

A Review of Kauri (*Agathis australis*) Nutrition and Assessment of Current Nursery Container Mixes

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INTRODUCTION

Kauri forests once covered much of the early land mass of New Zealand. Now only a remnant of the great forests remain—a mere 5% of the pre-European kauri forest has been spared from the axe and burning (Ahmed and Ogden, 1987).

Kauri is a large, long-lived tree which normally grows for more than 600 years with individuals exceeding 2 m d.b.h. (diameter at breast height) and often 1000 years of age (Ahmed and Ogden, 1987). Sale (1978) in his book, which reviews the history of the kauri in New Zealand, states that forest authorities consider this to be the tree capable of yielding the greatest volume of millable timber in the world. Sale goes on to explain the significance of this tree in the early maori history and European colonisation, including its uses and the wastage that has occurred. Fires were particularly common in logged kauri forests, many being deliberately lit by gum diggers (Ecroyd, 1982). Fortunately some great kauri giants have remained and are protected in reserves and parks. Many are seen as historic and notable trees and have been individually named (Sale, 1978; Burstall and Sale, 1984; Salmon, 1990). The kauri is therefore seen as having great historic and amenity value in New Zealand.

Recently there has been a new interest in it as a forestry tree. Early papers have recorded how the kauri is readily produced from seed (Morrison, 1955; Dakin and McClure, 1975; Barton, 1978) and also by vegetative propagation (Dakin and Mearns, 1975). Recent work by Graeme Platt and Jenny Aitken-Christie (Anon, 1993), funded jointly by the Forest Research Institute and Tasman Forestry, has involved the collection of seed and propagating material from outstanding forest trees. Selected clones have been raised using tissue culture, grafting, and cuttings. Plants grown from seed are reported to be very variable. The kauri is, therefore, seen as having potential in plantation forestry. It is a tree of great beauty and historically its uses have spanned from sailing ship masts to paving slabs, and more recently to furniture where the durable, short-grained, handsome, easily worked and lengthened nature of the kauri wood is used to an advantage (Sale, 1978).

SOILS AND HABITAT

Temperature appears to be an important determinant influencing the distribution of kauri. Pollen analyses are reported to show that the climate 4000 years ago was warmer than today (Kershaw and Strickland, 1988) and kauri were even distributed down to Otago, where fossil remains have been found (Oliver, 1953). They then receded and are now primarily found north of 38°07'S in the North Island and on many offshore islands (Ecroyd, 1982).

Soils are a key aspect in considering the nutrition of kauri, as well as their ecology and planting-out. Clayton-Greene (1978) has noted that kauri are particularly prevalent on greywacke, as well as on the younger andesitic and rhyolitic volcanic soils of the Waikato. He suggested that soil type has influenced kauri distribution and that the lack of suitable soils and terrain, rather than climatic limitations, has hindered extension further south. Platt (pers. comm.) has noted that kauri can grow in wet clays, peat, alluvial clays, and stabilised sand, but tends to be absent from recent volcanic soils and those based on limestone.

Molloy (1988) states that indigenous forest containing kauri once covered over 1 million ha of Northland and Coromandel. Most of these soils have now been cleared of kauri and he comments that today only 20,000 ha of state forest with a high proportion of kauri remain. There are 300,000 ha of kauri podzol soils which remain as a legacy of the original kauri vegetation. Kauri can grow on a wide range of soils, but under the influence of sufficient rainfall and the very acid litter of the tree species, on certain soil types, kauri podzols can form. These trees themselves are in fact a soil-forming factor, since where there is adequate rainfall the water combines with humic acids to dissolve and wash out most things including the clays. This results in a kauri podzol soil with a quartz rich E horizon (under the A horizon) which can be readily recognised due to its bleached and sandy nature. This type of impoverishment can also occur with other genera like *Nothofagus*, although the characteristic pale quartz layer of the podzol may not always develop.

Kauri trees can grow for hundreds of years on impoverished soils and may also establish on low fertility, and hilly or mountainous sites. It appears that this is not an indication of their need for low fertility but rather a tolerance of low fertility, which has given them a competitive edge compared to other trees that are less able to tolerate infertile soils. Mycorrhizal infection has been shown to markedly stimulate phosphate absorption in kauri (Morrison and English, 1967) which would be an added advantage for establishment. The kauri's ability to grow on ridges also indicates its relative wind tolerance compared to other species; it is among the most wind-firm of all trees (Ecroyd, 1982).

A further factor is their drought resistance once they are established at about one year old (Bieleski, 1959a), although young seedlings can die readily from desiccation (Mirams, 1957). So, therefore, this plant's adaptability allows it to grow on harsh, dry, ridge sites, although the largest specimens are usually found on flat relatively fertile locations. This is further borne out by the fact that kauri will often respond well to quite high fertiliser additions in potting mixes as discussed in the next section. Bieleski (1955) confirms this when he points out that the ridge-top habitat is the one normally occupied but that they grow readily on flat areas, and even in ground that is swampy for part of the year. Bieleski (1959 a,b) showed that the distribution of young kauri seedlings in the field can be limited by both low and high light intensities and it can, therefore, be concluded that not only are edaphic factors (soil and water regimes) important in governing establishment and distribution, but also light and temperature (Bieleski, 1959c) are strong growth factors. This was confirmed by Hawkins and Sweet (1989) who grew kauri in growth cabinets and found that maximum net photosynthesis was at 27°C and with high light intensities.

NUTRITION RESEARCH

Peterson (1961) studied the effect of different tree characteristics on foliar nutrient contents in kauri. Peterson (1962) then grew kauri seedlings for 100 days in solution cultures with specific supplies of six macronutrients, N, P, K, Ca, Mg, and S, and six micronutrients. The NZ native tanekaha (*Phyllocladus trichomanoides*) was also grown in the macronutrient solutions to provide a comparison. Both species responded to the range of nutrient levels with kauri appearing to prefer slightly higher concentrations of N, P, and K. It was noted that both species had low foliar N and P contents in comparison to other species and therefore have relatively low physiological requirements for these elements.

The kauri was also shown to be less severely affected by Mn and Fe deficiencies than the tomato, which was grown as a second test plant. Foliar Fe content in kauri rose to as high as 0.035 % when P was deficient. Peterson (1962) concluded that the kauri had greater tolerance than tanekaha to deficiencies and that it would be expected to grow more successfully in soils of low N and P status than other species. These and other factors help to account for observations like that of Burns and Smale (1990) who noted that in a forest study the kauri were inhibiting the growth of their associates, especially the tanekaha.

Morrison (1955) carried out an experiment with open-ground nursery-planted kauri which were supplied with ammonium sulphate, superphosphate, and muriate of potash. These treatments were applied to 2-year-old trees and 2 years after application the N and P fertilisers were found to have significantly increased the weight of the trees. Fertiliser trials in a stand of kauri aged 130 years were carried out by Barton and Madgwick (1987), where they found that the trees responded well to N fertilisers but that this was slow compared to *Pinus radiata*.

ASSESSMENT OF NURSERY MIXES

Several nurseries were requested to provide details of their container mixes used for growing kauri. A summary of the details is provided in Table 1.

Total available nutrients (for N,P,K) in g/m^3 were calculated from the rates of fertilisers incorporated in each mix multiplied by the percentage of each nutrient in the fertilisers. For comparative purposes a monthly release figure ($g/m^3/month$) was estimated based on the release periods of the individual fertilisers used in each mix. This method was described by Thomas and Spurway (1975) and can be illustrated using the following example:

- Applied 2 kg Osmocote 23-0-0 (5-6 month release)/ m^3
- Therefore total available N = $2000 \times .23 = 460 \text{ g N}/m^3$
- And monthly N release = $460 \div 5.5$ (5-6 month) = $84 \text{ g N}/m^3 \text{ month}$

This method assumes the release of nutrients from the fertiliser is uniform and while it may be simplistic it does provide a useful method of comparing mixes containing differing types of fertilisers. An estimate was made of the monthly release for both the first 3½ months (as some of the mixes include a relatively short-term fertiliser component), and the remaining term of the mix.

The stated release period or term of the mix was based on the reported release period of the slow-release fertiliser component of the base mix, e.g., 12-14 month

Table 1. Analysis of nursery container mixes used for kauri.

Mix	Media	Nutrient total (g/m ³)			Nutrients (g/m ³)						Term Lime (mo.)kg/m ³	Side dress.	
		N	P	K	First 3 mo.			After 3 mo.					
		N	P	K	N	P	K	N	P	K			
1	2 composted bark; 1 peat; 1 pumice	480	132	249	54	15	28	54	15	28	8-9	4	<input checked="" type="checkbox"/>
2	2 composted bark; 2 pumice; 1 peat	1060	299	489	209	72	105	61	9	22	8-9	5.5	<input checked="" type="checkbox"/>
3	2 composted bark; 1 pumice; 1 peat	260	114	216	29	13	24	29	13	24	8-9	3	<input checked="" type="checkbox"/>
4	2 punga fibre 1 peat; 1 pumice	950	110	315	194	20	62	51	7	19	8-9	4.5	
5	2 composted bark; 1 pumice	900	210	546	69	16	42	69	16	42	12-14	2	
6	1 peat; 1 composted bark; 1 compost; 1 pumice; 1 soil	1080	126	546	83	10	42	83	10	42	12-14	5	<input checked="" type="checkbox"/>
7	9 composted bark; 1 pumice	1010	265	455	132	39	35	58	13	35	12-14	4	<input checked="" type="checkbox"/>
8	1 peat; 1 sand	876	229	360	117	50	42	117	11	42	8-9	4	
9	3 peat; 1 pumice	140	340	100	12	28	8	12	28	8	12	?	<input checked="" type="checkbox"/>
10	composted bark	628	120	390	179	34	111	0	0	0	1-3	2.5	

Osmocote Plus, 270 day Nutricote. In some instances fertiliser side dressings were also applied although these tended to be done towards the end of this release period and have therefore not been included in the calculations.

As can be seen there is a wide variation in the nutrient levels of container mixes used for the commercial production of the kauri, and indeed native plants in general, as most nurseries did not have a specific mix for kauri. Several of the mixes contained a relatively quick-release component, e.g., calcium ammonium nitrate (CAN), PG mix, resulting in particularly high nutrient levels over the first 3½ months.

Past research work on a number of crops at Lincoln University (Thomas and Baird, 1985), and by other workers, has shown that, in general, nitrogen (N) has a greater influence on the growth of container-grown plants than any of the other nutrients. Based on their work, Thomas and Spurway (1975) have suggested a nitrogen level equivalent to 90 g N/m³/month provided optimum growth for a range of general nursery stock. Levels of 30 g/m³/month and 60 g/m³/month have been recommended for phosphorus (P) and potassium (K), respectively.

From Table 1 it can be seen that several of the mixes are well in excess of or below this nitrogen recommendation, with extreme N levels of about 30 and 200 g/m³/month being reported. Although the estimated N release for mix 9 was only 12 g N/m³/month, plants are also regularly fed with liquid fertiliser.

Growers reported steady kauri growth at the lower levels of nitrogen applications. Early unpublished research on kauri by the authors indicated that optimum foliage growth and dry matter production for container-grown plants can be obtained at relatively low levels of N, possibly as low as 60g N/m³/month. There was also a strong negative response to liming. Plants were superior in size when grown in nil lime which resulted in a pH of 4.5. These plants were greenhouse grown in 1 peat : 1 sand (v/v) medium.

Where higher levels of N have been incorporated into the commercial mixes, or when plants with low base N levels have been given a sidedressing of fertiliser, good growth response was observed by growers. This tends to indicate that while kauri are tolerant of and achieve reasonable growth with low N levels, under good growing conditions plants will respond to increased N levels. When plants are grown in less than ideal conditions and subjected to stress, e.g., hot or cold conditions, then nutritional growth responses will be limited.

From the results provided in Table 1, it can be seen that, in general, lower rates of P and K were supplied than for N. The application of low levels of these two nutrients is supported by the unpublished work of the authors who found that the kauri was less responsive to both P and K than N.

CONCLUSIONS

This review discusses the diverse soils and habitats in which kauri grow in the wild and under culture. They can be found growing in harsh conditions on soils of low fertility. Growers have reported steady growth of container-grown stock under relatively low nitrogen fertilisation. Unpublished work on kauri, by the authors, showed poor response to low nitrogen additions, although increasing lime levels strongly depressed growth. This tolerance of low fertility was also reported by Peterson (1962) and in an early New Zealand Forest Service bulletin (Anon, 1977).

Despite this tolerance, in the wild the largest specimens are normally found on flat, relatively fertile sites. Platt (pers. comm.) reports that container-grown kauri on his nursery in Auckland will normally put on four flushes of growth per year and he believes that the species responds dramatically to the correct nutrition. Some of the other growers observed good growth responses, when their plants were being grown in relatively low N base mixes, but had been given a supplementary feed. Research work by Morrison (1955), and Bartin and Madgwick (1987), on open-ground kauri, support the notion that they do respond to N applications.

Further research is required to clearly define an optimum N level for container-grown kauri. At present they are obviously being grown at a wide range of N levels. At low levels mild deficiency or at least sub-optimal growth is likely to occur, while with the very high monthly N release occurring in some of the mixes over the first 3½ months, there could be the risk of mild toxicity particularly in the first few months of potting up.

From what is known about kauri nutrition so far, and from work done on other species (Thomas and Baird, 1985), including two other native plants, a nutritional recommendation of nitrogen equivalent to about 90g N/m³/month is suggested. Further research may well confirm that this level is higher than the optimum for most rapid growth. Low phosphorus and potassium levels, and nil or low lime is recommended. Kauri are usually grown in a general potting mix, and these nutrient levels should also be suitable for other container-grown natives although they may require a higher level of lime.

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