Response of *Pinus radiata* (D. Don) to boron fertilisation under greenhouse conditions

Raza U. Khan[A], Christopher W.N. Anderson[A], Paripurnanda Loganathan[A], Jianming Xue[B] and Peter Clinton[B]

[A]Soil and Earth Sciences, Institute of Natural Resources, Massey University, Palmerston North, New Zealand.
[B]Scion Private Bag 29237, Christchurch, New Zealand.

Abstract
We studied the effect of different fertiliser boron (B) levels on growth, B uptake and photosynthesis of *Pinus radiata* and soil dehydrogenase activities under greenhouse conditions. Boron concentration in needle, stem and roots increased with increasing rates of B fertiliser. Boron at 4-8 kg/ha increased growth and net photosynthetic rate. However, higher rates reduced net photosynthetic rate and diameter growth. Soil dehydrogenase activity, an indicator of soil microbiological activities, was significantly reduced by B application at the rate of 16 and 32 kg/ha. Our findings confirm the narrow range between B deficiency and toxicity in a tree crop.

Key Words
Pine, B nutrition, soil microbial activity.

Introduction
Pinus radiata is the dominant plantation forestry species planted on over 1.8 million hectares of New Zealand's total geographical area of 26.9 million hectares. The New Zealand forest industry contributes 1.1% of the global and 8.8% of the Asia-Pacific forest product trade (NZFIC 2005). With respect to New Zealand's economy, the forestry sector contributed 3.2 % to total export earnings during 2003/2004; the major share of this earning attributed to *P. radiata* plantation (NZFIC 2005). Boron (B) deficiency is the most common micronutrient limitation in conifer forests (Shorrocks 1997). In *P. radiata,* B deficiency can cause the death of terminal buds, arrest the growth of leader shoots and lead to permanent stem malformation, which will reduce both wood volume and quality (Olykan *et al*. 1995). In New Zealand, B deficiency often occurs in coarse textured soils such as the pumice soils of the Central North Island and the Moutere gravels near Nelson in the South Island. The correction of B deficiency in *P. radiata* plantations involves the use of slow-release B fertiliser. However, very little information is available on the effect of different rates of slow-release B fertiliser on plant growth and physiological properties and soil microbiological activities.

Material and method
Trial design and plant growth condition
A pot trial was conducted at Palmerston North, New Zealand under greenhouse conditions by applying five levels of B in the form of ulexite (rate equivalent to 0, 4, 8 , 16 and 32 kg B/ha) to one year old radiata pine grown in 6 L plastic pots containing a Pumice Soil collected from the Taupo region. Each treatment was replicated five times and arranged in a randomised complete block design. The glasshouse temperature was maintained at 17.5 ± 1 °C (night) and 22.5± 1°C (day). Pots were irrigated regularly to maintain soil moisture at 80 % of field capacity.

Measurement and chemical analysis
Tree height and stem diameter were measured every two weeks and at harvest stage. Net photosynthesis was measured before harvesting by using a CIRUS-2 Portable Photosynthesis system. Plant B concentration was determined for each harvested organ (needle, shoot) by dry ashing followed by measuring the B in the ashed extract colorimetrically by the azomethine-H method (Gaines and Mitchell 1979). Soil dehydrogenase activity after harvest was determined through incubation of soil sub-samples at 37 °C for 24 h (Chander and Brookes 1991). Plant-available soil B was extracted using 0.02 M hot $CaCl_2$ method (Parker and Gardner 1981). The concentration of B in the extracts was determined using colorimetric analysis by the azomethine-H method (Gaines and Mitchell 1979)

Results and discussion

Plant growth

Different responses to B fertiliser rates were observed for plant height and stem diameter (Figure 1 a, b). Maximum plant height (47.13 cm) was obtained with B application at the rate of 8 kg/ha. Plant height appeared to be lower at 16 and 32 kg/ha than at 8 kg/ha, although there was no significant difference. Maximum stem diameter was obtained with B application at the rate of 4 kg/ha. Higher rates of B fertiliser reduced stem diameter growth. However, measured values were greater relative to the control (0 kg B/ha). These results were generally in agreement with the field observations of Olykan *et al.* (2008).

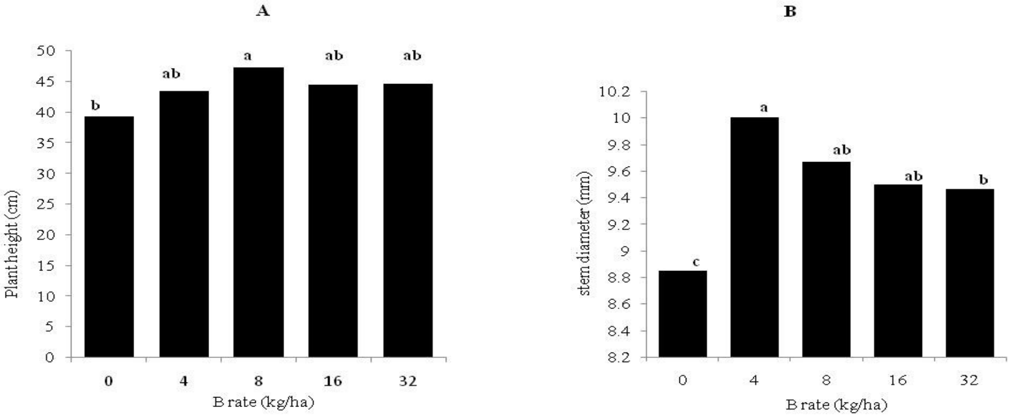

Figure 1. Effect of different B rates on A. Plant height and B. Stem diameter.

Net photosynthesis rate and soil dehydrogenase activity

Needle net photosynthetic rate (Np) was significantly lower at B rates of 0, 16 and 32 (Figure 2 a) relative to 4 and 8 kg/ha. The greater Np at B rates of 4 and 8 kg/ha could be responsible for the better growth of the trees observed for these two treatments. Both B deficiency and toxicity have been reported to influence photosynthesis (Dell and Huang 1997, Lee and Aronoff 1966). Soil dehydrogenase activity, an index of soil microbial metabolic activity, was significantly reduced at the B rates greater than 8 kg/ha (Figure 2 b). This implies that high rates of B fertiliser could be toxic to some soil microorganisms sensitive to added chemicals.

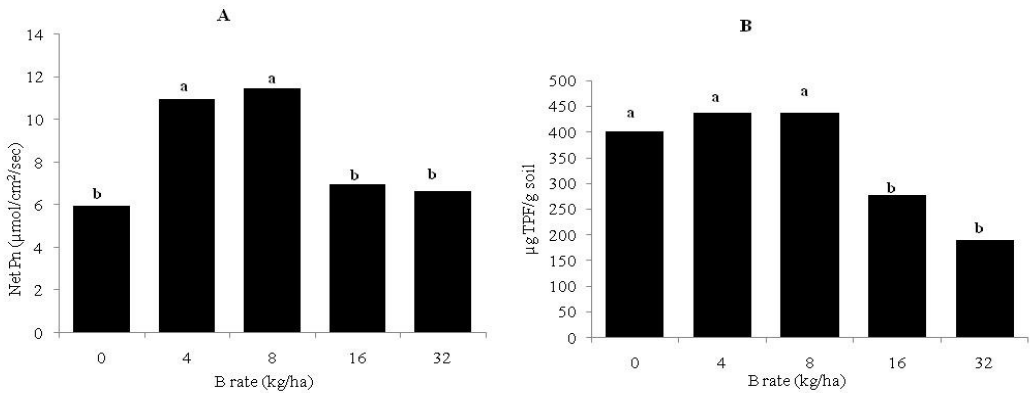

Figure 2. Effect of different B rates on A. Net photosynthesis and B. Soil dehydrogenase activities.

Needle and soil B concentrations

Across all ages of harvested needles (i.e. mature and immature needles) B concentrations significantly increased with increasing rates of B fertiliser (Figure 3). A greater increase in needle B concentration was found at B rates up to 16 kg/ha with little or no effect of further B fertilisation. The B concentration in currently mature needles for the control treatment was 12 mg/kg. This is approximate to the marginal level defined by Will (1985) and less than the 16-70 mg/kg range reported to be adequate for B in young mature foliage of *P. radiata* by Reuter and Robinson (1997). The needle B concentrations at the rates of 16 and 32 kg/ha were all greater than 170 mg/kg, which is reported to be the toxic threshold value for radiata pine growth (Reuter and Robinson1997). Toxicity of foliar B at high fertilisation rate may explain the observed declining plant growth and photosynthetic capacity. The concentration of $CaCl_2$ extractable soil B also increased with increasing rates of B fertiliser (Figure 4 a). The much greater availability of soil B at 32 kg/ha may have caused a toxic accumulation of B in the needles at this treatment.

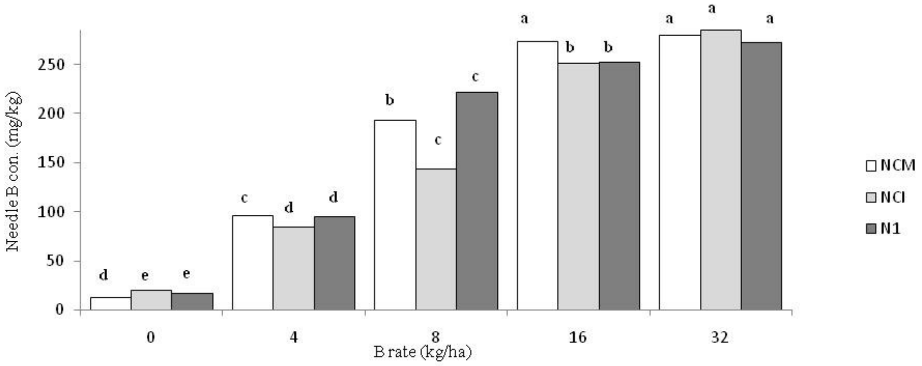

Figure 3. Effect of B rates on B concentration (mg/kg) in different age-group N1(1-year old), NC1 (currently immature) and NCM (currently mature) needles.

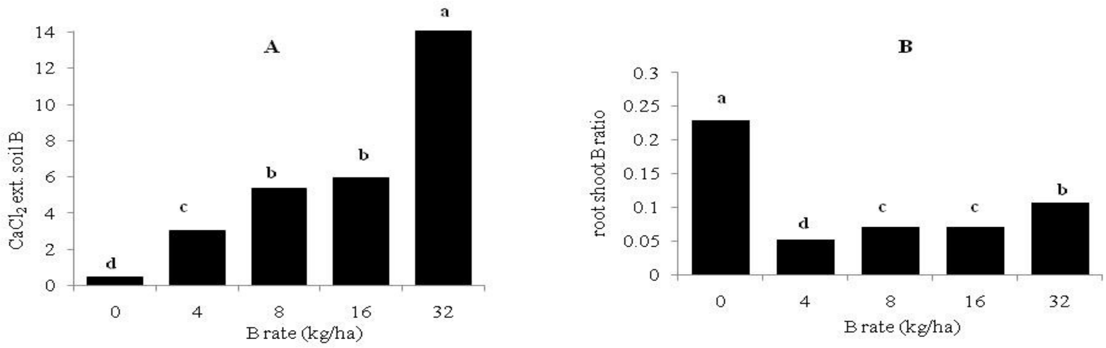

Figure 4. Effect of different B rates on A. $CaCl_2$ extracted soil Boron and B. Root : shoot B ratio.

Root /needle B ratio (RNR)

Greater RNR was found in the control (no B) and highest B rate (32 kg/ha) when compared with the optimum B application rates (Figure 4 b). Analysis of the B distribution among different plant parts indicated that translocation of B from root to the above-ground parts (e.g. needles) could be restricted under stress conditions caused by both low and high B levels. Our results agree with earlier reports where low translocation of B from roots to shoots promoted vascular impairment through B deficiency (Dell and Huang 1997). Our data suggests a similar response through B toxicity.

Conclusions

In this study we assessed the effect of increasing soil B levels on growth of *P. radiata.* Boron was found to increase plant height, diameter and dry weight up to an optimal level of soil B (3-6 mg/kg $CaCl_2$ extractable B). However, B in excess of the optimal concentration affected a decrease in photosynthetic activity. No level of application promoted an increase in soil microbiological activity. High application of B was found to be toxic to soil microorganisms.

References

Chander K, Brookes PC (1991) Is the dehydrogenase assay invalid as a method to estimate microbial activity in copper-contaminated soils ? *Soil Biol. Biochem* **23**, 909-915

Dell B, Huang L (1997) Physiological response of plants to low boron. *Plant and soil* **193**, 103-120.

Gaines TP, Mitchell GA (1979) Boron determination in plant tissues by the azomethine-H method. *Commu. soil sci. Plant Anal.* **10,** 1099-1108.

Lee SG, Aronoff S (1966) Investigation on the role of boron in plants. III anatomical observations. *Plant physiol* **41**, 1570-1577.

New Zealand Forest Industries Council (NZFIC) Fact and Figures 2004/2005, 85 The Terrace PO Box 2727, Wellington Website: www.nzfic.org.nz

Olykan ST, Adam JA, Nordmeyer AH, McLareen RG (1995) Micronutrients and macronutrients uptake by *P. radiata*, and boron fractions, as affected by added nitrogen and boron. *N.Z. J. For. Sci*. **25**, 61-72.

Olykan ST, Xue J, Clinton PW, Skinner MF, Graham DJ, Leckie AC (2008) Effect of boron fertiliser, weed control and genotype on foliar nutrients and tree growth of juvenile *P. radiata* at two contrasting sites in New Zealand. *For. Ecol. Manage*. **255**, 1196-1209.

Parker D, Gardner EH (1981) The determination of hot-water soluble boron in some acid Oregon soils using a modified azomethine-H procedure. *Comm soil sci. Plant Anal.* **12,** 1311-1322.

Reuter DJ, Robinson JB (1997) Plant Analysis - an interpretation manual Eds. CSIRO Publishing.

Shorrocks VM (1997) The occurrence and correction of boron deficiency. *Plant and Soil* **193,** 121-1489.

Will GM (1985) Nutrient deficiency and fertiliser use in New Zealand exotic forests. *N.Z .For. Res. Inst. Bull*. **97**, 53 pp.