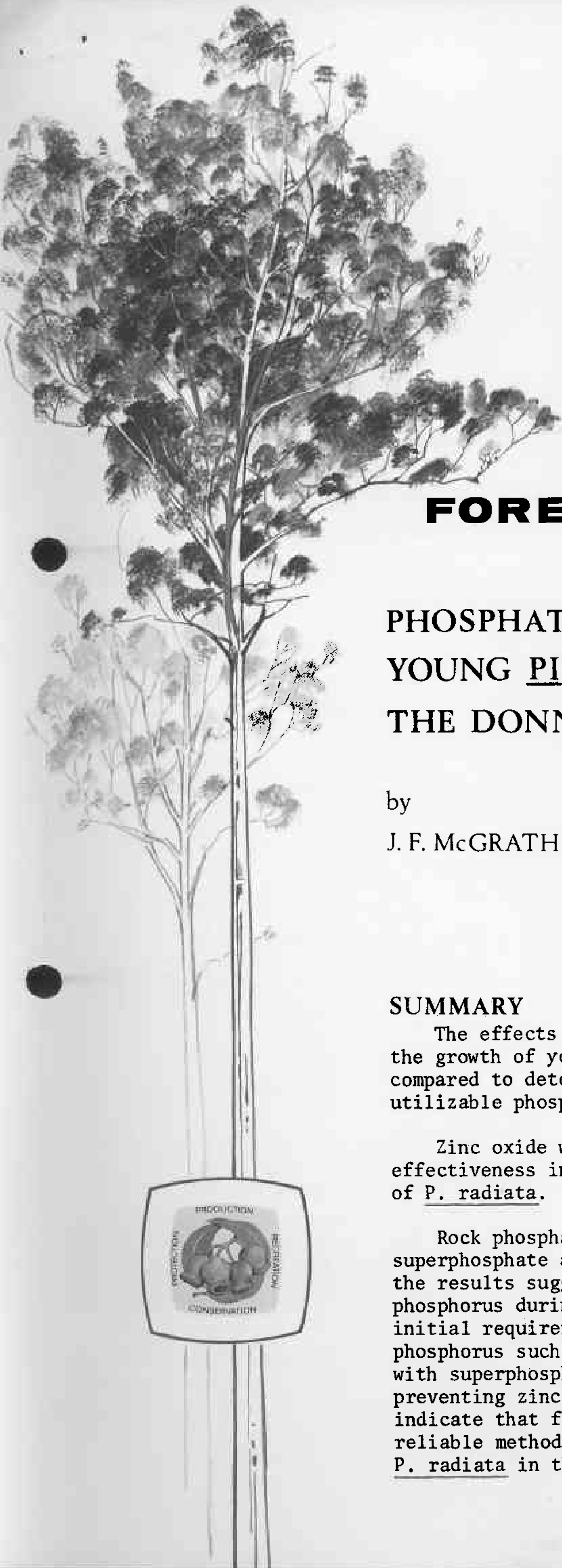

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PHOSPHATE AND ZINC NUTRITION OF YOUNG PINUS RADIATA D. DON IN THE DONNYBROOK SUNKLAND

by

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SUMMARY

The effects of rock phosphate and superphosphate on the growth of young *Pinus radiata* D. Don trees were compared to determine a suitable initial source of utilizable phosphorus.

Zinc oxide was evaluated to determine its effectiveness in supplying the initial zinc requirements of *P. radiata*.

Rock phosphate was found to be inferior to superphosphate as an initial phosphate source. However, the results suggest that it may be a valuable source of phosphorus during later growth, particularly when the initial requirements are met by a more available form of phosphorus such as superphosphate. Applying zinc oxide with superphosphate was only partially effective in preventing zinc deficiency of *P. radiata*. The trials indicate that foliar spraying is a more effective and reliable method of providing zinc requirements of *P. radiata* in the Donnybrook Sunkland.

INTRODUCTION

In 1971 trials were established in the Donnybrook Sunkland to evaluate rock phosphate as an alternative to superphosphate, and to determine the value of zinc oxide as a source of zinc for *Pinus radiata* D. Don.

The Donnybrook Sunkland has been described by McKinnell (1976) as the area south of Bunbury bounded by the Darling and Dunsborough Faults, the Whicher Scarp and the Scott Coastal Plain. It is an area of low relief and poor drainage.

The soils of the area have been described by Smith (1951). The soils on the low ridges are poor quality lateritic gravels interlaced with lateritic boulders (Forest Grove type); this soil type is classified by the Forests Department (unpublished data) as unsuitable for pines. The soils below the ridges are mainly grey sands and sandy loams which increase in texture with increased depth (Mungite type).

The slightly acid (pH 5.5 - 6.0) sands and sandy loams which constitute the majority of the soils classified by the Forests Department of Western Australia as suitable for pine plantation establishment require the addition of phosphorus, zinc, copper, manganese and probably nitrogen for the establishment of *P. radiata* D. Don (Forests Department, unpublished data).

The effectiveness of providing the phosphorus needs in a slow-release form of phosphate was investigated in order to reduce the frequency of phosphate refertilisation currently necessary to maintain a pine plantation in a healthy condition. A high percentage of the phosphorus in rock phosphate is in a slow-release water-insoluble form, possibly dicalcium phosphate (Russell, 1973).

The objectives of this trial were twofold:

(1) To determine the effect of the slower rate of phosphorus release by rock phosphate on the initial growth of *P. radiata*, and to determine whether any residual effect of the fertiliser is apparent in later growth.
(2) To determine whether zinc oxide applied with superphosphate at planting supplies adequate zinc for the establishment of *P. radiata*.

METHOD

The trial was located at three different sites on the Sunkland. The soils at Site 1 and Site 2 are grey sands which become more heavily textured with increased depth (Mungite). The soil at Site 3 is coarser and contains some lateritic gravel and scattered large lateritic boulders (Forest Grove).

The sites were cleared and burnt in 1970 and double ploughed and mounded in 1971. Sites were planted with one-year-old *P. radiata* seedlings in June 1971 at a spacing of 2.7 m between mounds and 2.1 m on the mounds.

Table 1 shows the fertiliser treatments applied at the initial planting.

TABLE 1

Initial fertiliser treatments applied in July 1971 (with chemical composition shown)

Treatment no.	Fertiliser	Rate of fertilisation (g/tree)
(1)	Superphosphate (9.6% P)	227
(2)	Rock phosphate (15.9% P)	142
(3)	Super copper zinc "A" (8.7% P, 0.66% Cu, 9.6% Zn)	227
(4)	Super copper zinc "B" (8.9% P, 0.33% Cu, 0.3% Zn)	227
(5)	Special super zinc oxide mixture: Superphosphate	227
	plus zinc oxide equivalent to 22.5 g Zn/tree	28

The zinc in treatments (3) and (4) is zinc oxide. Treatments were arranged in a 5 x 5 Latin Square on each site. Individual plot sizes varied slightly but were approximately 0.02 ha each.

Height of all trees was measured in August 1972, July 1973 and November 1974. Plot top height was measured in March 1976. The three tallest trees in each plot were used to compute top height for the 1972, 1973 and 1974 data.

Diameter breast height over bark was measured in 1976 and 1977, and this was used to calculate basal areas.

Two sample trees per plot were monitored annually from 1973 for nutrient concentrations in the foliage. Samples were collected in early autumn from the youngest developed whorl and analysed for phosphorus and zinc. Unfortunately the samples had to be bulked by treatment in 1975, 1976 and 1977.

Plots showing needle chlorosis were recorded in 1972. In 1973 the percentage of trees on each plot showing needle chlorosis was recorded.

RESULTS

The survival data presented in Table 2 show no significant differences in tree survival between the five treatments: neither the phosphate source nor zinc oxide application affected survival in the first year.

Although survival was not affected by treatment, the 1972 top height data showed that height growth on the rock phosphate plots was significantly poorer ($p < 0.01$) than on the superphosphate plots. This trend continued for the duration of the trial (Fig. 1). The 1976 and 1977 basal area measurements indicated that diameter growth was also poorer ($P < 0.01$) for trees fertilised with rock phosphate rather than superphosphate (Fig. 2).

The responses to treatment were similar on each plot and there was no significant interaction between sites and treatments. Height and diameter growth variations between the three sites were not significant.

The application of zinc oxide with superphosphate did not significantly increase height or diameter growth on any of the sites (Figs. 1 and 2).

The results of the foliar analysis for phosphorus (Table 3) and zinc (Table 4) did not show any statistically significant results, probably because of the large variability in the data. Statistical analysis of the 1975, 1976 and 1977 data was not possible as the replicates were bulked before analysis.

The main trends evident from the foliar analysis data are as follows. Phosphorus concentrations in the first two samplings (1973 and 1974) were low on all treatment areas, but lowest on the rock phosphate treatment areas. Following refertilisation in 1974 (Table 5) the 1975 phosphorus concentrations increased on all treatments. In contrast with the earlier results the 1975, 1976 and 1977 foliar phosphorus concentrations on the rock phosphate treatment areas were equal to or greater than the concentration of the superphosphate treatment areas.

TABLE 2

Mean per cent tree survival in first year

Site	Fertiliser treatment				
	Super-phosphate	Super Cu Zn "A"	Super Cu Zn "B"	Rock phosphate	Super ZnO
1	94.8	90.5	93.9	99.4	94.4
2	97.8	100.0	98.1	98.8	100.0
3	98.3	97.4	96.8	97.0	96.1
Mean aggregate	97.0	96.0	96.3	98.4	96.8

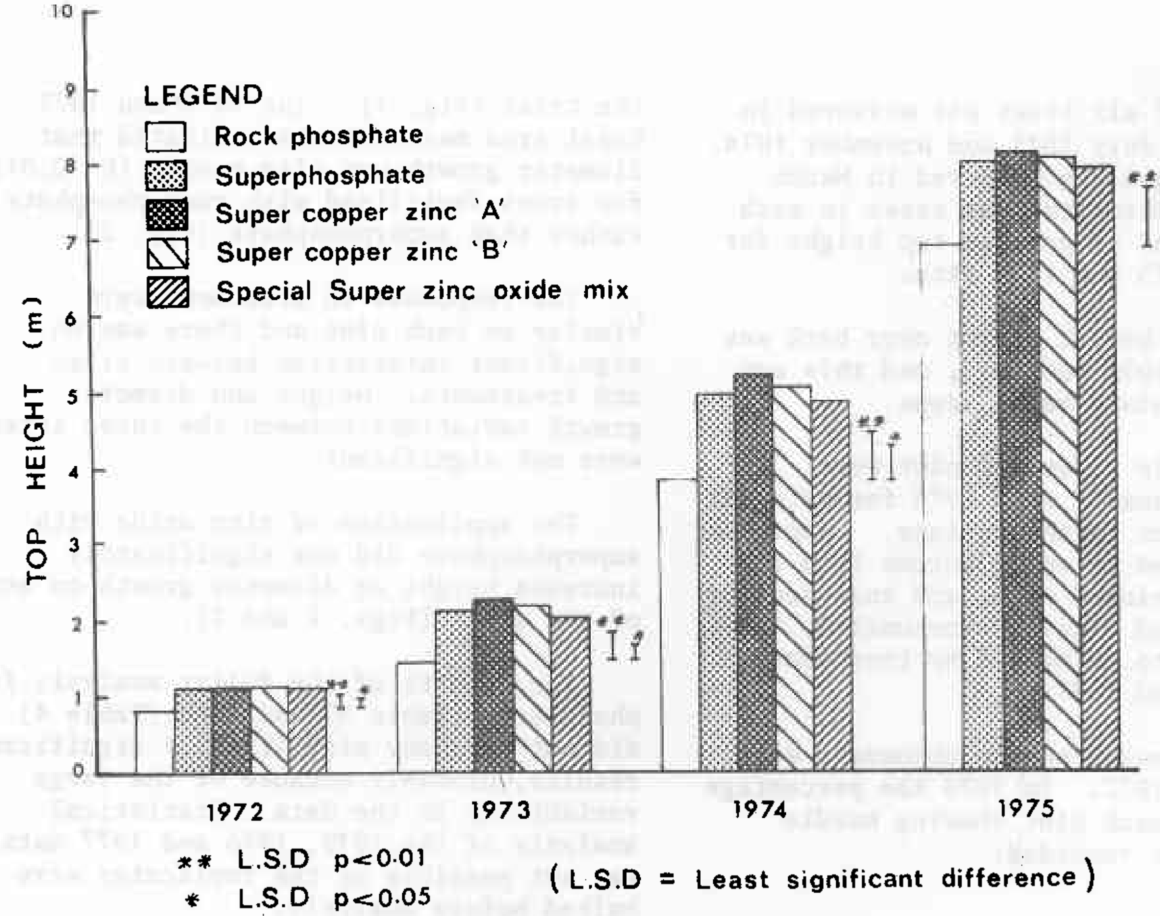

FIGURE 1: Mean top height for the three sites (1972 to 1976)

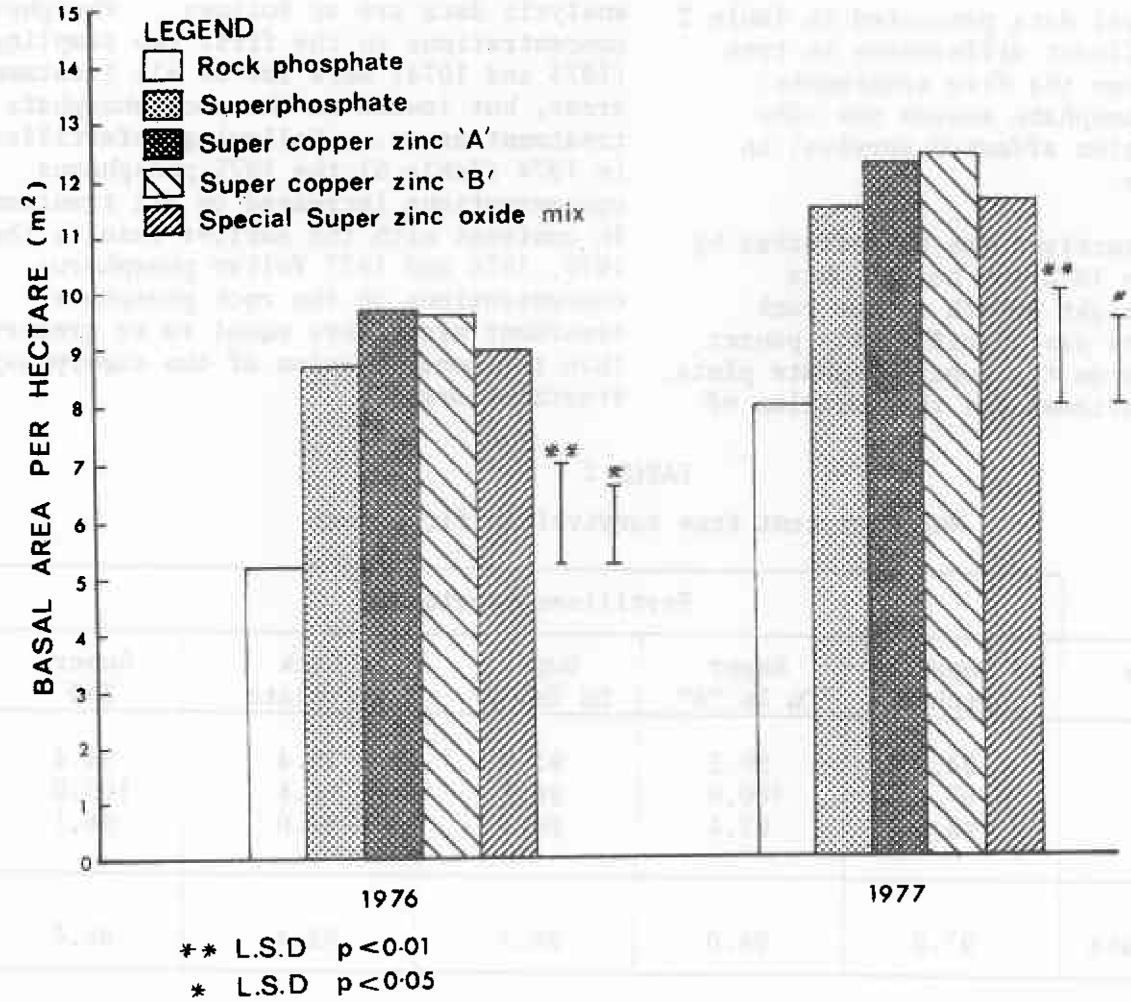

FIGURE 2: Mean basal areas for the three sites (1976 and 1977)

TABLE 3

Foliar phosphorus concentrations (per cent dry weight) 1973-1977

Site	Year	Fertiliser treatment: Rock phosphate	Super-phosphate	Super Cu Zn "A"	Super Cu Zn "B"	Super + ZnO	Mean
1	1973	0.068	0.081	0.081	0.069	0.060	0.071
	1974	0.100	0.109	0.113	0.114	0.123	0.111
	1975	NS	NS	NS	NS	NS	NS
	1976	0.139	0.123	0.126	0.119	0.103	0.122
	1977	0.102	0.112	0.101	0.097	0.102	0.103
2	1973	0.052	0.068	0.066	0.060	0.063	0.066
	1974	0.116	0.138	0.136	0.130	0.143	0.133
	1975	0.141	0.137	0.104	0.130	0.139	0.130
	1976	0.123	0.115	0.102	0.105	0.110	0.113
	1977	0.102	0.100	0.100	0.088	0.101	0.098
3	1973	0.056	0.071	0.104	0.085	0.086	0.080
	1974	0.091	0.113	0.135	0.112	0.106	0.111
	1975	0.148	0.154	0.185	0.162	0.181	0.166
	1976	NS	NS	NS	NS	NS	NS
	1977	NS	NS	NS	NS	NS	NS
Mean aggregate		0.103	0.110	0.113	0.106	0.110	

NS = not sampled

TABLE 4

Foliar zinc concentrations (ppm) 1973-1977

Site	Year	Fertiliser treatment: Rock phosphate	Super-phosphate	Super Cu Zn "A"	Super Cu Zn "B"	Super + ZnO	Mean
1	1973	15	17	22	13	17	17
	1974	21	18	25	23	32	24
	1975	NS	NS	NS	NS	NS	NS
	1976	31	34	39	38	36	36
	1977	38	37	34	31	39	36
2	1973	12	11	17	14	18	14
	1974	15	16	31	24	30	23
	1975	50	49	48	47	52	49
	1976	38	30	36	33	41	36
	1977	31	27	35	26	38	31
3	1973	13	10	17	15	18	15
	1974	14	15	20	19	26	19
	1975	47	42	50	46	55	48
	1976	NS	NS	NS	NS	NS	NS
	1977	NS	NS	NS	NS	NS	NS
Mean aggregate		27	26	31	29	34	29

NS = not sampled

TABLE 5

Fertiliser and silvicultural treatments

Site	Superphosphate application		Foliar sprays		**Pruning date
	Quantity (kg/ha)	Date	*Quantity (per cent)	Date	
1	200	26 August 1974	Zn : Mn : Cu 5.0: 5.0: 0.2	22 November 1974	August 1975
2	200	26 August 1974	Zn : Mn : Cu 2.5: 2.5: 0.1	17 November 1975	August 1975
3	400	12 February 1974	Zn : Mn 2.5: 2.5	12 February 1974	June 1975
			Zn : Mn : Cu 5.0: 5.0: 0.2	11 December 1974	

* Per cent by weight of Zn, Mn, Cu sulphates in aqueous solution

** Low pruned only at this stage (2.1 m)

Foliar zinc concentrations were marginal to deficient in 1973 and 1974 (Table 4); the lowest zinc concentrations were observed on the plots receiving treatments excluding zinc. Foliar zinc concentrations more than doubled between 1974 and 1975 at Sites 2 and 3 (no data was available for Site 1) after refertilisation and following the application of a foliar zinc spray (see Table 5). The zinc concentrations declined slightly in 1976 and 1977.

The low zinc concentrations in the minus zinc plots were reflected in the occurrence of needle chlorosis in 1972 and 1973. In 1972 needle chlorosis was evident on some superphosphate (minus zinc) plots at each site. (2 plots at Site 1, 2 plots at Site 2, 3 plots at Site 3).

Table 6 shows that in 1973 needle chlorosis was evident to some extent on all plots. The percentage of trees with needle chlorosis was significantly higher ($p < 0.01$) on the minus zinc plots than the plus zinc plots, and corresponded to the lower zinc concentrations found in the minus zinc plots.

DISCUSSION

Initial growth is depressed when phosphorus is supplied as rock phosphate

TABLE 6

Mean percentage of trees showing needle chlorosis (1973)

Fertiliser treatments	Sites			Mean aggregate
	1	2	3	
Rock phosphate	64	76	73	71
Superphosphate	48	76	81	68
Super Cu Zn "A"	25	23	56	35
Super Cu Zn "B"	30	23	59	37
Special super ZnO mix	34	58	53	48

L.S.D. $p < 0.01$ = 18.3
$p < 0.05$ = 13.8

(L.S.D. = least significant difference)

rather than superphosphate. The initial depression in growth remained throughout the experiment even though all plots were refertilised with superphosphate in 1974 (Table 1). This coincides with Waring's (1976) findings which indicated that the initial growth stages are most important in determining the ultimate plantation yield.

The foliar phosphorus concentrations in 1973 and 1974 were lower for the rock phosphate treatments than the superphosphate treatments, indicating that the poor initial growth on the rock phosphate plots was probably due to phosphorus deficiency. Rock phosphate was found to be an inferior source of phosphate for P. radiata establishment in the Donnybrook Sunkland.

Will (1965) showed that foliar phosphorus concentrations of P. radiata are a good indicator of tree phosphorus status. Will determined a critical phosphorus concentration of 0.11% in the needles of the top whorl. This is similar to the critical phosphorus concentration of 0.10% established by Raupach et al. (1969), who also suggest that an adequate concentration is 0.17% or greater. At a critical level of either 0.1 or 0.11% the phosphorus concentrations of all treatments were below the deficiency level in 1973. This suggests that the initial superphosphate application of 227 g per tree may not be adequate for optimum initial growth.

The highest phosphate concentrations were found at Site 3 in 1975 following refertilisation with 400 kg/ha of superphosphate in 1974 (twice the rate used at Sites 1 and 2). These concentrations (see Table 1) were close to the adequate concentration of 0.17% suggested by Raupach et al. (1969). The higher concentrations at Site 3 compared with those at Sites 1 and 2 are probably due to the higher rate of superphosphate applied at the 1974 refertilisation.

Refertilisation with superphosphate on all plots in 1974 (Table 1) three years after initial fertilisation did not reduce the difference in height growth between the rock phosphate and superphosphate treatments. Following refertilisation the rock phosphate treatments tend to have higher foliar phosphorus concentrations. As rock phosphate has a residual effect (Russell, 1973) the higher phosphorus concentrations may be due to the residual effect of rock phosphate or to the slower growth of these trees causing a concentration of nutrients in the foliage.

Although rock phosphate is not a good initial phosphorus source it could be useful as a slow-release fertiliser when the initial phosphate requirements are provided in a more available form such as superphosphate or Agras 18-18 (18% N, 7.9%P). Trials have been established to determine the effectiveness of rock phosphate as a slow-release fertiliser when used in conjunction with superphosphate.

Although zinc oxide application had no significant effect on height or diameter growth at any stage of the trial, the 1973 and 1974 foliar zinc concentrations of the plus zinc treatments were generally higher than the concentrations of the minus zinc plots.

If the zinc concentration of 14 ppm is taken as the critical foliar zinc concentration (Hatch, personal communication), then the zinc levels of the minus zinc plots were marginal or deficient in 1973 on all sites and marginal on Sites 2 and 3 in 1974. The zinc concentrations of the lowest zinc treatment (Super Cu Zn "B") were marginal in 1973. The lower zinc concentrations found on the minus zinc plots coincide with the higher percentage of needle chlorosis (Table 5), thus at least some of the needle chlorosis is attributable to zinc deficiency. Application of the zinc sulphate spray to the foliage resulted in the disappearance of the needle chlorosis.

Between 1974 and 1975 the foliar zinc concentrations at Site 2 and Site 3 more than doubled. The increase at Site 3 could be explained by the application of the foliar zinc spray in November 1974.

Site 2 did not receive a zinc spray until November 1975 and this makes the increase in zinc levels difficult to explain in terms of foliar zinc application.

The results of the zinc experiment are inconclusive concerning foliar spraying; however, as spraying remedied the needle chlorosis it is recommended as the best method of preventing zinc deficiency at present. Zinc oxide application with superphosphate at planting seemed to be only partially effective in preventing zinc deficiency.

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