ARTICLES

Response of a kauri stand to fertilizer addition and thinning

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ABSTRACT

In a stand of kauri (Agathis australis (D. Don) Lindl.) aged about 130 years, reduction of the number of stems per hectare by 75 per cent and basal area by about 55 per cent had only a negligible effect on stand basal area growth. Thinning stimulated growth of individual kauri. Addition of nitrogen fertilizer approximately doubled basal area growth after five years. Complete fertilizer gave an additional growth increment. The response to nitrogen fertilizer was slow compared with that of plantation-grown radiata pine, Pinus radiata (D. Don), but appears to be longer lasting.

Historically kauri has been a species of major economic importance in New Zealand. Old-growth kauri stands are now uncommon but second-growth stands are widespread in the northern half of the North Island (Ecroyd 1982). Silvicultural research on stands of kauri is limited (Barton and Horgan 1980). Our purpose was to examine growth responses of a pole kauri stand to fertilizer addition and thinning.

EXPERIMENTAL

The study was located in the Mangatangi region of the Hunua Ranges (37° 07' 20" S, 175° 12' 35" E). Mean annual precipation in Hunua is 1411 mm and mean annual temperature 14.1°C. Ring counts indicated that the dominant kauri were about 130 years old when the study commenced in late 1979. Foliar nitrogen (0.81%) and phosphorus (0.09%) suggested that the trees were nutrient deficient (Madgwick *et al.* 1982).

Basal area growth of kauri at two levels of stocking and four levels of nutrition, in a factorial design with two replicates, was measured. One replicate was on the lower part of north-east facing slopes and the other on upper slopes and ridge tops. Plots were 0.04 ha with an inner 0.01 ha measurement plot and were separated by 20 m-wide buffer strips.

The stand was thinned to waste in March 1980 to give plots with either high or low basal area. High basal area plots averaged about 3000 stems ha^{-1} after a light thinning. Low basal area plots were thinned to 700 uniformly stocked kauri stems ha^{-1} with all other tree species removed.

Addition of fertilizer was carried out in September 1980 (late winter) and comprised (i) no fertilizer addition, (ii) two levels of nitrogen application as ammonium sulphate, and (iii) addition of a "complete" fertilizer (Table 1). Fertilizers were broadcast by hand.

All trees over 5 cm diameter breast height in October 1979 were measured and these trees were again measured in 1981, 1982, 1983 and 1985. In 1985 a tally was made of additional stems which had grown to exceed 5 cm diameter (recruits). All stems were identified to species.

RESULTS

Kauri was the dominant species in all plots (Table 2). High basal area plots on the lower slopes averaged about 46 m^2 ha^{-1} of basal area and those on the ridge 32 m^2 ha^{-1} at the beginning of the experiment. This may be compared with 20 and 15 m^2 ha^{-1} in the low basal area plots. Over the total period of observation, the kauri in the control plot on the ridge grew 5.1 m^2 ha^{-1} in basal area while those on the slope grew 4.9 m^2 ha^{-1}.

Interaction between treatment effects (thinning, fertilizer and replicate (site)) was both biologically and statistically negligible; so thinning and fertilizer effects can be considered independently of one another. For example, the estimate of thinning effect in Fig. 1 is based on the mean differences in basal area increment of all eight pairs of plots for which the only difference in treatment was the presence or absence of thinning. The effects of the two different levels of nitrogen

Table 1: The composition and amounts of fertilizer additions

Treatment	Fertilizer Quantity kg ha^{-1}	 Type
Control	nil	—
Nitrogen	715	ammonium sulphate
Double nitrogen	1430	ammonium sulphate
Complete	715	ammonium sulphate
	1000	superphosphate
	700	dolomite
	280	potassium sulphate
	90	manganese sulphate
	45	borax
	45	copper sulphate
	45	zinc sulphate
	0.256	sodium molybdate

Table 2: The average stocking and basal area of high- and low-basal area plots at the beginning of the experiment.

	Site Slope		 Ridge	
	Stems per ha	Basal area sq.m./ha	Stems per ha	Basal area sq.m./ha
High basal area				
kauri	2325	36.1	1925	21.6
tanekaha	525	8.4	475	4.9
towai	0	0.0	375	2.1
kanuka	0	0.0	150	0.8
rewarewa	0	0.0	50	2.1
rimu	25	1.1	25	0.1
hard beech	25	0.1	0	0.0
Total	2900	45.7	3000	31.6
Low basal area				
kauri	700	20.0	700	14.6

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addition were so similar that they could not be adequately separated in Fig. 1.

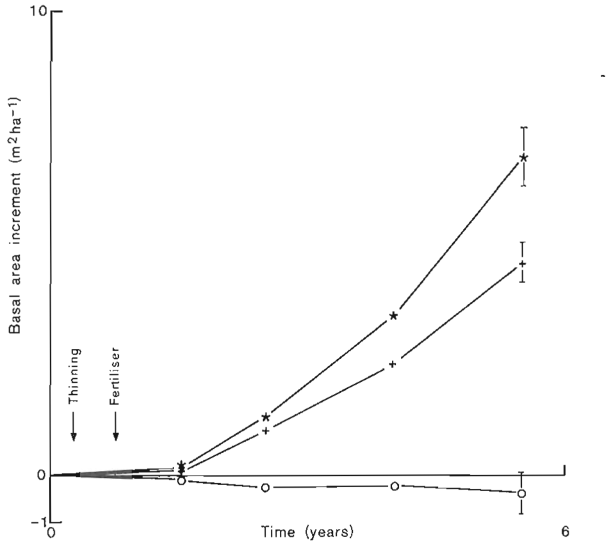


Figure 1: **The effects of thinning (o) and fertilizer addition (+ nitrogen; * complete fertilizer) on the basal area increment of kauri. Each plotted point is the mean difference in basal area increment between pairs of plots varying only in the presence and absence of the given treatment. The vertical bars indicate plus and minus one standard deviation of the means for the final measurement date.**

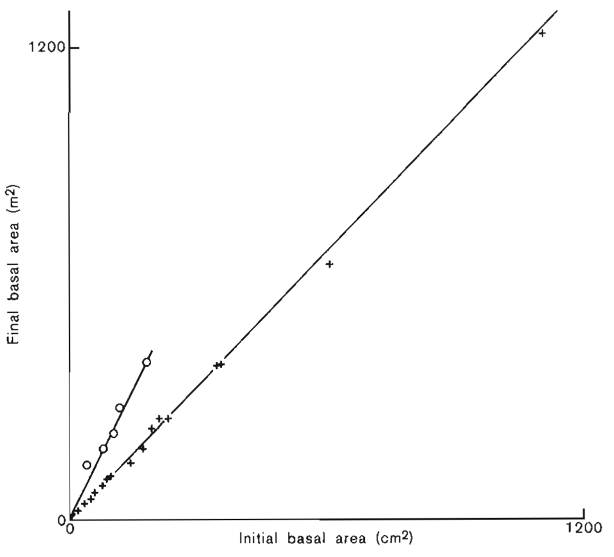
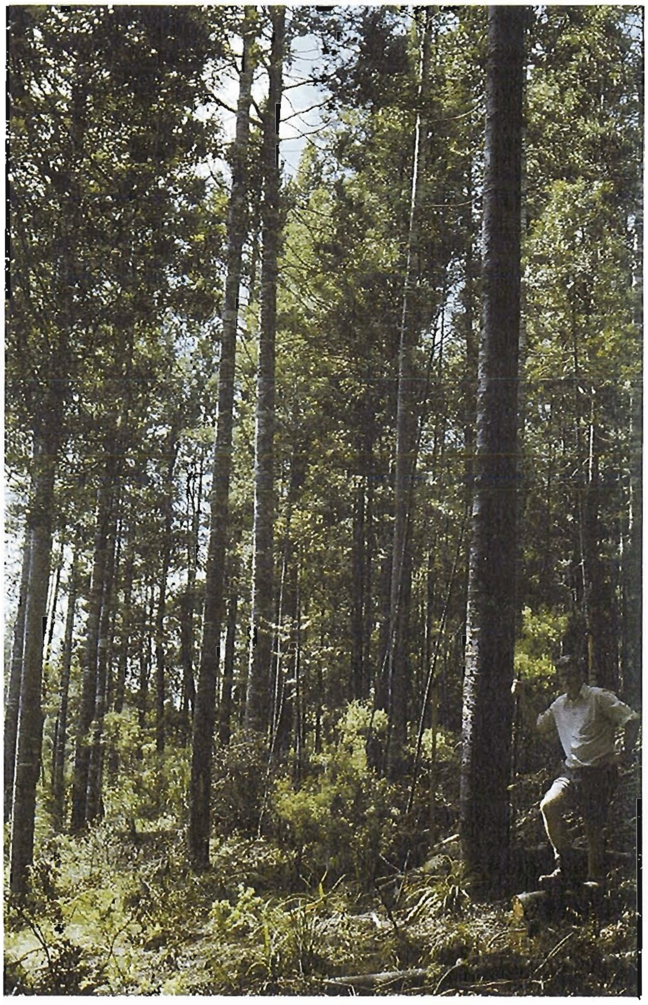


Figure 2: **The relationship between initial and final basal area of individual kauri trees in the plots with the highest (ridge, thinned, complete fertilizer, o) and lowest (lower slope, unthinned, no fertilizer, +) growth rates.**



The thinned-fertilized plot of 130-year-old kauri in the Hunua Ranges. Photo: D.J. Mead.

The response to all three fertilizer treatments increased with time, becoming significant ($p<0.05$) at the end of the second growing season and increasing in both magnitude and statistical significance throughout the remainder of the five-year period of observation. After five years, basal area growth per plot in plots with only nitrogen fertilizer added was approximately double that of the controls. Complete fertilizer gave an additional increment over nitrogen alone. Thinning had a negligible influence on plot basal area increment. The difference in absolute growth between the two replicates was not significant but the lower initial basal area of plots on the ridge and upper slopes meant that their growth rates per unit of initial basal area were higher on both a plot and an individual tree basis.

Within each plot, the basal area of individual kauri in 1979 and 1985 were linearly related, as illustrated in Fig. 2 for the slowest and fastest growing plots. The ratio of final to initial basal area of each tree was independent of the initial basal area of the tree.

Two of the originally measured kauri died during the five years of observation, both being small trees. A large number of additional stems grew to measurable size. Of these, kauri comprised 68 and tanekaha *(Phyllocladus trichomanoides* D. Don) 21 per cent with a relatively higher incidence of kauri on lower slopes than on the ridge. Recruits were more numerous in thinned (low basal area) plots (900 stems ha^{-1}) than in high basal area plots (450 stems ha^{-1}). No effect of nutritional status on numbers of recruits was apparent while their basal area was negligible compared with overstorey trees.

DISCUSSION

Foliar analysis before fertilizer addition, and Peterson's (1962) diagnostic levels, suggested that the kauri were deficient in both nitrogen and phosphorus (Madwick *et al.*). The marked growth response found in fertilized plots lends support to the use of these diagnostic criteria. Compared with the response to nitrogen documented by Hunter (1982) for radiata pine in New Zealand the kauri stand showed a slower but longer period of response. The negligible effect of heavy thinning on stand basal area increment indicates that thinning was compensated by increased diameter growth of individual stems.

Growing plantation kauri as a commercial venture is not competitive with radiata pine, given current technology and price structures (Barton and Horgan 1980). Profitability of radiata pine plantation forestry has been assisted by a multi-million-dollar annual expenditure on research. Barton and Horgan (1980) indicated that profitability of kauri forestry could be materially improved by reducing establishment costs. Results here indicate that growth of existing kauri stands can be manipulated by silvicultural treatment. There is a clear need to examine the costs and benefits of kauri silviculture on a range of sites to establish optimum management regimes and a realistic economic evaluation of potential kauri management alternatives. Such research would be inexpensive by current standards but could have significant value in the wise future management of this widespread resource.

REFERENCES

Barton, I.L. and Horgan, G.P. 1980 Kauri Forestry in New Zealand — a protagonists' point of view. New Zealand Journal of Forestry 25(2) 199-216.

Ecroyd, C.E. 1982 Biological flora of New Zealand. 8. *Agathis australis* (D. Don) Lindl. (Araucariaceae) Kauri. New Zealand Journal of Botany 20: 17-36.

Hunter, I.R. 1982 Growth increases following application of nitrogen fertilizers to exotic forests. In: Gander, P.W. ed. Nitrogen balances in New Zealand ecosystems. Department of Scientific and Industrial Research, Palmerston North, 131-135.

Thinned pole-stand of kauri in the trial area.
Photo: Forest Research Institute.

Madgwick, H.A.I., Oliver, G. and Holten-Anderson, P. 1982 Above-ground biomass, nutrients and energy content of trees in a second growth stand of *Agathis australis*. New Zealand Journal of Forestry Science 12: 3-6.

Peterson, P.J. 1961 Mineral nutrition of *Agathis australis* Salisb., the kauri. New Zealand Journal of Science 5: 141-64, 221-36.

Foresty on Erromango Island, Vanuatu

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ABSTRACT

The rugged, sparsely populated island of Erromango in the South Pacific nation of Vanuatu remains largely underdeveloped despite past European exploitation of its natural stands of kauri and sandalwood. Logging of native timber is poised to continue but exotic plantations have been established with the assistance of New Zealand aid and there are firm proposals for a significant area of kauri reserve to be established.

Vanuatu has extensive areas of forest but much of it is on broken or mountainous terrain, and resources of indigenous millable timbers are small. There is much forest of a secondary nature disturbed by cyclone or fire. One of the best timber resources in Vanuatu occurs on Erromango.

Erromango, the third largest of 80 islands in Vanuatu, previously the New Hebrides, has had an interesting forestry background. Between 1825 and 1865, not long after European discovery of sandalwood *(Santalum australocaledonicum)* in the Pacific, the wood was traded from several islands in Vanuatu, notably Erromango, which had the largest resource. A hundred years later a French logging company extracted kauri *(Agathis macrophylla)* from the island for several years. More recently plantation forestry has been introduced to the island, and today there are plans to continue logging of the kauri and other native species. There are also firm proposals to set up a kauri reserve on Erromango, an event that would be of international significance to those interested in the reservation of tropical rainforest in general and kauri species in particular.

It is hoped forestry will play an important developmental role. The potential for long-term logging is limited. However there is suitable land available for plantation forestry which is unlikely to be put to other productive uses. Population pressure is low — 1000 people over a land area of 887 square kilometres — and arguments about ownership are less of a problem than on more populous islands. In the future tourism may be attracted to the proposed kauri reserve. The local people find forestry compatible to their way of life and can see the potential benefits it will bring to the island.

Kauri Logging

On Erromango, kauri forest is concentrated in central and eastern areas in largely subtropical forest. An inventory carried out on the island in1971 identified 14,100 ha as a "potentially productive" forest. Within this area, scattered groups of kauri were found, with a total volume of c.118,100m^3 (17% of merchantable stems were over 60cm d.b.h.). The kauri stands were mostly between 200m and 400m elevation on basaltic soils. The distribution was patchy, but principally the best kauri stands were found in the southeast of the island with small groves around Mount William in the central north.

The main kauri-rich areas in the southeast were logged by Société d'Agathis from 1968 to 1974 from a base establishment at Ipota, which included a sawmill with a capacity of 400m^3 per month. An area of about 5000 ha was logged. This produced about 60,000m^3 of kauri mainly for export as logs to France, and to a lesser extent

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