RESPONSE OF RADIATA PINE TO SUPERPHOSPHATE AND CHRISTMAS ISLAND 'C' PHOSPHATE FERTILISERS

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ABSTRACT

Christmas Island 'C' phosphate ore (0, 52, and 104 kg/ha P) was compared with ordinary superphosphate (52 kg/ha P) in a fertiliser trial in 7-year-old radiata pine (**Pinus radiata** D. Don) regeneration growing on P-deficient soil in Maramarua Forest. Growth response and foliar P level confirmed that a soil phosphate deficiency existed, and indicated that the response was related to P availability, and that even the most effective treatment (104 kg/ha P as the ore) was insufficient for optimum growth.

It was estimated that 30% more fertiliser ore (67% more P) would be needed to produce the same volume of wood as the particular superphosphate treatment. There was no indication that the phosphate ore was a longer-lasting source of P.

Christmas Island 'C' phosphate ore shows promise as a fertiliser for trees on acid clay soils. However, at present its potential is limited because it is not available in a form suitable for distribution from the air.

INTRODUCTION

Superphosphate is the current source of P applied to forests on the phosphate-deficient soils of North Auckland; it has proved an acceptable fertiliser, producing good responses. Rock phosphates, which are cheaper per unit of P, have been suggested as possible alternative sources for trees, particularly if the problems of aerial spreading can be overcome (Knight and Will, 1971; Pritchett and Smith, 1969). On the acid, moderately P-fixing clay soils often found in North Auckland forests, rock phosphate should be a slowly available, long-lasting source of P to trees.

The Christmas Island 'C' grade phosphate ore used in this experiment is primarily crandallite and millisite and occurs as an overburden to the more valuable higher grade phosphates. From pot trial tests Knight and Will (1971) concluded that this phosphate source was only very slowly available to pine seedlings, compared with reverted or ordinary superphosphate, or calcined Christmas Island 'C' phosphate ore.

The present long-term field trial was designed to test the usefulness of the uncalcined Christmas Island 'C' grade phosphate ore.

METHOD

The experiment was established in a 7-year-old stand of radiata pine (*Pinus radiata* D. Don) natural regeneration growing on a phosphate-deficient clay soil in Maramarua

Forest. The topsoil (0-10 cm) was acid with a pH of 4.7 and had a medium P retention of 40% (New Zealand Soil Bureau, 1972).

The trial consisted of two replicates of four treatments:
(1) Control
(2) 52 kg/ha P as superphosphate
(3) 52 kg/ha P as Christmas Island 'C' phosphate
(4) 104 kg/ha P as Christmas Island 'C' phosphate

The superphosphate used had 8.3% total P compared to 10.7% in the Christmas Island 'C' phosphate ore. The latter fertiliser was in a finely ground form.

Plots were 0.1 ha in area and were separated by a 30 m buffer strip. Prior to topdressing, the regeneration was thinned to about 1,600 stems/ha. The remaining trees were, however, still extremely variable in size, ranging from 0.3 to 6 m in height. Height growth was followed on 20 trees/plot which were initially between 1.7 and 2.6 m tall. Heights were measured biennially for 8 years. At the end of the ninth growing season (age 16) all diameters greater than 6.4 cm at breast height and predominant mean heights were measured. From these measurements, basal area/ha, mean diameter of the 247 largest trees/ha (i.e., 100/acre) and volume/ha were calculated.

Upper crown current foliage was collected biennally from three trees/plot. These samples were analysed for total P.

RESULTS AND DISCUSSION

Growth Response

The response to fertilisers was dramatic. A significant height response was evident at the first remeasurement 2 years after fertiliser application (Table 1). Nine years after topdressing the control plots had only about 20% of the volume of the best treatment (Table 2).

TABLE 1—Influence of phosphate fertilisers on height growth
(means of two replicates)

Treatment	Years after topdressing* 0	2	4	6	8
	mean height (m)				
	0	2	4	6	8
Control	2.1	3.0	4.5	5.6	7.4
Superphosphate — 52 kg/ha P	2.1	3.5	6.4	9.4	12.6
Christmas Island 'C' — 52 kg/ha P	2.1	3.2	5.7	8.1	10.6
Christmas Island 'C' — 104 kg/ha P	2.1	3.9	7.4	10.7	14.5

* The treatments were significantly different at the 5% level at age 2, at the 1% level at ages 4 and 6, and at the 0.1% level at age 8. The 3 rates of Christmas Island phosphate show significant linear effects (1% level or better) but the quadratic effects are non-significant at the 5% level.

TABLE 2—Results, on a plot area basis, 9 years after treatment*
(means of two replicates)

Treatment	P. M. Ht.[a] m	B. A. m^2/ha	Mean top d.b.h.[b] mm	Total Vol. m^3/ha
Control	13.4	6.77	147	34.9
Superphosphte — 52 kg/ha P	18.00	22.46	231	146.8
Christmas Island 'C' — 52 kg/ha P	15.4	14.63	185	84.0
Christmas Island 'C' — 104 kg/ha P	20.1	25.44	259	181.5

* Treatments significantly different at 0.1% level for all parameters. The Christmas Island phosphate gave significant linear effects (0.1% level) for all parameters and significant positive quadratic effects (5% level) for P.M. Ht., mean top d.b.h., and total volume.

[a] Average height of the largest 100 trees/ha.

[b] Average diameter at breast height of the largest 247 trees/ha.

The response curve exhibited by the three rates of Christmas Island 'C' phosphate (0, 52, and 104 kg/ha P) was either linear or had a significant positive quadratic component, depending on the growth parameters (Tables 1, 2). This indicates that the rates only cover the lower portion of the theoretical response curve; even the highest rate is not optimal.

The superphosphate treatment produced a response intermediate between the two rates of phosphate ore. The rate of Christmas Island ore (in kg/ha of fertiliser and kg/ha total P) which would produce growth equivalent to the 52 kg/ha P as superphosphate, was graphically determined (Table 3). To produce the same volume response as in the superphosphate plots, it appears necessary when using the ore to add about 67% more total P or 30% more fertiliser. There is no evidence that the rock phosphate produces a more prolonged response than superphosphate. Rather, an increasing quantity of rock phosphate was apparently needed for equivalence to superphosphate at the later remeasurements (Table 3).

TABLE 3—Equivalent amount of Christmas Island 'C' phosphate ore needed to produce a similar response to 630 kg/ha superphosphate which contains 52 kg/ha P

Parameter	kg/ha P as Christmas Island 'C' ore	kg/ha Christmas Island 'C' ore
Height 2 years after topdressing	73	685
Height 4 years after topdressing	75	705
Height 6 years after topdressing	80	750
Height 8 years after topdressing	82	770
P. M. height 9 years after topdressing	84	790
B. A. 9 years after topdressing	90	845
Total vol. 9 years after topdressing	87	820

Foliage P Levels

The foliage P concentrations indicate that the control plots and those receiving the low rate of rock phosphate were very deficient (Table 4). The highest levels recorded

by the better treatments were about the critical level described by Will (1965). However, only the samples collected 8 years after the fertiliser was applied showed statistically significant differences between treatments.

TABLE 4—Foliage P concentrations
(means of two replicates)

Treatment	Years after treatment				
	0	2	4	6	8*
	% P				
Control	0.081	0.065	0.063	0.070	0.070
Superphosphate — 52 kg/ha P	0.082	0.095	0.115	0.088	0.100
Christmas Island 'C' — 52 kg/ha P	0.086	0.085	0.070	0.080	0.082
Christmas Island 'C' — 104 kg/ha P	0.081	0.090	0.100	0.100	0.090

* Treatments significantly different at 5% level

Height increments were linearly related to foliage P concentrations. The relationship between 2-year height increments between age 9 and 15 and foliar P concentration before the start of the increment periods was significant at the 0.1% level, and the inclusion of a quadratic term did not improve the fit:

P.M.A. Ht. incr. (m) = 17.25 (% P) — 0.15 R^2 = 0.585

P.M.A. Ht. incr. (m) = 16.63 (% P) + 2.54 (% P)^2 — 0.13 R^2 = 0.591

Foliage analyses thus confirm that the trial was carried out under deficiency conditions and indicate that the response was directly related to the uptake of P. They confirm that no treatment completely corrected the deficiency.

Potential for Christmas Island 'C' Phosphate Ore

The Christmas Island 'C' ore, even when uncalcined, proved about 75% as effective as superphosphate on the basis of an equal weight of fertiliser. The calcined material could be expected to have a greater availability, based on the study by Will and Knight (1971). The main problem in the use of these cheaper products now lies in the difficulty of spreading finely ground fertiliser from the air. This might be overcome in the future if suitable granulation techniques could be developed; in the meantime ground application might be feasible in some circumstances.

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REFERENCES

KNIGHT, P. J. and WILL, G. M. 1971: Pot trial evaluation and comparison of six potential sources of phosphate for forestry. **New Zealand Journal of Forestry Science 1:** 22-36.

NEW ZEALAND SOIL BUREAU, 1972: Soil Bureau Laboratory Methods. **New Zealand Soil Bureau Scientific Report 10.**

PRITCHETT, W. L. and SMITH, W. H. 1969: Sources of nutrients and their reactions in forest soils. **Soil and Crop Science Society of Florida Proceedings 29:** 149-158.

WILL, G. M. 1965: Increased phosphorus uptake by radiata pine in Riverhead Forest following superphosphate applications. **New Zealand Journal of Forestry 10:** 33-42.