PERFORMANCE OF *PINUS RADIATA* IN RELATION TO SEEDLING GRADE, WEED CONTROL, AND SOIL CULTIVATION IN THE CENTRAL NORTH ISLAND OF NEW ZEALAND

EUAN G. MASON

School of Forestry, University of Canterbury,
Private Bag 4800, Christchurch, New Zealand

DAVID B. SOUTH

School of Forestry, Auburn University,
Auburn, AL 36849-5418, United States

and ZHAO WEIZHONG

School of Forestry, University of Canterbury,
Private Bag 4800, Christchurch, New Zealand

(Received for publication 24 April 1995; revision 30 October 1996)

ABSTRACT

Two experiments were established in the central North Island of New Zealand to examine survival and growth of *Pinus radiata* D.Don in response to weed control and methods of soil cultivation. Fifth- and sixth-year tree height, diameter and survival were examined in relation to (a) initial tree size expressed in various ways, (b) intensity of weed control, and (c) method of soil cultivation. Of four measures of initial seedling size tested, seedling ground line diameter (GLD) was best correlated with tree performance at one site while initial GLD squared × height was most significant at the other. Control of weeds improved tree growth at both sites, and markedly improved survival of trees at the higher altitude site. Analysis of residuals of an initial growth model constructed with data from 27 experiments suggested that stocks of 1/0 seedlings with mean initial root collar diameters of less than 5 mm performed poorly compared with larger 1/0 stocks.

Keywords: seedling quality; competition; soil tillage; fertiliser; establishment.

INTRODUCTION

Performance of young trees in plantations is a function of both site quality and seedling quality (Mason 1992). The effects of site quality have been extensively studied, as modelled by Mason (1992) for *P. radiata* in the central North Island of New Zealand. Seedling quality has also been studied from genetic (Forest Research Institute 1987), physiological (Rook 1971), and morphological (Chavasse 1980) perspectives. Seedling handling during lifting and transport also profoundly influences the performance of seedlings after planting (Trewin & Hunter 1986). Measures of seedling physiology, such as water potential (Balneaves *et al.* 1992), or of actual seedling performance, such as root regeneration potential (Jenkinson *et al.* 1993), have been shown to be reliable predictors of seedling survival and growth. However, root regeneration potential is of little use for selecting quality seedlings (or predicting post-planting performance of the seedlings) when seedlings are planted immediately after lifting, and water potential can be difficult to measure. Consequently, managers in New Zealand commonly assess seedling quality from morphological features such as sturdiness (the ratio of height to diameter at the root collar), root collar diameter (RCD), height, or root/shoot balance (Chavasse 1980; Menzies 1988).

A few studies have included both site and seedling quality as factors. Trewin & Hunter (1986) found the effects of seedling handling and site amelioration were additive in one study. Results of two studies (Balneaves 1989; Albert *et al.* 1980) implied that planting large seedlings could improve growth to a greater extent than controlling weeds. This implication warranted further testing, and was the first subject of the studies reported here.

Ground line diameter (GLD) has been shown to be a good index of seedling quality within any given batch of seedlings, as has the ratio between height and GLD (Chavasse 1980), but these morphological measurements have not been tested as indices of seedling quality to compare batches of seedlings. It is not known whether reduced performance of small seedlings resulted directly from small seedling size or whether small sizes reflected excessive competition in a nursery bed, uneven conditioning practices, or inferior microsites in the nursery which through their impact on other important factors, such as nutrient reserves, caused the smaller trees in a batch to perform badly after planting. A whole batch of seedlings, however, can be reduced in mean GLD simply by being sown later than another batch, and this might not reduce seedling performance. It was not clear, therefore, that results obtained from comparisons between seedlings of different GLD grades within a batch could be applied to comparisons between batches. This was the second question explored during the studies described below.

METHOD

Studies within Seedling Batches

Two studies were located in the central North Island of New Zealand to examine seedling response to weed control, various methods of soil cultivation, and, on one site, to fertiliser treatment with 80 g diammonium phosphate (DAP)/tree. Each study consisted of four blocks.

Experiment R1835/2 was established at Ohakuri at an altitude of 450 m a.s.l. Weeds on the site comprised mainly bracken (*Pteridium esculentum* (Forst. f.) Cockayne) and Cape broom (*Teline monspessulana* (L.) Koch), although there were also patches of grass. Thirteen cultivation treatments and strip spraying with 8 kg hexazinone/ha were examined with a split-plot design.

Experiment R1846 was located at Wainui, at an altitude of 760 m a.s.l. The site was occupied by intensively grazed pasture. One-half of each block was completely sprayed with 5 kg hexazinone/ha. Nine cultivation treatments were randomly located as at Ohakuri, in a cross-over design with weed control, and then the cultivation×weed control plots were divided into subplots for comparison of growth with and without added fertiliser (80 g DAP/ tree). Weed control was expected to ameliorate frost, and therefore large contiguous areas free of weeds were required. It was not feasible to cultivate very small lines with a large bulldozer and this, coupled with the requirement for large areas of weed control, was the reason why a cross-over design was employed. The microsite occupied by each tree was classified as a gully, the slope of a gully, or the top area above gullies, because seedlings in the small (1-m-deep) gullies were expected to suffer more frost damage than those above the gullies. These gullies were a natural feature of the site, and had apparently resulted from erosion. There was no evidence, however, that topsoil was any shallower in the gullies, suggesting that they had formed long ago. There was no clear correlation between presence of gullies and treatments, and several gullies crossed the experiment.

In both experiments the cultivation treatments tested included various combinations of ripping to 60 cm, inverted discing, and v-blading (Table 1). Each cultivated plot comprised three 40-m lines. At Ohakuri these plots were split, with weeds controlled in one half and uncontrolled in the other half. At Wainui, the cross-over subplots were split, and 80 g DAP were placed into a slit 10 cm from each tree in one half of each subplot. Trees were spaced at 2 m within lines, and lines were 3 m apart at both sites. Each cultivation plot therefore comprised 60 trees, of which 20 were assessed. At both sites 10 of the measured trees in each plot had weeds controlled, and at Wainui, 10 in each plot received diammonium phosphate.

Sites were planted using 1/0 *P. radiata* seedlings grown from open-pollinated seed orchard seeds. Measurements of GLD and height of trees in each centre row were collected annually at each site, until such time as diameter at breast height outside bark (dbhob) could be measured, after which it was substituted for GLD. Initially 10 trees per subplot were measured at Ohakuri, and five trees per subplot at Wainui. By age 5 years, a total of 906 trees had been remeasured at Ohakuri, and 476 trees were remeasured at Wainui by age 6. Reductions in trees measured were brought about by mortality within the plots.

TABLE 1–Factors and treatments used in the experiments at Ohakuri and Wainui

Factor	Treatment	Ohakuri	Wainui
Weed control	Hexazinone (1 month after planting), slashing	8 kg/ha	5 kg/ha
	Control (no weed control)	Yes	Yes
Cultivation	Control (no cultivation)	Yes	Yes
	Rip	Yes	Yes
	Rip/flat roller	Yes	Yes
	Rip/two inverted discs	Yes	
	Rip/four inverted discs	Yes	Yes
	Rip/six inverted discs	Yes	Yes
	Six inverted discs only		Yes
	Rip/two inverted discs/hourglass-shaped roller	Yes	
	Rip/four inverted discs/hourglass-shaped roller	Yes	Yes
	Rip/six inverted discs/hourglass-shaped roller	Yes	Yes
	Single-pass v-bladed mound	Yes	
	Double-pass v-bladed mound	Yes	
	Double-pass v-bladed mound/rip	Yes	
	Hand cultivation (20×20 cm, 30 cm depth)	Yes	Yes
Fertiliser	80 g DAP/tree, age 0		Yes
	Control (no fertiliser)	Yes	Yes

After 3 years, as weeds began to reinvade the plots treated with hexazinone, spot-spraying with hexazinone and manual slashing were used to further control weed competition.

Analyses of variance of height increment to and dbhob at ages 5 (Ohakuri) and 6 (Wainui) were conducted using SAS software. Subsequently, four (Ohakuri) and three (Wainui) classes of initial GLD, height, GLD squared × height (d^2h), and height:GLD were established, and models were refitted incorporating these seedling classes and their interactions with the site preparation and weed control treatments.

The effects of site amelioration and initial seedling size class on tree survival were analysed using procedure FREQ in SAS software, using chi square as a measure of the significance of treatments and classifications.

Studies between Seedling Batches

Mason (1992) modelled the initial (ages 0 to 5 years) growth of seedlings planted in 27 experiments in the central North Island of New Zealand. The model was sensitive to altitude, weed control, ripping, mounding, fertiliser treatment with 80 g DAP/tree, and initial stocking. The equation used to model height was:

$$H_T = H_0 + \alpha\, T^{\beta}$$

where T = time since planting, H_T = mean height at age T, and α and β were linear functions of altitude (m), weed control (1 = weed control, 0 = no weed control), ripping (1 = ripping, 0 = no ripping), mounding (1 = mounding, 0 = no mounding), and fertiliser (1 = 80 g DAP/tree after planting, 0 = no DAP).

As the model did not explicitly include seedling size as an independent variable, the effect of initial seedling size on growth could be examined across sites by plotting deviations from the model against mean initial GLDs calculated from the dataset which had been used for estimating the model's coefficients. GLDs of 15 of the 27 batches of seedlings planted in experiments used for constructing the model (Mason 1992) had been measured after planting. The residuals of the height model were plotted against the mean initial GLD of each batch.

RESULTS

Within Seedling Batches

Controlling weeds increased height growth from 5.17 m to 6.13 m (Ohakuri, age 5, $p<0.0007$) and from 4.16 m to 4.74 m (Wainui, age 6, $p<0.0001$). Dbhob was increased from 83 mm to 104 mm (Ohakuri, $p<0.0001$) and from 79 mm to 90 mm (Wainui, $p<0.0003$). The analyses of variance are shown in Tables 2, 3, 4, and 5. Weed control profoundly affected survival at Wainui, especially in gullies ($p<0.001$) where cold air would have settled (Fig. 1), but did not significantly affect survival at Ohakuri.

Cultivation increased survival from 84% to 96% at Ohakuri ($p<0.001$) but did not affect growth significantly when tested against the cultivation×weed control mean square. It was noted that cultivation partially controlled brushweeds, and the effects of weed competition on dbhob were more marked in those treatments which lacked cultivation ($p<0.05$). Cultivation treatments were confounded with a site gradient at Wainui and so the observed

TABLE 2–Analysis of variance of height increment between planting and age 5 at Ohakuri

Source	d.f.	Sum of squares	Mean square	F	P>F
Block	3	880 412.60	293 470.86	4.26	0.0066
Cultivation	12	1 140 703.32	95 058.61	1.38	0.2236
Cultivation×block	33	2 270 795.32	68 811.98		
Weed control (WC)	1	878 470.54	878 470.54	20.83	0.0007
Cultivation×weed control	12	506 099.05	42 174.92	1.79	0.0889
Cultivation×weed control×block	36	850 483.68	23 624.55		
Ground-line diameter class (GLD)	3	541 428.94	180 476.32	13.34	0.0001
Cultivation×GLD	36	534 654.73	14 851.52	1.10	0.3416
Weed control×GLD	3	114 814.58	38 271.52	2.83	0.0411
Cultivation×WC×GLD	36	406 347.76	11 287.43	0.83	0.7366
Cultivation×block×WC×GLD	126	1 691 864.58	13 534.92		
Residual	605	7 169 043.65	11 849.66		
Total	905	20 131 245.63			

TABLE 3–Analysis of variance of diameter at breast height at age 5 at Ohakuri

Source	d.f.	Sum of squares	Mean square	F	P>F
Block	3	33 225.06	11 075.02	4.50	0.0094
Cultivation	12	39 241.65	3 270.14	1.33	0.2494
Cultivation×block	33	81 193.70	2 460.42		
Weed control (WC)	1	47 183.31	47 183.31	50.67	0.0001
Cultivation×weed control	12	22 854.92	1 904.58	2.05	0.0485
Cultivation×weed control×block	36	33 522.08	931.17		
Ground-line diameter class (GLD)	3	27 609.68	9 203.23	13.45	0.0001
Cultivation×GLD	36	29 438.81	817.74	1.19	0.2393
Weed control×GLD	3	2 248.16	749.39	1.09	0.3559
Cultivation×WC×GLD	36	19 250.64	534.74	0.78	0.8037
Cultivation×block×WC×GLD	126	85 550.14	684.40		
Residual	604	341 009.81	564.58		
Total	904	892 260.81			

TABLE 4–Analysis of variance of height increment between planting and age 6 at Ohakuri

Source	d.f.	Sum of squares	Mean square	F	P>F
Weed control (WC)	1	215 625.003 62	215 625.003 62	21.74	0.0001
Block	3	72 067.963 38	24 022.654 46	2.42	0.0756
Cultivation (CULT)	8	407 370.085 06	50 921.260 63	5.14	0.0001
Block×WC×CULT	55	545 400.409 05	9 916.371 07		
D^2H size (DHSIZE)	2	76 418.485 54	38 209.242 77	5.24	0.0072
WC×DHSIZE	2	7 201.581 17	3 600.790 59	0.49	0.6122
Block×WC×DHSIZE×CULT	84	612 869.025 32	7 296.059 83		
Residual	319	2 093 077.598 8	6 561.371 8		
Total	474	4 515 030.631 6			

effects of cultivation are not reported here. This gradient was due to a gentle slope which resulted in greater frost damage on one side of the experiment. The effects of weed control and fertiliser were not confounded with the gradient, and could therefore be tested. Application of DAP influenced neither growth nor survival.

TABLE 5–Analysis of variance of diameter at breast height at age 6 at Ohakuri

Source	d.f.	Sum of squares	Mean square	F	P>F
Weed control (WC)	1	8 035.489 521	8 035.489 521	14.86	0.0003
Block	3	5 638.565 973	1 879.521 991	3.48	0.0219
Cultivation (CULT)	8	11 898.092 708	1 487.261 588	2.75	0.0215
Block×WC×CULT	55	29 735.838 638	540.651 612		
D^2H size (DHSIZE)	2	4 561.307 378	2 280.653 689	5.25	0.0071
WC×DHSIZE	2	609.658 202	304.829 101	0.70	0.4985
Block×WC×DHSIZE×CULT	83	36 034.672 427	434.152 680		
Residual	319	139 824.903 57	438.322 58		
Total	473	252 926.447 26			

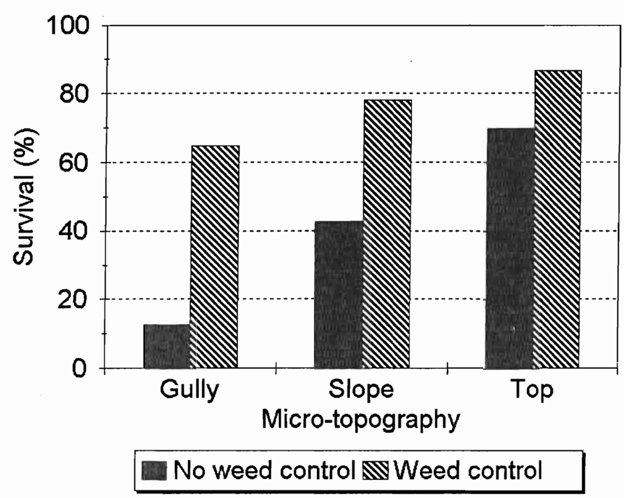

FIG. 1–Survival *v.* weed control and microtopography at Wainui.

GLD was the initial size classification most related to seedling height (p<0.0001) and dbh (p<0.0001) growth at Ohakuri (Fig. 2). The weed control × GLD interaction was significant for height increment (p<0.04). There was a greater increase in height growth with seedling GLD class when weeds were not controlled than when they were controlled. Survival was not significantly related to initial seedling size on this site.

Initial d^2h class was a better indicator of seedling survival (p<0.001), height growth (p<0.0071), and dbh growth (p<0.0072) at the higher altitude site than were the other size classifications (Table 6). Survival was strongly related to microtopography and seedling size (Fig. 3).

Between Seedling Batches

Analysis of residuals of the initial growth model showed a trend with initial GLD. In particular, stocks of 1/0 seedlings with mean initial GLDs of less than 5 mm grew more consistently slowly in height than larger 1/0 stocks (Fig. 4).

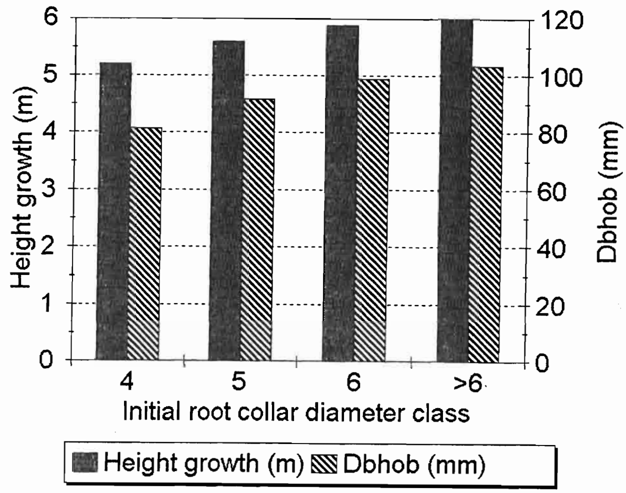

FIG. 2–Height growth and dbhob *v.* GLD at Ohakuri, age 5.

TABLE 6–Effect of initial d^2h class on dbhob and height growth at Wainui (age 6)

Initial d^2h class	Dbhob (cm)	Height growth (m)
400	8.32	4.48
1200	8.74	4.53
2000	8.96	4.61

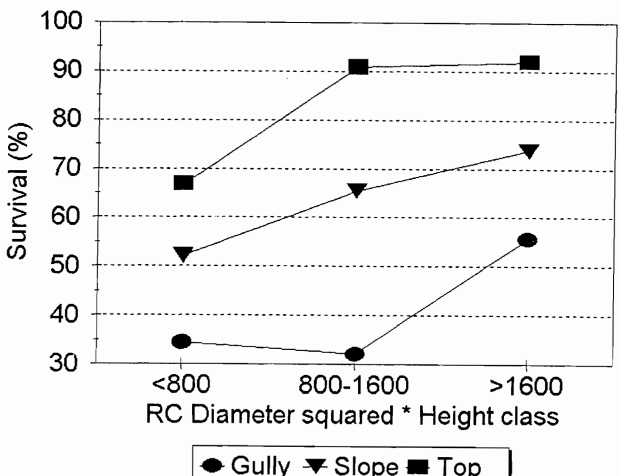

FIG. 3–Survival *v.* ground line diameter squared × height at Wainui.

DISCUSSION

The effects of weed control, cultivation, and fertiliser treatment on growth and survival were consistent with those predicted by the central North Island initial growth model (Mason 1992), and re-emphasise the importance of weed control in this region.

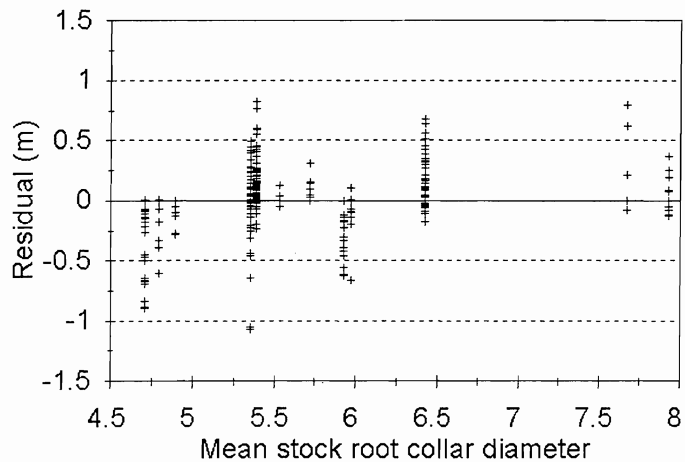

FIG. 4–Residuals of an initial height growth model plotted against the mean initial root collar diameter of seedling batches within experiments used for fitting the model.

The effects of cultivation observed at Ohakuri are consistent with a trend among other experiments which suggests that cultivating light, well-drained soils is unlikely to greatly affect pine height and diameter growth (Somerville 1979; Mason & Cullen 1986; Mason 1992), while cultivating wet, poorly drained ones often results in large growth increases (Hetherington & Balneaves 1973; Williamson 1985; Hunter & Skinner 1986; Mason *et al.* 1993; Derr & Mann 1970; Wilhite & Jones 1981; Haywood 1983; Outcalt 1984). Cultivation with disks was found advantageous, however, on frost-prone central North Island pumice sites where weeds were not controlled chemically, because it incorporated weeds in the soil, thereby exposing mineral soil and raising the albedo of the ground surface (Menzies & Chavasse 1982).

The lack of a response to application of DAP at Wainui is consistent with earlier studies in New Zealand. Phosphorus is applied at establishment mainly on weathered and leached clays or podsolised sands in Northland, or on leached alluvial gravels in the Nelson region. At establishment, nitrogen is sometimes applied in the same localities as phosphorus, but it is also regularly applied to landings throughout New Zealand in attempts to rejuvenate them after logging (Ballard 1978; Will 1985).

Analyses of tree performance after planting suggest that, within a seedling batch, plant size can be a good indicator of potential field performance. Size may represent factors such as root mass, root growth potential, nursery treatment, or genetics which can affect survival and growth. However, size is not an infallible predictor of field performance (especially when comparing seedlings from different nurseries and/or different genotypes). For instance, Mason *et al.* (1988) reported that small (4.7 mm GLD, 23 cm height) 1/0 seedlings performed as well as larger (6.9 mm GLD, 39 cm height) 1.5/0 seedlings from a different nursery. Zwolinski *et al.* (1995) found similar differences between seedling grades within a batch, and concluded that planting large seedlings was economically preferable to controlling weeds. It should be noted that the smaller grade of seedlings in Zwolinski *et al.*'s study (14–20 cm in height and 2.8 mm mean RCD) was much smaller than grades commonly planted in New Zealand. However, a similar conclusion might be drawn from the results reported here if the effects of weed control and seedling size were to be compared by tabulating the differences in performance between the lowest grade with weed control and the largest grade without weed control (Table 7). This sort of inference would be appropriate if managers were actually planting seedlots with only the smallest grade of seedling. However, the seedlings planted at Wainui and at Ohakuri were ungraded, and managers would have had to cull the seedlings in order to increase mean seedling GLD. At both sites, culling small seedlings would have been much less effective than controlling weeds. Effects of culling seedlings less than 5 mm and less than 6 mm on dbhob distributions were compared with effects of weed control using data from Ohakuri (Fig. 5).

TABLE 7–Comparison of effects of weed control with effects of planting only the smallest or the largest seedling grade

Experiment	Initial GLD	Weed control	Height increment (m)	Dbh (cm)	Survival (%)
Wainui	7.5	No	4.5	8.7	66
	3.5	Yes	4.8	8.4	73
Ohakuri	7	No	5.5	9.1	97
	4	Yes	5.7	9.1	92

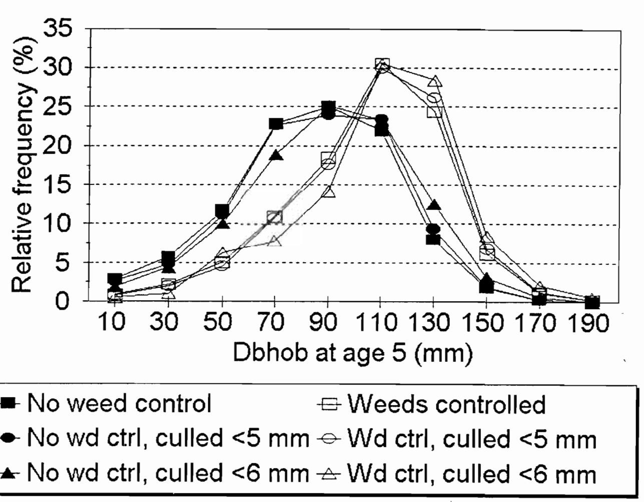

FIG. 5–Consequences of culling seedlings and of weed control on dbhob distributions (age 5) at Ohakuri. The overall mean initial GLD was 5.3 mm. Removing GLD classes less than 5 mm and 6 mm would have resulted in means of 5.6 mm and 6.2 mm, respectively.

The study of residuals from the initial growth model was the first analysis of the effects of GLD measured at planting conducted across a large number of seedling batches in New Zealand. It suggested that managers should aim to plant 1/0 *P. radiata* seedlings with mean GLDs greater than 5 mm. Seedlings planted in the experiments used for model construction were all carefully handled and were planted well (Mason 1992). It is likely that the correlation between GLD and subsequent height growth would have been less evident among batches of seedlings which had been subjected to different levels of abuse during outplanting (Trewin & Hunter 1986).

CONCLUSIONS

Weed control greatly improved growth of *P. radiata* at two sites, and survival at one site where frosts were a problem. Cultivation improved survival at Ohakuri, and facilitated the chemical control of brush weeds. Application of fertiliser at 80 g DAP/tree 1 month after planting made no difference to growth or survival of seedlings planted at Wainui.

Growth and survival were related to initial seedling size expressed as GLD at Ohakuri and d^2h at Wainui. Seedling batches with GLDs less than 5 mm performed poorly compared to other batches in experiments used for the estimation of coefficients during initial growth modelling in the central North Island of New Zealand.

ACKNOWLEDGMENTS

Thanks are due to the former Silvicultural Equipment Development Committee for financing construction of the cultivation rig used during these studies. Permission to use land granted by Carter Holt Harvey Forests (Kinleith) Ltd and Tasman Forestry Ltd was also greatly appreciated. The senior author wishes to thank members of the former Forest Establishment and Equipment research group at the New Zealand Forest Research Institute (NZ FRI) who helped establish the experiment and assisted him with data collection during this study. Thanks also to Noel Davenhill of the NZ FRI for chemical weed control prescriptions and assistance with implementing them.

REFERENCES

ALBERT, D.J.; FRY, G.; POOLE, B.R. 1980: An industrial company's view of nursery stock quality. *New Zealand Journal of Forestry Science 10*: 2–11.

BALLARD, R. 1978: Use of fertilisers at establishment of exotic forest plantations in New Zealand. *New Zealand Journal of Forestry Science 8(1)*: 70–104.

BALNEAVES, J.M. 1989: Root collar diameter of 1/0 radiata pine influences growth following planting. *Forestry Supplement 62*: 125–30.

BALNEAVES, J.M.; MENZIES, M.I.; HONG, S.O. 1992: *Pinus radiata* seedling water potential and root and shoot growth as affected by type and duration of storage. *New Zealand Journal of Forestry Science 22(1)*: 24–31.

CHAVASSE, C.G.R. 1980: Planting stock quality: A review of the factors affecting performance. *New Zealand Journal of Forestry 22(2)*: 144–71.

DERR, H.J.; MANN, W.F. Jr. 1970: Site preparation improves growth of planted pines. *USDA Forest Service Research Note SO-106.*

FOREST RESEARCH INSTITUTE 1987: Which radiata pine seed should you use? *New Zealand Ministry of Forestry, What's New In Forest Research No.157.*

———1988: Seedling quality and seedling specifications of radiata pine. *New Zealand Ministry of Forestry, What's New in Forest Research No.171.*

HAYWOOD, J.D. 1983: Small topographic differences affect slash pine response to site preparation and fertilisation. *Southern Journal of Applied Forestry 7(3)*: 145–8.

HETHERINGTON, M.W.; BALNEAVES, J.M. 1973: Ripping in tussock country improves radiata growth. *Forest Industries Review 4(12)*: 2–7.

HUNTER, I.R.; SKINNER, M.F. 1986: Establishing radiata pine on the North Auckland podsols. *New Zealand Forestry 31(3)*: 17–23.

JENKINSON, J.L.; NELSON, J.A.; HUDDLESTON, M.E. 1993: Improving planting stock quality—The Humbolt experience. *USDA Forest Service, General Technical Report PSW-GTR-143.*

MASON, E.G. 1992: Decision-support systems for establishing radiata pine plantations in the central North Island of New Zealand. Ph.D. Thesis, University of Canterbury: 301 p.

MASON, E.G.; CULLEN, A.W.J. 1986: Growth of *Pinus radiata* on ripped and unripped Taupo Pumice soil. *New Zealand Journal of Forestry Science 16(1)*: 3–18.

MASON, E.G.; CULLEN, A.W.J.; RIJKSE, W.C. 1988: Growth of two stock types on uncultivated, ripped, and ripped and bedded soil at Karioi Forest. *New Zealand Journal of Forestry Science 18(3)*: 287–96.

MASON, E.G.; MILNE, P.J.; CULLEN, A.W.J. 1993: Establishment regimes for radiata pine on yellow brown earths in Southland. *New Zealand Forestry 37(4)*: 24–9.

MENZIES, M.I.; CHAVASSE, C.G.R. 1982: Establishment trials on frost-prone sites. *New Zealand Journal of Forestry 27(1)*: 33–49.

OUTCAULT, K.W. 1984: Influence of bed height on the growth of slash and loblolly pine in a Leon Fine Sand in Northeast Florida. *Southern Journal of Applied Forestry 8(1)*: 29–31.

ROOK, D.A. 1971: Effect of undercutting and wrenching on growth of *Pinus radiata* D.Don seedlings. *Journal of Applied Ecology 8*: 477–90.

SOMERVILLE, A.R. 1979: Root anchorage and root morphology of *Pinus radiata* on a range of ripping treatments. *New Zealand Journal of Forestry Science 9*: 294–315.

TREWIN, A.R.D.; HUNTER, J.A.C. 1986: A containerised handling system for bare-rooted seedlings. *In* Proceedings of the 18th IUFRO World Congress, Ljubjana, Yugoslavia.

WILHITE, L.P.; JONES, E.P. Jr. 1981: Bedding effects in maturing slash pine stands. *Southern Journal of Applied Forestry 5(1)*: 24–7.

WILLIAMSON, M.J. 1985: Cultivation in Northland. *New Zealand Journal of Forestry 30(2)*: 218–31.

WILL, G.M. 1985: Nutrient deficiencies and fertiliser use in New Zealand exotic forests. *New Zealand Forest Service, Forest Research Institute Bulletin No.97.*

ZWOLINSKI, J.B.; SOUTH, D.B.; CUNNINGHAM, L.; CHRISTIE, S.I. 1995: Weed control and large planting stock improve survival and early growth of *Pinus* radiata. Pp.106–8 *in* Gaskin, R.E.; Zabkiewicz, J.A. (Ed.) "Popular Summaries from Second International Conference on Forest Vegetation Management". *New Zealand Forest Research Institute, FRI Bulletin No.192.*