senescence (Fig. 1). In deciduous species this decline was rapid compared to the evergreen species in which it was a gradual process.

At bud-break and senesced stages nitrogen concentrations were significantly higher (P<0.05) for deciduous species than evergreen species among each of the three pairs (t-test).

At mature stage this difference was significant only for the overstory tree pair of *Q. floribunda* and *F. micrantha* (P<0.05).
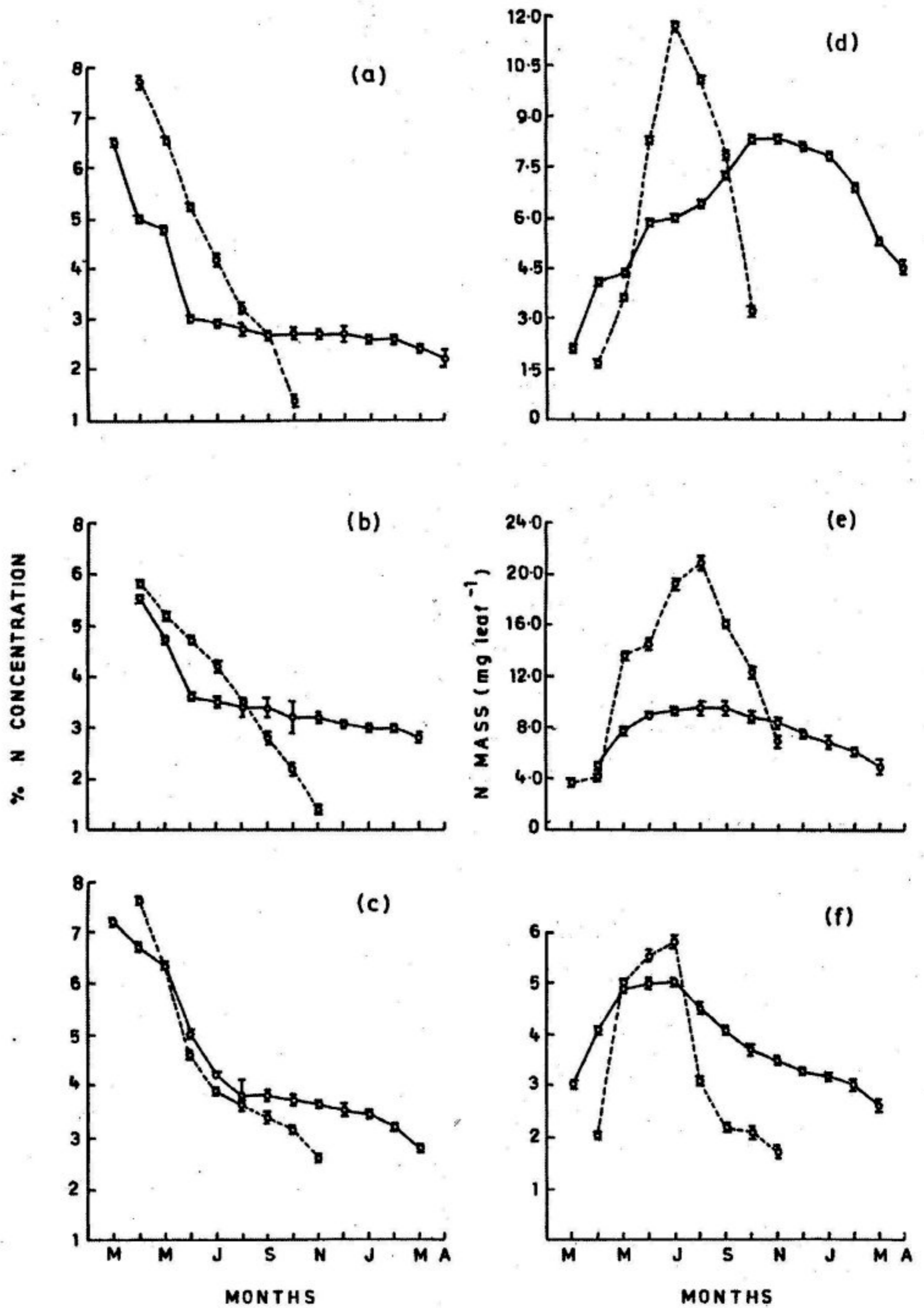
Leaf nitrogen mass

The leaf nitrogen mass (mg leaf^{-1}) increased rapidly as leaves gained in mass. This increase was markedly rapid in deciduous species compared to evergreen species. A phase of steady state at the peak leaf

Pair	Species		August	September	October	November	December	January	February	March	April	Total
							N %					
I	*Q. floribunda*	(e)					3.22	3.58	9.31	20.78	7.88	44.77
	F. micrantha	(d)	13.26	20.15	40.39				73.80			
II	*L. umbrosa*	(e)			6.51	2.73	9.34	8.92	6.30	13.23		47.03
	P. ciliata	(d)		23.28	17.47	26.16						66.91
III	*S. hookeriana*	(e)	9.52	7.53	9.52	3.57	3.17	2.57	4.40	8.09		48.09
	R. virgata	(d)	45.51	9.48	7.06	7.58	.					69.63

e=evergreen; d=deciduous

Table 1. Loss of nitrogen mass in different months of leaf senescence. Values are percent of leaf nitrogen mass.

Fig. 1 Monthly changes in leaf nitrogen concentration (a,b,c,) and mass (d,e,f). Solid line-evergreen, dashed line-deciduous
a, d.   *Quercus floribunda* (evergreen) & *Fraxinus micrantha* (deciduous)
b, e.   *Litsea umbrosa* (evergreen) & *Populus ciliata* (deciduous)
c, f.   *Sarcococca hookeriana* (evergreen) & *Rhamnus virgata* (deciduous)

nitrogen mass was observed in all the evergreen species, which lasted for about two months, compared to about two weeks in deciduous species (Fig. 1). Subsequent to this phase leaf nitrogen mass of senesced leaves declined in all the species. Nitrogen mass per leaf at mature stage was significantly (P<0.05) greater for deciduous species compared to evergreen species.

Temporal trends of decline in nitrogen mass

The leaf nitrogen decline, that occurred during senescence varied in time across the species (Table 1). The decline began to occur earlier in each of the deciduous member of the pair. This process continued up to March and April (of next year) in evergreen species, and up to October-November in deciduous species. Thus, in evergreen species the decline in leaf nitrogen mass was spreaded over five to eight months, compared to three to four months in deciduous species.

Percentage of nitrogen retranslocation

Percentage of nitrogen retranslocation was significantly (P<0.01) greater for each of the deciduous species of the pair. Across the species, the fraction of leaf nitrogen mass retranslocated during senescence was maximum (73.7%) for *F. micrantha* and minimum (44.8%) for *Q. floribunda)* (Table 1).

In the evergreens the peak retranslocation of nitrogen mass coincided with initiation of new leaves. In two of the three deciduous species the transfer of nitrogen to older parts peaked just prior to leaf abscission. Interestingly, in *R. virgata* (deciduous) peak nitrogen mass loss was recorded in August, i.e., just at the onset of phase of declining leaf nitrogen mass (Table 1), and in this species leaf fall also started from July-August.

Discussion

An initial decline in leaf nitrogen concentration as observed in the present study is attributed to addition of structural tissues and cell elongation in the leaves (Ostman and Weaver 1982. Chapin and Kedrowski 1983). The decline in leaf nitrogen concentration was more rapid in deciduous species which showed more rapid expansion and dry mass accumulation in leaves than did the evergreen species. Similar are the conclusions of earlier studies carried out in this region (Ralhan and Singh 1987, Negi and Singh 1992). In deciduous species the earlier commencement of decline in leaf nitrogen mass also caused a shorter duration of stable phase in leaf nitrogen concentration. In deciduous species nutrients are withdrawn shortly before leaf fall (McHargue and Roy 1932, Niering 1953, Hoyle 1965, Mutoh 1968, Small 1972, Bernard and Solski 1977, Chapin et al. 1980), whereas in evergreens with several years leaf life span withdrawal of nutrient occurs over a period of year, rather than a few weeks.

Nutrient retranslocation from senescing leaves declines significantly with increasing fertility of soil, and is considered a mechanism for coping with low nutrient supply (Bowen 1980; Singh and Bisht 1992). In a nutrient-rich condition plants have better

accessibility to nutrients of soil and intra-nutrient cycling becomes less important (Johnson et al., 1982). Our results are contrary to this, as species occupying the same microsites differed markedly in nitrogen retranslocation during leaf senescence. However, nutrient availability to plants rooted at a microsite may differ because of differences in spread of roots, forms in which nutrients are available (e.g., NO_3, vs. NH_4 in case of N) and growth phenologies of species. The deciduous species retranslocated greater nitrogen percentages than did the evergreen species in all the three study pairs. It can be argued that the evergreens were deeply rooted, while the deciduous species were rooted in shallow soils having higher nutrient concentrations (Sobrado and Cuenca 1979). If species occupying nutrient poor sites were to retranslocate more nutrients, then the evergreen species of the present study should have retranslocated higher percentage of nitrogen mass. But this was not the case. It seems that high nutrient retranslocation efficiency is not an adaptation to low nutrient status but a characteristic of most trees (Chapin and Kedrowski 1983).

Our findings are consistent with that of Chapin and Kedrowski (1983) who found a significant positive correlation between nitrogen concentration in mature leaves and the extent of nitrogen retranslocation from leaves during senescence. The deciduous species of each pair of the present study which retranslocated clearly higher fraction of leaf nitrogen mass than the adjacently rooted deciduous species also had generally greater nitrogen concentration in their mature leaves.

Plants of high nutrient status (as indicated by high nutrient concentration in mature leaves) retranslocate larger proportions of their leaf nitrogen and other phloem-mobile nutrients than do plants with low nutrient status (Turner and Olson 1976, Miller et al. 1979).

Deciduous species need to retranslocate proportionately higher nutrient mass from leaves during senescence, to compensate for the shorter leaf span and to produce heavy leaf crop annually (Chapin and Tryon 1983).

To conclude, this study suggests (i) that in deciduous species greater nutrient concentrations, than in evergreen species is not due to nutrient rich locations, (ii) that they retranslocate greater fractions of leaf nitrogen mass than their adjacently rooted evergreen counter parts, (iii) and that this difference is not related to soil nutrient factor.

Variations in leaf life-span has long been regarded as of ecological significance, and leaf life span is known to be related to other leaf traits, such as photosynthesis and nutrient cycling (Chabot and Hicks 1982, Mooney and Gulmon 1982). This comparative study of evergreen and deciduous species whose individuals were rooted adjacent to each other clearly shows that these two growth forms also differ in the extent of nutrient retranslocation from senescing leaves. And at least from the stand point of internal nutrient cycling evergreen species are not more efficient than the deciduous species occupying same sites. Thus, our findings do not support the relationships, generally suggested between evergreens and nutrient conservation (Chabot and Hicks 1982, Reich et al. 1992).

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