COPPER DEFICIENCY IN RADIATA PINE PLANTED ON SANDS AT MANGAWHAI FOREST

G. M. WILL
Forest Research Institute, New Zealand Forest Service, Rotorua

(Received for publication 7 October 1971)

ABSTRACT

Twisting of branches and leaders in radiata pine (**Pinus radiata** D. Don) in Mangawhai Forest has been relieved by applications of copper. The growth distortion is accompanied by a flatter branch angle, needle tip burn, and needle fusion. Levels of copper in the foliage of deficient trees are less than **ca.** 3 ppm.

INTRODUCTION

Mangawhai Forest is being established on a strip of coastal sand dunes that lie on the east coast of New Zealand's Northland peninsula between Mangawhai Harbour and Cape Rodney, *ca.* 65 km south of Whangarei. Establishment practice is similar to that developed on the more extensive sand dunes on Northland's west coast; sand stabilisation with marram grass (*Ammophila arenaria* (L.)) Link and yellow perennial lupin (*Lupinus arboreus* Sims) is followed by planting with radiata pine (*Pinus radiata* D. Don). Planting commenced in 1962, and to date *ca.* 285 ha have been planted.

In 1968, it was noticed that the oldest stands of trees were exhibiting an unusually severe distortion of the main stem and branches. This distortion appeared similar to that caused by copper (Cu) deficiency in Douglas fir (Oldenkamp and Smilde, 1966; van Goor, 1968), and while visiting New Zealand, Mr J. H. Ruiter of South Australia, found the symptoms very similar to suspected copper deficiency he had induced in radiata pine in nitrogen plus phosphorus plots in a fertiliser experiment there (Ruiter, 1969).

Particularly in fast growing stands, radiata pine in New Zealand is subject to a degree of twisting and bending in both leader and branches. However, in the worst affected trees at Mangawhai, very severe bending had occurred about 1 m above the ground, and at age 6 yr some leaders had bent over to be growing horizontally, if not looping downwards. Needle-tip burning and a higher than normal incidence of fused needles were also present.

New Zealand Soil Bureau (1954) has mapped the area as "blown sand", but no chemical analyses have been reported. Adjoining areas of stabilised sand of the same origin are classified as Whananaki sand — a young podzolic soil from aeolian sand which Wells (1957) found contains 25 ppm total Cu. This is relatively high amongst New Zealand soils whose Cu contents range from 2 to 150 ppm with a mean of 17.5 ppm. However, Wells reported that the availability of copper as assessed by uptake by the grass sweet vernal (*Anthoxanthum odoratum* L.) was low; 2.1 ppm Cu in the foliage is second lowest in a country-wide range of 2.0 to 7.3 ppm (159 soils). This low availability of copper seems to be related to the unweathered nature of the sand and the high pH (6.3). It is likely that copper availability in the recently stabilised "blown sand" (pH 7.0) would be even lower.

EXPERIMENTAL

In 1968, foliage samples were taken from distorted trees in the 1962 planting area. Analyses showed levels of less than 1 ppm Cu which is well below the usual 3-5 ppm Cu found in the foliage of healthy trees on other soils in New Zealand and is within the deficiency range suggested by Stone (1968).

On the basis of these analyses and the observations described above, a fertiliser trial was established in December 1968 in Compartment 25, Mangawhai Forest, which had been planted in 1964.

Eighteen plots each of 0.02 ha were laid out, and the following six treatments were each applied to three plots selected at random:

1. Control
2. Copper sulphate (bluestone) 28 kg/ha
3. Potassium sulphate (626 kg/ha)
4. Ammonium sulphate (626 kg/ha) plus superphosphate (1,253 kg/ha)
5. (2) + (3) + (4) plus Mg, B, Zn (complete)
6. (3) + (4) plus Mg, B, Zn (complete minus Cu)

A treatment with potassium was included as branch twisting is known to be a symptom of K deficiency (Hall and Raupach, 1963); also an N plus P treatment was included in line with Ruiter's (1969) trial. When the trial was established, some trees were showing slight branch and leader twisting, and it was expected that this would increase with age as it had in earlier plantings.

No improvement was observed during the remainder of the 1968-69 growing season, and a further 56 kg/ha of copper sulphate was applied to all copper-treated plots in July 1969. At about this time a pot trial with barley seedlings showed that some stimulation of growth in Mangawhai sand followed the addition of copper (Gadgil, 1970).

In April 1970, near the end of the 1969-70 growing season, there were obvious treatment differences, and an assessment was made of the degree of twisting in the current season's leader and branch growth. It was found that in any one tree intensity of branch twisting was directly related to twisting in the leader, and the more severe the branch twisting, the flatter the branch angle. As a result it was decided to classify overall distortion into three classes:

1. Severe
2. Slight
3. Absent (normal growth)

The tree shown in Fig. 1 would have been classified 1 (severe distortion) but it was not as bad as some. In the non-copper plots, it was noticeable that some of the most severely distorted trees suffered from needle-tip burn, but in this coastal forest it was impossible to judge whether this was due to copper deficiency itself or to an increased susceptibility to salt burn. There was also a higher than usual incidence of fused needles, an abnormality known to be caused by nutrient imbalance; it is also associated with P and B deficiencies.

FIG. 1—Mangawhai Forest 7-yr-old radiata pine tree showing twisting of branches and leader, and flat branch angle symptomatic of copper deficiency.

If there was any doubt whether or not a slight distortion was present, trees were classified 2 rather than 3. This almost certainly led to a number of trees being classified 2 while in fact they were not copper deficient, but showed some slight branch waver or flatter branch angle possibly of genetic origin.

TABLE 1—Numbers of radiata pine trees per 0.02 ha in each distortion class 16 months after fertiliser treatment. Figures are the mean from three plots of each treatment

Treatment	Severe	Slight	Absent
Control	8 a	15 cd	4 e
Cu	0 b	8 c	19 f
K	7 ab	20 d	2 e
N + P	10 a	17 d	2 e
Complete	3 ab	15 cd	9 f
Complete minus Cu	11 a	15 cd	2 e

Values not having a letter in common are significantly different at the 1% level

Results of the assessment are given in Table 1. At the time of the assessment, composite foliage samples were collected from four of the six treatments; foliage copper concentrations are given below. Composite samples were taken from at least 10 trees in each treatment. The following figures (ppm Cu) are means of duplicates that did not differ by more than 10%: control, 1.6; N + P, 1.4; Cu, 2.9; complete, 2.8. The data in Table 1 were converted into percentages, angularly transformed, and examined by analysis of variance. Values for least significant difference were calculated using the table by Duncan (1955), and results are included in Table 1. While the application of copper significantly reduced the distortion, there is an indication that it was more effective alone than in combination with other elements; this agrees with the findings of Ruiter (1969) who found that the addition of N and P increased the need for copper.

It appears certain that the effective agent in copper sulphate is in fact the copper and not the sulphate; greater quantities of sulphate contained in the potassium sulphate, ammonium sulphate and superphosphate treatments had no beneficial effect.

The development of permanent branch twisting has been observed on a pumice soil at the Forest Research Institute, in a clonal trial where some trees received a restricted supply of N and P. Those ramets which were slightly deficient in N or P had short needles and were unaffected by periods of rain in the early summer. Trees with normal supplies of N and P developed longer, heavier needles, and during periods of rain the additional weight of water on the needles weighed down newly-developed shoots. When rain persisted for more than 3 or 4 days the proximal part of the resulting downward bend became permanent and the later correction of the distal part of each bend produced an upward turn. The excessive twisting found in trees on copper deficient sites suggests a lack of stiffness in branches and leaders which makes them more susceptible to the effects of rain.

CONCLUSIONS

1. Copper deficiency is the cause of severely distorted growth in radiata pine in Mangawhai Forest.

2. Copper deficiency in radiata pine results in:
   (1) Twisting of branches and a flatter branch angle.
   (2) Twisting of the leader; in severe cases the leader bends to grow horizontally.
   (3) A higher than normal incidence of needle fusion.
   (4) Needle tip burn—whether caused by the deficiency itself or by an increased susceptibility to salt burn.
3. The critical level of copper in radiata pine foliage is *ca.* 3 ppm but may vary with the levels of other nutrients, particularly N and P.

ACKNOWLEDGMENTS

The help of Mr N. Wells of Soil Bureau, who made the initial copper analyses is gratefully acknowledged; also the work of Dr D. J. Mead and Messrs J. F. F. Hobbs, D. Graham and R. Ballard in the field, and Messrs P. J. Knight and P. Hodgkiss in the laboratory.

REFERENCES

DUNCAN, D. B. 1955: Multiple range and multiple F tests. **Biometrics 11:** 1-42.

GADGIL, R. L. 1970: Miscellaneous glasshouse experiments on the nutritional potential of some North Island coastal sands. **New Zealand Forest Service, Forest Research Institute, Soils and Nutrition Report 17** (unpublished).

HALL, M. J. and RAUPACH, M. 1963: Foliage analyses and growth responses in **Pinus radiata** showing potassium deficiencies in Eastern Victoria. **Appita 17:** 76-84.

New Zealand Soil Bureau 1954: General survey of the soils of the North Island, New Zealand. **New Zealand Department of Scientific and Industrial Research, Soil Bureau Bulletin 5.**

OLDENKAMP, L. and SMILDE, K. W. 1966: Copper deficiency in Douglas fir. **Plant and Soil 25:** 150-2.

RUITER, J. H. 1969: Suspected copper deficiency in radiata pine. **Plant and Soil 31:** 197-200.

STONE, E. L. 1968: **In** "Forest Fertilisation—Theory and Practice". Tennessee Valley Authority, Norris.

van GOOR, C. P. 1968: Spurenelemente bei der Ernahrung von Koniferen. (Trace elements in conifer nutrition) **Tagungsberichte, Deutsche Akademie der Landwirtschaftswissenschaften zu Berlin 84:** 147-55.

WELLS, N. 1957: Soil studies using sweet vernal to assess element availability. Part 3: Copper in New Zealand soil sequences. **New Zealand Journal of Science and Technology 38B:** 884-902.