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Altitudinal Variation in Leaf N and P Concentrations in *Frasera speciosa* (Green Gentian)

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1995 Final Report for the City of Boulder Open Space and Mountain Parks Research/Monitoring Program

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Abstract

Leaves were collected several times during the growing season from *Frasera speciosa* plants in 7 populations, spanning an altitudinal gradient from 1800 m to 3500 m for measurement of leaf N and P concentrations. The purpose of the measurments was to determine 1) if leaf N concentrations increased with elevation, 2) if the trend in increasing N concentration with increasing elevation was related to phenological differences between the populations, and 3) whether P showed the same trend, indicating an increasing metabolic demand for these nutrients with increasing elevation. Leaf N concentrations were significantly correlated with increasing elevation, a trend which was independent of phenology. Maximum leaf N concentrations varied from 1.68 ± 0.03 at the lowest site to $3.19 + 0.09$ at the highest site. Although maximum P concentrations showed only a weak correlation with elevation, leaf N and P were strongly correlated when all samples were used in the analysis, and leaf N:P ratios did not significantly vary with elevation, indicating some degree of metabolic demand for higher N at high elevations. Mass per unit area of leaf decreased with increasing elevation, indicating the increased N concentrations may be the result of thinner leaves at higher elevation. Future work will concentrate on the photosynthetic characteristics of these populations, to further elucidate the altitudinal trends in leaf nutrient concentrations.

Objectives and Hypotheses

Nitrogen is a critical element required for a variety of metabolic functions in plants. Because the majority of enzymes in leaves are associated with photosynthesis, leaf N closely correlates with maximum photosynthesis rates in plants (Field and Mooney 1986, Evans 1989). Natural variation in leaf N among natural populations of plants provides information about allocation of nutrients under different environmental regimes. For example leaf N concentrations have been reported to increase in congeneric groups with increasing elevation (Körner 1989). This trend has been suggested to be the result of decreasing partial pressure of CO_2 at high elevations, requiring more photosynthetic enzymes to compensate for the decreased photosynthetic substrate (Körner 1989, Friend and Woodward (1990) and lower temperatures and higher evaporative demand of the atmosphere, which also potentially lower photosynthetic rates (Terashima et al. 1995).

The goal of the present study is to examine more closely the trends in leaf N and P concentration with changes in elevation. The majority of the studies examining elevational effects on nutrient concentrations in leaves have failed to account for phenological differences in sampling (i.e. collection at different stages of leaf maturity). Collecting leaves at one time period during the growing season may be misleading, as plants at each elevation may be at a different stage of growth. Plants at higher elevations may still be growing, and thus leaf nutrient concentrations may not be diluted yet. Additionally there may be structural differences in the leaves that explain the differences in N concentration. Plants at high altitude tend to have thicker leaves (Körner and Larcher 1988), and thus may have more N per unit area of leaf. The following hypotheses were derived from the above considerations:

H_o^1: leaf N concentrations do not change with change in elevation
H_1^1: leaf N concentrations increase with increasing elevation, but only as a consequence of differing phenologies
H_2^1: leaf N concentrations increase with increasing elevation, independently of phenological patterns

H_o^2: concentrations of N and P in leaves will be independent of each other, indicating higher N concentrations are the result of "luxury uptake" (i.e. uptake above what is needed for metabolic demand).
H_1^2: concentrations of N and P will be tightly correlated, indicating concerted metabolic demand for these nutrients

H_o^3: variation in leaf N among populations at different elevations is independent of differences in leaf thickness
H_1^3: differences in leaf N in populations along an altitudinal gradient are the result of differences in leaf thickness

Methods

Populations of *Frasera speciosa* (Green Gentian) were selected in 7 locations in Boulder County, Colorado, representing an altitudinal gradient from 1800 to 3500 m. The popuation sites are Flatirons Open Space Park, 1830 m elevation (City of Boulder Open Space), Walker Ranch, 2210 m elevation (Boulder County Park), a site near Gold Hill, 2680 m elevation, the C1 climate station of the Mountain Research Station at 3050 m elevation, the Caribou townsite at 3080 m elevation, the east flank of James Peak at 3470 m elevation, and Niwot Ridge, 3500 m elevation. The populations were near vegetation types that encompass all of the major ecosystem types of the Front Range of the Rocky Mountains, from mixed-grass prairie to alpine tundra. Leaves were collected from plants found in open microsites, receiving nearly full sun for the majority of the day.

Leaves were collected from 10 non-flowering plants of approximately the same age (estimated using leaf numbers, Inouye 1994) during at least 2 periods during the growing season. Only fully expanded leaves were collected. The leaves were oven dried at 70°C. for 2 days, and then ground to a fine powder using a mortar and pestle. The ground leaf material was analyzed for N and P concentrations as described in Bowman (1994), using a peroxide/acid digestion, and analysis on a Lachat colorimetric analyzer.

The data were statistically analyzed using a one-way ANOVA, with elevation as a class variable.

Results

The leaf samples are still in the process of being chemically analyzed, but the available data allow the following conclusions to be made:

1) Leaf N concentrations increase with increasing elevation, independently of phenological differences among the populations (figures 1, 2).

2) Leaf P concentrations are very weakly correlated with increasing elevation (Figures 1, 2).

3) A strong correlation exists between leaf N and P concentrations (figure 3), and the ratio between N:P does not vary with elevation (figure 4), indicating higher N concentrations at high elevation reflect higher metabolic demand, or that "luxury uptake" of P also occurs at high elevation sites. Further work will concentrate on differences in photosynthetic capacities and respiration rates of leaves from these different populations.

4) Contrary to most other studies *Frasera* leaves had lower specific leaf weights (were thinner) at higher elevation. The higher leaf N concentrations may therefore result from higher N per unit leaf area, but the same density of photosynthetic proteins.

Conclusions

The trends in leaf N and P found in this preliminary study indicate increases in leaf N with elevation in *Frasera* populations result from metabolic demand, as indicated by N:P ratios, and may simply be the result of the production of thinner leaves at high elevation.

The implications of this research on management and planning for the Mountain Parks/Open Space are nil.

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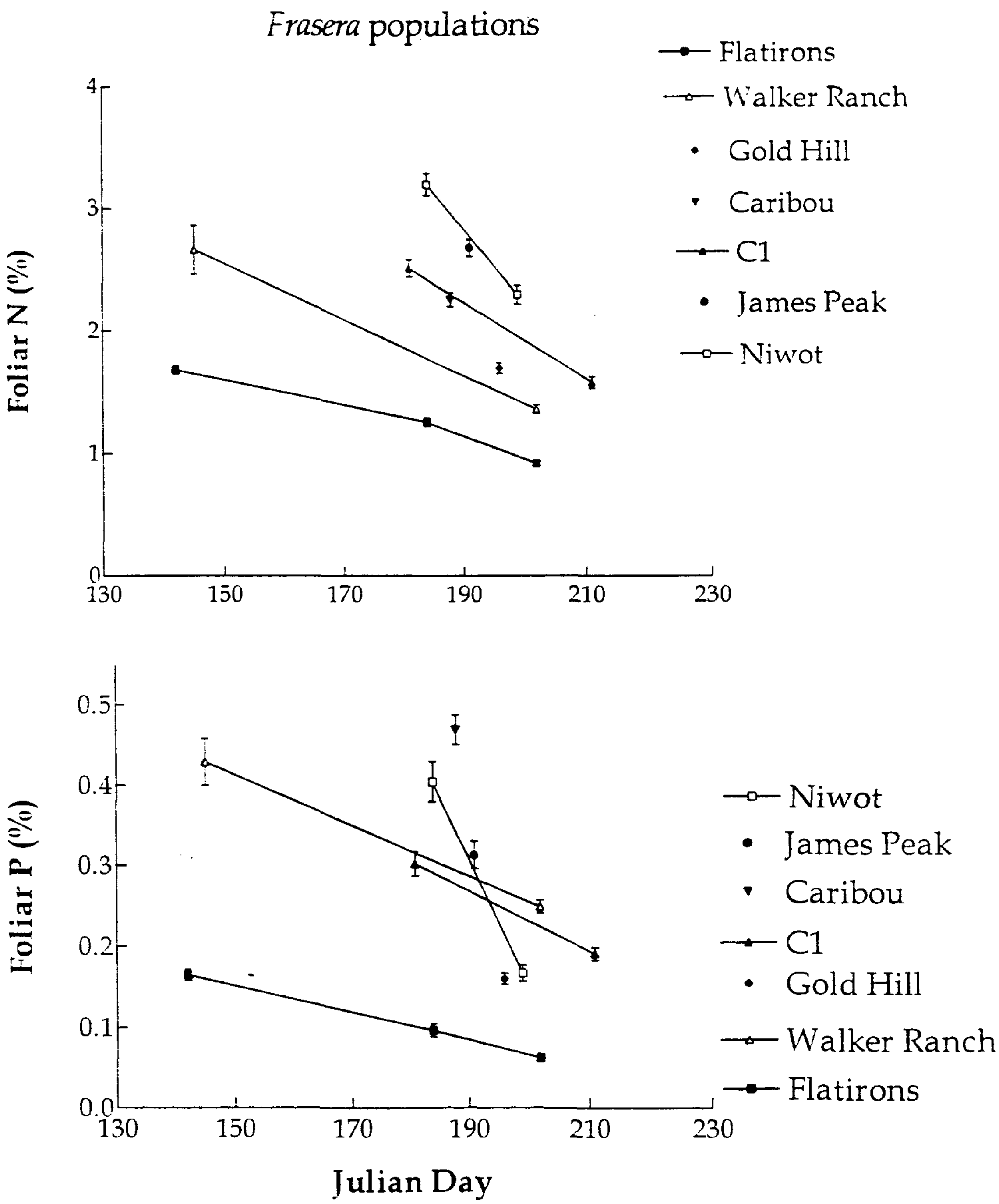
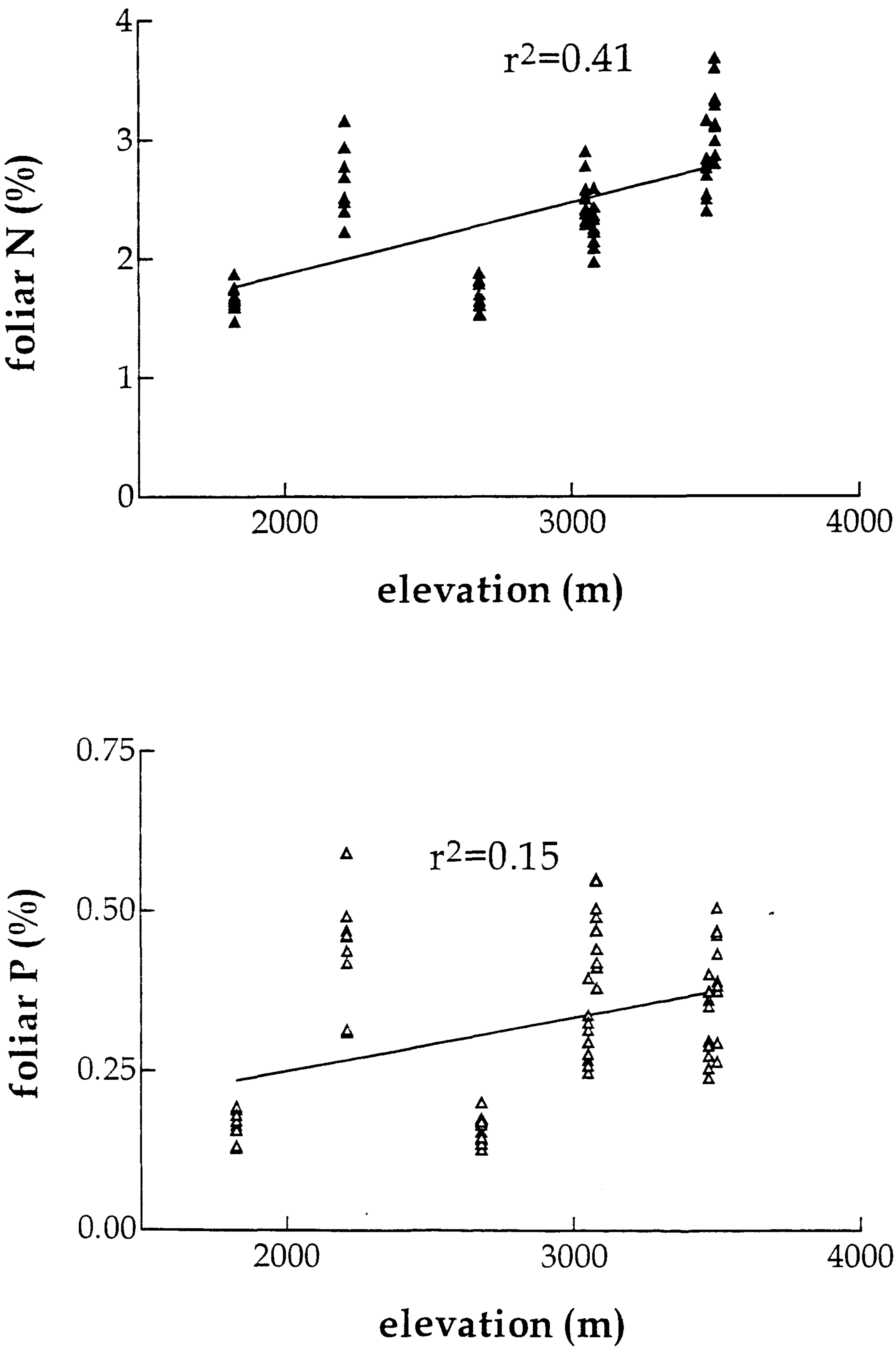


Frasera populations
Flatirons
Walker Ranch
Gold Hill
Caribou
C1
James Peak
Niwot
Foliar N (%)
0
1
2
3
4
130
150
170
190
210
230
Niwot
James Peak
Caribou
C1
Gold Hill
Walker Ranch
Flatirons
Foliar P (%)
0.0
0.1
0.2
0.3
0.4
0.5
130
150
170
190
210
230
Julian Day

FIG 1



4
3
2
1
0
r2=0.41
foliar N (%)
2000
3000
4000
elevation (m)
0.75
0.50
0.25
0.00
r2=0.15
foliar P (%)
2000
3000
4000
elevation (m)

FIG 2

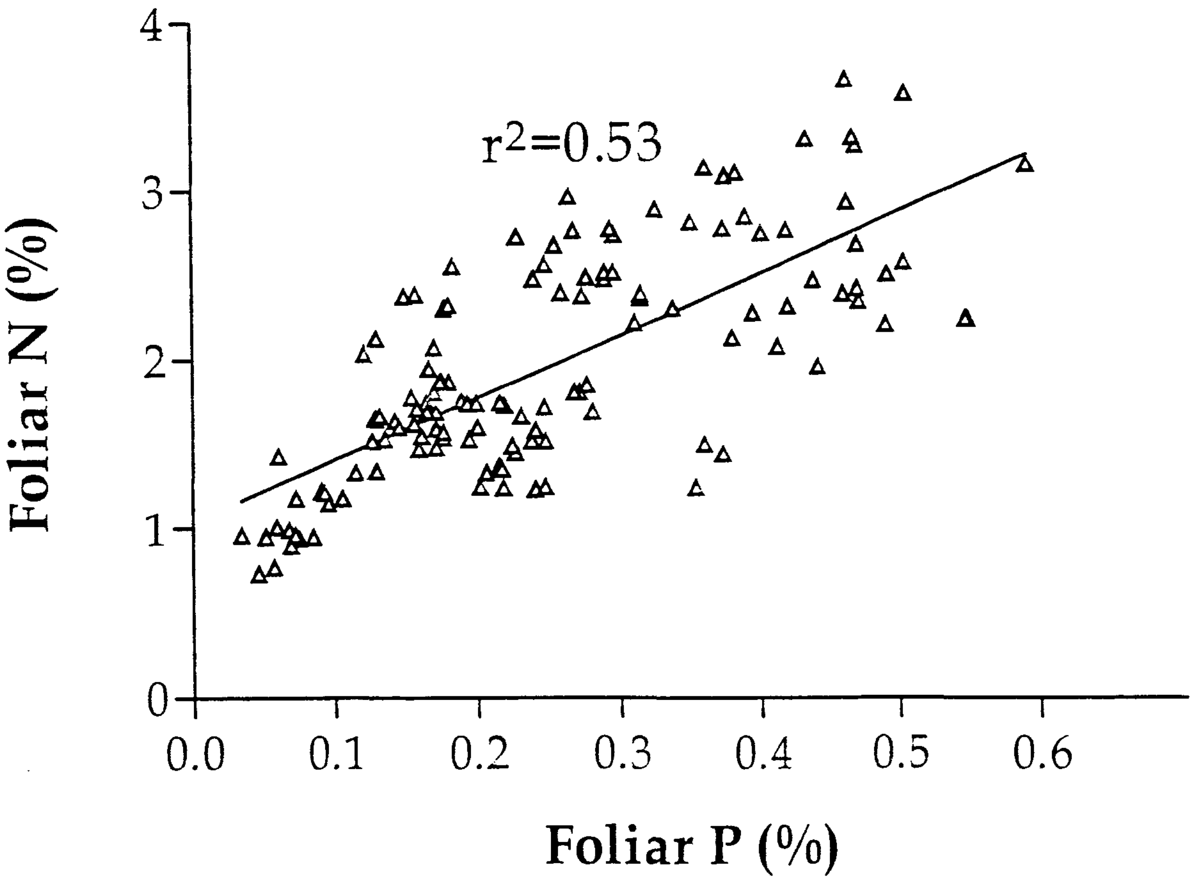


FIG 3

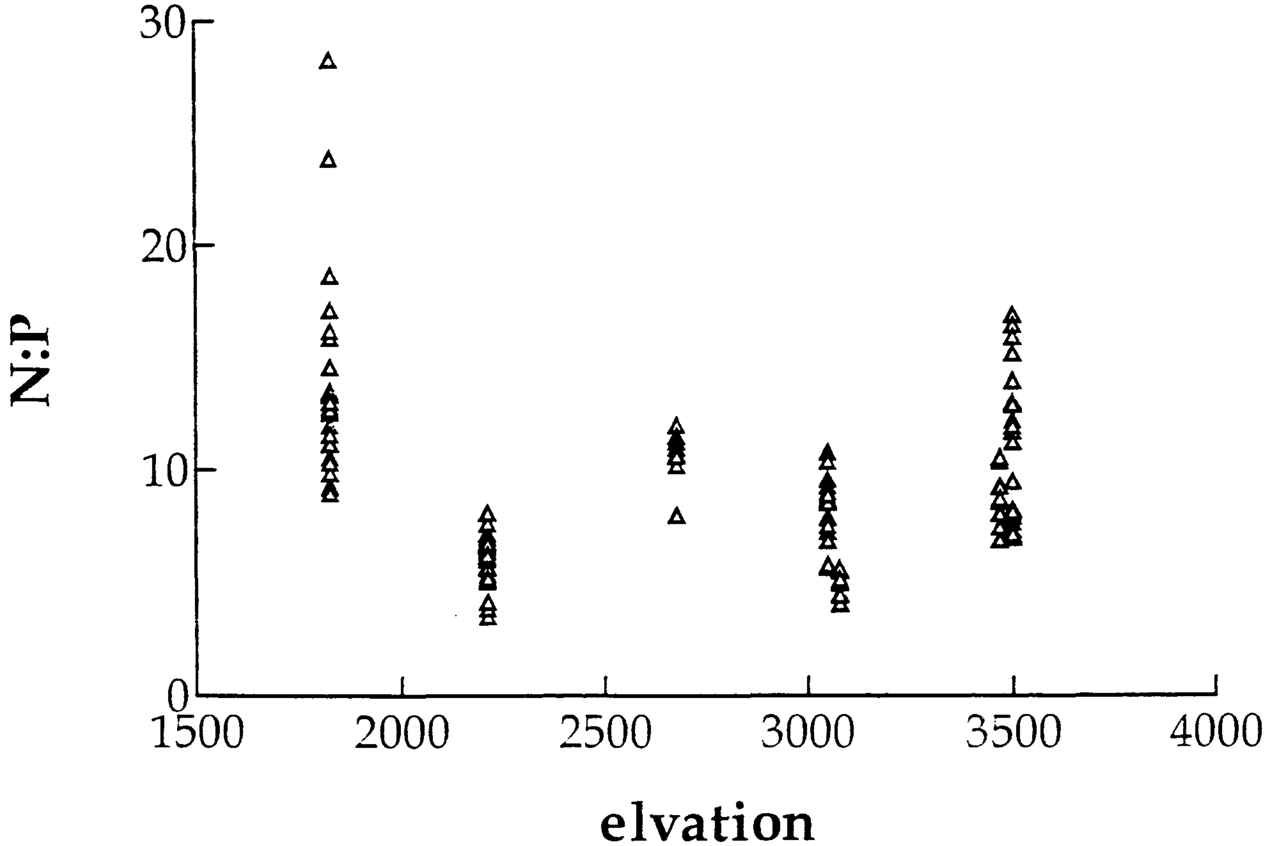
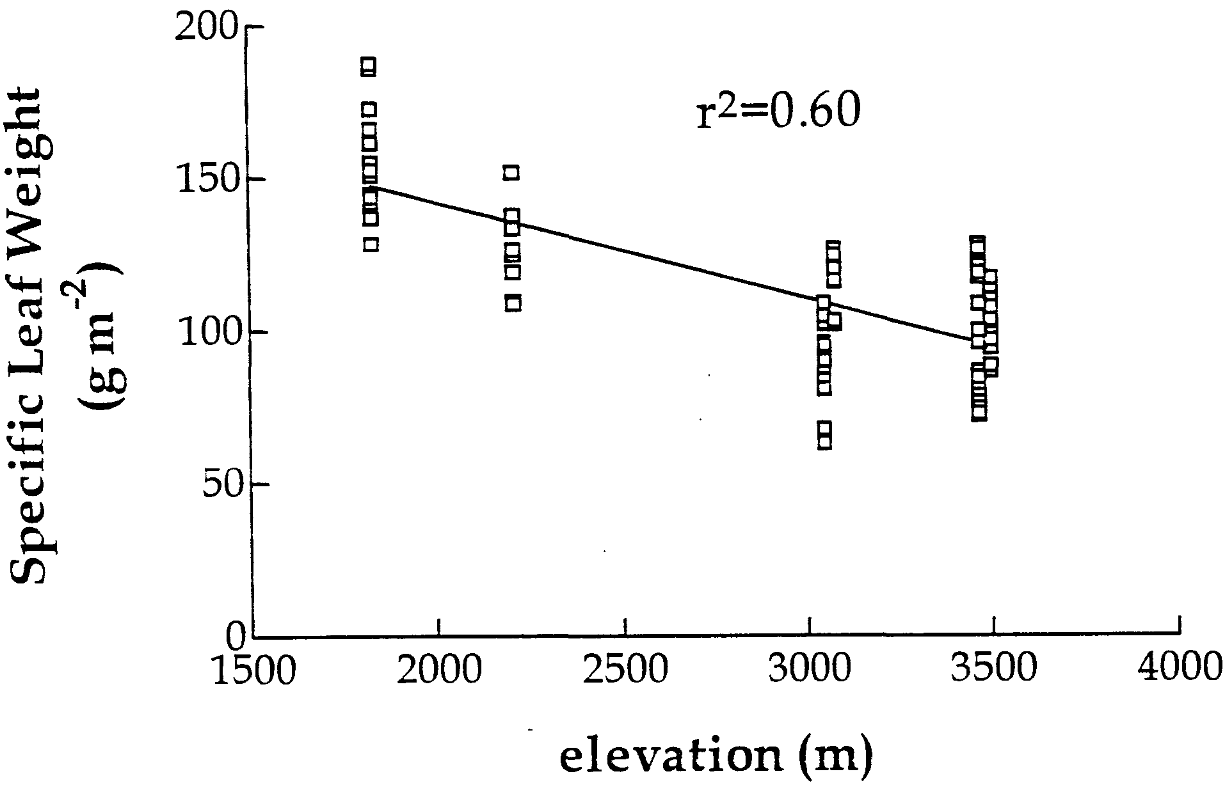


FIG 4



Specific Leaf Weight (g m^-2)
200
150
100
50
0
r^2=0.60
1500
2000
2500
3000
3500
4000
elevation (m)

FIG 5