PART A

NURSERY AND FIELD STUDIES

AN INDUSTRIAL COMPANY'S VIEW OF NURSERY STOCK QUALITY

D. J. ALBERT, G. FRY and B. R. POOLE

New Zealand Forest Products Limited, Tokoroa

(Received for publication 22 January 1980)

ABSTRACT

Experimental trials with **Pinus radiata** D. Don and **Eucalyptus regnans** F. Mueller are presented. The trials relate to the effects of seedling size, chemical treatment, handling and storage period on subsequent survival and growth. The trials have led to operational changes in nursery practice, e.g. wider spacing in nursery beds, different fertiliser regimes and the more careful handling of plants between the nursery bed and the field planting site.

INTRODUCTION

New Zealand Forest Products Limited process the wood from their own forests. Some 176,000 ha of their total land holding of 192,000 ha is sited on the pumice country of the Central North Island of New Zealand. The pumice country is noted for the high volume production of the major plantation species, *Pinus radiata* D. Don. The high production is made possible by the favourable pumice soil and the equable climate. The pumice soils are mainly deep, free draining, but capable of good water storage. The climate is temperate with mild winters and the rainfall is abundant (1500 mm) and distributed uniformly throughout the year. Frosts, however, can occur in any month of the year and the out-of-season frosts are particularly damaging to young planted trees. Apart from this feature of frosts, the climate is suitable for plantation forestry.

The pumice soil is an asset in the nursery since machinery can work whatever the weather conditions and the water storage capacity, coupled with even rainfall, allow *P. radiata* crops to be grown without irrigation.

The wood-flow position of the company requires high standards of establishment and re-establishment for *P. radiata* plantations. A high standard is also required of eucalypt plantations in order that they may replace *Beilschmiedia tawa* (A. Cunn.) Benth et Hook f. ex Kirk, a native hardwood presently being used as a source of short fibre pulp.

ESTABLISHMENT TRIALS WITH *P. RADIATA*[1]

The effect of fertilisers at establishment was examined in a preliminary trial set up in 1973. One of the most striking features of the trial was the performance of the experimental "control" plots compared with routine planting nearby. This performance was attributed to the experimental control imposed; grading of nursery stock, cultivation of the site, careful handling of the plants between the nursery and the field and post planting weed control.

In 1975 it was decided to attempt to measure the individual contribution to plantation success made by five factors: fertilisation, weed control, grading of nursery stock, cultivation, and machine planting. Two levels of each factor were involved:

1. Fertiliser (60 g urea) *v* No fertiliser
2. Graded Nursery Stock (graded to 30 cm in height) *v* Ungraded nursery stock (size not recorded)
3. Machine Planting *v* Hand Planting
4. Weed control (according to site) *v* No weed control
5. Cultivation (Rotary Hoe) *v* No cultivation

The design was a full 2^5 factoral design laid out in blocks of eight and replicated twice. The blocking resulted in the confounding of higher order interactions.

Two sites were chosen for the trials. One was a pasture site of rye grass (*Lolium perenne* L.) and clover (*Trifolium repens* L.) and the other was a scrub site of manuka (*Leptospermum scoparium* J.R. et G Forst.). The scrub site had been prepared for planting by tractor crushing the vegetation and burning; the pasture site had no site preparation but had been grazed up until a short time before planting.

The results of the trial are given in Table 1. There were no important interactions.

TABLE 1—Stem diameters of treatment plot seedlings expressed as deviations from control plot seedling diameters

Treatment	12 months	24 months	36 months
	Ground level		30 cm above ground level
Pasture site:			
Fertilisation	− 1.2	− 2.7	− 2.5
Weed control	+ 7.7	+ 20.7	+ 32.5
Graded nursery stock	+ 2.8	+ 6.8	+ 13.5
Cultivation	+ 1.5	+ 3.8	+ 5.4
Machine planting	+ 1.4	+ 2.0	+ 6.9
Control	2.0	3.5	10.5
Scrub site:			
Fertilisation	+ 2.7	+ 10.3	+ 6.8
Weed control	+ 1.7	+ 10.5	+ 7.7
Graded nursery stock	+ 3.0	+ 12.2	+ 10.4
Cultivation	N.S.	N.S.	N.S.
Machine planting	N.S.	N.S.	N.S.
Control	10.0	27.5	57.5

NOTE: All indicated differences are highly significant ($P < 0.01$).

[1] All nursery stock 1 year old from seed, bare rooted.

The results showed that the use of weedicide affected survival as well as growth. Plots not treated with weedicide had lower survival. Therefore in calculating treatment effects, gross differences have been used.

$$\text{Gross mean diameter} = \frac{\text{sum of diameters of surviving trees}}{\text{total number of trees planted}}$$

The high natural fertility level at the pasture site was expected to result in little or no response to applied nitrogen. The actual result showing a negative response to applied nitrogen is thought to be due to placing urea too close to the roots.

The management implications of these trials were:

(a) For satisfactory survival and growth in the pasture the use of herbicides is obligatory

(b) On both sites important advantages were obtained through the grading of nursery stock

(c) The benefits from nursery grading can be applied, at moderate cost, to all establishment and re-establishment sites. In our own case, with *P. radiata* plants lifted by machine, the extra costs involved are in-bed culling, extra packing, and extra planting costs.

In the following year a factoral trial involving time of planting and the grading of nursery stock was set up. Two planting times and four grades of nursery stock from two nurseries were used. A summary of the results, after three years, is given in Table 2.

Statistical analysis showed that the differences between the three graded tree stocks were highly significant ($P < 0.01$). A significant difference was also detected between the two planting times.

Figure 1 relates the collar diameter at planting to the 1, 2, and 3 year results of this trial. The results for the two planting times have been combined. The figure shows how the trees used in the trial compared with routine nursery production. The advantage of the larger seedlings from the lower altitude nursery (Kaipaki) is clearly shown as is the need to eliminate the production of small nursery stock. The revised prescription achieves this. The other finding of the trial, desirability of June planting, has not been applied in practice. While earlier planting is of advantage other management considerations require that the planting season be extended.

Two trials have examined the effect of opossum damage to newly planted seedlings.

TABLE 2—Overbark diameters at 30 cm ground level three years after planting

	Gross mean diameter (mm)	
	June planting	September planting
Ungraded	51.3	47.1
Graded to 20 cm; 3-4 mm collar diameter	47.0	36.8
Graded to 25-30 cm; 4.5-5.5 mm in diameter	54.0	51.3
Graded to 35-40 cm; 6-7 mm in diameter	70.3	66.3

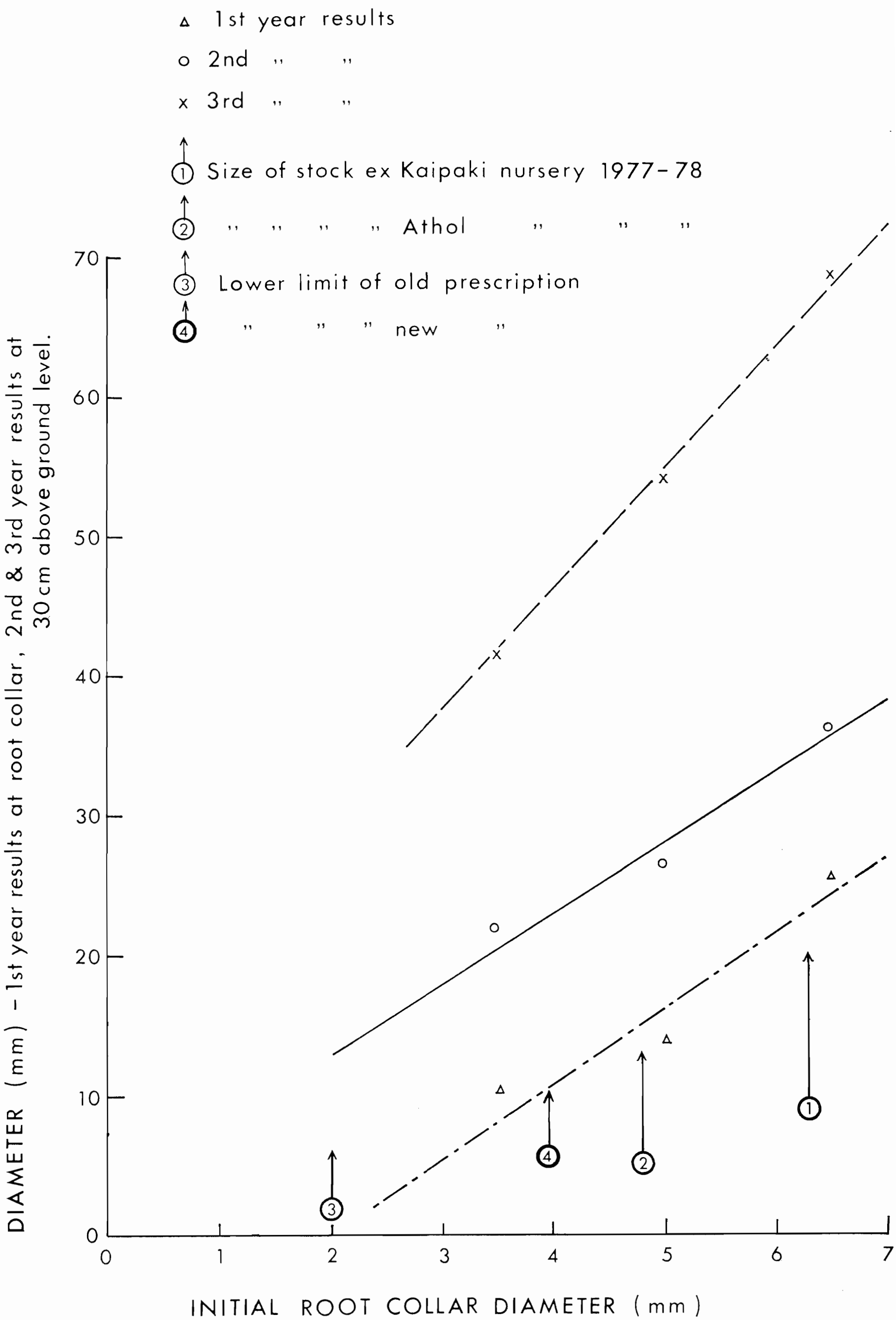

FIG. 1—Relationship between initial root collar diameter and subsequent performance of ***P. radiata.***

Opossum damage which at this age usually takes the form of the removal of the growing tip together with a few centimetres of stem, was simulated by removing fixed portions of the stem, after the trial planting stock had been graded to uniform size. The proportions removed were 0, 10, 25 and 50% in the first trial and 0, 12½, 25 and 50% in the second. In the second trial, the diameter loss at age two was directly proportional to the percentage of stem removed (Fig. 2), and in the first,

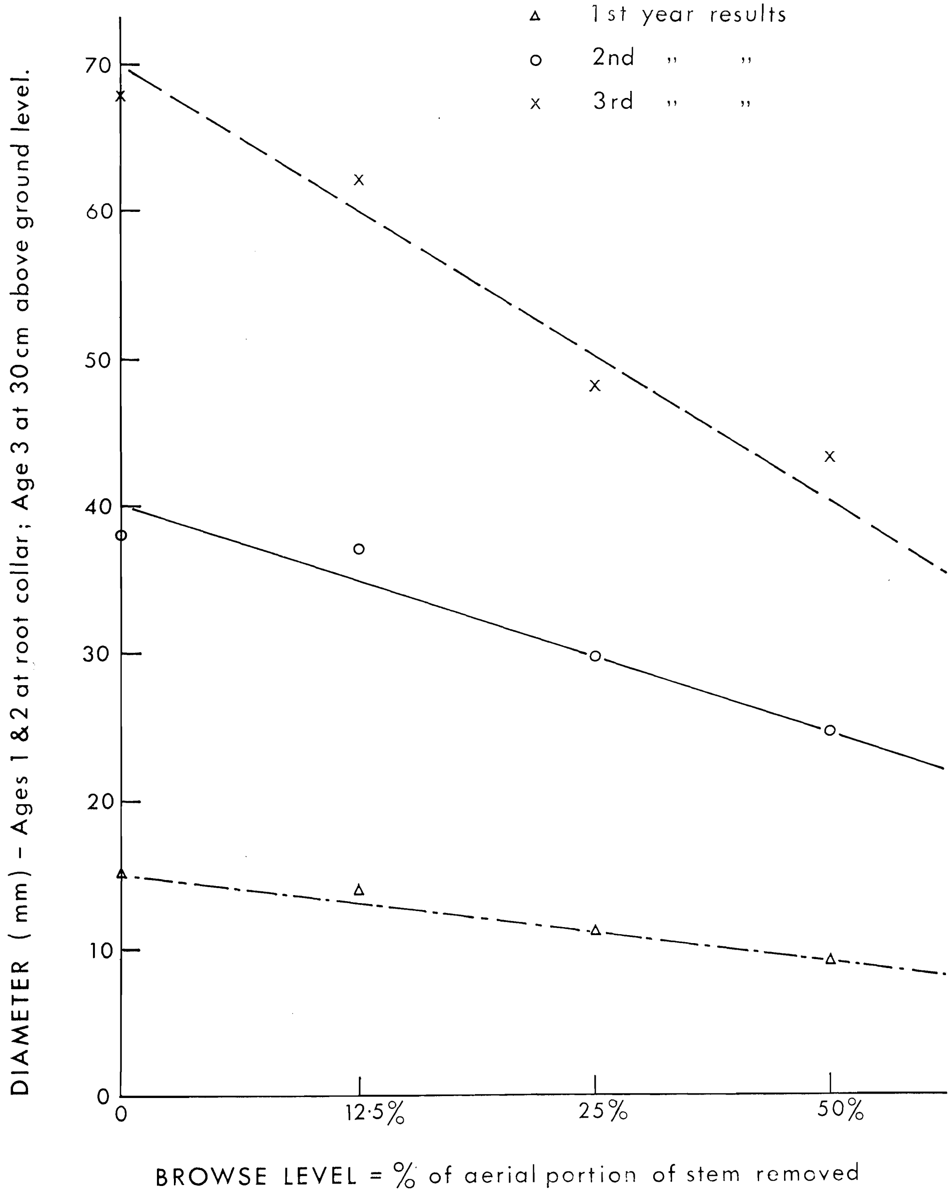

FIG. 2—Effect on subsequent growth of browsing after planting.

there was little difference between control and 10% browse but losses were more severe at the 25% and 50% level of browse.

ESTABLISHMENT TRIALS WITH *EUCALYPTUS REGNANS*[1]

The importance of size of planting stock was studied for *E. regnans* in 1972 and 1973. The stock was graded according to root collar diameter. For the 1972 exploratory trial three grades of stock were chosen.

1. Root collar diameter 3 mm
2. Root collar diameter 3-4 mm
3. Root collar diameter > 4 mm

The seedlings were also classified as either "red" or "green" plants. Although not formally tested it was assumed that the tree colour differences reflected nutrient status, and in fact, it was not possible to find "red" trees of the largest root collar diameter. The results of an unreplicated trial are given in Table 3.

TABLE 3—Heights of graded **E. regnans** seedlings (12 months after planting)

Grade of nursery stock	Height (cm) Red plants	Green plants
Ungraded	100	110
Root collar diameter < 3 mm	70	102
Root collar diameter 3-4 mm	106	131
Root collar diameter > 4 mm	—	122

This exploratory trial led to a more comprehensive trial in 1973 where the following treatments affecting field performance of planting stock were investigated at three levels:

1. Size of nursery stock	Small 6 mm, medium 6-7 mm, large greater than 7 mm. (The grades chosen reflect the improvement in seedling quality between the years 1972 and 1973).
2. Planting date	Planting in June, July and August.
3. Storage period	Plants stored for 1, 5 or 10 days following lifting.
4. Chemical treatment	Plants received no treatment, treatment with anti-transpirant, or treatment with anti-transpirant together with root dipping in a vermiculite slurry. The anti-transpirant used with a 20% latex solution. Seedlings were dipped in this solution and excess allowed to run off while the roots were protected by moist hessian.

This trial was affected by severe frosts at the time of the June planting, and later by an unseasonal frost. The June planting with an initial survival of 33% was judged

[1] All nursery stock 1 year old from seed, bare rooted.

to be a failure and omitted from the results. On 13th January 1974, following a day maximum of 20.7°C, the overnight minimum recorded was 0°C. At the experimental site frost damage became evident in a few days. Measurement of the trial was made immediately and it was abandoned in February 1974. Since treatment had affected survival up to the time of the unseasonal frost, gross mean height was used in the analysis. The results are given in Table 4.

TABLE 4—Effect of size of stock, storage period, chemical treatment and date of planting on survival and gross mean height of **E. regnans** seedlings

		Survival %	Gross mean height (cm)*
	Small	77	62
Size of stock	Medium	89	95
	Large	95	117
	1 day	96	106
Storage period	5 days	86	85
	10 days	82	83
	No treatment	80	80
Chemical Treatment	Anti-transpirant	91	100
	Anti-transpirant + Vermiculite slurry	89	94
	June	Initial survivals unsatisfactory	
Date of planting	July	85	98
	August	88	85

$$* \text{ Gross mean height} = \frac{\text{Sum of heights of all surviving trees}}{\text{Total number of trees planted}}$$

As a result of the trial, emphasis was placed on the use of large nursery stock, the anti-transpirant was brought into operational use and plant storage periods were kept to a minimum. The frost damage the trial plantings suffered also underlined the importance of site selection in a eucalypt planting programme.

The effects of anti-transpirants and storage period on *E. regnans* were re-examined in 1978. The storage period was reduced to three days as this represents the longest period likely to be experienced operationally. No significant effects for anti-transpirant or storage were found in a 2^2 factorial replicated four times. The results are given in Table 5.

TABLE 5—Effect of storage period and anti-transpirant treatment on survival and gross mean height of **E. regnans** seedlings

	Gross mean height (cm)	Gross mean root collar diam. (mm)
Anti-transpirant	194	24.0
Storage (3 days)	199	25.9
Storage and Anti-transpirant	198	26.7
Control	198	26.0

Compared with the previous trial the weather conditions at planting were more favourable and the planting stock of higher quality (in respect of root mass). These factors may have contributed to the very high survival (only 1 death in the 480 trees comprising the trial), and apparent inconsistency with the previous trial.

EFFECT OF HANDLING ON *P. RADIATA*[1]

An assessment of the handling system was carried out in 1971 to measure the subsequent performance of trees at points in the handling system. The handling system at that time had the following steps:

a. Lifting of seedlings by a modified potato digger;
b. Transport of the lifted seedlings to a packing shed;
c. Grading and packing of seedlings into waxed cardboard containers (*ca.* 250 trees/box);
d. Packing of the containers into a plywood crate (*ca.* 27,000 plants) for direct transport to the nursery.
e. Transference of seedlings at the planting site from the crates and containers into the planters' bags.

On average the time from lifting in the nursery to planting in the field was five days; exceptionally trees could be up to ten days in the handling system.

The sample points chosen for the assessment were the lifter, the crate leaving the nursery after the plants had been through a grading/packing shed, and the planter's bag of plants. At various times during the planting season samples were taken on the same day at these points and planted in the nursery. At the end of the first growing season the mortality figures were:

Lifter	0.6%
Crate	1.6%
Planter's bag	7.0%

The measurement figures relating to the assessment are presented in Table 6.

This assessment of the operational practice showed a progressive deterioration of planting stock quality from the lifter to the planter's bag. Therefore attempts were made to minimise the number of handling operations and time in transit.

TABLE 6—Effect of handling on gross mean height and gross root collar diameter of **P. radiata** seedlings

	Gross mean height (cm)		Gross root collar diameter (mm)
	1 Year	2 Year	3 Year
Lifter	71	119	28
Crate	62	107	25
Planter's bag	50	88	21

[1] All nursery stock 1 year old from seed, bare rooted.

In 1975 a self-propelled belt lifter was purchased. It was envisaged that packing would be direct into cartons and the packing shed eliminated from the system. This also meant that grading of seedlings would no longer be possible. A trial was set up to examine the three types of lifting: belt lifting, modified potato digger and careful hand lifting. The plants were either planted directly, or passed through the packing shed system. All plants used in the trial were graded to a uniform size. There was no mortality attributable to treatment. The potato lifter was significantly different from the belt lifter and careful hand lifting. A weakly significant difference between trees planted directly into the field and those routed through the packing shed did not persist into the second year. The results are given in Table 7.

TABLE 7—Effect of lifting and packing methods on performance of **P. radiata** seedlings

		Lifting Method		
		Belt Lifter	Potato Lifter	Hand Lifting
Mean root collar diameter (mm) (1 year)	Direct to field	11.5	10.0	12.0
	Packing shed	11.0	8.5	9.0
Mean root collar diameter (mm) (2 year)	Direct to field	35.5	28.5	33.3
	Packing shed	33.5	27.0	32.2
Mean d.b.h. (mm) 3 year)	Direct to field	31.4	23.6	29.0
	Packing shed	32.5	32.9	30.4

These results indicated that the shift to a belt lifter gave better results than the potato digger.

DISCUSSION

During the 1960s the nursery was preoccupied with the production costs of *P. radiata* nursery stock. The mechanisation of operations was regarded as the way in which cost savings could be made. *P. radiata* was commonly regarded as a plant that could be abused. These trials have helped to reverse a trend where the cheapest method was regarded as good enough. The trials have shown that for *P. radiata* considerable benefits can accrue from improvements in planting stock quality as measured by the simplest of size criteria. The nursery offers an area of yield improvement that is competitive, on a cost benefit basis, with many other establishment practices. This has led to an acceptance of higher nursery costs where an improvement in nursery stock is achieved. As a result the prescription for the minimum size of *P. radiata* nursery stock for the company's own nurseries has been raised from 17 cm height, 2 mm collar diameter to 25 cm height, 4 mm collar diameter. Raising the prescription to this minimum at the altitude of our main Athol nursery (370 m) represents a challenge. To meet the prescription it will require the sowing of seed at the earliest in the springtime; precision in the application of weedicides and fungicides so that weed and disease control is achieved without growth checks; a fertiliser regime to realise the site potential; and finally in-bed culling to remove the poorer trees.

The handling trials have led to the present system which aims to minimise root exposure between lifting and the planting site. The system also aims to minimise root damage through crushing. The essential part of the system is that the cardboard container into which plants are packed in the nursery is used by the planter in the field, as the equivalent of a planting bag. Plants are therefore handled at two points only; at the time of lifting and packing in the nursery, and at the moment of planting. Operationally the average time in transit has been reduced to three days.

The eucalypt trials have emphasised the role of the nursery in a successful plantation programme. *P. radiata* plantations can be established, after a fashion, with indifferent techniques; eucalypt plantations cannot. For this reason the eucalypt crop is still lifted by hand and endeavour is made to match the numbers lifted with the requirements for the following day. Other aspects of handling are the same as for *P. radiata.*

The need for lower seedling densities in the eucalypt beds has been clearly demonstrated. This has led us to accept a low yield of seedlings per unit area. The seed sowing machinery presently available and the seed quality does not allow the precise sowing of a viable seed at regular intervals. We cannot sow thickly and achieve an even density of seedlings through in-bed culling because of the scarcity of *E. regnans* seed and the cost of labour. We endeavour to sow thinly and the result is an irregularly stocked seedling bed. Nevertheless we are satisfied that our production costs are considerably less than they would be for potted stock.

The results of the 1973 and 1978 trials with eucalypts and anti-transpirants are conflicting. The results illustrate some of the difficulties of interpretation of experiments based on field performance. The second trial was planted when weather conditions were favourable and it is possible that the plants suffered no transplanting stress. On the other hand improvements in conditioning regimes between 1973 and 1978 had given the latter plants a much larger root mass and it would be expected that these plants were better able to withstand stress. For the most part, the careful application of a simple technique, the measurement of field performance, has enabled the role of nursery stock quality to be evaluated.

We are now at the point where further improvements in nursery stock quality will be less easily obtained. At this point it could be said that if the nursery system and the geneticist determined crop spacing we could reduce initial plantation density. The present densities in excess of 1500 stems/ha could be reduced to 1,000 stems/ha and this latter figure would satisfy most maximum yield objectives. Unfortunately other environmental factors have to be considered in the determination of initial spacing.

ACKNOWLEDGMENTS

The work of other N.Z. Forest Products Limited staff has been used in preparing this paper. R. Woollons was responsible for all statistical design and analysis and M. McAlonan was responsible for the browsing trials and the **P. radiata** stock assessment. Acknowledgment is due to N.Z. Forest Products Limited for permission to publish this paper.