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ORIGINAL PAPER

Influence of ammonium and nitrate supply on growth, dry matter partitioning, N uptake and photosynthetic capacity of *Pinus radiata* seedlings

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Abstract Growth and physiological responses of *Pinus radiata* D. Don seedlings to a combination of N supply regimes (low N = 1.78 mol m^{-3}, high N = 7.14 mol m^{-3}) and ammonium:nitrate ratios (80:20, 50:50 and 20:80; molar basis) were assessed in a hydroponic experiment run over the course of 105 days. Highly significant ($P < 0.001$) increases in seedling diameter, height, leaf area and dry mass occurred at lower ammonium:nitrate ratios and were two to fourfold greater than the non-significant (for diameter) to marginally significant ($P < 0.05$ for other dimensions) increases in these dimensions that occurred with greater N supply. Increases in N supply resulted in a highly significant ($P < 0.001$) reduction in biomass partitioning to roots and highly significant ($P < 0.001$) increases in allocation to foliage. The ammonium:nitrate ratio was not found to significantly change biomass partitioning to either foliage, stems or roots. Ammonium and nitrate uptake was significantly influenced by N supply and N form and conformed to ammonium and nitrate concentrations in nutrient solution. Uptake rates of ammonium were twice those of nitrate at comparable concentrations suggesting that *P. radiata* is in the lower end of the ratio of uptake of ammonium to nitrate reported for conifers (range from 2 to 20 mol mol^{-1}). Despite this, plants growing in high ammonium:nitrate ratios were smaller, exhibited luxurious N consumption and lower N use efficiency. Differences in productivity among treatments were partially explained by greater rates of light-saturated photosynthesis associated with nitrate nutrition.

Keywords Ammonium · Growth · Isotopes · Nitrate · Photosynthesis · Radiata pine

Introduction

Nitrogen (N) availability is the primary factor limiting productivity in most natural and managed ecosystems (Berendse and Aerts 1987; Aerts and Chapin 2000). Although some plants are reliant on organic forms of N (Ohlund and Nasholm 2004) most N is supplied to plants through ammonification and nitrification (Haynes and Goh 1978; Bloom 1985; Chapin et al. 1987; Marschner 1995). Nitrification plays a minor role in climax communities whereas in most disturbed and cultivated soils, where early successional species dominate, it may assume a major role (Haynes and Goh 1978). Consequently, plants exhibit great differences in their ability to take up and use ammonium and nitrate as sources of N (Haynes and Goh 1978), which reflects the environment to which the species are adapted (Kronzucker et al. 1997, 2003; Min et al. 1999).

Conifers are usually reported to grow faster under ammonium than nitrate (McFee and Stone 1968; van Den Driessche 1971; Kronzucker et al. 1997). However, this generalisation could be biased as most research has been undertaken in temperate and boreal ecosystems in the

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