THE INFUENCE OF SEEDLING DENSITY ON 0/1 *EUCALYPTUS REGNANS* SEEDLING CHARACTERISTICS AND THEIR SUBSEQUENT GROWTH (FRI NURSERY — RANGIORA)

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ABSTRACT

Eucalyptus regnans *seedlings were raised at five spacings in the Forest Research Institute nursery at Rangiora to determine the influence of spacing on seedling characteristics and their subsequent growth after planting out.*

Growing space available to each seedling in the nursery production phase had a highly significant ($P < 0.001$) effect on seedling size and root mass. Seedling size increased when spacings increased from 10 × 10 cm to 15 × 20 cm/tree but decreased when growing space was further increased to 20 × 20 cm. The initial growing space not only influenced seedling dimensions but larger seedlings maintained their advantage after planting out. The best results, combining both size and survival, were from seedlings raised at 15 × 15 cm in the nursery.

INTRODUCTION

Numerous trials over recent years have demonstrated the effect that seedling spacing within drills has on radiata pine (*Pinus radiata* D. Don) seedling quality and growth after planting. The earlier work was summarised by Bowles (1981), and more recent work at Edendale Nursery was reported by Balneaves (1983), and Balneaves and Fredric (1983).

In contrast, little work has been done with other species. Albert *et al.* (1980) demonstrated that a "large" *E. regnans* seedling was desirable, and there was a need to accept lower densities of seedlings in the nursery beds to achieve this.

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Franklin (1971) noted that seedling density should be around 70–80 seedlings/metre of bed (6 drills 15 cm apart) for raising 1½/0 eucalypts, with final seedling height of 40-50 cm at planting. In the Forest Research Institute nursery at Rotorua, eucalypts are generally raised as 1/0 seedlings; the object is to: "produce lightly branched seedlings 45–60 cm in height with a minimum root collar diameter of 7 mm, a short calloused taproot (7 cm), a proliferation of fibrous and feeding roots and dark green foliage without deficiency symptoms" (van Dorsser, 1981). To achieve this, seeds were sown in drills 15 cm apart and, after thinning, 8 cm apart within drills, *i.e.*, around 120 cm^2 growing space/seedling. In his paper, van Dorsser (1981) gave several options for raising *Eucalyptus* species to meet the above specifications.

In the South Island, at least, there is considerable interest in growing *Eucalyptus* species both in forest holdings and in farm woodlots or shelterbelts. Concern has been expressed about the quality of barerooted nursery stock and failures have been high. In an effort to avoid these problems, greater emphasis has been directed toward raising *Eucalyptus* planting stock in containers — which in itself is fraught with difficulties (Chavasse, 1981).

For reasons of the cost and logistics of handling large numbers of seedlings from the nursery to the planting hole (Albert *et al.,* 1980; Chavasse, 1981) emphasis is placed on improving the quality of barerooted planting stock and improving tree handling procedures.

To this end a programme has been initiated to determine nursery regimes that will give a rapid improvement in production of quality barerooted *Eucalyptus* planting stock; the trial described here is the first stage of that programme.

METHOD

Eucalyptus regnans seed (Seedlots FRES 78/425), was stratified for 2 months and then germinated in trays of fine-grade vermiculite in a glasshouse. One week after sowing (6 April 1981) the germinated seedlings were pricked out into 50 cm^3 capacity rootrainers using a mixture of 8 parts finely shredded bark, 3 parts sphagnum moss, 2 parts of sand, and appropriate fertilisers (Prasad, 1981). After pricking out the seedlings were sprayed at 2–week intervals with the fungicide iprodione. On 16 June 1981 they were shifted into a shade house for hardening-off.

On 10 September 1981, the seedlings were removed from their rootrainers and lined out into a prepared seedbed at five spacings (Table 1).

TABLE 1: SPACINGS (cm) FOR LINING-OUT OF *EUCALYPTUS REGNANS* SEEDLINGS

Treatment	*In-drill Spacing*	*Between-drill Spacing*	*Available Growing Space (cm^2/seedling)*
10 × 10	10	10	100
10 × 15	10	15	150
15 × 15	15	15	225
15 × 20	15	20	300
20 × 20	20	20	400

Seedlings were irrigated as required to ensure survival and quick initial growth. No side dressings of fertilisers were required. Conditioning of the stock in preparation for lifting and planting used a combination of undercutting, wrenching and lateral pruning (on four sides), starting in February (Table 2).

TABLE 2: HISTORY OF TREE CROP IN NURSERY BED (RATES/ha)

Pre-lining out fertiliser	14 kg of P in reverted superphosphate and 16 kg of S (these rates vary annually and are dependent on results of soil tests)
	Ground continues to be cultivated. Beds thrown up 2–3 weeks in advance of lining-out. Weeds sprayed with 0.8 kg/ha of paraquat as they appeared.
Lining-out date	10 Sep. 1981
Handweeding	Regularly
Undercut — depth 13 cm	21 Feb. 1982
Box-prune (lateral pruning)	28 Feb. 1982
Wrench — depth 14 cm	1 Mar. 1982
Box-prune	12 Mar. 1982
Box-prune	10 Apr. 1982
Box-prune	14 May 1982
Wrench	14 May 1982
Lift and plant	28 May 1982

In late May (1982), 30 trees were selected from each treatment for morphological measurements. The root collar diameter and shoot length of each was measured before the roots and shoots were oven-dried separately at 80°C for 48 hours and weighed. A further five lots of 16 trees were randomly selected from each treatment, and the root collar diameter and shoot length of each

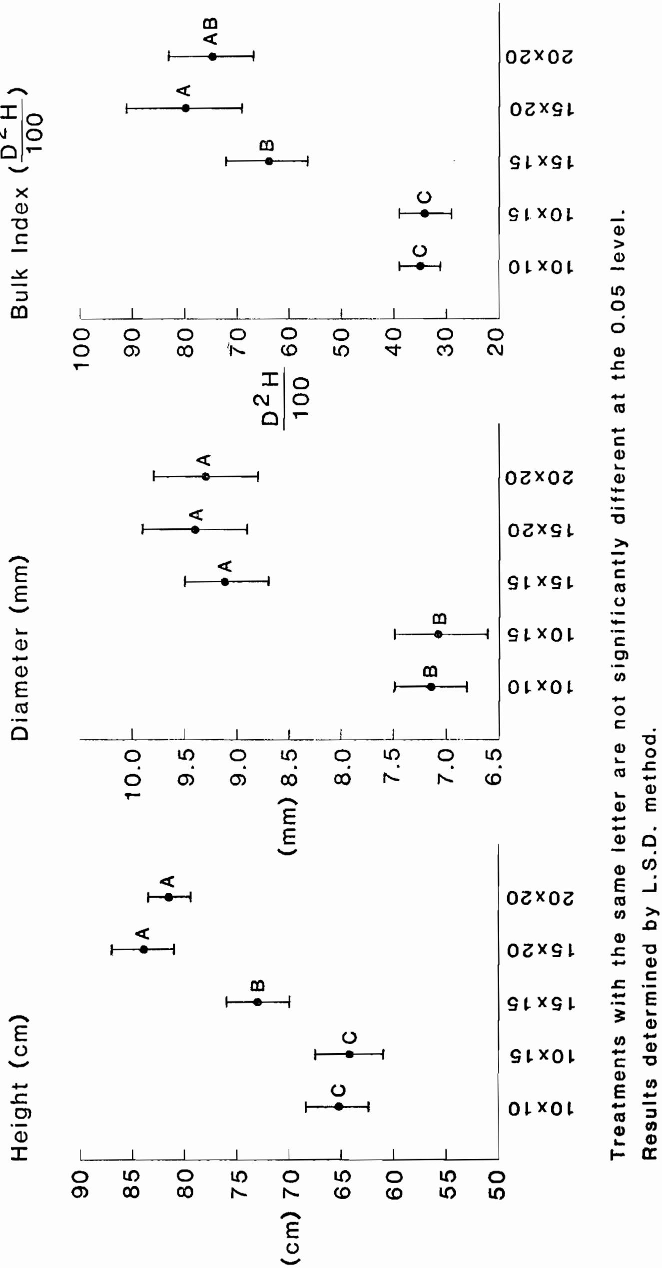

FIG. 1: *Mean and 95% confidence limits of initial measurements of seedlings at lifting.*

seedling were measured. These seedlings were planted out in a randomised block design with seedlings from each treatment being planted in blocks of 16 trees at 0.5 cm spacings. Surround trees were also planted to avoid edge effects and to delineate blocks and treatments.

The area was kept free of weeds by regular hand-weeding for the duration of the trial. Observations were made at 1, 2, 3, 6, and 9 months and the health of each tree noted. A final assessment was made in May 1983 when all seedlings were measured for shoot length, and stem diameter at a point 10 cm above ground level.

Analysis of results was by analysis of variance and covariance. Differences between treatment means were tested at the 95% confidence level using the least significance difference (LSD) test.

RESULTS AND DISCUSSION

Impact of Growing Space on Seedling Morphology

Growing space available to each seedling during the nursery production phase had a significant influence on seedling diameter, height, and D^2H (Fig. 1). The size of the seedlings increased as spacing increased from 100 cm^2 (10 x 10) to 300 cm^2 (15 x 20) but decreased at 400 cm^2 growing space.

These results provide evidence of a statistically significant curvilinear relationship between growing space and seedling size. However, the range of spacings was not wide enough to estimate reliably the form of the relationship.

The oven dry weight (ODW) of shoots follows the growth trends in Fig. 1, while the ODW of roots increases over the range of increasing growing space (Table 3), with a big increase in ODW of roots when spacing was increased from 10 x 15 cm spacing to 15 x 15 cm spacing. This is a reflection of the lateral root pruning

TABLE 3: A SUMMARY OF MEAN ODWs (g) RELATIVE TO GROWING SPACE

Spacing	*10×10 (100 cm²)*	*10×15 (150 cm²)*	*15×15 (225 cm²)*	*15×20 (300 cm²)*	*20×20 (400 cm²)*
ODW shoots	10.71a*	14.52b	27.57c	34.30d	32.74cd
ODW roots	3.38a	3.78a	7.64b	7.95b	8.78b
Sht:Rt ratio	3.12	3.84	3.61	4.31	3.73

* Treatments with the same letter are not significantly different at 0.05 level (working horizontally). Results determined by LSD method.

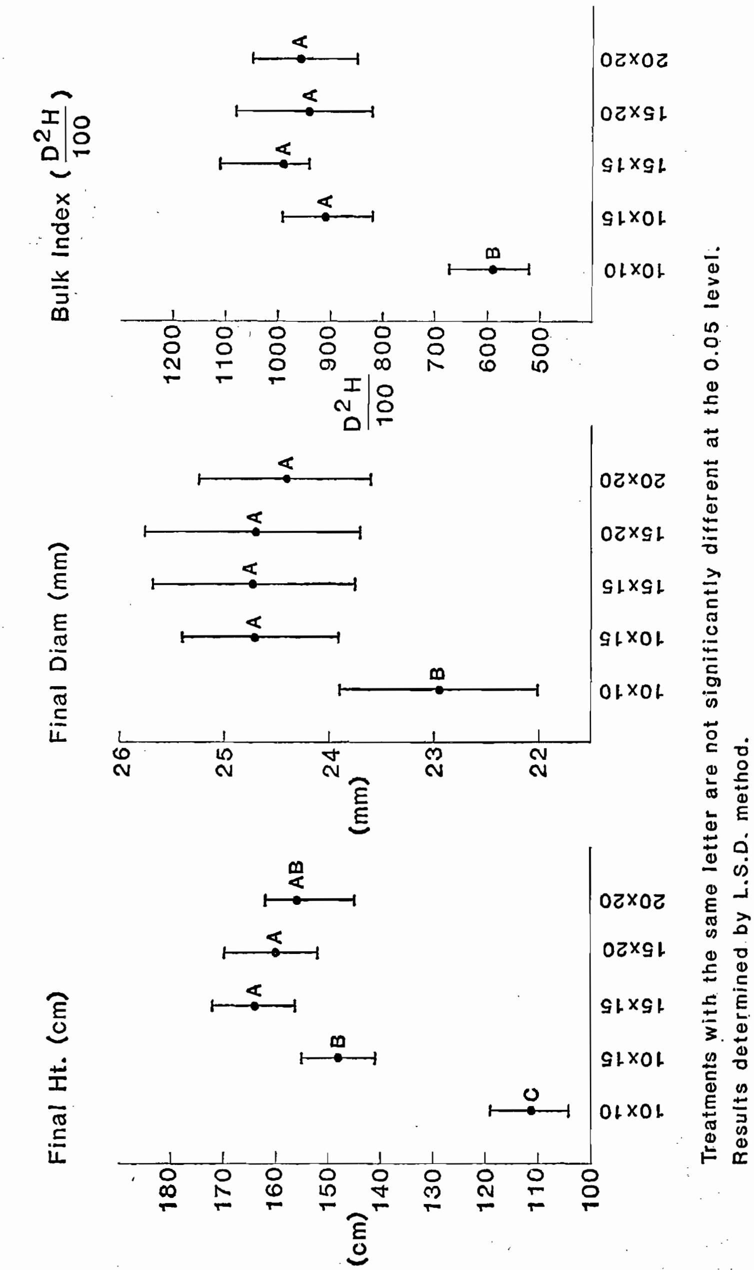

FIG. 2: *Final measurements adjusted for initial variation (covariance) and 95% confidence limits.*

treatment. Lateral root growth was contained by "box-pruning" — that is, by pruning the roots on four sides of each seedling at a point midway between the individual seedling being treated and its neighbours. For example, at 10 x 10 cm spacing roots were pruned 5 cm away from the centre stem point and at 20 x 20 cm spacing, 10 cm away.

Impact of Nursery Spacing on Survival and Growth 12 Months after Planting

There were significant differences in survival between treatments ($P < 0.05$; Table 4) with the best treatments being the 10 x 15 cm and 15 x 15 cm spacings. The seedlings raised at 15 x 20 cm spacing gave the lowest survival figure (85%).

TABLE 4: SURVIVAL (%) IN RELATION TO INITIAL SEEDLING SPACING

Spacing (cm)	10×10	10×15	15×15	15×20	20×20
Survival %	90a*	99b	96ab	85a	88a

* Treatments with the same letter are not significantly different at the 0.05 level. Results determined by LSD method.

Initial, final, and increment data were analysed separately for each variable (*i.e.*, diameters, heights, D^2H, and ODW of roots and shoots), using analysis of variance. Also covariance analysis was used for the variables of diameter, height, and D^2H to get an overall analysis on adjusted means. These are illustrated in Fig. 2. The 15 x 15 cm spacing showed the best height, diameter, and D^2H growth, and the 10 x 10 spacing the worst.

From these data it can be concluded that for *Eucalyptus regnans* planting stock at FRI Rangiora nursery, the optimal spacing treatment was 15 x 15 cm. Spacings greater than this resulted in a drop off in growth.

TABLE 5: MEAN ODW OF ROOTS AND SHOOTS 12 MONTHS AFTER PLANTING

Spacing (cm)	10×10	10×15	15×15	15×20	20×20
ODW roots (g)	81.1a*	101.5a	99.2a	110.6a	86.2a
ODW shoots (g)	265.9a	346.4a	332.3a	325.7a	348.1a
Rt: Sht ratio	3.15	3.53	3.63	3.00	4.03

* Treatments with the same letter are not significantly different at the 0.05 level (working horizontally). Results determined by LSD method.

Finally, correlations between initial parameters and final parameters, and initial parameters and incremental parameters were highly significant ($P < 0.005$). The strongest correlation in growth parameters was that between initial stem diameter and final D^2H ($r = 0.39$, df = 354, $P < 0.005$). This has also been found in work with radiata pine seedlings (Balneaves and Fredric, 1983).

CONCLUSIONS

1. Growing space available to each seedling in the nursery production phase had a highly significant ($P < 0.001$) influence on seedling diameter, height, D^2H, and ODW of roots and shoots at time of lifting.
2. Initial growing spacing significantly influenced survival after planting out. The best results were from trees raised at 10 x 15 cm spacing (99%) and 15 x 15 cm (96%).
3. Seedlings raised at 15 x 15 cm spacing grew best in terms of final diameter, height, and D^2H measurements in the 12 months after planting, while seedlings raised at the closest spacing (10 x 10 cm) were distinctly smaller than all others.
4. Correlations between initial parameters and incremental parameters or final parameters were highly significant ($P < 0.005$). There existed a stronger relationship betwen initial stem diameter and final D^2H ($r = 0.39$, df = 354, $P < 0.005$), than initial height and final D^2H ($r = 0.03$, df = 354, $P < 0.005$). Size advantages gained in the seedbed as a result of seedling spacing and cultural practices are maintained after planting and justify such practices.

ACKNOWLEDGEMENTS

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with the less site-demanding southern pines such as *Pinus taeda* or *P. elliottii*. However, cultivation and fertilisation techniques adopted since 1970 have extended the range of sites where radiata pine can now be successfully established. On the North Auckland peninsula there are 173 000 ha of podzolised yellow-brown earths and 74 000 ha of podzols, which, if used for plantation forestry, could benefit from cultivation.

Over the past ten years, a series of cultivation trials have been established on State forests within the Kaikohe Ranger District. Some of these have been co-operative Forest Research Institute (FRI)-Auckland Conservancy trials and have been reported on in unpublished FRI reports (*e.g.,* Hunter and Thode, 1980).

This report describes the results of some local investigations, and the management prescriptions subsequently adopted.

TRIALS AND PRINCIPAL RESULTS

1972 Waitangi State Forest

Investigations commenced in 1972 at Waitangi State Forest on a strongly rolling site previously under a cover of gorse. The soil type is a Hukerenui silt-loam derived from greywacke. The structure and drainage of this strongly podzolised soil are both poor but there is no hardpan. Treatments on this site included:

(1) 100% rotary-hoeing to a minimum depth of 15 cm in a single cut.

(2) Ripping to a depth of 46 cm with trees subsequently planted in the rip.

(3) Ripping to a depth of 46 cm with trees planted approximately 15 cm to the side of the rip line.

(4) Control (no cultivation).

Trees were assessed annually for survival and height over five years. Ripping improved survivals over control treatments but no significant differences in tree height were measured. The extent to which other factors such as climate, tree handling, fertilising practices and gorse competition may have influenced results is unknown. By Northland standards, growth in tree height was very slow for the first three years after planting. The result points to the danger in assuming that cultivation automatically confers an advantage to tree growth. Results are shown in Fig 1.