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UNDERSTOREY TO BROADCAST
NITROGEN AND PHOSPHORUS FERTILIZER
ON A REHABILITATED BAUXITE MINE

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SUMMARY

The effect of a factorial combination of four nitrogen (0, 30, 60, 90 kg ha⁻¹ elemental) and four phosphorus (0, 30, 60, 90 kg ha⁻¹ elemental) fertiliser rates on four seeded plant species was examined in a field experiment on a rehabilitated bauxite mine. Two of the species (Eucalyptus maculata and E. marginata) were overstorey trees and the other two were understorey legumes (Acacia lateriticola, Kennedia coccinea).

At 2.5 years of age, both E. maculata and E. marginata showed a growth response to increasing both nitrogen and phosphorus fertiliser rates. For both species, when the nitrogen (N) rate was low there was response to phosphorus (P). As N rates increased, there was an increasing response to P, even at the highest rate of 90 kg ha⁻¹ P. Similarly the response to N by both species was limited by the rate of P fertiliser. This shows a strong interaction between these two elements.

After one year A. lateriticola height growth was significantly affected by both N and P rate; after 2.5 years only P had a significant effect. The ability of this legume to fix nitrogen is probably the reason for this lack of response to N in the second year.

There was a trend for higher P rates to produce a greater percentage cover of the creeper Kennedia coccinea. However, this effect was not significant due to the patchiness of the cover and the tendency of this species to grow into neighbouring plots.

Weed densities were significantly higher when N and P fertiliser were applied but increasing the rate of fertiliser had no effect.

For areas to be rehabilitated in 1988 using seeded Eucalyptus species, a rate of 72 kg ha⁻¹ N and 80 kg ha⁻¹ P will be applied. These rates are based on this and other experimental results.

INTRODUCTION

Until recently, the standard fertiliser application for rehabilitation of bauxite mined areas was 450 kg ha⁻¹ of superphosphate as a broadcast application, plus a 200g tablet of diammonium phosphate (DAP) placed near the base of each planted tree seedling.

Work commenced in 1985 to examine the feasibility of establishing Eucalyptus species, particularly E. marginata, using seed instead of planted tree seedlings. In 1988, 174 ha out of a total of 330 ha will be rehabilitated using seed. This different technique necessitated a change in the methods of fertiliser application. A 200g tablet of DAP near each seedling was no longer possible and a broadcast fertiliser containing N was believed to be necessary.

Stoate (1953 cited in Abbott and Loneragan 1986) concluded that fertiliser did not affect the growth of E. marginata (jarrah) trees in the forest. In contrast Barrow (1977) showed a strong response to phosphorus by jarrah grown in pots and Kimber (1976) indicated that jarrah pole stands responded to urea (N) fertiliser. Hingston and Dimmock (1984) showed mature jarrah trees produced significant increases in girth when supplied with N or P. There was also a significant interaction between the two elements. All work carried out in rehabilitated bauxite mined areas and in coal mine wastes in W.A. has shown jarrah to respond strongly to N and P fertilisers, although its response is not as great as that of other faster growing eucalypts (Alcoa unpublished data, Koch 1984).

Other experiments have shown that a spring application produces better growth in seeded eucalypts than winter fertiliser application and that DAP is a suitable fertiliser (Alcoa unpublished data).

This report examines the performance of E. maculata, E. marginata, A. lateriticola, K. coccinea and the establishment of weed species in response to factorial combinations of four N and four P levels. The results will be used in selecting a fertiliser regime for the establishment of eucalypts by seed in rehabilitated bauxite mined areas.

METHODS

The experiment was established at Scarp Road (Del Park minesite) in July - September, 1985. Four species were selected for assessment - Eucalyptus marginata, Eucalyptus maculata, Acacia lateriticola and Kennedia coccinea. A seeding rate of 1.5 kg ha⁻¹ for jarrah and 0.8 kg ha⁻¹ for E. maculata was used. This produced about 10,000 stems ha⁻¹ of each species.

All areas were prepared for seeding according to standard practice (Nichols et al 1985), except that no basal broadcast fertiliser was applied.

The experiment consisted of a factorial combination of 4 nitrogen rates x 4 phosphorus rates x 4 species, giving a total of 64 treatments (Table 1). Each treatment was applied to a 4m x 4m plot and there were 4 replicate blocks. Seeding was carried out in July and fertilising in September.

The experiment was first assessed in July 1986 at one year old by measuring the height of the ten tallest E. marginata, E. maculata and A. lateriticola seedlings in each of the 4m x 4m treatment plots. The growth of K. coccinea was not assessed in 1986. The trial was re-assessed in December 1987 (2.5 years old) by measuring, in each plot, the height of all E. marginata, E. maculata and A. lateriticola individuals, and estimating the percentage cover of K. coccinea.

The total number of weeds was determined in each 4m x 4m plot. The weeds were Hypochoeris glabra, Senecio spp., Conyza bonariensis and Dittrichia graveolens, all annuals from the family Asteraceae.

Soil samples were taken at 0-10cm depth from five locations along each of five transects within each block. The samples from each transect were bulked together giving five samples per block.

The samples were dried at room temperature for approximately 72 hours and passed through a 2mm square-holed sieve. The fine earth fraction and the coarse gravel fraction of the samples were weighed and the percentage gravel calculated.

TABLE 1 - The 16 different fertiliser treatments used in the experiment. The weights are the amounts applied to each 4m x 4m plot. The subscripts refer to the elemental application rate in kg ha⁻¹

TITLE	FERTILISER
N_0P_0	Nil
N_0P_{30}	571g super No.1
N_0P_{60}	1143g super No.1
N_0P_{90}	1714g super No.1
$N_{30}P_0$	104g Urea
$N_{30}P_{30}$	104g Urea +571g super No.1
$N_{30}P_{60}$	104g Urea +1143g super No.1
$N_{30}P_{90}$	104g Urea +1714g super No.1
$N_{60}P_0$	208g Urea
$N_{60}P_{30}$	208g Urea +571g super No.1
$N_{60}P_{60}$	208g Urea +1143g super No.1
$N_{60}P_{90}$	208g Urea +1714g super No.1
$N_{90}P_0$	313g Urea
$N_{90}P_{30}$	313g Urea +571g super No.1
$N_{90}P_{60}$	313g Urea +1143g super No.1
$N_{90}P_{90}$	313g Urea +1714g super No.1

The fine earth fraction was analysed by a commercial laboratory. Total N was determined by Kjeldahl digestion, total P by tri-acid digestion followed by inductively coupled plasma emission spectrophotometry (ICP). Organic carbon was measured using the Walkley and Black method.

Data analysis was carried out using the SAS package (SAS 1982).

RESULTS

The mean height of Acacia lateriticola individuals at one year old was significantly affected by the application of nitrogen fertiliser. The best growth occurred in the N₃₀ treatment (Figure 1a). When assessed after 2.5 years A. lateriticola height was not significantly affected by the application of N fertiliser (Figure 1a).

Phosphorus fertiliser significantly affected the growth of A. lateriticola at both 1 and 2.5 years old. A. lateriticola with P₉₀ and P₆₀ fertiliser application were significantly taller than with P₃₀, which in turn were significantly taller than with P₀ (Figure 1b).

Kennedia coccinea was not assessed in 1986 but was assessed in 1987. Nitrogen and phosphorus fertiliser did not have a significant effect on percentage cover (Figure 2) although there was a trend of increasing cover particularly as P was increased. Because of its spreading habit the Kennedia plants often grew into neighbouring plots. It is likely that had the plot sizes been larger the response to N and P would have been significant.

The mean height of Eucalyptus maculata individuals at 1 and 2.5 years old was significantly affected by the application of nitrogen fertiliser (Figure 3). In a descending order the heights were N₉₀ = N₆₀ > N₃₀ > N₀ (p < 0.05).

Phosphorus fertiliser significantly affected the growth of E. maculata at both ages. After one year the height rankings were P₉₀ > P₆₀ > P₃₀ > P₀ (p < 0.05) (Figure 4). After 2.5 years the height rankings were P₉₀ > P₆₀ > P₃₀ > P₀ (p < 0.05) (Figures 4,5).

E. marginata responded to N fertiliser and P fertiliser in a similar manner to E. maculata. There was a significant response to the application of N. The jarrah increased in height as N rate was increased. The response to P was similar. In the absence of either N or P the response to increasing the application rate of the other element was limited thus indicating a strong interaction between the two

elements (Figures 6,7,8). Although E. maculata was taller than E. marginata when N and P were added, if N or P or both elements were missing then E. marginata grew taller than E. maculata (Figures 3 to 8).

The density of weeds was significantly affected by adding nitrogen and phosphorus fertiliser. Increasing the rate of application of nitrogen or phosphorus fertiliser above the N₃₀ P₃₀ level did not cause an increase in weed density (Figures 9,10).

There was a significant block effect. The plants in block 4 were taller than those in the other three blocks. Block 1 showed the poorest growth of E. maculata and A. lateriticola while E. marginata was shortest in block 3 (Figure 11).

Analysis of the soils collected from the four blocks showed that the surface of block 4 was mostly pit floor material brought up by the ripping operation. The pit floor material had a lower total N and organic carbon content and a sandy clay texture while the topsoil material from blocks 1 and 2 was of a sandy gravel texture. Block 1 soil had the highest organic matter and total N content (Table 2).

TABLE 2 - Soil parameters (0-10cm) for the four replicate blocks.

In columns, numbers followed by the same letter are not significantly different at the 5% level.

BLOCK	TOTAL N (PPM)	TOTAL P (PPM)	ORGANIC CARBON (%)	GRAVEL (%)	C:N	DESCRIPTION
1	662.0a	107.0	3.22	65.67a	49	All topsoil sandy gravel.
2	450.0b	172.0	1.92	69.21a	43	Mixture: mostly topsoil sandy gravel.
3	394.0b	194.0	2.54	52.46c	64	Mixture: mostly pit floor sandy clay.
4	390.0b	111.0	1.68	58.25b	43	Pit floor sandy clay.
		N.S.	N.S.			

DISCUSSION

The lack of response of A. lateriticola to N at 2.5 years old is probably due to the species ability to fix N and fulfil its own requirements. It did, however, show a continued response to P fertiliser which is expected with a legume species. The phosphorus response curve flattened off at a level of 60 to 90 kg ha⁻¹. Where Eucalyptus is planted in rehabilitated areas, the broadcast fertiliser is superphosphate (P only) at a rate of 500 kg ha⁻¹ (45.5 kg ha⁻¹ elemental P). This P is applied primarily to benefit the legume understorey. These results indicate that better understorey growth might be obtained by increasing this rate.

Although they responded similarly to the application of N and P, jarrah was always taller than E. maculata, when no N was applied or when no P was applied. This probably reflects the adaptation of jarrah to low fertility soils. The low rate of growth of jarrah was said by Chapin (1980) to be an important characteristic which reduces its nutrient requirement.

These lateritic soils are highly P adsorbing but very low in available P (Barrow 1977). They have high C:N ratios of 43-64 which indicates low N mineralisation rates. The low availability of N and P would explain the strong growth response by the eucalypts to both N and P. There was a significant interaction between N and P application. An interaction between application of N and P was also reported for jarrah by Abbott and Loneragan (1986). An N and P containing fertiliser must be used for the establishment and growth of seeded eucalypts on mined areas on the Darling Plateau.

Although any application of N and P fertiliser increased the density of weeds, there were less weeds in plots where good growth of Acacia or Eucalyptus occurred. The cover of weeds was never very high and it is not considered that they are a problem in rehabilitated bauxite mines provided a good cover of understorey legumes and overstorey trees is established.

The different growth performance in the four blocks is, at first sight, contrary to what was expected. Block 1, with the most topsoil and the highest total N and organic C content, produced the poorest growth while block 4 with lowest total N and organic C content produced the best growth. However, the growth difference is caused by differences in the textures of the soils and the type of N fertiliser used. Block 4 had a sandy clay texture which may have provided better retention of the urea N than block 1 which had a sandy gravel texture. Urea was found in other experiments to be an unsuitable source of N for new rehabilitated areas due to its high leachability. In addition, the higher clay content of the soils in blocks 3 and 4 provided better moisture holding capacity, possibly resulting in less water stress than blocks 1 and 2 and hence taller tree growth.

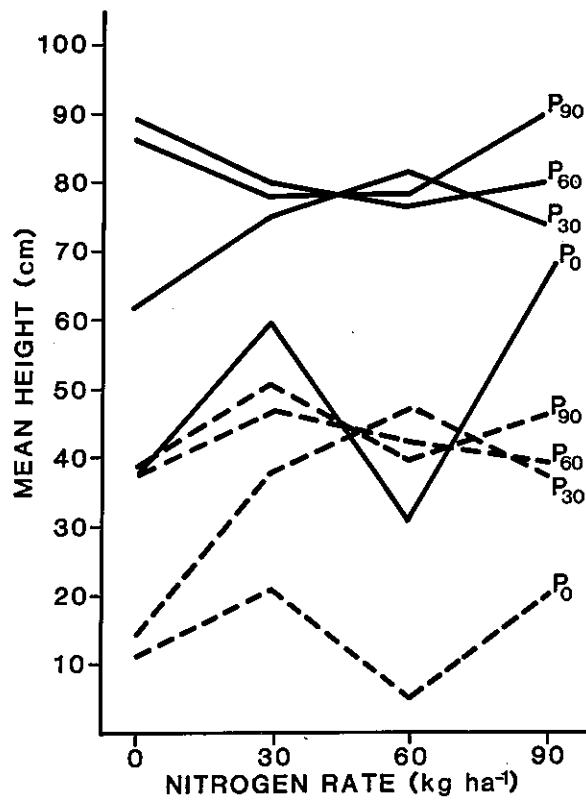
For both of the eucalypts the response to both N and P flattened off substantially between the 60 and 90 kg ha⁻¹ application rate. Another experiment (Alcoa, unpublished data) showed that a N application rate of 40 kg ha⁻¹ was below the optimum N level for seeded jarrah. Taking into consideration these results an application of 400 kg ha⁻¹ DAP will be used for seeded eucalypts in 1988 rehabilitated areas. This rate provides N and P at 72 and 80 kg ha⁻¹ respectively.

ACKNOWLEDGEMENTS

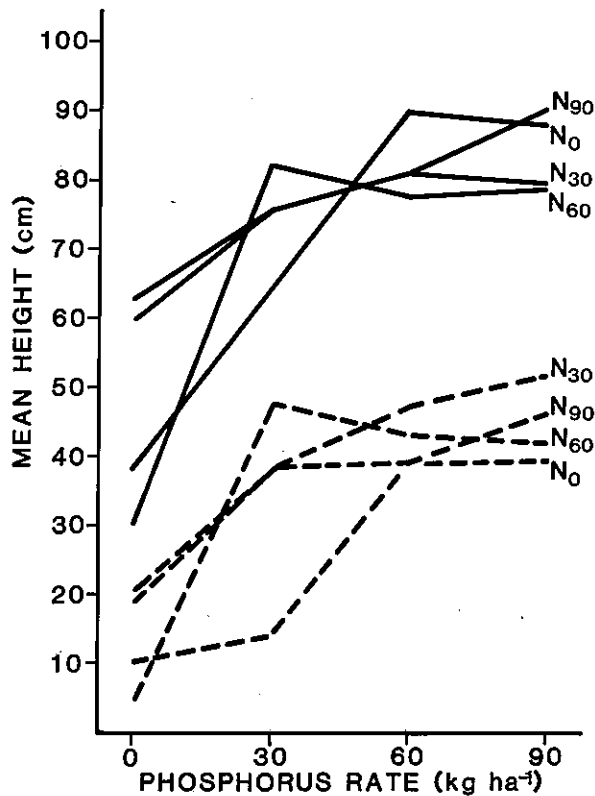
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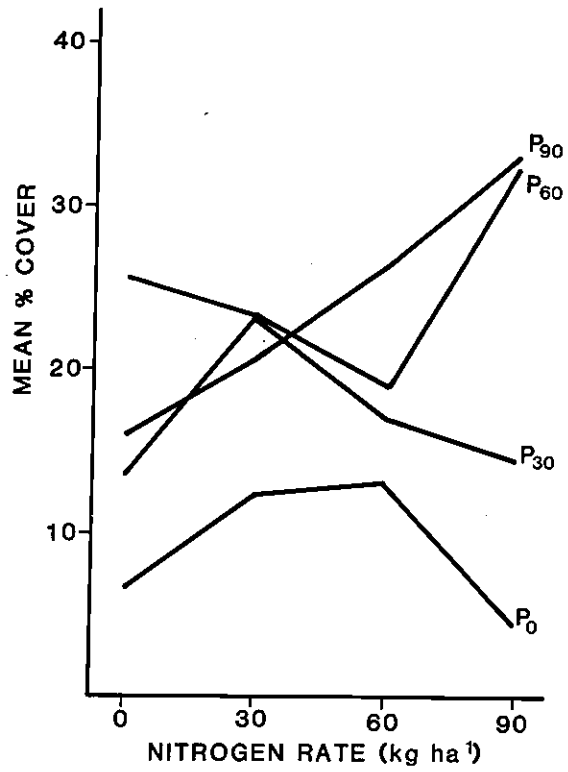


1a) 1 Year old $N_{30} > N_{90} = N_{60} > N_0$
 2.5 Year old $N_0 = N_{30} = N_{60} = N_{90}$ (N.S.)

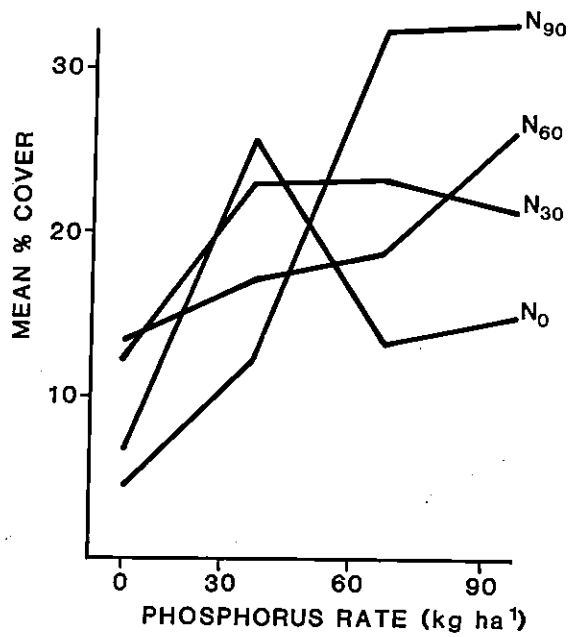


1b) 1 Year old $P_{90} = P_{60} > P_{30} > P_0$
 2.5 Year old $P_{90} = P_{60} > P_{30} > P_0$

Figure 1: Height of *Acacia lateriticola* in response to varying N and P rates. Dotted lines are 1 year old. Solid lines are 2.5 years old.

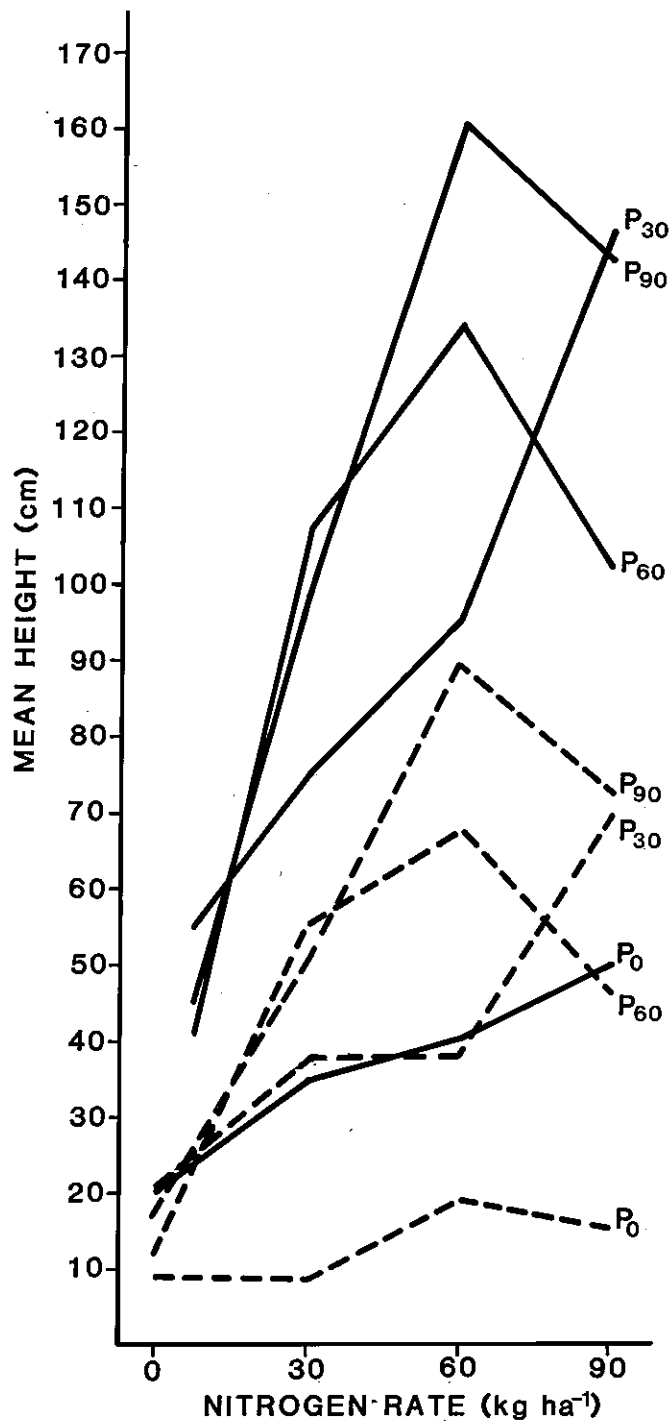


2a) $N_0 = N_{30} = N_{60} = N_{90}$ (N.S.)



2b) $P_0 = P_{30} = P_{60} = P_{90}$ (N.S.)

Figure 2 : Percentage ground cover of *Kennedia coccinea* in response to varying N and P rates at 2.5 years old.



1 year old, $N_{90} = N_{60} > N_{30} > N_0$
 2.5 years old, $N_{90} = N_{60} > N_{30} > N_0$

Figure 3. : Height of Eucalyptus maculata in relation to N application rate.

Dotted lines are 1 year old. Solid lines are 2.5 years old.

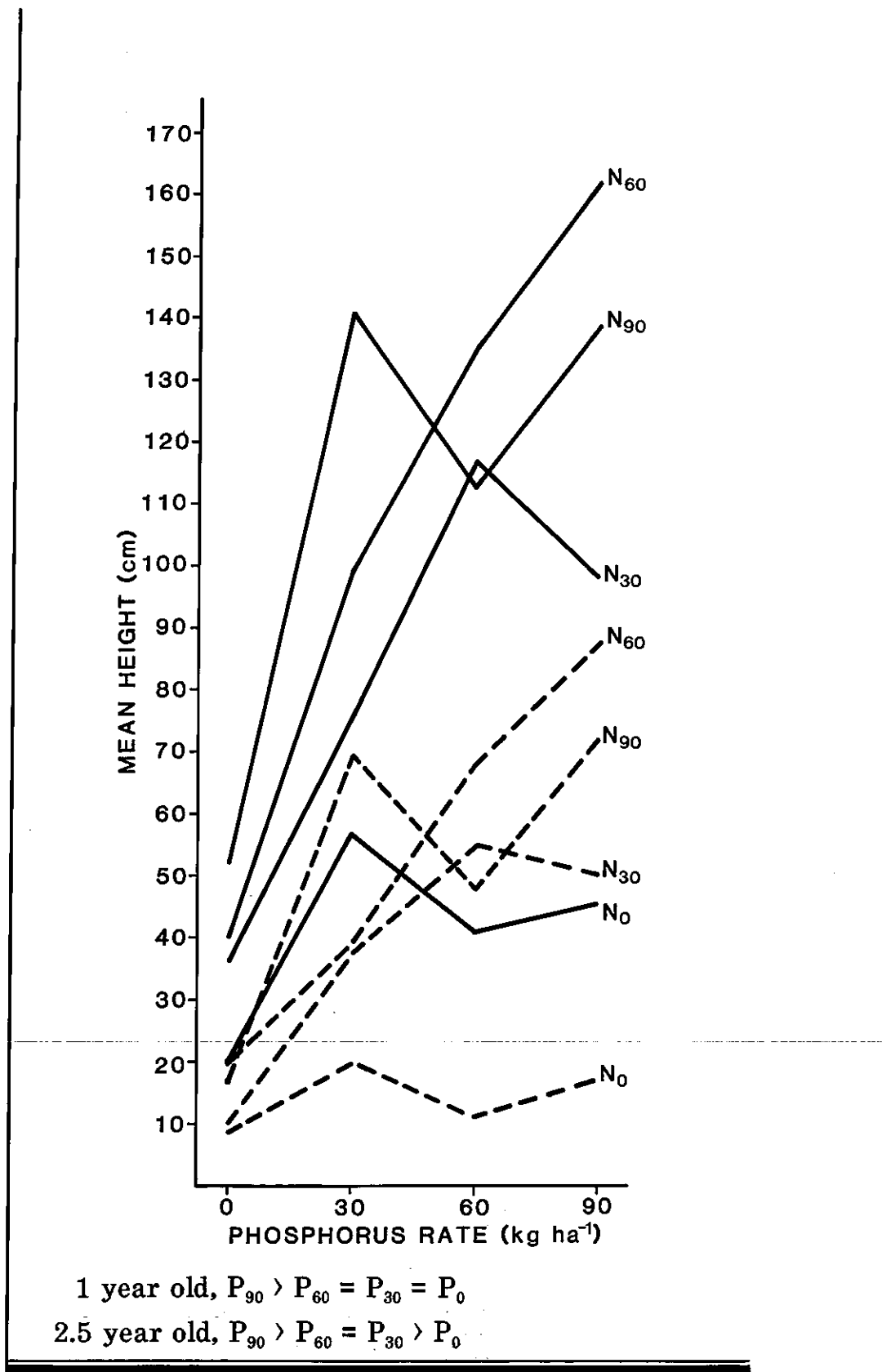
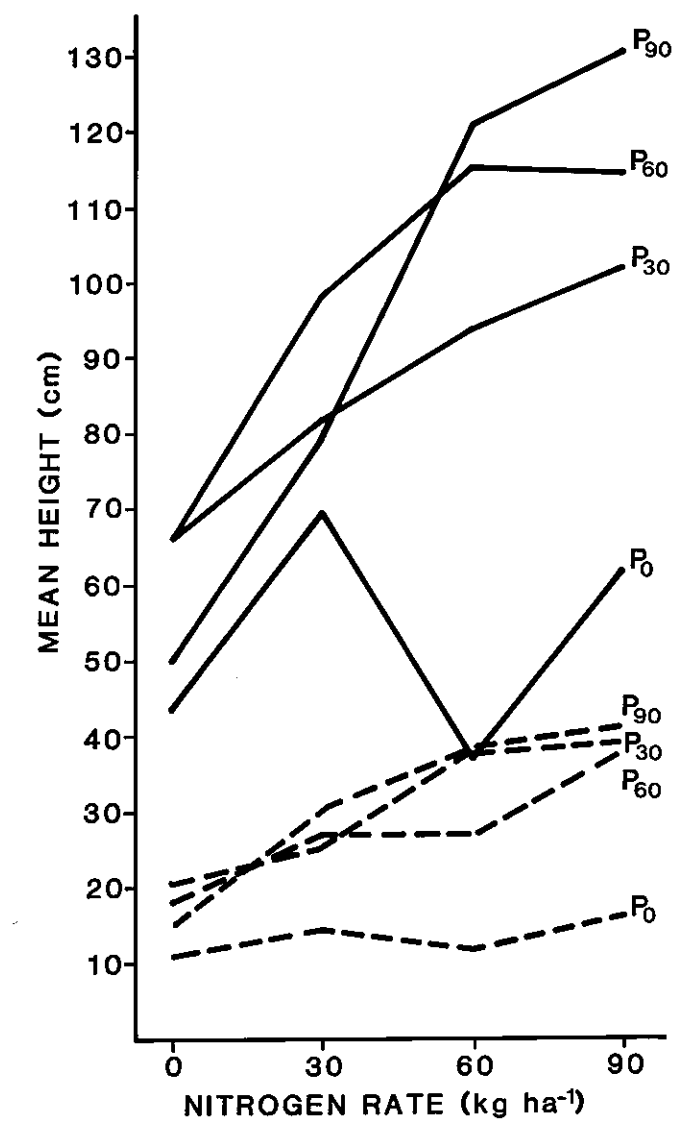


Figure 4.: Height of *Eucalyptus maculata* in relation to P application rate.
 Dotted lines are 1 Year old. Solid lines are 2.5 years old.



1 year old, $N_{90} > N_{60} > N_{30} > N_0$
 2.5 years old, $N_{90} > N_{60} > N_{30} > N_0$

Figure 6 : Height of *Eucalyptus marginata* in relation to N application rate.
 Dotted lines are 1 year old. Solid lines are 2.5 years old.

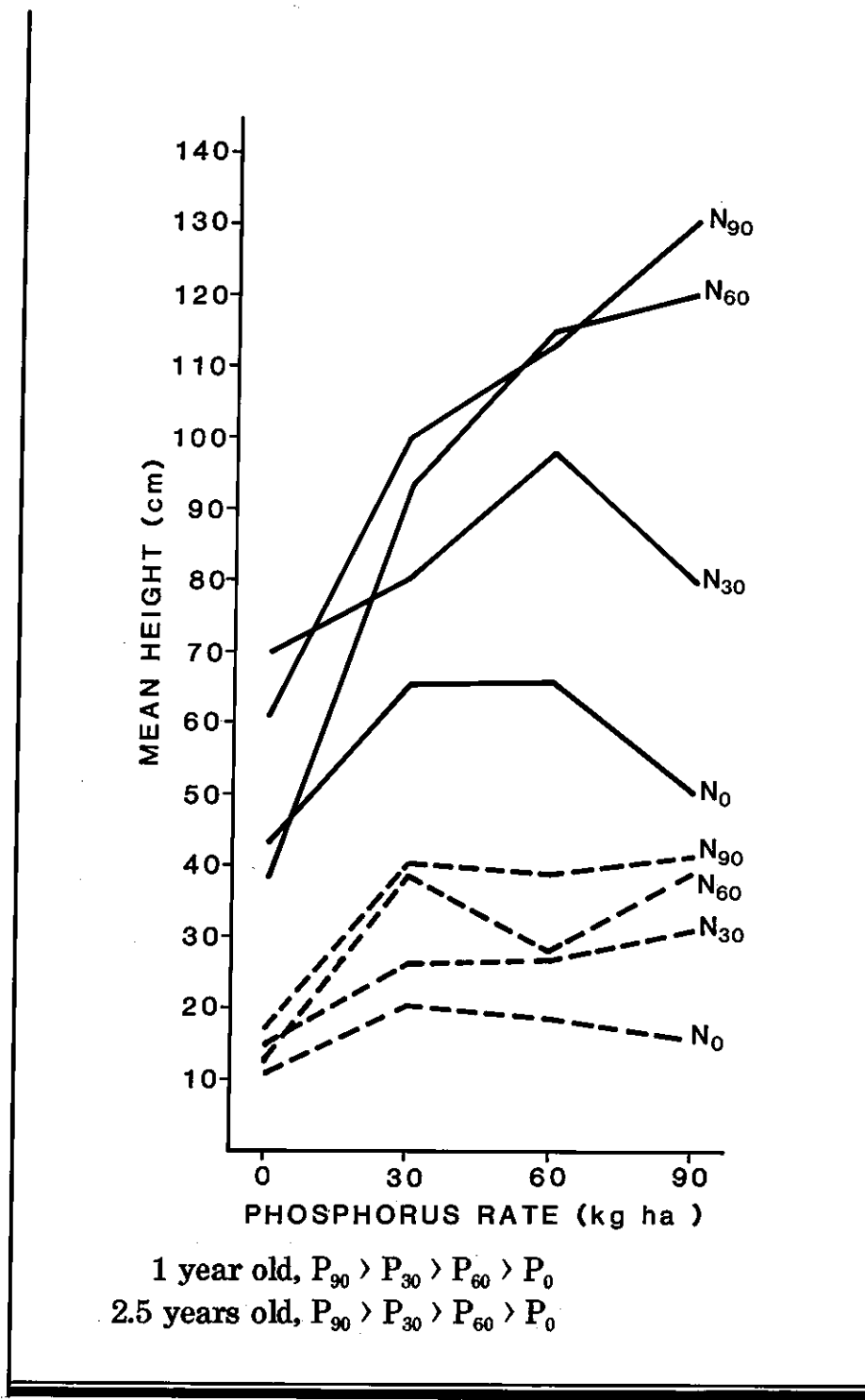


Figure 7. : Height of Eucalyptus marginata in relation to P application rate.

Dotted lines are 1 year old. Solid lines are 2.5 years old.

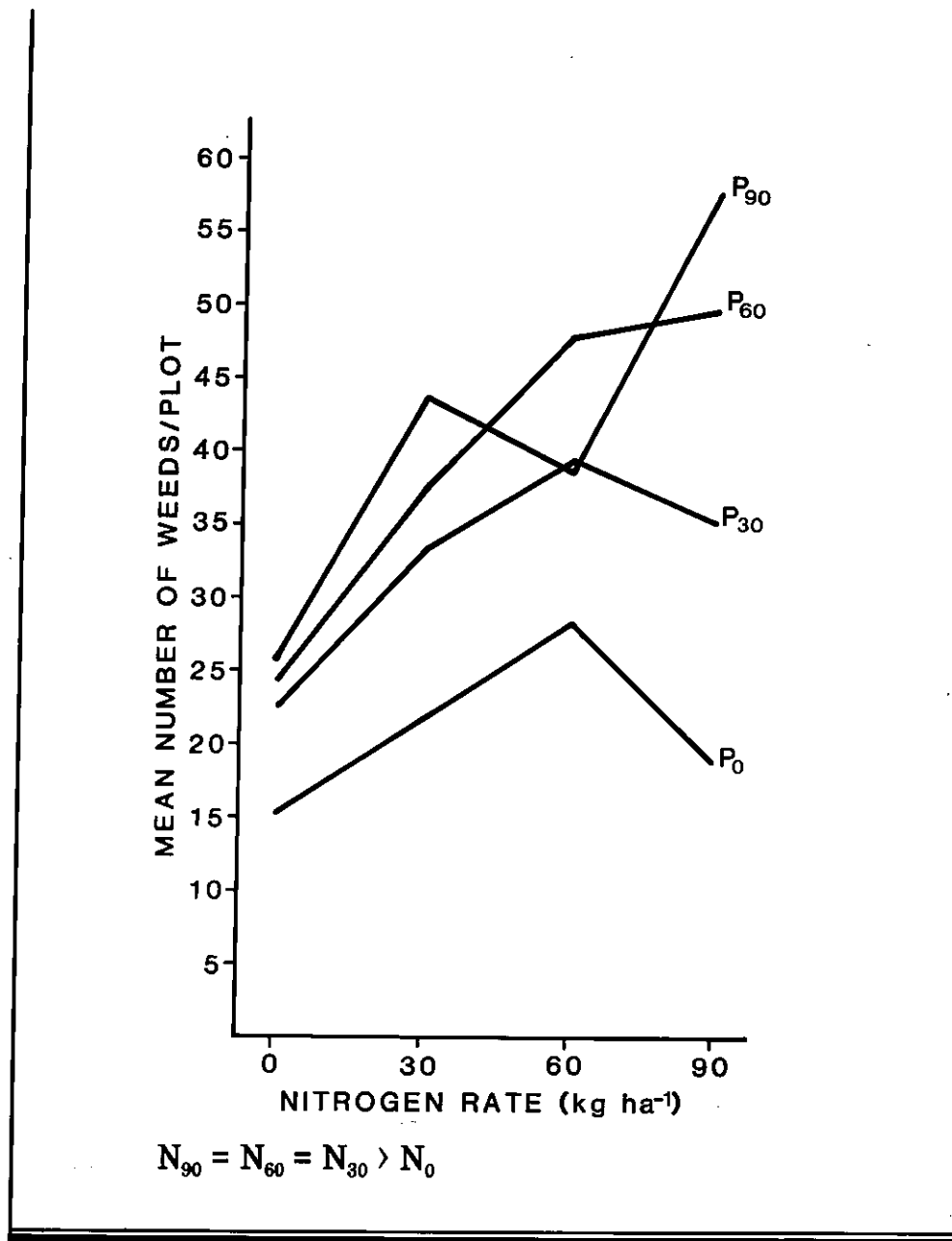


Figure 9 : Effect of N application rate on the number of weeds at 2.5 years old.

Each plot is 4m x 4m.

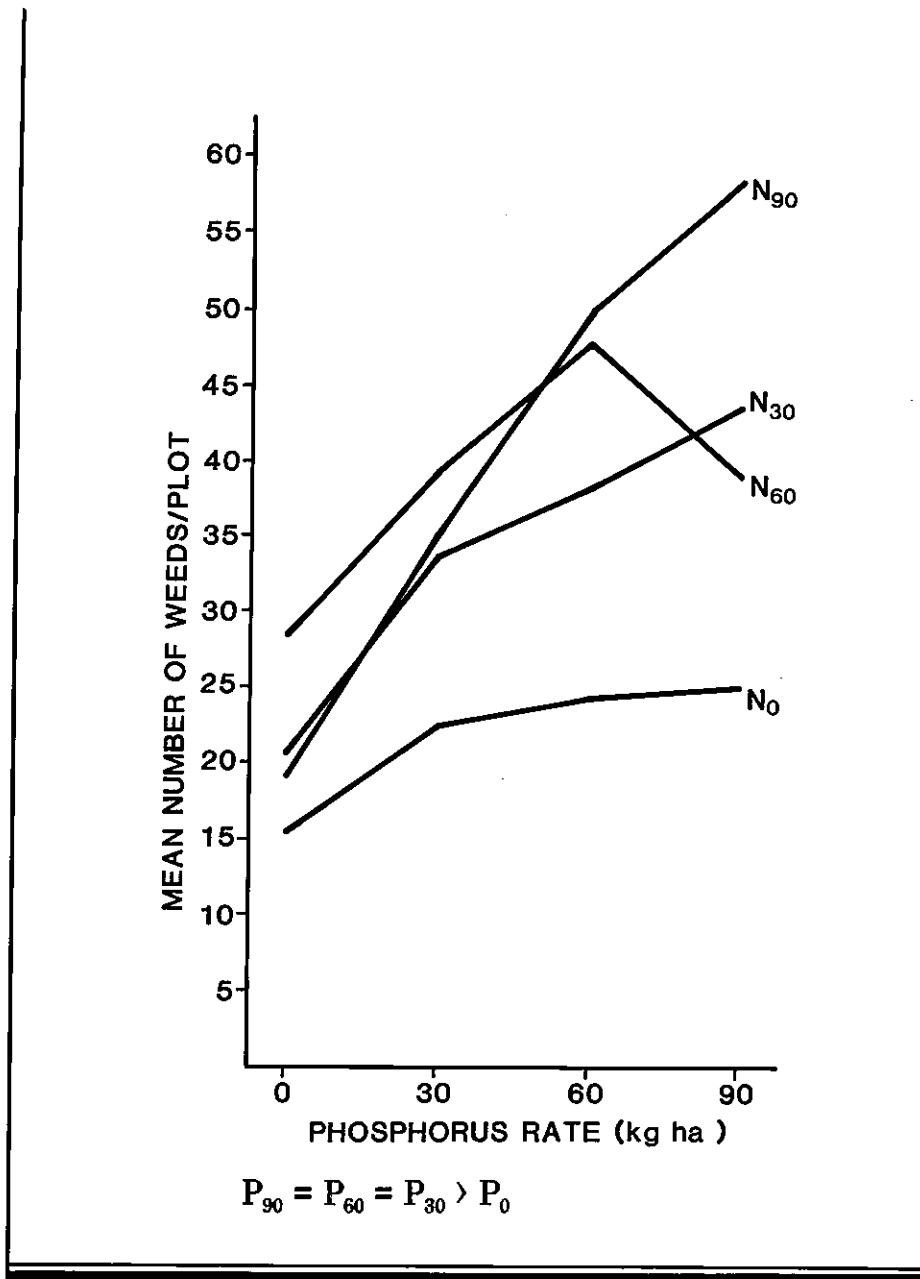
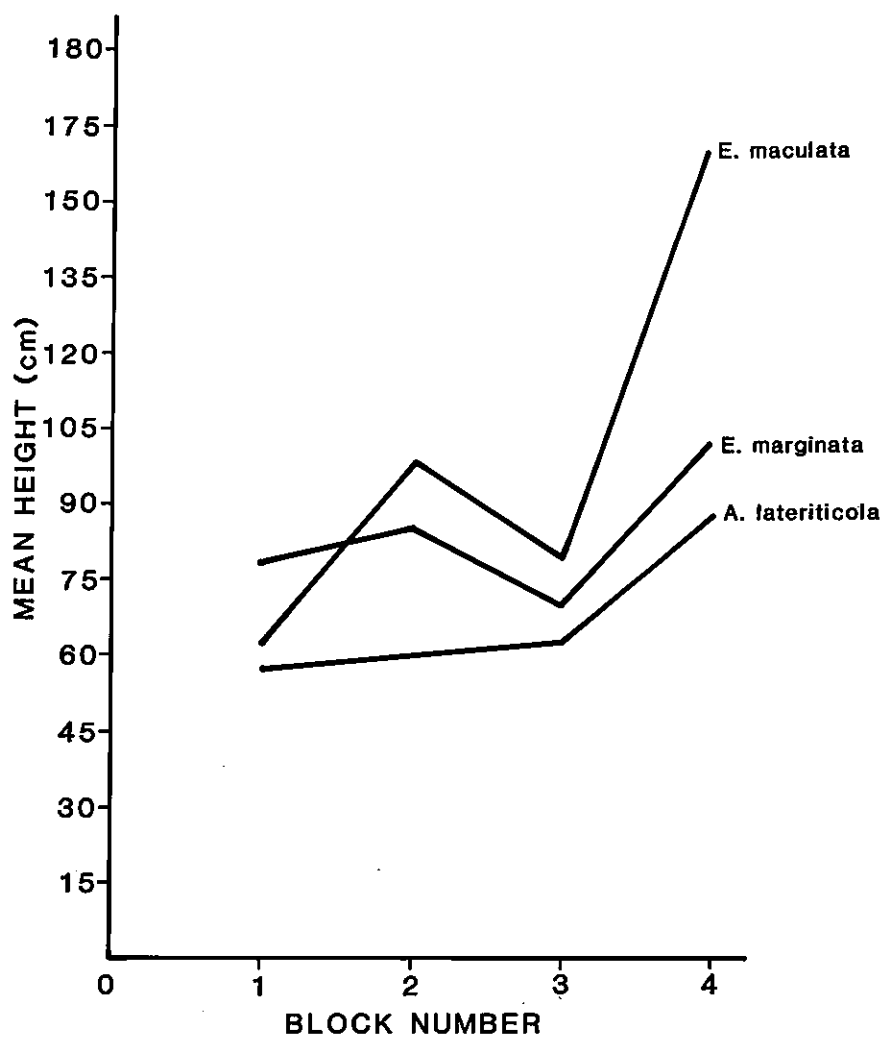


Figure 10 : Effect of P application rate on the number of weeds at 2.5 years old.

Each plot is 4m x 4m.



E. maculata 4 > 2 > 3 > 1

E. marginata 4 = 2 = 1 > 3

A. lateritcola 4 > 3 = 2 = 1

Figure 11 : Mean height of *Eucalyptus maculata*, *Eucalyptus marginata* and *Acacia lateritcola* for all treatments in the four replicate blocks at 2.5 years old.