THE ROLE OF FERTILIZATION IN INCREASING WOOD YIELD FROM WESTERN AUSTRALIAN PINE PLANTATIONS

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SUMMARY

This paper provides a brief summary of: the pine plantation resource in WA; the major constraints on tree growth in WA; the fertilizer trial work which provides the basis for fertilization of thinned stands; an outline of current fertilizer use in WA plantations.

PLANTATION RESOURCE IN WESTERN AUSTRALIA:

The pine resource in WA currently stands at 83,500 ha, of which 67,000 ha is owned by the state and 16,500 by private companies. The state owned plantations comprise 40,300 ha of *Pinus radiata* and 26,700 ha of *Pinus pinaster* (Figure1). The plantations are scattered widely throughout the coastal and near coastal areas from slightly north of Perth to Albany (Figure 2). Most plantations are located in areas with greater than 750 mm annual rainfall.

The largest concentration of plantations is on the Swan Coastal plain north of Perth where the majority of the *P. pinaster* plantations are located. The soils of this area are deep aeolian sand dunes. The soils are very infertile and the annual rainfall is approximately 750 mm. Virtually all the *P. pinaster* plantations are planted on ex bush sites and thus have no history of fertilization.

The bulk of the *P. radiata* plantations are located south of Perth and are scattered widely. However, while the radiata plantations are scattered they are concentrated in five main land systems/areas:

1. Harvey coastal plain plantations, which features deep aeolian sand dunes varying from the very infertile grey sands (Bassendean) to the slightly more fertile yellow sands (Spearwood and Karrakatta). The annual rainfall is 800 - 900 mm.
2. 'Hills' plantations, are located on the younger soils along the rejuvenated drainage lines of the rivers and streams that traverse the Darling Scarp. The soils are reasonably

fertile and the annual rainfall varies between 900 and 1100 mm. Most plantations are on ex bush sites.

3. Blackwood Valley plantations are located on the valley systems of the Blackwood River and its tributaries. The soils are similar to those in the 'Hills' plantations but are more fertile as most of the plantations are located on ex farmland. The soils in these valleys tend to be shallow, particularly on the steeply incised valley sides. Rainfall is less than in the 'Hills' plantations and varies between 750 and 900 mm. The shallow soils, and the lower rainfall makes these plantations prone to drought.
4. The Donnybrook Sunkland features very infertile leached lateritic soils and a rainfall of 900 to 1000 mm. These plantations perform poorly if not fertilized both in the early stages of the rotation and after thinning.
5. The South Coast plantations are located on a range of soil types on ex farmland around Albany. While the rainfall is lower than some of the areas on the west coast, a greater proportion of the annual rainfall falls during the summer months. Fertility is generally good as the result of agricultural fertilization.

PINE SILVICULTURE IN WESTERN AUSTRALIA

P.radiata:

The silvicultural regimes used in WA were initially aimed at producing sawlogs as early as possible and minimising the possibility of drought deaths. These objectives led to early cull thinning and early commercial thinning in WA pine plantations. Three commercial thinnings were planned to maintain low basal area throughout the 30 year rotation. However, the more recent development of a demand for industrial wood (chipwod for particle board and medium density fibreboard), and the planting of less drought prone areas such as the Donnybrook Sunkland has changed the silvicultural philosophy. The radiata plantations are now planted at 1500 stems ha^{-1} rather than the previous density of 1000 or 1100 stems ha^{-1}. Plantations are no longer cull thinned at age 5 to 7 years as this reduced the yield of chipwood at the first commercial thinning (10 to 14 years). Depending on the age at which the first commercial thinning occurs, only two commercial thinnings may be done prior to clearfelling. Plantation stockings are now maintained at a higher density for the whole rotation.

P. pinaster

The same constraints of drought and the desire to produce sawlogs as quickly as possible were applicable to the *P pinaster* plantations. In addition the *P.pinaster* plantations on the Swan coastal plain north of Perth are located on the Gnangara water mound which is used to supply water for Perth. Thus plantations on the water recharge areas have to be maintained at a low stocking so that the aquifer is recharged. The high demand for water by Perth will ensure that these plantations are maintained at a low density throughout the rotation.

AGE STRUCTURE OF CALM PLANTATIONS

There has been a relatively uniform rate of plantation establishment in WA during the last two and a half decades, with an average of 2000 ha year^{-1} being planted (Figure 1). The rate of *P. pinaster* establishment declined during this period, from about 1000 ha year^{-1} in the 1960's and 1970's to only 300 ha year^{-1} in the last decade. The rate of P. radiata establishment increased to about 1600 ha per year in the early 1970's and has remained at this level since then. Thus, a large proportion of the plantation resource will be thinned in the next few years and will be in a suitable condition to be fertilized.

MAJOR CONSTRAINTS ON TREE GROWTH IN SOUTHERN WA

Water supply

The overriding constraint on tree growth in southern WA is the availability of soil moisture during summer. While the annual rainfall in the area in which most plantations are grown exceeds 750 mm year^{-1}, the rainfall distribution is very seasonal with more than 80 percent of rain falling in the six months between April and September. On the west coast, the summers are extremely dry with less than eight percent of rainfall falling in the driest four months (December to March) (Figure 3). On the south coast, where less than 10 percent of the current pine resource is located, there is slightly more summer rainfall with about 13 percent of rain falling in the driest four month period. Rainfall declines from south to north and the evaporative demand increases from south to north. For example, summer evaporation increases from less than 500 mm at Albany to greater than 800 mm north of Perth.

Nutrient supply

The other major limitation to tree growth in WA is the extremely low fertility of soils. The majority of pine plantations are grown on the infertile sands of the coastal plain and the ancient leached lateritic soils of the Darling scarp and plateau inland of the scarp. About half of the *P.radiata* plantations located on the west coast south of Perth (a quarter of the total plantation area) are located on the more fertile soils found in the valleys of the rejuvenated drainage lines of the river systems that flow west across the Darling scarp. While these younger soils are more fertile than the coastal sands and the lateritic soils, they are still deficient in phosphorus and nitrogen.

All of the 28,000 ha of *P. pinaster* plantations are located on previously unfertilized land cleared from native bush. About 60 percent of the *P. radiata* plantations are located on ex bush sites while the remainder are located on ex farmland sites. The recent sharefarm plantings in the South Coast area account for about 6000 ha of the ex farmland sites. Thus the majority of sites that will be thinned in the next few years will be on ex bush sites.

On the unfertilized soils the primary nutrient deficiency is phosphorus, followed by nitrogen. On some sites, particularly the leached sand dunes, potassium deficiency may occur. Trace element deficiencies (Cu, Zn, Mn) also occur on some areas. Providing the water supply is sufficient, responses to fertilization will occur at most stages of the rotation on ex bush sites.

Although nutrient supply is less likely to limit tree growth on the ex farmland plantations, responses to both nitrogen and potassium have been found on some sites in the early part of the rotation. This suggests that substantial responses to fertilization may occur later in the rotation.

PROSPECTS FOR INCREASING WOOD PRODUCTION BY FERTILIZATION

P. pinaster:

The major limitation to the growth of the plantations north of Perth appears to be the availability of water during summer. Dense plantations use all the available soil moisture during spring and then cease growing, while less dense plantations deplete the available water more slowly and continue growing during summer. Butcher and Havel (1977) demonstrated that it took the whole summer for trees at a basal area of 7 m^2ha^{-1} to use all the available soil water, while in stands at a basal are of 25 m^2ha^{-1}, soil water was exhausted by early summer(Figures 4A, 4B). Stands at the higher densities did not respond to fertilization whereas thinned stands did respond to fertilization(Figure 4A). Trials have shown that basal area responses to phosphorus in thinned plantations are in the order of 30 to 50 percent. On these sites further responses to nitrogen were either small and ephemeral or non existent (Hopkins and Burcher unpublished).

The current fertilizer use in the *P.pinaster* plantations is concentrated on ensuring that the plantations have an adequate supply of phosphorus. The constraints of managing the plantations for both wood and water yield mean that the environmental problems associated with fertilization have to be considered in any fertilization program. To date there have been no problems with elevated nutrient levels in the ground water below the plantations. This is probably due to the relatively low applications of phosphorus used in the plantations and the capacity of the sands to adsorb the applied phosphorus.

P. radiata

The constraint on growth due to the limited water supply in plantations north of Perth appears to be less severe in at least some of the *P. radiata* plantations in the south west. For example, on the infertile and wetter sites in the Sunkland there was a similar volume increase in the five years after fertilization (90 $kgPha^{-1}$, 270 $kgNha^{-1}$ and 200 $kgKha^{-1}$) in stands at both 375 and 750 stems ha^{-1} (Figure 5A). The similar volume response in the five years following fertilization is explained by the low water stress experienced by stands at both 375 and 750 stems ha^{-1} (Figure 5B). During this period average or above average rainfall was experienced. In dry years, as experienced in 1993 and 1994, the water stress during summer increased particularly in the fertilized treatments (Figure 5C). While fertilization does not cause mortality on sites with a good water supply, fertilization on sites with low rainfall and/or low water storage capacity may cause severe water stress and tree death.

Fertilization following thinning has increased volume increments by between 50 to 75 percent. Trials on the infertile coastal plain sands in low density stands (200 250 stems ha^{-1}, basal area 14 m^2ha^{-1}) showed a 50 percent increase in volume production with an application of 175 $kgNha^{-1}$ and 75 $kgPha^{-1}$, the response to increasing applications of nitrogen and phosphorus was linear up to this application (Figure 6A). As no higher rates were applied it is not known if a greater response could have been achieved. The response was relatively short lived with increments in fertilized trees remaining above the unfertilized control treatment for only four years (Figure 6B). In a factorial phosphorus by nitrogen rate trial, on a deep loam soil on an ex bush site with 1100 mm rainfall, volume increment was increased by 75 percent (Figure 7B).

Partitioning the response between nitrogen and phosphorus in this trial over 10 years showed a strong response in basal area to phosphorus and a significant, but short lived, response to nitrogen (Figure 7A). In the first four years after fertilization phosphorus accounted for about two thirds of the response while nitrogen accounted for the remaining one third. After the first four years only phosphorus had a significant influence on basal area and volume growth.

IMPACT OF FERTILIZATION ON WOOD DENSITY

The impact of fertilizer on wood density was determined on the nitrogen by phosphorus factorial experiment outlined above. Phosphorus alone and nitrogen alone reduced wood density by 10 percent relative to the unfertilized control, from 550 kgm^3 to 500 kgm^3 while nitrogen and phosphorus at high rates (560 $kgNha^{-1}$, 360 $kgPha^{-1}$) resulted in a 20 percent reduction in wood density for three years after fertilization (Figure 7C).

FERTILIZER USE IN CALM PLANTATIONS

In the last decade there has been considerable use of fertilizers in both the *P pinaster* and *P. radiata* plantations following thinning. This upsurge in fertilizer use was due to information from trials that indicated that growth could be increased by fertilization following thinning and secondly by a projected high demand for sawlogs and industrial wood.

A total of 39,000 ha has been fertilized following thinning (21,000 ha *P.radiata* and 18,000 ah of *P. pinaster*), at a cost of approximately $6.6 million. In the radiata plantations both phosphorus and nitrogen have been applied(1671 tonnes of elemental P, 3759 tonnes of elemental N), while in the pinaster plantations the majority of the fertilizer applied has been phosphorus (433 tonnes of elemental P and only 80 tonnes of elemental nitrogen). The difference in fertilizer used has resulted from the trial work which indicated that in the pinaster plantations, on the coastal plain north of Perth, there was a substantial response to phosphorus, but little response to nitrogen fertilisation, wheras in the plantations south of Perth, radiata responded to both phosphorus and nitrogen fertilization.

FUTURE DIRECTIONS:

Research to date has concentrated on quantifying the response to fertilization and the interaction between plantation density and fertilization. Areas in which more information is required are:

- Determining the rates of fertilizer application and the frequency of fertilization required to maximise economic returns from fertilization.
- Prediction of fertilizer responses on the basis of either soil or tree nutrient status. This is necessary to overcome the prescriptive nature of current fertilizer recommendations, and to take into account changes in nutrient status over time.
- Definition of the limits of wood yield on plantation sites in southern WA. Trials in young radiata plantations using optimum establishment techniques and repeated fertilizer applications have shown that wood production of nearly 300 m^3ha^{-1} in the first ten years of a rotation is possible on sites that would fail to produce a crop of trees without fertilization. Knowledge of the potential of a site to produce wood is necessary to determine the success of silvicultural inputs in achieving maximum productivity.

Figure 1

AREA OF PINUS SPECIES IN W.A. AS AT 31-12-93

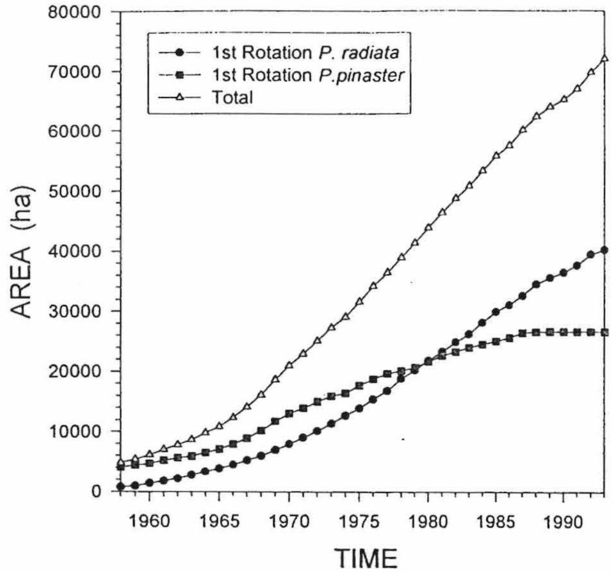


Figure 2

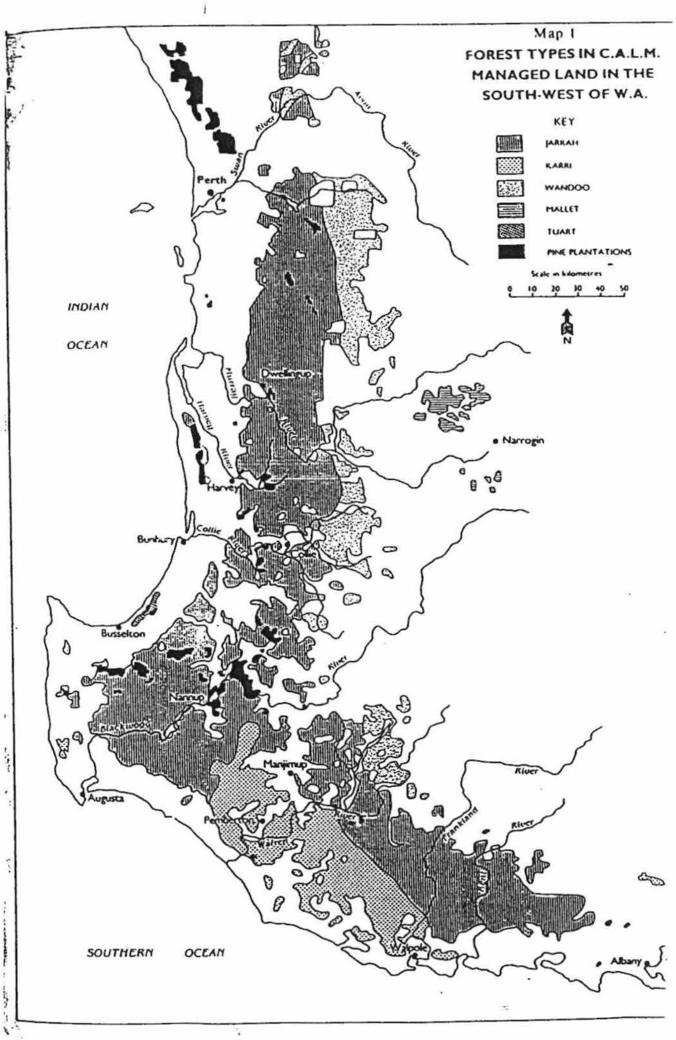


Figure 3

Rainfall distribution in South West WA

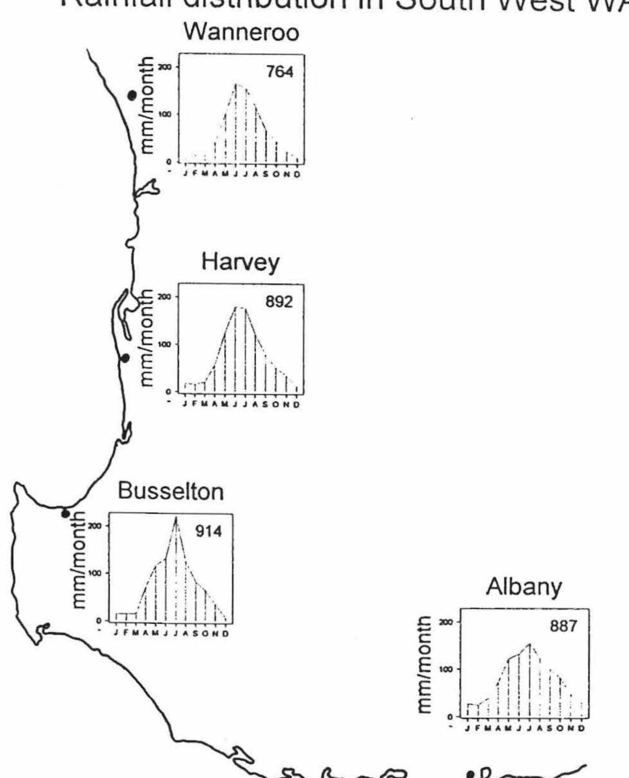
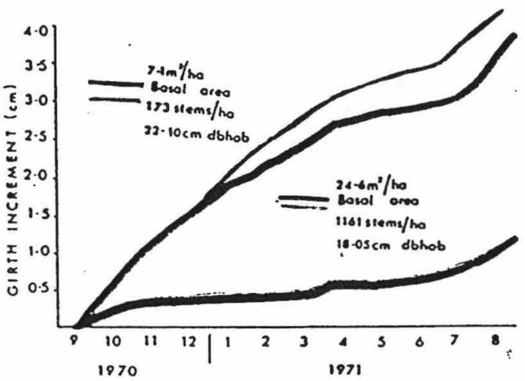


Figure 4A



Cumulative girth increment in densely and lightly stocked pine stands at Yanchep (*P. pinaster*)

Figure 4B

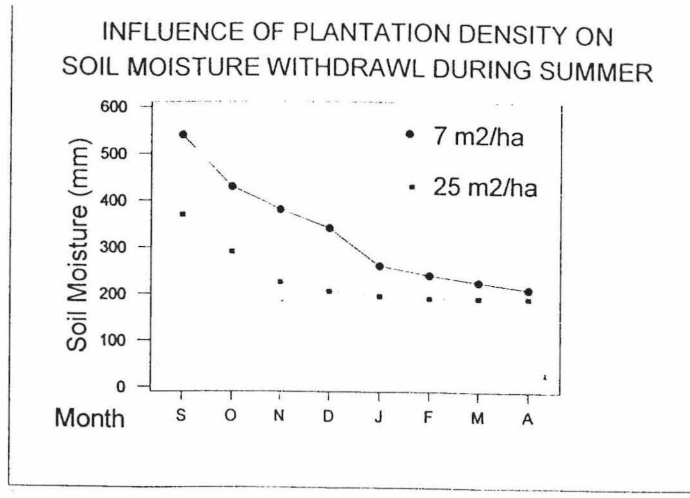


Figure 5A

INFLUENCE OF FERTILIZATION AND STAND DENSITY ON VOLUME GROWTH OF *P. radiata*

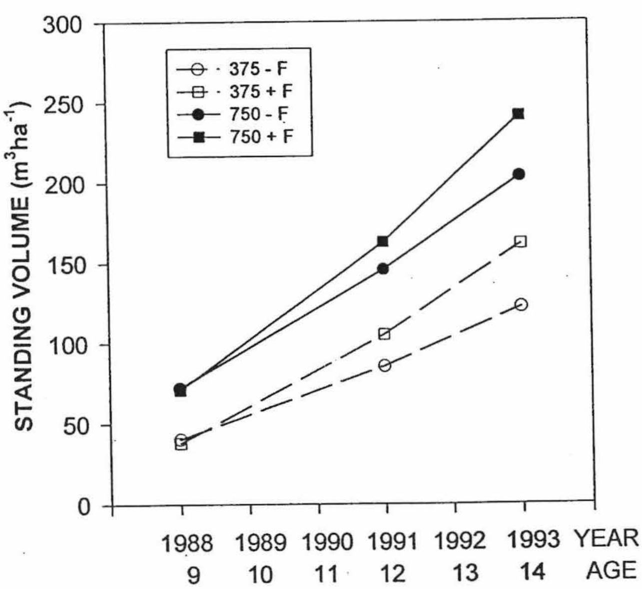


Figure5B

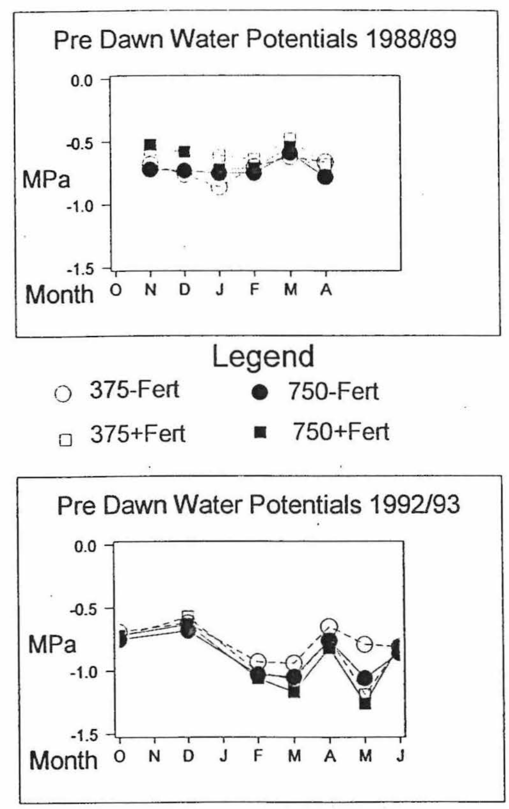


Figure 5C

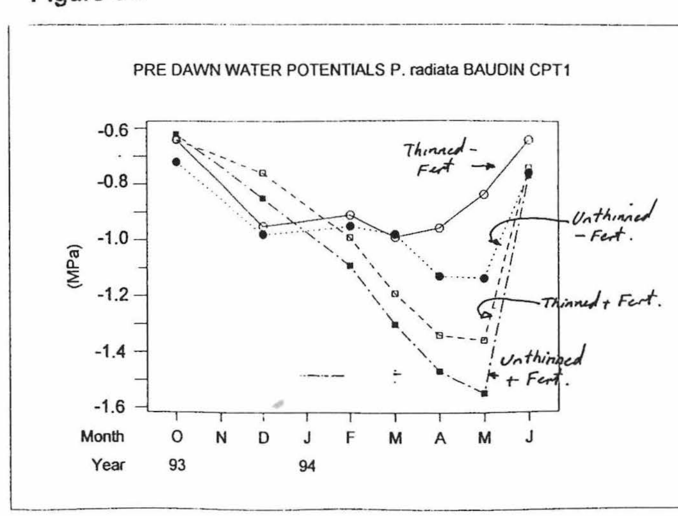
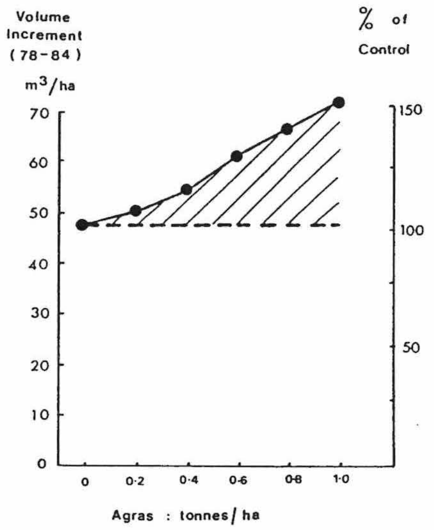


Figure 6A



EFFECT OF AGRAS APPLICATION ON
VOLUME PRODUCTION BY 23 y.o. *P. radiata*

Figure 6B

TREE VOLUME RESPONSE TO INCREASING N & P APPLICATIONS

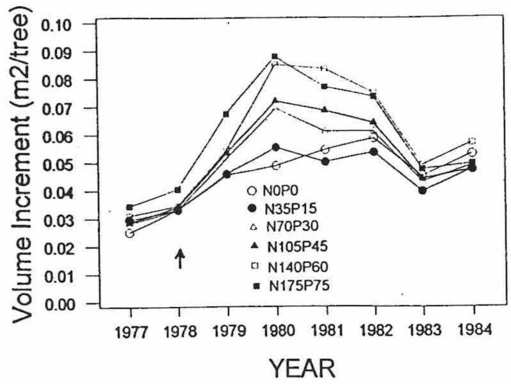


Figure 7A

Response to N and P by
Thinned *P. radiata*

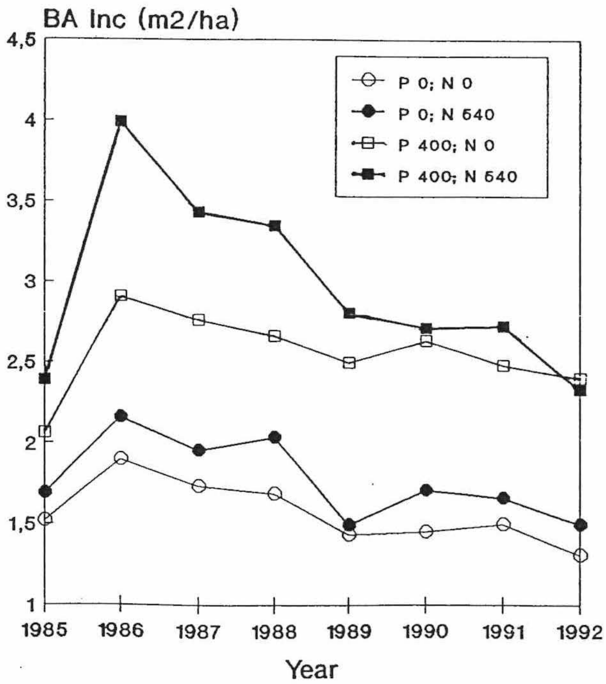


Figure 7B

Basal Area Increment vs
Nitrogen and Phosphorus Application

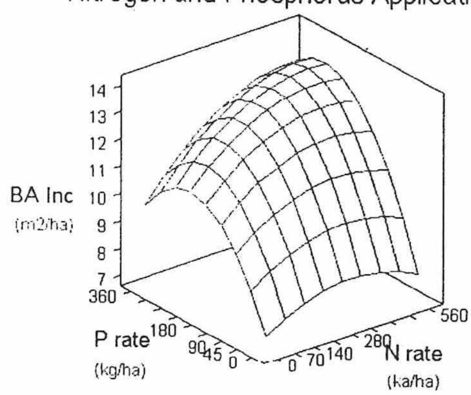


Figure 7C WOOD DENSITY RADIAL TRENDS

TALLANALLA