NOTE

BORON, COPPER, MANGANESE, AND ZINC IN STEMWOOD OF PINUS RADIATA

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ABSTRACT

Boron and zinc concentrations increased with wood age in four **Pinus radiata** D. Don trees. Manganese increased with wood age in three trees and decreased in one tree. Copper concentrations were unrelated to age. Zinc concentrations varied significantly among trees.

Keywords: boron; copper; manganese; zinc; stemwood; wood age; **Pinus radiata**.

INTRODUCTION

There is an increasing interest in micronutrients in forest trees, particularly in *Pinus radiata,* as a result of the recognition of micronutrient deficiencies (Will 1985).

Average concentrations of boron, copper, and zinc decline slightly and that of manganese increases in stemwood of whole trees ("whole-stemwood") of *P. radiata* in stands of increasing age (Madgwick *et al.* 1977, 1988). Changes in concentrations of micronutrients in whole-stemwood with increasing tree age may be explained either by changes in concentration within tissue formed at different stages of tree growth or, as for macronutrients (Orman & Will 1960), by removal or accumulation of nutrients in aging tissue.

We report concentration variations of four micronutrients across discs cut from stems near ground-level. It is important to note that the oldest tissue sampled was produced when the trees were young as it is easy to confuse tree age and tissue age when considering patterns of change.

MATERIALS AND METHODS

Four 27-year-old *P. radiata* trees growing in Cpt 69 of Kaingaroa Forest were selected for study. Detailed descriptions of the site have been given by Knight &

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Will (1977) and Ballard & Will (1981). Ballard & Will (1981) reported that three aerial applications of copper oxychloride at 2.24 kg/ha were made between 1968 and 1972 to control *Dothistroma pini* Hulbary infection. No subsequent copper spray was applied but there is a possibility that drift from neighbouring areas could have reached the stand. No fertiliser treatment involving boron, manganese, or zinc could have affected the results.

A disc approximately 10 cm thick and located near ground-level was cut from each tree. A strip of wood across the diameter of each disc was removed and subdivided into growth increments, each including 4 years of growth. The samples were oven dried at 70°C and ground to pass a 1-mm sieve. Subsamples were ashed in a muffle furnace at 480°C for 4 hours followed by digestion with 2N hydrochloric acid and hydroxylamine hydrochloride. Boron was determined by the colorimetric curcumin method, and copper, manganese, and zinc by atomic absorption spectrophotometry.

Statistical analyses included regressing nutrient concentrations on average wood age, with tree effects being accounted for by using dummy variables.

RESULTS AND DISCUSSION

Boron and zinc concentrations increased with wood age in all four trees examined (Fig. 1). Manganese increased with wood age in three trees and decreased in one tree. Copper concentrations were unrelated to age. Only zinc concentrations varied significantly among trees (Table 1).

The most comprehensive sets of whole-tree data in the same geographical locality are for zinc and manganese (Madgwick *et al.* 1977, 1988; Webber & Madgwick 1983; Frederick *et al.* 1985). Zinc concentrations in whole-stemwood of young *P. radiata* were comparable to those found in the oldest tissue tested in the present trees which was formed when the trees were 2 to 7 years old. Similarly, zinc concentrations in the whole-stemwood of 29-year-old trees reported by Webber & Madgwick (1983) were of the same order as those in tissues formed when the trees currently examined were 23–27 years old. This suggests that zinc concentrations in stemwood may be a function of tree age when the wood is formed.

The predominant increase in manganese concentration with tissue age is contrary to data for whole-stemwood reported previously (Madgwick *et al.* 1977, 1988; Webber & Madgwick 1983). In these earlier studies manganese concentrations in whole-stemwood were found to increase with tree age except for an apparent decline after thinning. It is possible that manganese concentrations increase within all parts of the stem as trees age, though the apparent thinning effect remains an anomaly.

Boron concentrations reported here were substantially lower than those reported for whole-stemwood samples in earlier studies (Webber & Madgwick 1983; Madgwick *et al.* 1988). However, as for zinc, the trend for boron concentration to increase with tissue age helps to explain why boron levels in whole-stemwood tend to decrease with increasing tree age. Copper concentrations were also lower than reported earlier but, unlike zinc and boron, failed to demonstrate any age effects which could explain changes observed in whole stems.

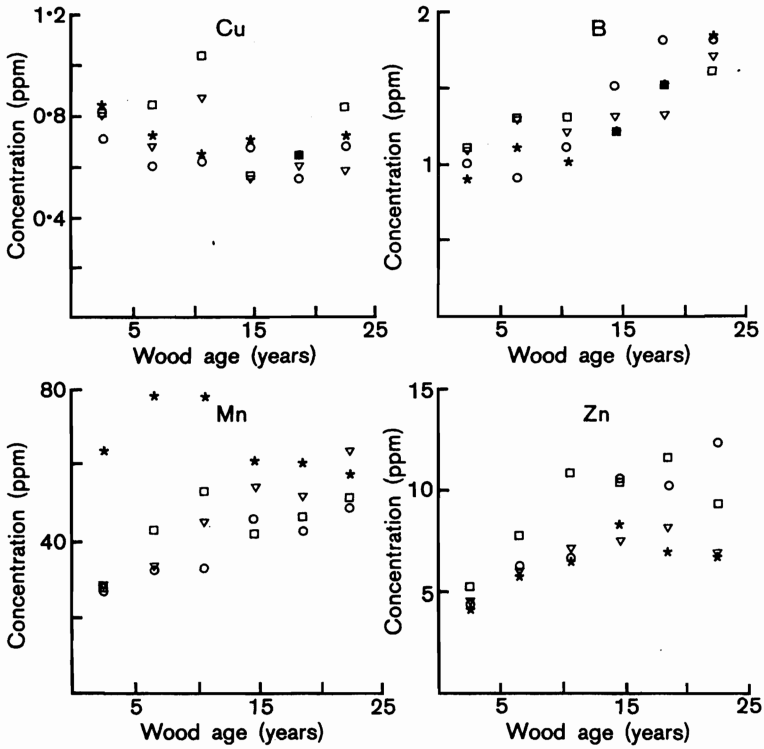

FIG. 1—Relationship between copper, boron, manganese, and zinc concentrations and stemwood age in **P. radiata**. Each tree is identified by a different symbol.

TABLE 1–Effects of tissue age, sample tree, and their interaction (AxT) on concentrations of boron, copper, manganese, and zinc within stemwood of *P. radiata* expressed as a fraction of variance accounted for in regression analysis. The regression coefficients (Regr. coeff.) are the minimum and maximum values for age effects in individual tree regression equations. The means are overall sample means.

Nutrient	Mean	Age	Tree	AxT	Regr. coeff.	
					Min.	Max.
Boron	1.31	0.72***	0.02	0.10	0.021	0.050
Copper	0.70	0.14	0.19	0.04	–0.012	0.002
Manganese	48.8	0.13	0.57	0.19**	–0.70	1.76
Zinc	7.7	0.44***	0.26**	0.11	0.121	0.391

The effect of aerial applications of copper fungicide during the stand's early years on copper levels in wood is not known. However, in one young stand subjected to copper sprays the variation in whole-stemwood copper concentrations was not closely linked to variation in foliar copper (Madgwick *et al.* 1988).

The dissimilarity in patterns of change in nutrient concentrations with tree and wood age among nutrients indicates that different mechanisms are operating for different nutrients. For zinc and boron concentrations, at least part of the observed variation appears due to changes in concentration within tissue formed at different stages of growth. The higher concentrations in older tissue, formed when the trees were young, are reminiscent of the higher concentrations found in complete discs sampled in upper portions of stems (Madgwick & Frederick 1988).

A complicating factor in assessing causes for the observed patterns is the potential effect of weather variations with time. Over the life of the trees included in this study there has been a general decline in annual precipitation (as recorded at Wairapukao, 4 km south from the study site) from 1500 mm to 1180 mm a year over the 4-year periods corresponding to sample wood ages. Consequently, average wood age and average annual precipitation were correlated ($r = 0.89$, $n = 6$, $p = 0.01$). Boron concentrations in *P. radiata* foliage are known to be positively correlated with annual precipitation (Knight *et al.* 1983). Variations in annual precipitation could have affected our results but cannot be separated from wood age effects because of the high correlation between the two variables. It is possible that both the results in this study and previously reported data for whole trees could reflect changes in rainfall over the years. Consequently, when predicting nutrient removal in harvesting it would be prudent to treat any estimates based on limited sampling over time and space with reservation. Genetic variability is known to occur in foliar nutrient concentrations (Knight 1978) and requires study in other tree components to ensure that estimated harvesting effects are based on an adequate number of sample trees.

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