EFFECTS OF THINNING AND FERTILISER APPLICATION ON WOOD PROPERTIES OF PINUS RADIATA

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(Received for publication 4 April 1981)

ABSTRACT

Wood samples were obtained from three plots subjected to different treatments (N_0P_0, N_1P_1, and N_3P_1; N_1 = 69.5 kg N/ha in calcium nitrate, N_3 = 208.5 kg N/ha in calcium nitrate, P_1 = 112 kg P/ha in superphosphate) in a **Pinus radiata** D. Don (radiata pine) thinning and fertiliser trial in Tasman Forest, 11 years after the initial treatments were applied to 14-year-old natural regeneration. Analyses of a number of wood properties were carried out on wood from the butt, 6-m, and 12-m levels in the stem.

At the time of measurement, volume responses of up to 20% were recorded. Densitometric analyses showed that there was an immediate decrease in wood density after the 1969 fertiliser treatment and thereafter a recovery to pre-treatment levels over about 5 years. The maximum decrease in mean density was 20% in the 1969–70 growth period at the butt level and 12% at 12 m. Differences in whole-tree density, however, were only about 20 kg/m^3, i.e., well under 5%. It was concluded that the effects of fertiliser treatment on wood density were of little technological significance.

Analyses of tracheid length, shrinkage, spiral grain, and resin content showed that treatments had no significant influence on these characteristics. The one property which showed a marked response to accelerated growth was the incidence of mild compression wood, which closely followed the pattern for basal area increment response. However, the high levels of such reaction wood in the rings after treatment were not reflected in abnormal shrinkage values and would hence have little impact on utilisation.

The improvement in volume production far outweighed any deleterious effect on wood properties.

INTRODUCTION

There are many forest site types in New Zealand in which the application of fertilisers can benefit tree growth, and the use of such remedial treatments is predicted to increase, particularly as planting extends to less favourable sites (Ballard & Will 1978).

The Wood Quality section of FRI has to date examined a number of fertiliser trials around the country to assess the impact of tree nutrition on basic wood properties. The results of these studies on radiata pine have been in general agreement with those published overseas (Cleaveland *et al.* 1974; Brazier 1977), and can be summarised as follows (Cown 1977):

> Trees growing under conditions of nutrient deficiency exhibit slow radial growth and wood properties somewhat different from those found in healthy crops in the same region. Characteristically, the wood has narrower growth rings, a greater amount of latewood, longer tracheids, and higher density than would otherwise be expected. The transition from corewood to outerwood also tends to occur at an earlier age so that the extent of the central low-density region is reduced (Cown 1974a).
>
> The addition of fertilisers can often result in dramatic increases in volume production, with associated modifications to the wood properties, the most significant being a reduction in the latewood percentage, and hence a decrease in mean density of the order of 10–15% immediately after treatment. Tracheid length has been found to decrease in proportion to the growth acceleration by up to 25%. The reduction in wood properties continues for as long as the fertiliser growth response lasts, and is more pronounced when treatment is carried out in conjunction with thinning.

One of the aspects which appears to have been overlooked in overseas reports is that post-treatment wood properties, although often significantly different from pre-treatment levels, are usually similar to those in "normal" stands and hence do not represent a real loss in quality. Sudden changes in growth rate and wood properties, while not desirable, do not appear to have a significant effect on the utilisation potential of the timber.

So far there has been no evidence to suggest that different nutrients have different effects on wood properties, as reported by Rudman & McKinnell (1970) for 7-year-old radiata pine in New South Wales. It may also be worth noting that the New Zealand results seem to be at variance with some of the results published in Australia which showed that there was no response in wood properties to the application of superphosphate, despite very significant increases in growth (Fielding & Brown 1961; Gentle *et al.* 1968).

During 1979 an opportunity arose to examine wood samples from a well-documented fertiliser trial established in Tasman Forest near Motueka, an area renowned for its low nutrient status. It was decided that a comprehensive analysis should be undertaken to assess the effects of thinning and fertiliser application on a range of wood properties.

MATERIALS AND METHODS

Trial N 191 was initiated in 1968 in 14-year-old natural regeneration in Tasman Forest (H. Baigent & Sons), Nelson Conservancy. A partial stand history is given in Table 1. The trial originally comprised six 0.4-ha replications of nine treatments, but after the 1974 thinning it was reduced to six combinations of N and P. Boron was applied to all plots at both first and second thinnings.

D. J. Mead (unpubl. results) examined growth responses 5 years after treatment and reported 18, 10, and 62% increases in basal area for N, P, and NP respectively. A subsequent assessment in 1979 (M. L. Carey & R. Keizer, unpubl. results) confirmed a sustained response to N in the presence of P, although the volume data were somewhat inconsistent due to between-plot variations in stocking levels.

The stand was clearfelled in 1979 and samples were offered by H. Baigent & Sons for assessment of wood properties. Diametric wood strips (100 mm wide × 50 mm deep) were removed at three stem levels (butt, 6 m, and 12 m) from each of 10 trees in the three treatments detailed in Table 1. The tree samples were evenly divided between two replications per treatment (i.e., five trees/rep.).

TABLE 1—History of three treatments in Trial N 191

Treatment	1954	1968	1974
N_0P_0	Regen. established	Slasher-thinned B applied	Thinned to 300 stems/ha P_1B applied
N_1P_1	Regen. established	Slasher-thinned N_1P_1B applied	Thinned to 300 stems/ha N_1P_1B applied
N_3P_1	Regen. established	Slasher-thinned N_3P_1B applied	Thinned to 300 stems/ha N_3P_1B applied

B = 9 kg B/ha in sodium borate (Timbor)
P_1 = 112 kg P/ha in superphosphate
N_1 = 69.5 kg N/ha in calcium nitrate
N_3 = 208.5 kg N/ha in calcium nitrate

In the laboratory the wood samples were broken down to yield material for assessment of:

(a) Wood density (gravimetric and densitometric);
(b) Tracheid length — five trees per treatment only;
(c) Shrinkage (green to air-dry and green to oven-dry);
(d) Compression wood;
(e) Spiral grain;
(f) Resin content.

Wood blocks for gravimetric density, shrinkage, spiral grain, and resin content measurements were cut with reference to the two treatment years. From each stem level three subsamples were obtained representing the growth periods pre-1968, 1969–74, and 1975–79. Spiral grain was recorded on either side of the blocks by means of a grain scribe and protractor; resin contents were determined on thin samples cut from the tangential faces of the density blocks and extracted with methanol in a Soxhlet apparatus.

Compression wood was assessed visually for each growth ring in all wood samples and recorded according to grade: 0, 1 (up to 25%), 2 (25–50%), 3 (50–75%), 4 (75–100%).

Tracheid lengths were measured according to the method of Harris (1966) on samples from the growth rings on either side of the treatment years and the outerwood complete ring (i.e., years 1967, 1969, 1975, and 1978).

Radial samples for wood densitometry were conditioned to 12% moisture content, machined to 2 mm thickness in a twin-blade saw, and scanned in an X-ray densitometer.

RESULTS AND DISCUSSION

Growth Response

The analyses performed by Carey & Keizer (unpubl. results) showed there were significant increases in basal area and volume increment due to added nitrogen in the period 1975–79, but only small differences in total volume production (11.4% between N_0 and N_3). These results were supported by the volume data generated in the current study (Table 2), although differences of up to 20% were observed in the plots chosen.

Densitometric analyses of radial wood samples enabled a more detailed examination of growth responses at the three stem levels since individual ring widths as well as density information were recorded. Figure 1 gives the ring width data, converted to basal area increment, at two stem levels.

The ring-by-ring data show that the response to treatments in 1968 was much greater when thinning and fertiliser were combined. The control (N_0P_0) plots showed very little growth increase at any stem level in the absence of applied N and P. The

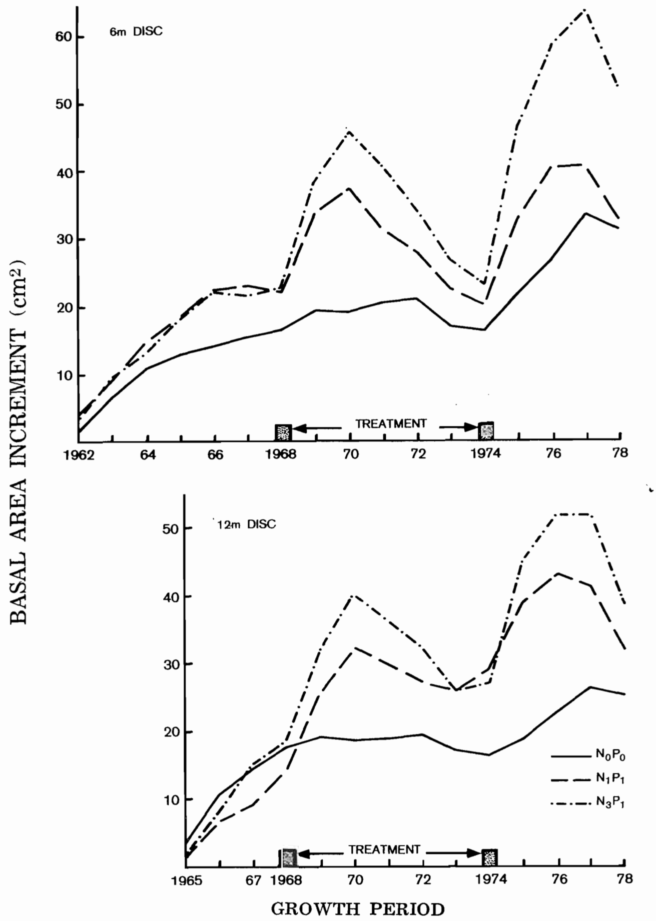

FIG. 1—Basal area increment (cm^2/yr)

TABLE 2—Volume, heartwood (%), and weighted density for the sample trees

Treatment	Plot no.	Tree no.	Volume (m³)	Heartwood (%)	Weighted density (kg/m³) Basic	Air-dry
N_0P_0	23	1	0.52	9.4	451	549
		2	0.59	8.5	480	592
		9	0.86	9.4	438	536
		10	0.79	7.8	449	546
		20	1.17	11.4	459	556
		Means	0.79	9.3	455	556
	37	1	0.55	9.7	470	575
		12	0.53	17.4	440	533
		16	0.85	5.4	433	525
		20	0.74	15.5	452	557
		25	0.79	11.4	497	608
		Means	0.69	11.9	458	560
Overall means			0.74	10.6	456	558
N_1P_1	1	6	1.11	17.3	447	534
		8	0.57	10.9	392	469
		15	0.69	13.3	446	535
		16	1.07	6.5	439	528
		17	0.49	8.0	407	607
		Means	0.79	11.2	444	535
	12	7	–	–	–	–
		12	0.63	8.4	419	502
		15	0.82	5.0	405	485
		18	0.66	7.0	621	513
		20	0.50	3.9	444	531
		Means	0.65	6.1	422	508
Overall means			0.72	8.7	433	521
N_3P_1	3	3	0.89	11.1	463	566
		5	0.87	13.8	411	496
		7	0.57	15.3	425	510
		15	0.61	8.9	404	487
		18	0.94	7.7	433	524
		Means	0.78	11.6	427	517
	51	10	1.09	11.1	414	495
		26	1.14	8.3	457	553
		27	0.94	13.4	448	545
		32	0.80	7.4	452	547
		33	1.04	12.6	408	488
		Means	1.00	10.6	436	526
Overall means			0.89	11.1	432	522

higher level of N gave the greatest boost, and accelerated growth lasted about 5 years, at which time the second treatments were applied. This time (1974) the superphosphate given the controls elicited a significant response in combination with the thinning, but again the NP treatments responded best at all stem levels. At the time of sampling in 1979 the NP treatments were still showing the highest increments, but the trends suggest that growth in all plots would be similar in about one more year (i.e., again 5 years after fertiliser application).

Wood Density (gravimetric)

Basic densities are given in Table 2; the fertilised plots showed slightly lower averages than the controls (432 and 433 compared with 456 kg/m^3). These differences are minor compared to the tree-to-tree variation documented in Table 2 and to the differences between radial positions and stem levels given in Fig. 2 (resulting from cambial age effects).

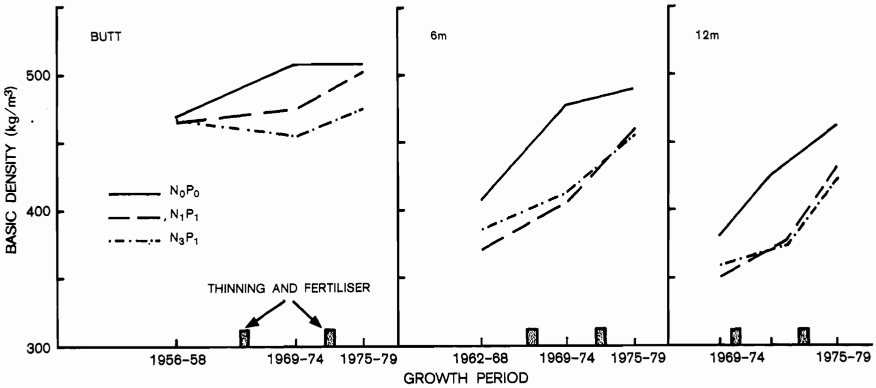

FIG. 2—Effects of treatments on basic density at three stem levels

These gravimetric data indicated that treatment differences were most apparent at the butt level, where average density decreases of 7 and 10% were observed for the years 1969–74 for the N_1P_1 and N_3P_1 applications respectively. In the growth period after the second treatment, when P was added to the control plots, density differences were less apparent (1 and 7%). At the 6- and 12-m stem levels, it appeared that there were significant density differences before treatment, but if allowance is made for these a similar pattern occurs.

The conclusion which can be drawn from the gravimetric density analysis is that the density of the wood formed after thinning and fertiliser application is lower than that after thinning alone.

Wood Density (densitometric)

Densitometer summary charts (Fig. 3) give the patterns of variation for ring mean, earlywood minimum, and latewood maximum densities across the entire radius of the

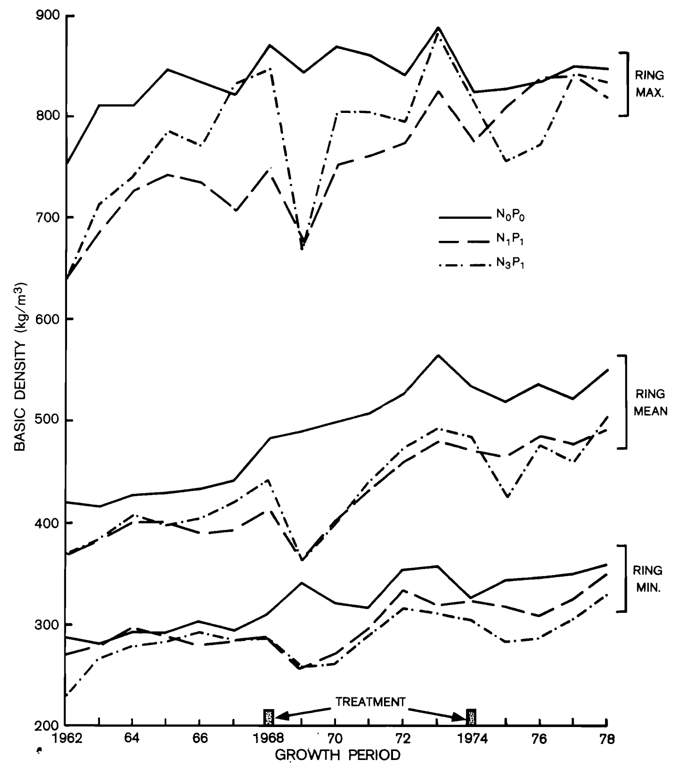

FIG. 3—Densitometric records: 6-m discs

stem. These show very clearly the effects the various treatments have had on density parameters.

At the time of first thinning and fertiliser application in 1968 there was a dramatic response in all density factors at all stem levels in the NP plots. In the year after treatment, mean density in the N_3P_1 plots dropped by 20, 18, and 12% at the butt, 6-m, and 12-m levels respectively. Over the subsequent 3–5 years densities gradually reverted towards the levels in the control plots. Latewood maximum densities seemed to show a marked response only in the year of treatment.

Although there was no apparent wood density response in the control plots, it must be remembered that there was also virtually no basal area increment in response to the first thinning (Fig. 1).

After the second treatment in 1974 there was a trend to lower densities in the controls (thinning + P) and also slightly lower densities in the NP plots. However, it is interesting that despite the large growth response in all plots, the wood density changes are small compared to those after the 1968 treatments when the N and P deficiencies were first relieved.

Using a densitometric definition for latewood percentage, it was shown that mean ring density responses were closely related to variations in the amount of latewood present (Fig. 4). In this study an earlywood/latewood boundary of 500 kg/m³ was used.

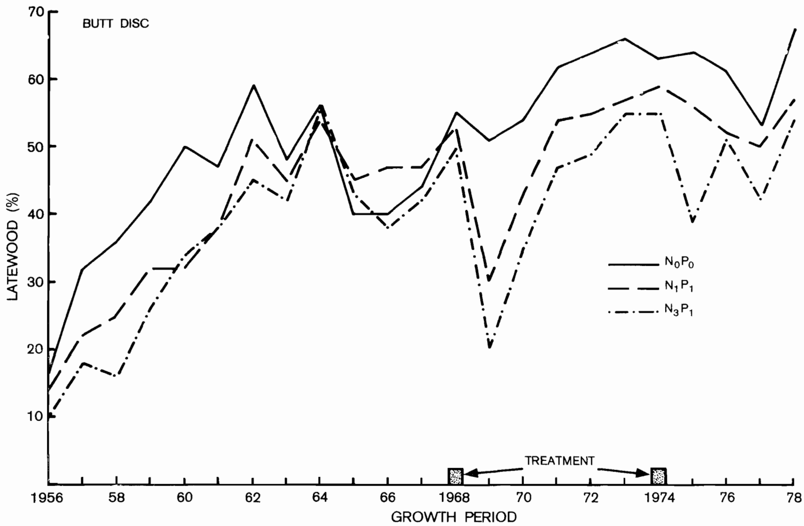

FIG. 4—Variation in latewood percentage

Tracheid Length

Summaries of the tracheid length data are given in Table 3. Although there was a tendency to slightly shorter cells immediately after the 1968 treatment, the effects were not consistent and the magnitude of the change (about 0.2 mm) was insignificant in relation to the between-tree variation recorded.

Shrinkage

Measurements of dimensional changes in the density blocks were taken as the wood was air-dried to 12% moisture content and subsequently oven-dried. Shrinkages green to air-dry are summarised in Fig. 5.

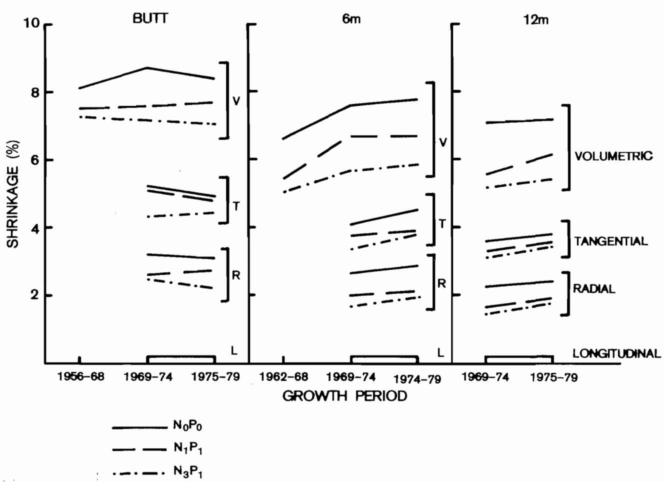

FIG. 5—Effects of treatments on shrinkage (green to air-dry)

TABLE 3—Tracheid length data

Treatment	Stem level	Plot no.	Tree no.	Tracheid length (mm) for ring: 1967	1969	1973	1975	1978
N_0P_0	Butt	23	2	2.9	3.3	3.2	3.6	3.2
		23	20	3.6	3.7	3.7	3.8	3.9
		37	1	3.4	3.9	3.3	4.1	4.0
		37	16	3.6	3.7	3.9	4.0	3.9
		37	25	3.4	3.4	3.9	3.9	4.2
		Means		3.4	3.6	3.6	3.9	3.8
N_1P_1	Butt	1	6	3.4	3.4	3.6	4.2	4.3
		1	15	4.2	4.3	3.6	4.1	3.7
		1	17	3.0	2.9	3.0	3.3	3.2
		12	12	2.7	2.5	3.1	3.3	3.3
		12	18	3.2	3.0	4.1	3.5	3.8
		Means		3.3	3.2	3.5	3.7	3.7
N_3P_1	Butt	3	3	2.4	2.9	3.4	4.2	3.6
		3	7	3.0	2.8	3.5	3.5	3.5
		3	18	3.3	3.4	3.6	3.5	3.4
		51	10	3.6	3.5	3.5	3.5	3.6
		51	33	4.0	3.4	4.0	4.2	3.9
		Means		3.3	3.2	3.6	3.8	3.6
N_0P_0	6 m	23	2	3.9	4.1	4.5	3.4	3.9
		23	20	4.0	3.9	4.3	3.9	3.5
		37	1	3.8	3.7	3.8	3.9	3.9
		37	16	3.6	3.8	3.9	4.2	4.3
		37	25	3.7	3.8	3.5	4.2	4.4
		Means		3.8	3.9	4.0	3.9	4.0
N_1P_1	6 m	1	6	4.0	3.8	4.6	4.5	4.9
		1	15	4.0	4.1	4.5	4.4	4.0
		1	17	3.2	3.5	3.8	4.0	3.8
		12	12	2.8	3.3	3.8	4.3	4.0
		12	18	3.1	3.3	3.7	3.5	3.9
		Means		3.4	3.6	4.1	4.1	4.1
N_3P_1	6 m	3	3	3.2	3.4	4.4	4.9	4.1
		3	7	2.4	2.8	3.8	3.4	4.2
		3	18	3.3	3.2	3.4	3.8	3.7
		51	10	3.6	3.4	3.8	3.9	3.4
		51	33	4.1	3.6	4.0	3.9	4.0
		Means		3.3	3.3	3.9	4.0	3.9

As was found with wood density, the control trees had higher average values before treatment and these were sustained for the period of the trial. For volumetric shrinkage, values for the controls were consistently 1–2% greater than for the stems in the NP plots. As there is a close relationship between wood density and shrinkage (Cown & McConchie 1980) it can be assumed that part of the observed differences is due to the density responses discussed above. All shrinkage values were well within the range normally found in radiata pine, and all treatments exhibited the characteristic decrease with height in the stem.

Compression Wood

As a result of an observation in 1973 that increased radial growth in radiata pine could lead to a higher incidence of mild compression wood (Cown 1974b), it has become a common practice to assess visually the extent of reaction wood in wood samples. In the current study, the average grades for each treatment were converted to ring area percentage and are shown in Fig. 6.

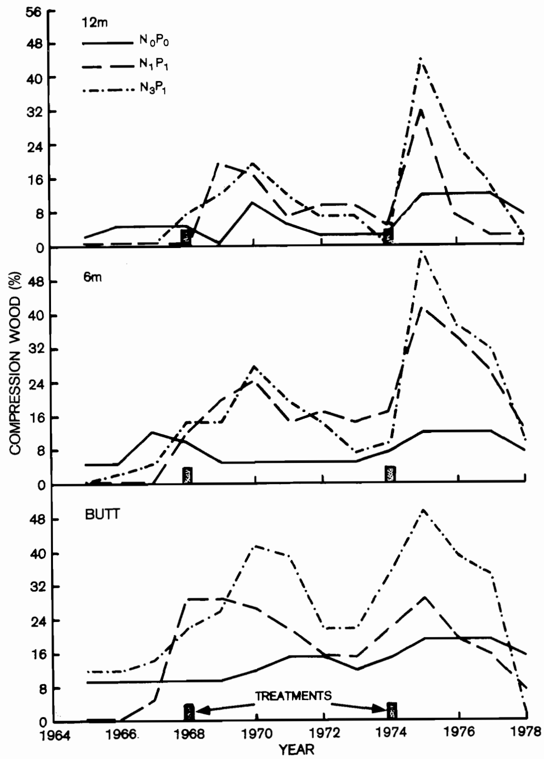

FIG. 6—Incidence of compression wood

These results clearly confirm that growth acceleration and compression wood formation are related. In fact, the similarity in pattern between Figs 1 (basal area increment) and 6 is striking, confirming that the faster growth leads to more reaction wood. Despite the high incidence in individual rings, the shrinkage data (on blocks of five rings or more) did not reflect a response in terms of excessive longitudinal movement on drying. This would tend to suggest that this low-grade but widespread form of compression wood has little technological significance.

Spiral Grain

Pronounced spiral grain is a serious defect of timber, resulting in distortion on drying and loss of strength in structural products. In radiata pine, the most severe grain distortions are restricted to the innermost growth rings and are seldom a real problem (Harris 1969). The influence of growth rate on spiral grain is not clear (Nicholls & Fielding 1965), but recent work in New Zealand has suggested a positive correlation between ring width and grain angle.

Spiral grain was assessed on the outer longitudinal/tangential surface of each density block to give an impression of treatment differences. Results are given in Fig. 7.

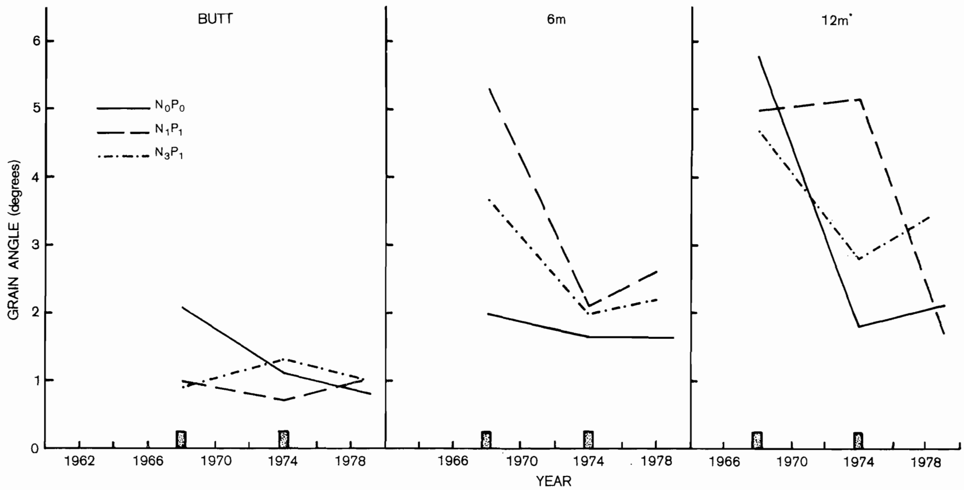

FIG. 7—Spiral grain patterns

There was a great deal of variation in grain angles within and between stems, but no consistent effect of thinning or fertiliser treatment was observed. The statistical significance of the differences in the treatment means would not be high and hence it must be concluded that there was no treatment effect of practical importance.

The increase in grain angle with tree height is a reflection of the decreasing physiological age of the wood as the sample years were located closer to the pith.

Resin Content

Resin content values for wood samples are summarised in Fig. 8. The data show clearly that there was no significant differential response to fertiliser treatments at any stem level.

CONCLUSIONS

In common with other studies on the effects of fertilisers and thinning on the wood characteristics of radiata pine (Cown 1974a, 1977), responses were observed in the levels of some properties. It seems that when there is an increase in radial growth

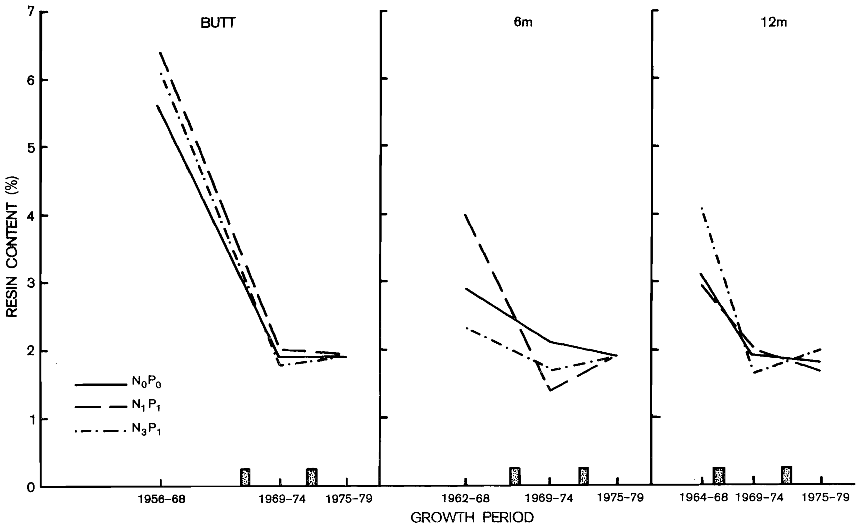

FIG. 8—Effect of treatments on resin content

there is usually a concomitant decrease in latewood percentage and wood density. This is best shown by densitometric analyses, and in the current study the N_3P_1 treatment gave a basal area increase of 150% and a density decrease of 20% in the first year after application. The response occurred throughout the tree but was progressively less pronounced with increasing height in the stem.

Although the immediate response to growth stimulus can be dramatic, density-related properties usually revert back to the pre-treatment levels within a number of years (in the present study 5 years) unless the treatment is re-applied. However, a point often overlooked in wood property analyses is that the pre-treatment values may be abnormal because of the nutrient deficiencies, which would make the observed response simply a reversion to more "normal" levels. The densitometer records presented support this thesis, showng control plot densities reaching 500 kg/m^3 within four rings from the pith at the butt level and within 10 rings at the other levels. These values would be considered high even for coastal Nelson (unpubl. data) and hence the average post-treatment densities of 460–500 kg/m^3 do not represent a real loss in quality. In fact, on the positive side, the thinned and fertilised trees provided wood which had a slightly less-pronounced radial gradient and had lower shrinkage values.

In contrast to the findings in other trials (e.g., Bisset *et al.* 1951; Cown 1977) the effect of both thinning and fertilisers on tracheid length appeared to be minimal.

An attempt was made to investigate all aspects of the wood properties/fertiliser interaction by measuring other characteristcs such as compression wood formation, spiral grain incidence, and resin content. Of these, only compression wood showed a definite response to treatment, and the results confirmed previous observations that growth rate and compression wood incidence are positively related. However, the degree of severity was typically very mild and no significant utilisation problems are anticipated.

ACKNOWLEDGMENTS

The authors express their gratitude to the staff of H. Baigent & Sons Ltd (Nelson) for providing the wood samples used in this experiment, and to Mr G. D. Young and Mrs C. Colbert in the Wood Quality laboratory for their technical assistance throughout.

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