Can Foliar Analysis be Used to Determine the Nitrogen Status of Young *P. radiata* ?

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Summary

The response to increased nitrogen supply by young *P. radiata* was determined by applying rates of nitrogen up to 272 kg $ha^{-1}yr^{-1}$, and monitoring the annual pattern of biomass production, foliar nitrogen concentrations and needle water potentials on a monthly basis.

Application of an optimum nitrogen supply doubled the biomass production relative to the nil nitrogen treatment. The intensity of water stress during summer increased progressively over the three year monitoring period. When the trees were small and summer water stress was low a strong relationship existed between needle nitrogen concentrations and relative growth rate. This relationship broke down as the trees became larger and the water stress during summer became greater. However a strong relationship existed between the spring nitrogen concentrations and the percentage response in annual biomass relative to the control. No relationship was found between autumn nitrogen concentrations and growth rates. It is suggested that needle nitrogen concentrations during spring may provide a good indicator of tree nitrogen status.

Introduction

Foliar analysis is widely used for the diagnosis of nutrient deficiencies in *Pinus radiata*. In New Zealand the recommended time for sampling is February - March during the period of maximum nutrient stress and during which nutrient concentrations are relatively stable (Will 1985). The critical nutrient concentrations used in New Zealand were based on comparisons of nutrient concentrations from healthy and deficient trees. A similar recommendation to sample trees in autumn when nutrient concentrations are most stable and tree growth is minimal was made for *P. radiata* in South Australia (Raupach *et al* 1972). However in south west WA sampling young *P. radiata* at this time of year has often proved ineffective in separating healthy and deficient trees. More recently it has been suggested that nutrient concentrations in litter may reflect the nutrient status of *P.radiata* plantations (Benson *et al* 1992). While this may be useful in plantations in which litter fall is significant it would not be useful in young plantations where litter fall is minimal. This paper outlines some results from a field trial in young *P. radiata* where the supply of nitrogen was manipulated and the growth and nitrogen concentrations in the foliage were measured with the aim of determining if foliar nitrogen concentrations can be used as an indicator of tree nitrogen status in young *P. radiata*.

Methods

Seedlings were planted in June 1983 at 1330 sph. The data presented here are for the period from May 1985 - June 1988 (age 2 to 5 years). Both the nitrogen treatments and the basal application of Super Cu Zn were applied in autumn or early winter each year. Nitrogen was applied as NH_4NO_3 at 0, 68, 136, 204, 272 kg N ha^{-1} annually. The total basal nutrients (kg ha^{-1}) applied between planting and 1987 were: 192 P; 236 S; 8.8 N; 13.1 Zn; 12.6 Cu. Plots were maintained weed free by ploughing the area between the rows 7 months after planting and by applying glyphosate in 1984 and 1985.

The trial was replicated in three randomised blocks, plots were 0.09 ha with an internal 0.036 ha measurement plot. Height and diameter at 30 cm above ground level were measured each month and needle samples at various ages and positions were taken at the same time. Above ground biomass was estimated from an alometric equation relating diameter to biomass. Needle water potentials were measured each year from October until water stress was relieved by autumn rains. Rainfall during the 3 year period of the study was below the long term average of 903 mm: 876 mm in 1985-86; 826 mm in 1986-87; 765 mm in 1987-88.

Results and Discussion

Biomass increased progressively with increasing nitrogen application up to 204 kg ha^{-1} (Fig 1). The seasonal pattern of stem growth changed over time (Fig 2). In 1985-86 and 1986-87 stem growth continued throughout the year although it slowed during summer. During the 1987-88 summer growth in the high nitrogen treatments ceased (Fig 2). This cessation in growth was associated with needle water potentials below -1.5 MPa (Fig 3). This was similar to the water potential of -1.4 MPa at which leaf growth ceased in *P. radiata* (Sands and Correll 1976)

During 1985-86 strong relationships were found between mean monthly needle nitrogen concentrations and relative growth rates (RGR), data for one year old needles are shown in Figure 4A. A segmented linear regression explained 77% of the variation in the data for one year old needles. Similar relationships were found for younger needles,except that the critical nitrogen concentrations were higher in young needles. The relationships between nitrogen concentrations and RGR were not as strong in subsequent years (1986-87, 1987-88 Fig 4B). This was probably due to the increased influence of water stress during summer on growth, and the problem of comparing RGR's between trees of different size. To overcome this problem the annual biomass increment data were expressed as a percentage of the unfertilized control increment. These data were regressed against nitrogen concentrations at various stages of the growing season. A strong linear

relationship (R^2 = 0.86) was found when the percentage response was regressed against spring nitrogen concentrations (Fig 5A). No relationship existed between the percentage response and autumn nitrogen concentrations (Fig 5B).

The seasonal trend in nitrogen concentrations in one year old needles (Fig 6) may explain this observation. In autumn there was little difference between the nitrogen concentrations in any of the treatments while in late winter and spring there were substantial differences between the nitrogen concentrations of the different treatments. In this region nutrient absorption by young pines is restricted to the period when the surface soil containing most of the nutrients is moist. Tree growth continues throughout the year resulting in the dilution of nutrient concentrations during summer (McGrath and McArthur 1990). This effect was also evident in this trial (Fig 6). While the nitrogen concentrations in needles were lowest in late summer and autumn and the concentrations were most stable in this period, criteria that were used by Raupach *et al* (1972) and Will (1985) to recommend this as the most suitable sampling period, it appears that nitrogen concentrations during winter and spring reflect more accurately the nutrient status of the trees during the period of rapid growth during spring and early summer.

It was concluded that in areas with maximum rainfall in winter and a strong summer drought, foliar sampling for estimating the nitrogen status of young *P. radiata* should be done during early spring. The nutrient concentrations in this period reflect the potential of the trees to grow during the period of rapid growth in spring and early summer. Nutrient concentrations in late summer and autumn probably do not reflect the potential of trees to grow as water stress may override the influence of nutrient status or the nutrient concentrations may have been diluted due to growth during spring and summer.

References

Benson, M.L., Myers, B.J. and Raison, R.J. 1992. Dynamics of stem growth of Pinus radiata as affected by water and nitrogen supply. *For. Ecol. Manag.* 52: 117-137.

McGrath, J.F. and McArthur, S.L. 1990. Influence of fertilizer timing on seasonal nutrient uptake and dry matter production by young Pinus radiata in southern Western Australia. *For. Ecol. Manag.* 30: 259-269.

Raupach, M., Clark, A.R.P. and de Vries, M.C.P. 1972. An investigation of four forest sites in South Australia on the optimum tree position and time of year for foliar sampling of *Pinus radiata* for thirteen elements. *Australian Forest Tree Nutrition Conference.* Canberra.

Sands, R. and Correll, R.L. 1976. Water potential and leaf elongation in radiata pine and wheat. *Physio. Plant.* 37: 293-297.

Will, G. 1985. Nutrient deficiencies and fertiliser use in New Zealand exotic forests. *FRI Bulletin* 97, pp 53. New Zealand Forest Service, Rotorua, New Zealand.

List of Figures.

Figure 1 Biomass response by *P. radiata* to nitrogen application 23(●), 35(▲), 47(▼), 59(■) months after planting. Standard errors are shown as vertical bars on the data points.

Figure 2 Effect of nitrogen supply (○, 0; △, 68; ▽, 136; □, 204; , ■, 272 kg N $ha^{-1}yr^{-1}$) on the above ground biomass production by *P. radiata* from two to five years of age. Standard errors are shown as vertical bars on the data points for May each year.

Figure 3 Influence of age and nitrogen application (○, ●; 0N; □, ■; 272 kg N $ha^{-1}yr^{-1}$) on the pre-dawn (solid symbols) and midday (open symbols) needle water potentials of *P. radiata* from spring until the break of the summer drought, for the period October 1985 to May 1988.

Figure 4 Relationship between mean monthly nitrogen concentration in one year old needles and relative growth rates in young *P. radiata* (A) for 2 year old trees (B) for 4 year old trees. The segmented linear regression shown by the solid line in (A) has an $R^2 = 0.77$, there was no significant relationship for the data in (B)

Figure 5 Relationships between (A) spring and (B) autumn needle nitrogen concentrations and the response in annual biomass increment relative to the nil nitrogen control. For part (A) $R^2 = 0.86$.

Figure 6 Effect of nitrogen supply (● ,0; ▲ ,136; ■ ,272 kg N $ha^{-1}yr^{-1}$) on the seasonal pattern of nitrogen concentrations in one year old needles from age 2 to 3 years.

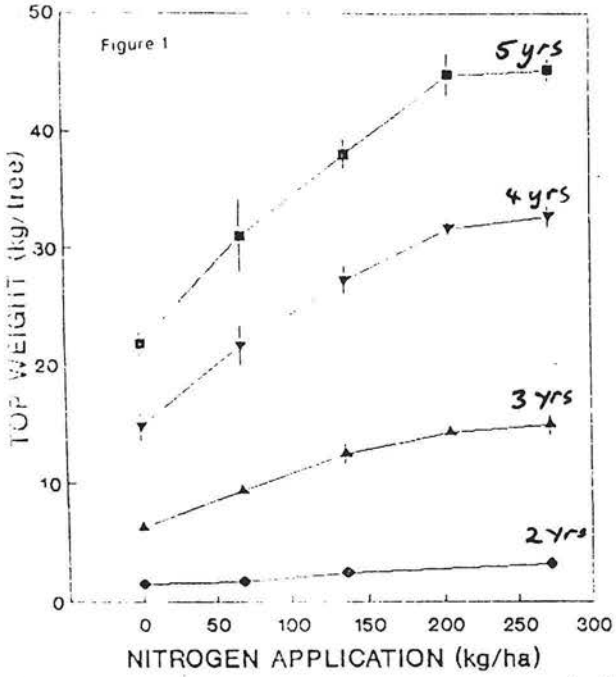
Figure 1
5 yrs
4 yrs
3 yrs
2 yrs
TOP WEIGHT (kg/tree)
NITROGEN APPLICATION (kg/ha)

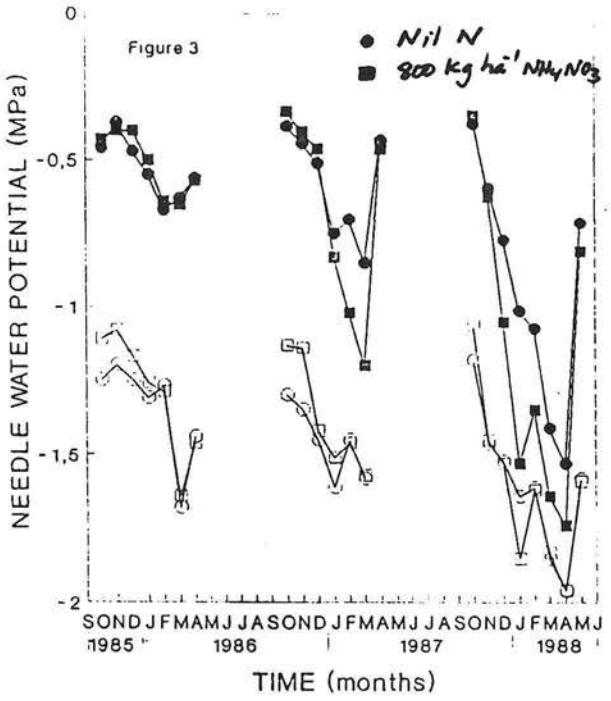
Figure 3
Nil N
800 kg ha⁻¹ NH4NO3
NEEDLE WATER POTENTIAL (MPa)
SOND J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J
1985
1986
1987
1988
TIME (months)

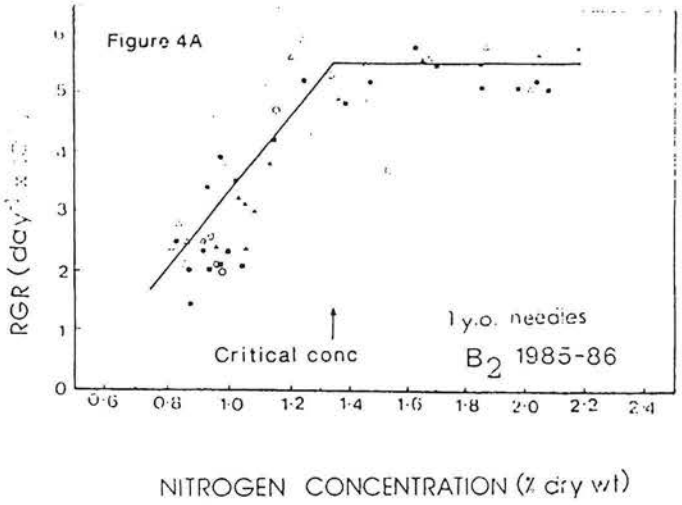
Figure 4A
RGR (day⁻¹ x 10³)
1 y.o. needles
Critical conc
B2 1985-86
NITROGEN CONCENTRATION (% dry wt)

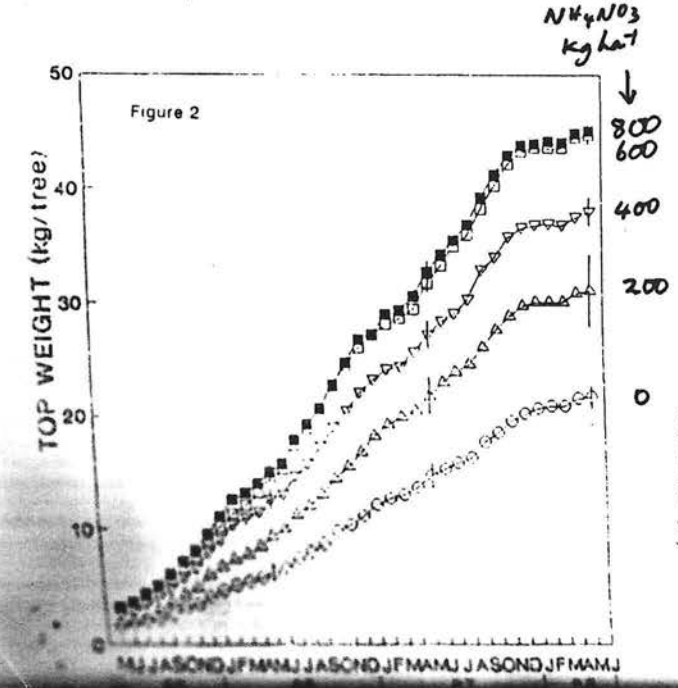
Figure 2
NH4NO3 kg ha⁻¹
800
600
400
200
0
TOP WEIGHT (kg/tree)

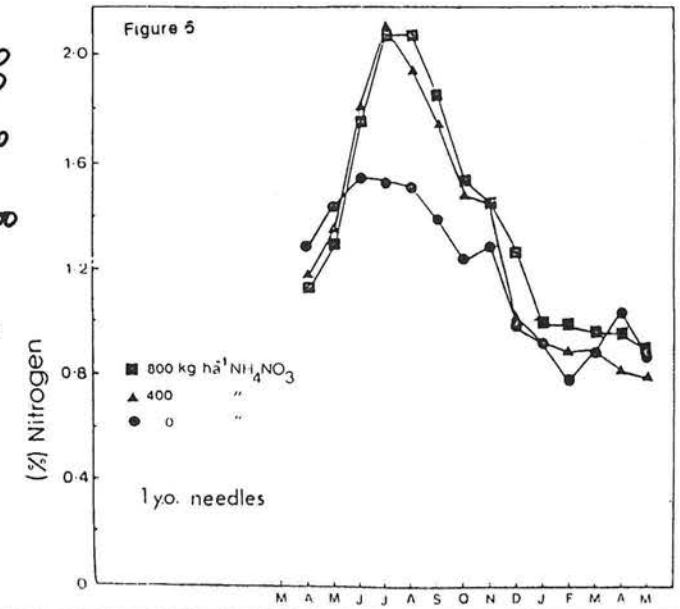
Figure 5
800 kg ha⁻¹ NH4NO3
400
0
(%) Nitrogen
1 y.o. needles
M A M J J A S O N D J F M A M

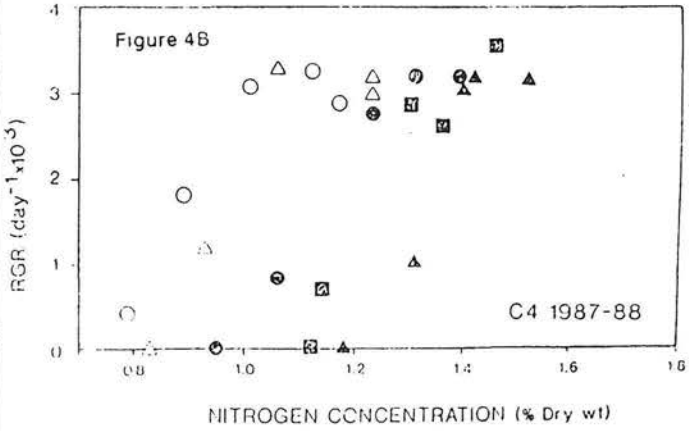
Figure 4B
RGR (day⁻¹ x 10³)
C4 1987-88
NITROGEN CONCENTRATION (% Dry wt)

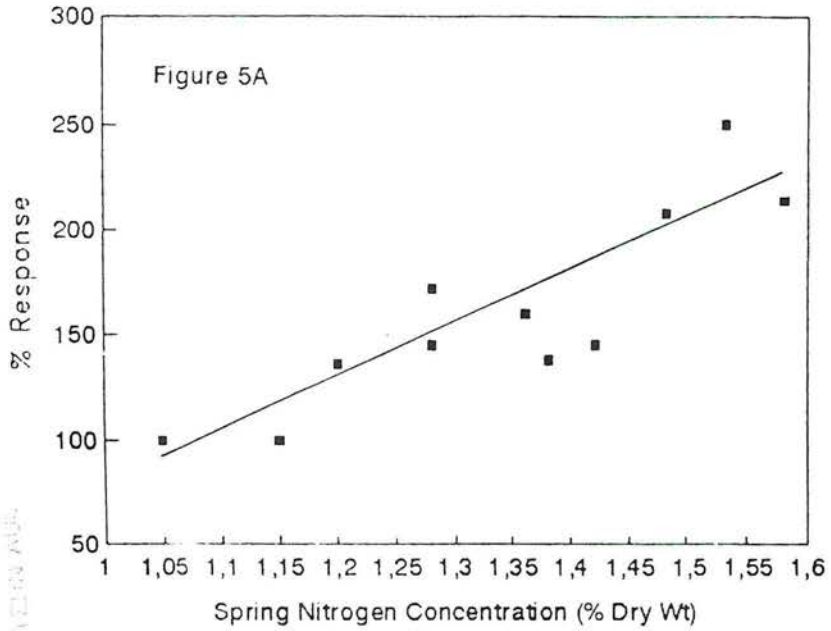
Figure 5A
% Response
300
250
200
150
100
50
1
1,05
1,1
1,15
1,2
1,25
1,3
1,35
1,4
1,45
1,5
1,55
1,6
Spring Nitrogen Concentration (% Dry Wt)

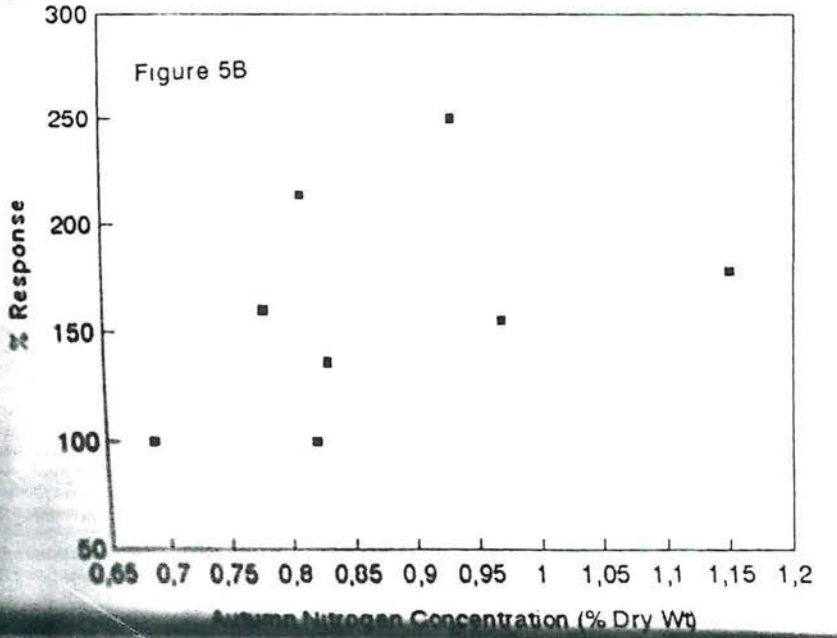
Figure 5B
% Response
300
250
200
150
100
50
0,65
0,7
0,75
0,8
0,85
0,9
0,95
1
1,05
1,1
1,15
1,2
Autumn Nitrogen Concentration (% Dry Wt)

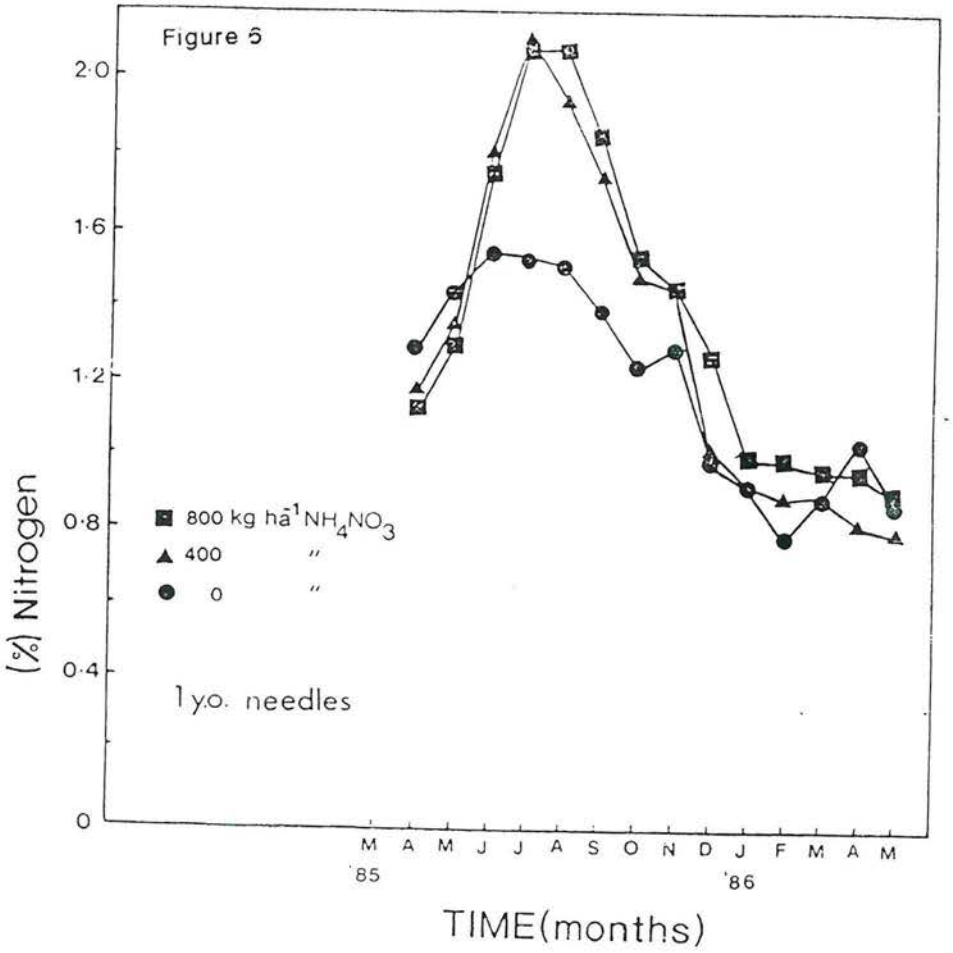
Figure 6
2·0
1·6
1·2
0·8
0·4
0
(%) Nitrogen
800 kg ha⁻¹ NH4NO3
400 "
0 "
1 y.o. needles
M A M J J A S O N D J F M A M
'85
'86
TIME(months)