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SOME EFFECTS OF FERTILISER LEVELS ON WOOD DENSITY

by

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EXECUTIVE SUMMARY

Using an X-ray densitometer wood samples from three sites in the Nelson region were examined for effects of boron deficiency on wood properties.

Any effects of lack of boron on one site were masked by phosphorus deficiency resulting in abnormally high latewood percentage and therefore high wood density.

On a second site where boron was known to be deficient but where nitrogen and phosphorus had been applied wood density appeared "normal". On the same site from a plot where boron was also added any effects were again masked by sample trees having extremely low levels of density and latewood percentage.

These results although inconclusive suggest that a more formal examination should be undertaken, with more trees examined per treatment, to achieve an understanding of the effects of this mineral element.

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INTRODUCTION

There have been many examinations of the effect of soil mineral deficiency and fertiliser addition to the wood properties of radiata pine and these have been carried out over the last 30 years or so covering a range of sites throughout the country. Most have investigated the effects of added nitrogen and phosphorus. The summary of Cown (1977) succinctly describes the findings over the previous 25 years.

> "Trees growing under conditions of nutrient deficiency exhibit slow radial growth and wood properties 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 wood density than would otherwise be expected. ...
>
> The addition of fertilisers can often result in dramatic increases in radial growth with associated modification of wood properties; the most important being a reduction in latewood percentage and hence a decrease of up to 10 or 15% in wood density. ... There is no evidence to suggest that different nutrients have a different influence on wood structure, the rate of growth itself being the important factor. ...
>
> It is important to bear in mind that post-treatment wood properties, although often significantly different from pre-treatment levels, are usually similar to those in nearby healthy stands and thus do not represent a real loss in quality. ..."

The trials have generally examined the effects of nitrogen and phosphorus applications, or these two in combination with boron, so specific details for the effect of boron alone are not available.

As some limited funding was available through the National Forest Fertilising Cooperative recent studies have been undertaken, at the Forest Research Institute, to examine some of the effects of boron treatment using samples from the Canterbury area. These preliminary investigations indicated that there may be some differences in cellular structure between treated and untreated trees (Adya Singh and Andrew Tan pers. comm.).

In general these finding have been that in unfertilised stands growth rings are indistinct, earlywood cells appear smaller and more variable in size, that there may be less lignin in the cell walls (indicated by toluidine blue staining), that some cell corners have cavities and finally that tracheid lengths are shorter.

Due to the limited number of samples available it was not possible to show properties to be statistically different between treatments, nevertheless there were some indications that further work might be appropriate.

Availability of further samples from the Nelson area provided the opportunity for some further brief investigations of wood density.

MATERIAL AND METHODS

From discs provided for microscopic assessment of the effects of fertiliser levels on wood structure, pith to bark samples were removed for densitometric analysis. From each of three sites (Table 1) two discs were provided, each being sampled from separate trees at breast height (1.4m).

Preparation of samples involved using a band saw to remove a 10mm square section from bark to pith on each disc. These samples were then conditioned over a period of six weeks to an equilibrium moisture content of 10%. Using an FRI designed and built saw (Harris & Hiscock, 1976) samples were further reduced to 2mm radially by 5mm longitudinally. These small strips were then refluxed in heated methanol for 72 hours to remove all resin present, followed by a further two weeks of conditioning to regain 10% e.m.c.

The FRI direct scanning densitometer system has been well described by Cown and Clement (1983) but in brief is as follows. The 2mm thick sample is passed between a radioactive source (Fe^{55} in this case) and a scintillation counter. The variation in particle count over a set time represents absorption of the particles by the wood which varies depending on wood density. Using a series of custom designed computer programs the data are manipulated to produce information on a wide variety of parameters. Of special interest to this study were whole ring, earlywood and latewood mean densities, and latewood percentage.

RESULTS AND DISCUSSION

For each of the stands examined the full results shown in Appendices I, II and III were obtained and from these the average results in Tables 2-4 were calculated. Included in these data are details of the tree growth and wood density values by year of formation. Tree growth measurements include individual ring widths and the latewood/earlywood components of those rings, a cumulative measure of inside bark radius, the cross sectional area represented by each ring at breast height and cross sectional area as a cumulative measure. These data show how poor the growth rate was, and what a high percentage of latewood was produced in the samples from Waiwhero forest, and also that for the two plots from Motueka forest, Plot 7 had slightly better growth rate but also had a much lower latewood percentage than plot 26.

Latewood percentage has a marked effect on average wood density which can also be seen in detail in the density data presented. For each site the individual results for whole ring density, latewood mean density and earlywood mean density are shown in Figures 1-3. In each graph, the lines showing the trends from pith to bark for each of these parameters, are consistent with the very general trend for radiata pine. However there are widely different levels of results within these broad trends.

To enable comparison with an "average" example for radiata pine Figure 4 has been presented. For the first ten years of growth these data should represent Nelson radiata pine well. In the national radiata pine wood properties survey, reported by Cown and McConchie (1983a), radiata wood density was found to be related to mean annual temperature. This enabled areas of the country to be classified into three broad groupings of those producing wood with low, medium and high density. The general Nelson region is designated high density, (outerwood at age 25 years > 475 kg/m^3), hence the comparison here is also with other high density sites.

Typically, as shown in this graph, mean ring density begins around 330 kg/m^3, climbing to 400 kg/m^3 at about ring 6 and by ring 10 is approximately 450 kg/m^3. Earlywood begins at roughly 310 kg/m^3 and only increases by 30-40 kg/m^3. Latewood ranges from initial levels around 420 kg/m^3 to 520 kg/m^3 at ten rings.

In Figure 1, which shows the data for Waiwhero forest, the curve for mean whole ring density begins at a "normal" level for radiata pine, however the density increase with increasing ring number from the pith is much greater than would be expected. By the sixth ring density is approximately 530 kg/m^3 and levels off at this higher level. There are similar differences between the earlywood and latewood levels and those shown in Figure 4. The probable reason for these anomalies is in the title for Figure 1; Phosphorus deficiency. As early as 1963 Orman and Harris described a drop in basic density levels in radiata pine following phosphate application to phosphorus deficient sites in North Auckland. In a similar study in 1966 Harris recorded a drop of 80 kg/m^3 in basic density between 5 rings before and 5 growth rings following phosphorus addition. It should be pointed out that wood formed prior to treatment was "abnormal" so the drop in density was simply to return the wood to something like expected levels on a site with normal phosphorus levels available.

As this study was to make a preliminary investigation of the effects of boron on wood properties, namely density, the inclusion of this site as perhaps representing medium boron levels has resulted in very little value other than providing a further example of the effects of phosphorus. Any relevant information as to the effect of the boron has been well and truly masked by this over-riding effect.

Figure 2, provides an example of a control, (low foliar B; Table 1), plot of radiata pine planted in Motueka forest in 1978, using climbing select seed (NN76/10; ex Golden Downs Cpts. 95 and 106), as part of a fertiliser trial (NN518). The addition of nitrogen and phosphorus in 1983 is marked on the graph and is followed by only a slight drop in density for the following year. Again this is an expected result and has been well documented by Cown and McConchie (1981). The important point to note from Figure 2 is that the three lines closely approximate the "typical" lines in Figure 4. In other words the low foliar B status does not appear to adversely affect wood density examined at this level (although this does not discount the possibility of some changes at the microscopic level).

The difference in smoothness between this graph and that in Figure 4 is simply a matter of numbers of samples. Figure 2 represents two trees hence some unevenness in the general pattern, whereas Figure 4 represents something in the order of 90 samples from a range of sites. Considering these differences the lines are surprisingly close. Taking the mean whole ring values as examples they begin at very similar densities, both cross the 400 kg/m^3 level at similar ages and at ten rings from the pith the "typical" line ended at 450 kg/m^3 and the test trees having mean levels of about 430 kg/m^3. In other words the control is a near perfect example of the norm.

Examination of the data in Figure 3 comes as rather a shock then. With the addition of boron to the fertiliser application in 1983 there is a slightly greater drop in density than for the control, although with so few trees this may or may not be significant. But the over-riding difference between these two figures is that the overall density levels in Plot 7 are extremely low. Latewood density is quite similar to the control values but both earlywood means and whole ring mean densities are some of the lowest that the authors have ever encountered in radiata pine. The density levels are low before the addition of any fertiliser so it can not be attributed to that source.

Factors affecting density can also be due to seed source or site. Although both the control and this plot were from the same seed source it is not inconceivable that two seedlings arising from a single abnormally low density parent may have been unfortunately sampled. Density variation within stands of 12-year-old trees can be greater than 100 kg/m^3 (Cown and McConchie; 1983b) so although unlikely, this is possible.

The second cause of variation, that of site, is also a likely source of the anomaly. Trial NN518 has been sited straddling a ridge. Unfortunately, although the two plots sampled here were adjacent, they were on opposite sides of this ridge (Doug Graham pers. comm.). Obviously many factors could then be contributing to the influence on density levels. Prevailing winds, direction of sunshine and even hours of sunshine could all contribute to micro-climate effects on temperature, and soil fertility and types may also be different on each side of the ridge top.

Figure 5 shows latewood percentage for each of the three study sites. Latewood percentage has a high bearing on mean whole ring density levels and examination of this diagram can help in further understanding the wide range in results found. Again the line for Motueka Plot 26 (Control) can be taken as relatively normal levels. The high density of the phosphorus deficient site can be largely attributed to the very high levels of latewood (also often associated with extremely poor growth rate) whereas the "balsa wood producing" plot 7 at Motueka has extremely low levels of latewood which combined with the extremely low density earlywood resulted in the overall abnormally low density described.

CONCLUSIONS

It is not always easy to obtain appropriate samples, at short notice, for an investigation such as this one and inconclusive results can eventuate as was the case here. As a preliminary investigation of the effects of boron deficiency on wood density of radiata pine this trial raised more questions than it answered. It did show that these techniques are a valid system for this type of investigation, as, for example, in the way the fertiliser addition was recorded in the density profiles in Figures 2 and 3.

From the small sample representing trees with low foliar B it appears that the basic density levels are "normal" for radiata pine grown in this area. More samples would be required to confirm this observation as would be necessary to discern why samples from plot 7 Motueka forest are so low in density.

As the effect on wood properties of boron addition has not been answered by this brief study it would seem appropriate to plan a non-destructive sampling (breast height 5mm diameter increment cores) of 10 to 15 trees per site and to include similar sites with and without the addition of boron to determine the effect of this element.

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Table 1. Sample Tree Details.

Waiwhero Forest, Compartment 60.

	DBH (mm)	Green Crown (m)	Total Height (m)
Tree 1	134	2.0	9.5
Tree 2	100	0.8	7.4

Motueka Forest, Compartment 58, Trial NN518.

Planted 1878. Nitrogen & phosphorus fertiliser trial established September 1983 and a base dressing of boron fertiliser applied at 8 kg/ha.

1. Plot 26.

1984 B level	7 ppm
1986 " "	11 ppm
1987 " "	9 ppm

	DBH (mm)	Green Crown (m)	Total Height (m)
Tree 1	203	2.3	20.0
Tree 2	215	4.2	18.4

2. Plot 7. Boron applied 1983.

1984 B level	34 ppm
1986 " "	38 ppm
1987 " "	19 ppm

	DBH (mm)	Green Crown (m)	Total Height (m)
Tree 1	241	2.9	17.3
Tree 2	214	5.2	20.0

Table 2. Densitometer Summary for Waiwhero Forest, Compartment 60.

	Widths (mm)					Areas (cm^2)		Densities (kg/m^3)						
Year #	Outer Rad.	Ring	Erly Wood	Late Wood	% LW	Incr	Total	Ring mean	E/Wd mean	L/Wd mean	Unif	Min	Max	Range
1981	6.3	6.3	6.0	.3	4	1.2	1.2	322	317	467	120	227	458	231
1982	13.5	7.2	5.4	1.8	25	4.5	5.7	396	348	534	186	284	623	338
1983	19.2	5.7	3.0	2.7	48	5.9	11.6	459	369	553	184	298	684	386
1984	25.8	6.3	3.9	2.4	39	9.3	20.9	453	387	555	168	327	696	369
1985	31.8	6.0	2.7	3.0	52	10.9	31.8	476	377	565	188	328	714	386
1986	35.7	3.9	1.2	2.7	68	8.3	40.0	531	414	587	173	393	707	314
1987	38.7	3.0	.9	1.8	64	7.0	47.1	546	415	616	200	398	705	307
1988	42.0	3.3	1.2	2.1	65	8.4	55.4	535	413	596	183	402	699	297
1989	45.3	3.0	1.2	1.8	61	9.1	64.5	538	401	622	221	371	696	325
1990	50.4	3.3	.9	2.4	72	15.3	79.8	540	411	588	177	389	666	277

Table 3. Densitometer Summary for Motueka Forest, Compartment 58.
Trial NN518, Plot 26 : Control.

	Widths (mm)					Areas (cm^2)		Densities (kg/m^3)						
Year #	Outer Rad.	Ring	Erly Wood	Late Wood	% LW	Incr	Total	Ring mean	E/Wd mean	L/Wd mean	Unif	Min	Max	Range
1980	7.2	7.2	6.9	.3	4	1.6	1.6	329	323	463	140	294	463	169
1981	12.6	9.0	8.4	.6	6	3.4	5.0	348	333	556	223	268	602	334
1982	21.0	8.4	7.2	1.2	14	8.9	13.9	371	341	548	207	271	611	340
1983	30.3	9.3	7.5	1.8	20	15.0	28.8	388	353	527	173	304	597	293
1984	42.6	12.3	10.5	1.8	14	28.2	57.0	381	354	546	191	281	597	315
1985	54.6	11.7	8.7	3.0	25	36.6	93.7	413	369	537	168	335	640	305
1986	62.7	8.1	5.7	2.4	30	29.8	123.5	411	363	555	191	320	614	294
1987	69.6	6.9	4.8	2.1	30	28.7	152.2	409	357	518	161	310	593	283
1988	76.8	7.2	4.8	2.4	33	33.1	185.3	420	352	560	208	309	678	369
1989	81.9	4.8	3.0	1.8	39	25.4	210.7	435	341	572	231	303	642	339
1990	82.8	4.8	3.6	1.2	25	4.7	215.4	424	369	588	219	292	631	339

Table 4. Densitometer Summary for Motueka Forest, Compartment 58.
Trial NN518, Plot 7 : Boron added.

	Widths (mm)					Areas (cm^2)		Densities (kg/m^3)						
Year #	Outer Rad.	Ring	Erly Wood	Late Wood	% LW	Incr	Total	Ring mean	E/Wd mean	L/Wd mean	Unif	Min	Max	Range
1981	6.3	6.3	6.3	.0		1.2	1.2	238	238			151	371	220
1982	14.4	7.8	7.8	.0	2	5.3	6.5	241	237	450	206	168	443	275
1983	23.1	9.0	8.7	.0	2	10.2	16.8	257	253	452	210	164	447	283
1984	34.8	11.7	11.7	.0		21.3	38.0	222	222			152	402	250
1985	47.7	12.9	12.3	.6	4	33.4	71.5	257	247	456	208	146	458	312
1986	59.7	12.0	11.4	.6	4	40.5	112.0	267	258	461	203	158	465	307
1987	69.3	9.6	8.7	.9	9	38.9	150.9	280	260	475	215	145	482	337
1988	79.5	10.2	8.7	1.2	13	47.7	198.6	286	254	491	236	165	518	353
1989	90.0	10.5	8.7	1.8	17	55.9	254.5	311	272	500	228	185	540	355
1990	96.6	6.6	6.0	.3	7	38.7	293.2	287	272	480	208	170	489	318

Figure 1. Effect of Fertiliser on Wood Density
Waiwhero Forest, Compartment 60.
Medium Boron Levels: Phosphorus Deficient.

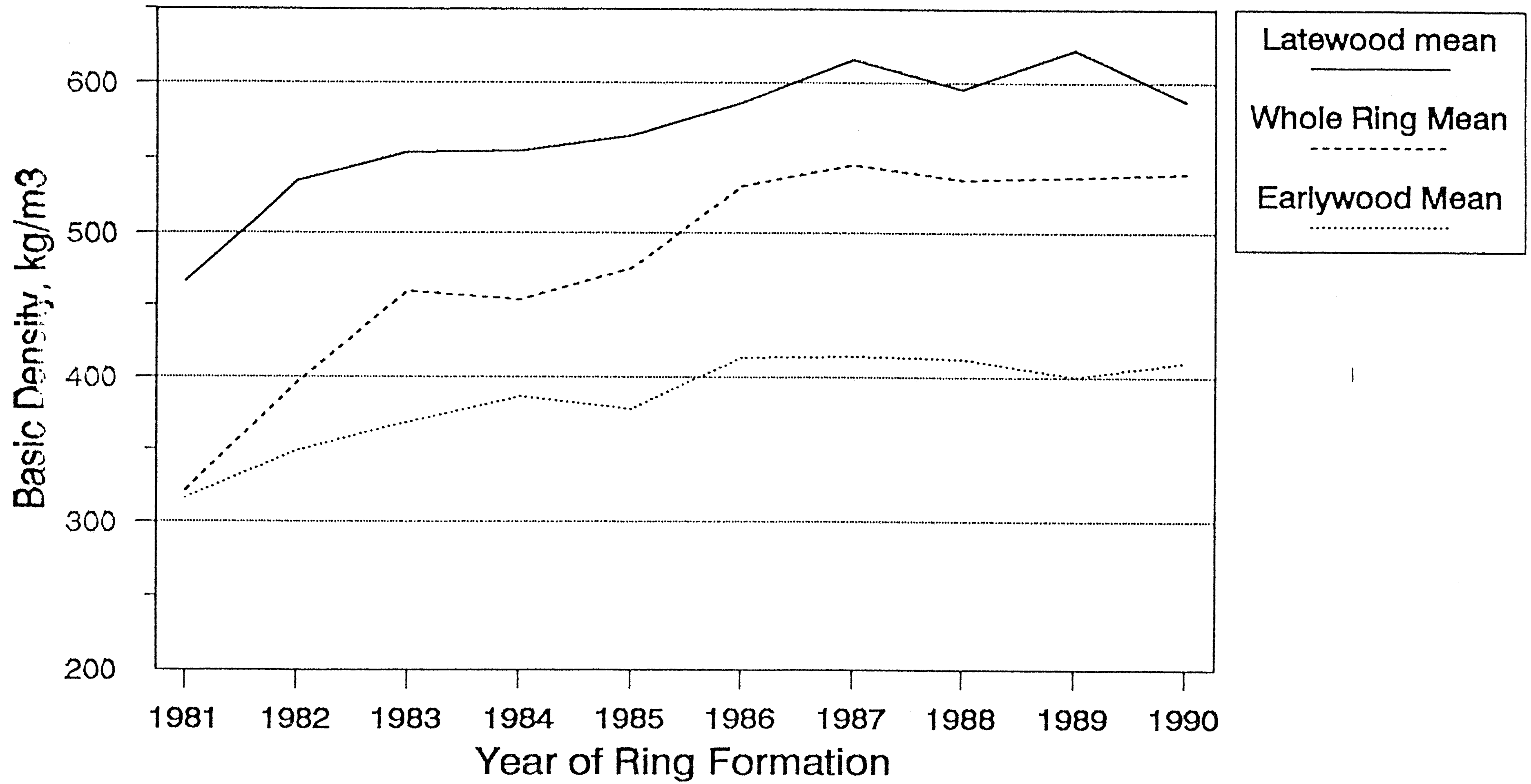

Figure 2. Effect of Fertiliser on Wood Density
Motueka Forest, Compartment 58, Trial NN518.
Plot 26. Control: No Boron Added.

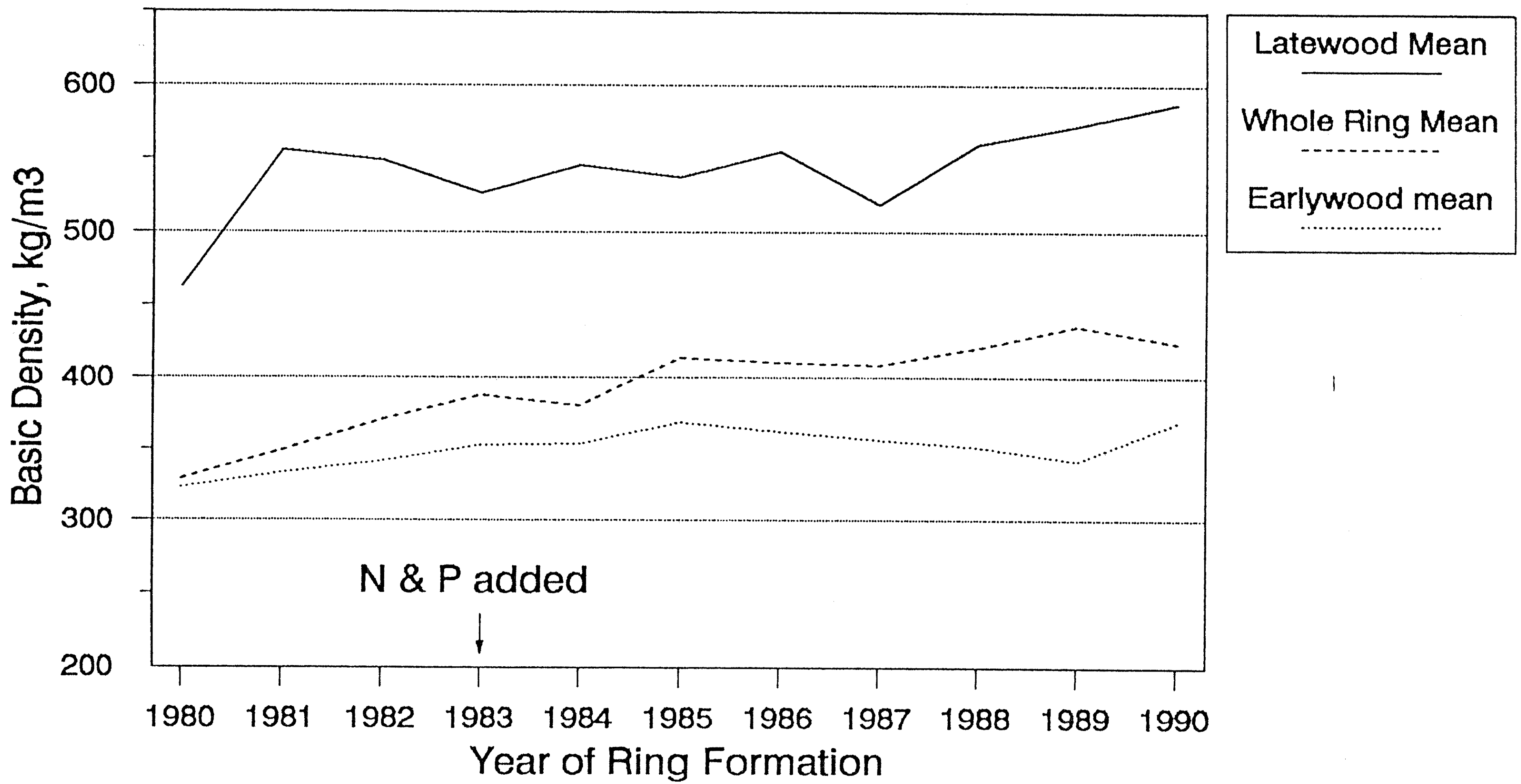

Figure 3. Effect of Fertiliser on Wood Density

Motueka Forest, Compartment 58, Trial NN518

Plot 7: N, P & B Added.

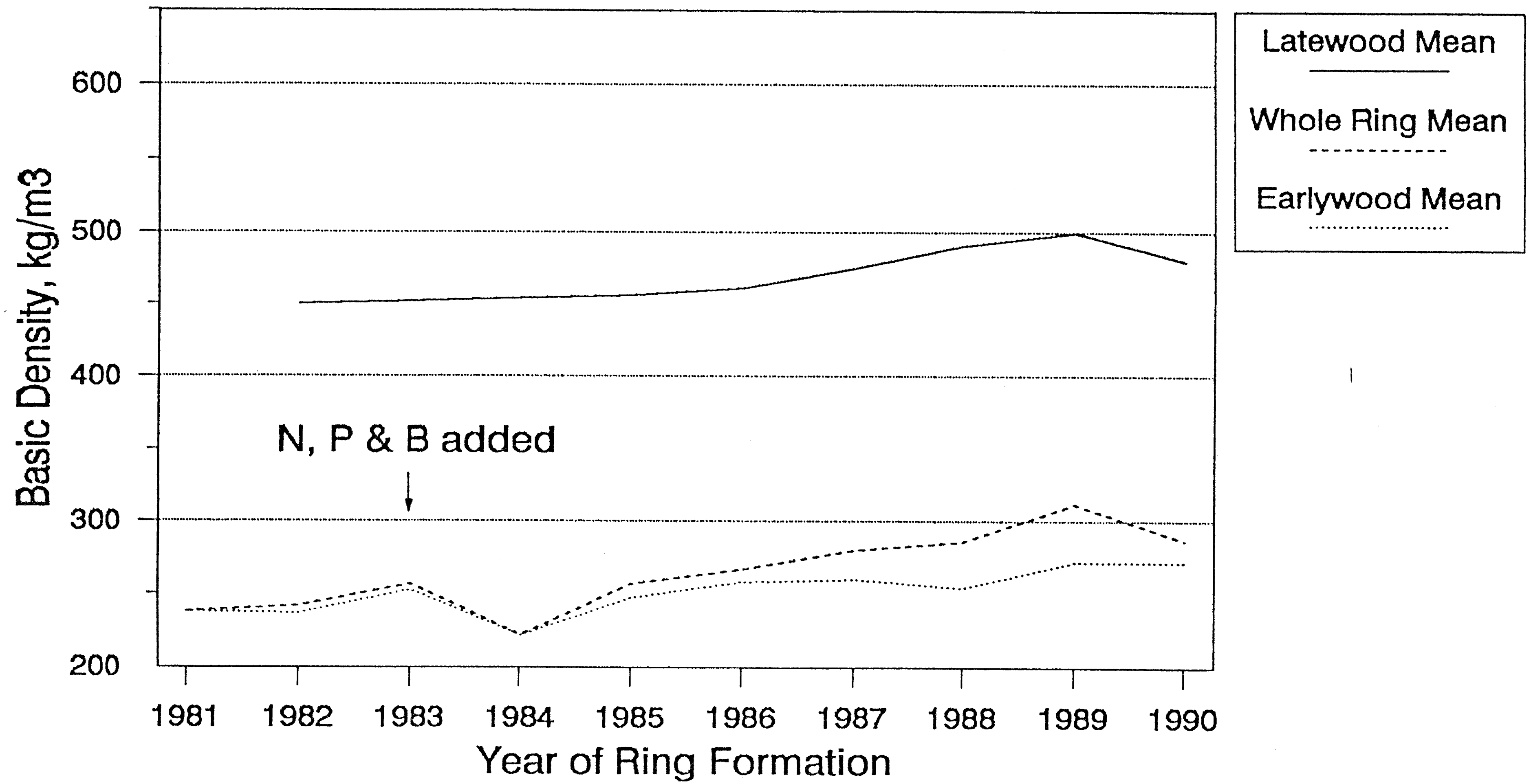

Figure 4. Typical Density Profiles for Radiata Pine on High Density Sites.

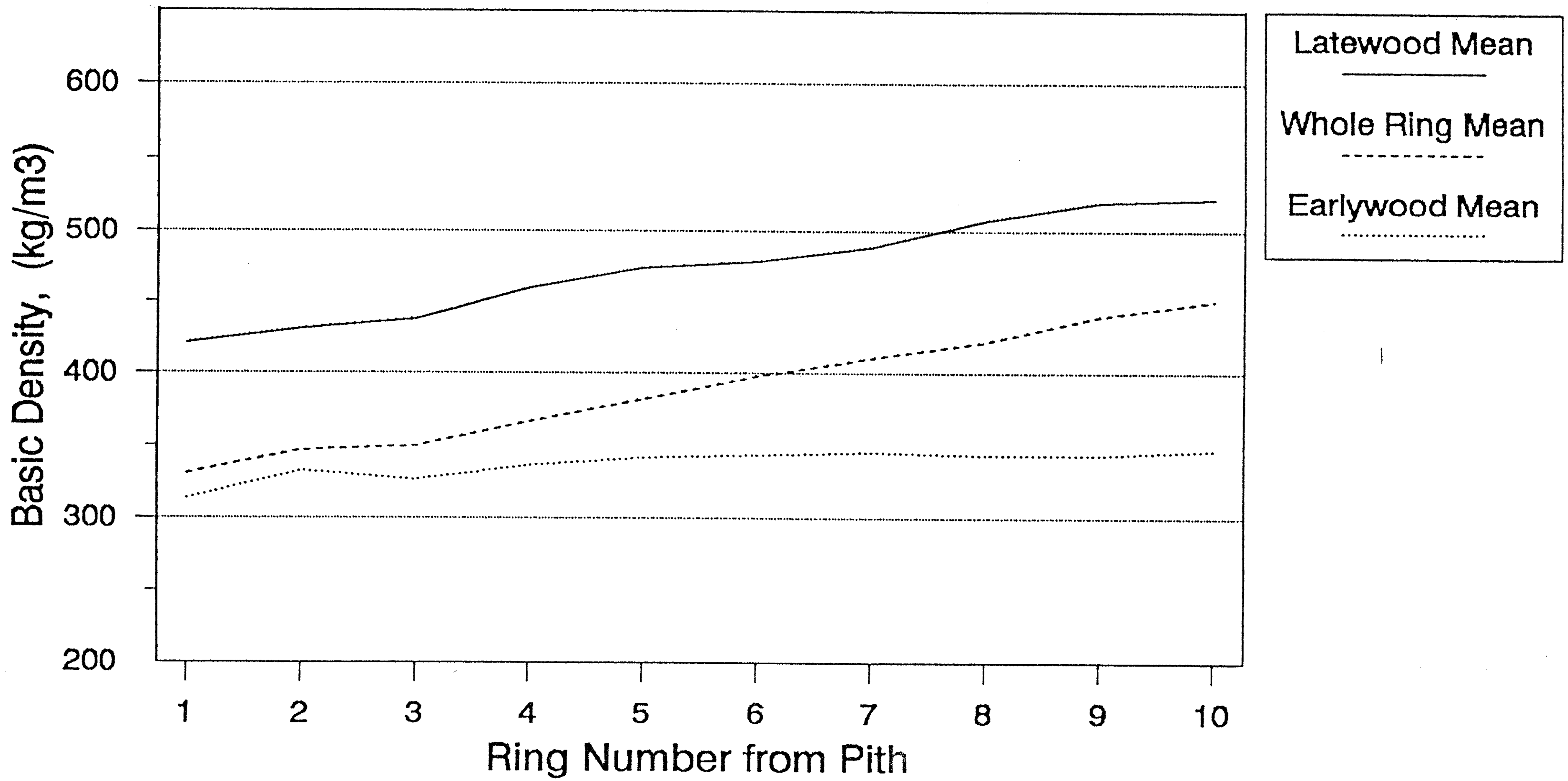

Figure 5. Comparison of Latewood Percentage on Three Sites.