Establishment regimes for radiata pine on Yellow-Brown Earths in Southland

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ABSTRACT

An analysis of five years' growth in two factorial experiments is described. Three factors were included: cultivation, fertilisation, and weed control.

Cultivation significantly improved both height and diameter growth, and treatments involving discs had higher rates of survival and faster growing trees than those involving only a ripper. Cultivation also significantly improved crop uniformity. Results suggested that drainage of the topsoil was the most important improvement brought about by cultivation.

Weed control improved height growth by 0.3 m.

Fertilisation without weed control decreased survival by 10%.

Weed control increased the incidence of multiboling from 18% to 30%.

Plantation managers are advised to consider cultivation with ripper tines and discs followed by spot weed control as site amelioration treatments on Yellow-Brown Earths in Southland and Otago.

KEYWORDS: cultivation, stability, weed control, fertilisation.

INTRODUCTION

Forest Managers can adopt one of a number of alternative site preparation strategies when they are establishing plantations. The effects of these strategies on crop survival and growth vary from site to site for reasons that are not always clear, and empirical experiments are still the usual way of determining how beneficial alternative strategies might be. Generally, strategies involve combinations of options for land clearing, weed control, fertilisation, and soil cultivation (Mason 1992).

Cultivation with winged ripper tines followed by discs has been employed in New Zealand forest plantations since the mid 1970s (Page 1978). The equipment used varies considerably, with no discs employed, only two or four discs, or sometimes six discs followed by a compacting roller (Cullen & Mason 1981). It is clear that the type of equipment employed can have a dramatic effect on the response to cultivation on some sites (Mason et al. 1988).

In order to provide forest managers with adequate information to allow them to select cultivation techniques on a range of sites, a cultivation rig was built which could cultivate in a variety of ways. A series of experiments were established with the rig on sites around New Zealand. Where possible complete factorial experiments were established, employing levels of fertilisation and weed control as well as cultivation. This type of design allows an examination of all combinations of treatments.

The experiments described here were located at Berwick Forest and Glendhu Forest on upland Yellow-Brown Earth soils. Yellow-Brown Earths are common in Southland, and are typically the soils where plantations have been established in the region. The topsoils are wet and puggy, while the lower layers have more large pores, and hold less water. Soil penetration resistance is below 3 megapascals to a depth of about 35 cm. Beyond this level of resistance, pine roots will either stop growing, or be diverted (Mason & Cullen 1986). The resistance to penetration of yellow-brown earths probably increases as soil moisture decreases. The soil was reasonably wet when measurements of penetration resistance were taken.

METHOD

Berwick

An experiment was established on rolling, tussock-covered land, at an altitude of 500 metres above sea level. Cultivation treatments were established with contractors' and New Zealand Forest Service machinery, and included the following cultivation techniques:

1. Rip, 6 discs (bed), and roll with an hourglass shaped roller.
2. Removal of tussock and surface soil with a bulldozer blade, followed by ripping.
3. Bed only.
4. Rip only.
5. Blade only.
6. Control (no cultivation).

These treatments were arranged in three randomised complete blocks.

Cultivated plots were 60 metres long, and contained four planting rows at 3 metre centres. Within rows 1/0 radiata pine seedlings were planted at 1.8 metre spacing in September 1977.

Each plot was split into four subplots, and two diagonally opposite portions were sprayed with Velpar(R) at a rate equivalent to three kg/hectare 10 days after planting.

At age five the height of each tree in blocks one and two were measured, and the numbers of buttswept, toppled, or socketed trees per plot were recorded. By this age it was clear that block three was unrepresentative of the surrounding plantation due to excessively poor drainage.

During 1984, the experiment suffered considerably from snow damage, with many broken tops, and a thinning was carried out which reduced stocking to 200 stems per hectare. The heights and diameters of the remaining stems were measured.

The data were subjected to analysis of variance, and general contrasts were employed to examine the main effects of ripping, discing, and blading on growth, as well as the effect of weed control and weed control x cultivation interactions.

Glendhu

A second experiment was established in Glendhu Forest during the winter of 1983 at an altitude of 490 m.a.s.l.. The site had rolling topography, yellow brown earth soil, and native tussock was the principal ground cover. An attempt was made to burn the ground cover, but the climate was too moist at the time, and burning had little impact on the tussock sods. Cultivation was performed with the experimental cultivation rig and included the following:

1. Control (C).
2. Ripping (R).
3. Ripping/flat roller (RR).
4. Ripping/2 inverted discs (Pulling the topsoil in over the rip) (R2).

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5. Ripping/4 inverted discs (R4).
6. Ripping/6 inverted discs (R6).
7. Ripping/2 inverted discs/hour glass roller (R2R).
8. Ripping/4 inverted discs/hour glass roller (R4R).
9. Ripping/6 inverted discs/hour glass roller (R6R).

These treatments were applied in 80 metre long plots within five randomised complete blocks. Each plot contained three rows at three metre centres.

During cultivation with discs, long lengths of sod were turned over by the machine, and the earth did not appear to fracture as in other soils where similar treatments had been employed.

Each line was planted with 1/0 stock from Edendale Nursery that had been lifted and trimmed in bundles of ten and transported in cardboard boxes. Spacing within lines was 2 metres. The initial height and diameter (5 cm above ground level) of each tree in the centre line of each plot was recorded. The two outer lines were employed as buffer lines.

The 80 metre plots were then divided into four subplots with random treatments of weed control (two kg of Velpar(R)/hectare applied manually) and fertiliser (Appendix 1) in a factorial design.

The survival, height, and basal diameter were re-assessed after the second, third and, excepting basal diameter, the fourth and fifth years. Diameter at breast height was measured after year four. By the end of the third year, significant amounts of toppling had occurred. The stem condition of each tree was recorded after the third and fourth and fifth years.

In addition, where trees exhibited "multiboling", this was recorded, and the largest stem was measured. Multiboled trees appeared to have several stems competing with one another. Excavation showed that the competing stems emerged from the main bole below ground.

Analysis of variance was employed, with general contrasts to determine the significance of the effects of rolling, discing, and ripping. Measurements resulting in proportions were adjusted to normality using an arcsin(square root) transformation.

RESULTS

Berwick

Survival

Cultivation significantly ($P<0.006$) improved survival as measured at age five (Figure 1) and treatments fell into three significantly ($P <0.05$) different groups. In order of decreasing survival these were: cultivation that included blading, other cultivation treatments, and the control treatment.

Weed control improved survival by 9% ($P<0.002$), and the interaction between weed control and cultivation was not significant.

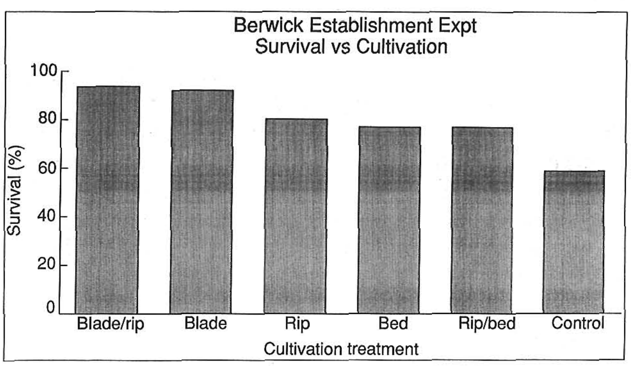

Figure 1 - Survival of trees measured at age five vs cultivation at Berwick.

Growth

Cultivation significantly ($P<0.001$) increased height as measured at age five (Figures 2 and 3). All cultivation treatments were significantly different from the control treatment. Blading, bedding, and ripping each had a positive effect on growth when included in any given treatment ($P<0.005$).

Weed control had improved growth by 0.29 metres at the end of five years, and did not significantly interact with cultivation.

Crop uniformity was markedly improved by cultivation, especially blading, and weed control (Figure 4).

The height difference between the control and the best cultivation treatment (blading and ripping) had increased from 0.7 m at age five years to 1.3 m at age seven years.

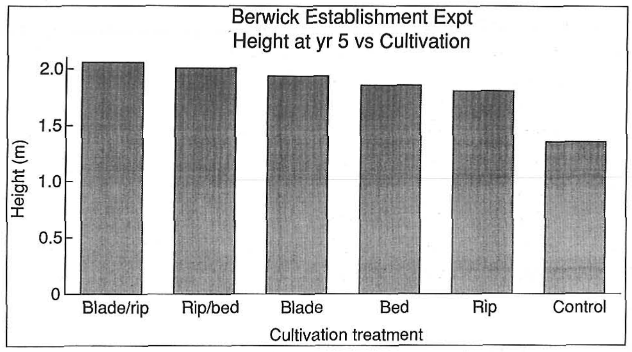

Figure 2 - Height at age five vs cultivation at Berwick.

Toppling and socketing

The proportions of trees socketed and/or toppled by age five was significantly affected by cultivation ($P<0.02$). 8% of trees in the control plots were affected versus 15% in the ripped only plots. The other cultivation treatments had 26% of trees affected. Although the effect within the control treatment was significantly different from the other cultivation treatments, it did not differ significantly from the ripped treatment.

Glendhu

Survival

Average survival for the control treatment was 89%, for the two ripped treatments 90%, whilst the ripped and disced treatments averaged 95%. Virtually all mortality occurred prior to the measurement at age two.

When fertiliser was applied without weed control, survival averaged 86%, while the other three treatments defined by the weed control x fertiliser interaction had a mean survival of 95%.

Growth

Average height after year five was 3.6 m and the average diameter at breast height was 6.4 cm.

Figures 5-8 show the growth in height and diameter during the first five years. There was a continuing divergence in growth between the best and worst treatments. Growth in the control plots was far more variable than in the cultivated plots, as shown by an analysis of coefficient of variation (Figure 9).

Ripping and discing resulted in a greater improvement than simply ripping. The main effect of using discs was statistically significant for both height and diameter ($P<0.002$). Those treatments with discs averaged 3.8 m in height and 6.8 cm in diameter, while the ripped only treatments averaged 3.4 m and 5.7 cm respectively.

Figure 3 - The trees on the left were growing in bladed and ripped soil, while those on the right grew in uncultivated soil.

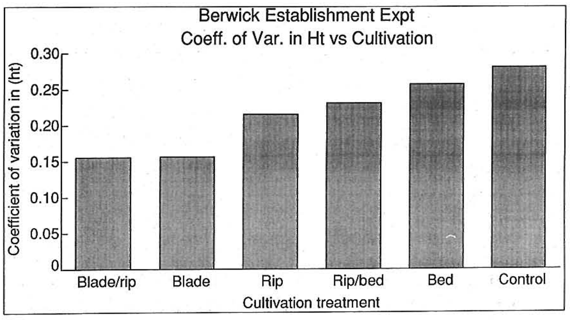

Figure 4 - Variation in height at age five vs cultivation at Berwick.

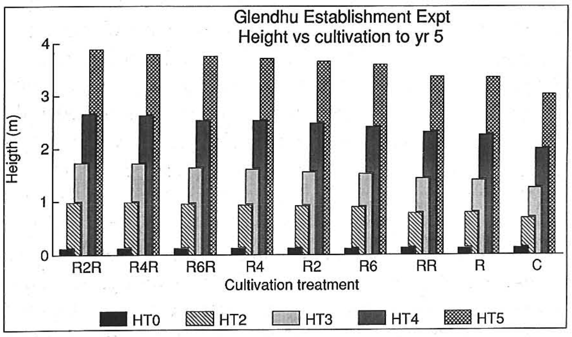

Figure 5 - Height growth vs cultivation during the first five years at Glendhu.

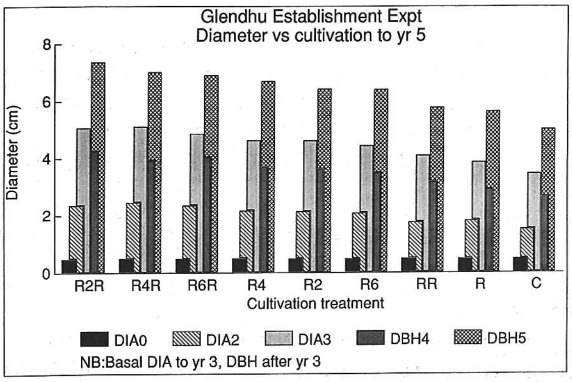

Figure 6 - Root collar diameter and diameter at breast height growth during the first five years at Glendhu.

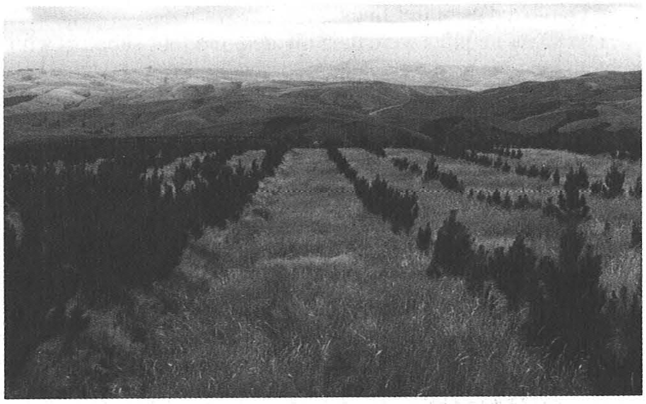

Figure 7 - Ripped and bedded (left) and uncultivated (right) treatments at Glendhu.

Figure 8 - Trees in the three uncultivated lines (left of centre) are visibly smaller in this general view of a block in the Glendhu experiment.

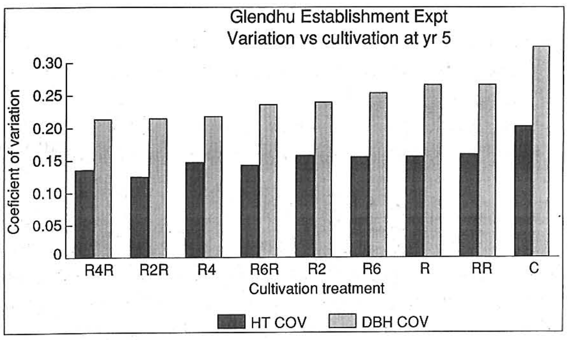

Figure 9 - Variation in height and diameter vs cultivation at Glendhu.

Using a roller with the discs brought about no improvement in height, but significantly improved diameter by 0.6 cm (P <0.02).

The number of discs used did not significantly affect growth.

Weed control added 0.3 m in height, and 0.9 cm in diameter by age five. The height increase was unchanged between ages four and five, whilst the diameter difference increased marginally.

Fertiliser was interactive with cultivation, adding growth with the best treatments, and reducing growth with the poorer treatments (P <0.02). The overall effect of fertiliser on growth was quite small, however.

Toppling

Toppling frequency by age four was significantly less in the slower growing treatments, but was not significantly affected by cultivation, fertilisation, or weed control by age five. 15% of the crop toppled during the first five years.

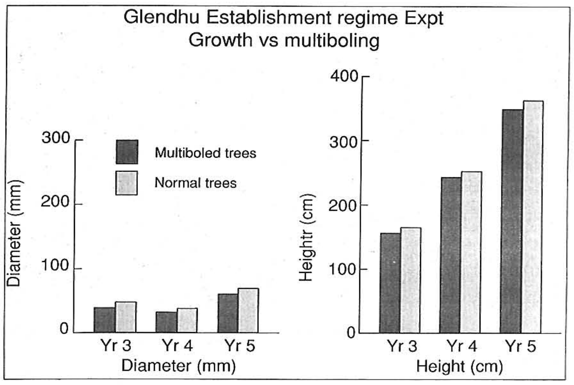

Figure 10 - Growth in height and diameter of multiboled and singleboled trees at Glendhu.

Multiboling

Multiboled trees had smaller (P<0.0004) main stems than the other trees in the experiment at age five (Figure 10). An analysis of initial measurements demonstrated that there were no differences in height and diameter immediately after planting between those trees which subsequently became multiboled, and those which didn't.

Frequency of multiboling was significantly increased by fertiliser (P <0.02) and weed control (P <0.0001), but the interaction between the two factors was not significant. The effect of fertiliser was relatively small, while weed control increased the frequency from 18% to 30%.

DISCUSSION

Survival

Improvements in survival were correlated with improvements in initial growth, and reflected the improved microsites provided by the various treatments.

Adding fertiliser without weed control at Glendhu encouraged weed growth around the trees, and survival was depressed.

Growth

The improvement in growth brought about by cultivation was quite dramatic, and consistent between the two experiments. Not only did cultivation improve average growth, but the resulting crops were significantly more uniform. Balneaves (1988) indicated that survival and growth of radiata pine were similarly improved by cultivation on a frost flat at Mahinerangi Forest near Dunedin.

The effect of cultivation could theoretically have been due to control of weeds, despite the insignificant weed control x cultivation interaction, as weeds were only controlled in spots around the trees by the Velpar (R). However, with a range of cultivation techniques involving ripping only and a variety of discing options, it might be expected that the interaction term would have been significant if weed control was the primary reason for the large cultivation effects.

It is perhaps more likely that the effect of cultivation was brought about by an improvement in drainage of the topsoil. Yellow-brown earths in Southland have wet surface horizons. This would help to explain the difference in response between trees growing on bladed lines and those in other cultivation treatments at Berwick as well as between ripped lines and those on ripped and disced lines at Glendhu - both successful treatments involve more intensive cultivation of the topsoil. Mounding with discs is routinely employed as a means of draining sites in the Southern United States (Derr & Mann 1970, Wilhite & Jones 1981, Haywood 1983, Outcalt 1984).

The use of a roller had a positive, albeit small, effect on growth, and this suggests an avenue for further research. The inverted discs turned long "sausages" of topsoil over, and did not appear to dramatically improve soil tilth. If rolling caused a real increase in growth, then this could be because the soil clods were further fractured as the roller passed over them. Future research should concentrate on further improving the structure of the topsoil, in conjunction with ripping of the subsoil.

Improvements in growth due to ripping and bedding may be a consistent feature on poorly drained sites with heavy soils. The effectiveness of cultivation on poorly drained podsols in Northland is well known (Williamson 1985; Hunter & Skinner 1986). A wet pumice soil with a high clay content at Karioi was also improved more by ripping and bedding than by ripping alone (Mason, Cullen & Rijkse, 1988). However, Mead (1990) showed that on a clay site in Nelson, ripping increased volume measured at age 11 by 27 m^3/ha, while double discing had a negligible effect. Bedding is a more effective drainage technique than double-discing, which may explain the results from Nelson.

Ripping may have increased the usable soil volume, but this was probably less important during the first three years than it may be subsequently. In Kaingaroa Forest, soil volume was not a significant factor until after age three (Mason & Cullen, 1986). The difference in average tree size (>1.5 m) at age five between the two sites may be partly due to improvements in planting stock quality and transport systems which occurred between the two planting dates (Trewin & Cullen 1985). Although the altitudes were the same, site differences may also have been a factor.

It should be noted that, at both sites, employing ripping and discing with subsequent weed control added a year's growth by age five, and that, whilst the difference due to weed control was not increasing, the trajectories of the control and cultivated treatments were continuing to diverge.

Increases in survival and growth after cultivation and weed control have been consistently demonstrated in experiments in Southland (Hetherington and Balneaves 1973, Balneaves 1988), and data from these experiments could be used to build an initial growth model for Southland similar to that developed for the Central North Island (Mason 1992). This would provide managers with a means of accurately predicting the results of site preparation on these sites at differing locations.

Toppling

Toppling increased in frequency with increasing tree size at Berwick, and up to age four at Glendhu. This correlation has been observed in several other trials at ages two and three (Mason, 1985, 1992). That the differences had disappeared by age five suggests that they were more a function of tree size than of soil strength or root development at Glendhu. At Berwick, reductions in soil strength caused by cultivation may have been a factor.

Multiboling

Multiboling occurred more frequently in the Glendhu experiment than in any other experiment the authors have measured in New Zealand. Comments by Dennys Guild (pers. comm.) suggest that the problem is widespread in Southland.

The growth of the largest stem within multiboled trees was significantly less than that of normal trees, and with average diameters reduced by 9 mm. Some multiboled trees may never contribute much to the crop, even if the other boles were cut out at age three or four. It may be that, in the course of normal operations, a salvage operation should be implemented by age two at the latest.

The results have also provided a few hints about the process of multiboling. Weed control and fertilisation significantly increased the frequency of multiboles. Since adding fertiliser stimulates weed growth, it appears that thick weeds around the base of a tree can suppress the development of multiboles.

It has been suggested (M. Menzies pers. comm.) that multiboling might be a result of branches on young seedlings being buried at the time of planting. However, there were few, if any, small branches present on the seedlings planted in the Glendhu experiment, and it would appear that many of them were initiated after planting.

Future research should concentrate on identifying at planting time characteristics of seedlings which subsequently develop multiboles, environmental conditions which may encourage the phenomenon, and aspects of planting practice such as planting depth which may influence multiboling frequency.

Implications of these results for managers

The very low survival in the control treatment at Berwick compared to the cultivation treatments indicates that the risk of mortality after planting might be greatly lessened by cultivation on some sites. There was also an improvement in survival due to cultivation at Glendhu, albeit considerably smaller. The difference in survival between sites might have been expected, given the extreme variation in survival observed in analyses of large numbers of site preparation experiments (Mason 1992). The best that can be said on the basis of these results is that managers should expect some improvement in survival, and the expected improvement may be between 5 and 30%.

The risk of toppling may have been increased by cultivation at Berwick, but not when tree size was taken into account at Glendhu. Mason (1985, 1992) reported inconsistent effects of cultivation on toppling, and suggested that toppling may be increased by cultivation where planting is poor, but decreased by ripping where compact soils would otherwise limit vertical root development. Concern about toppling should not prevent managers from cultivating soil in Southland if they can achieve high quality planting.

Managers may well be wondering what, if any, increases in growth might accrue from these treatments by the end of a rotation. This question was discussed at length by Snowdon and Waring (1984), and by Mason (1992), and cannot be answered accurately by analyses of experiments at age five. It is relevant, however, to observe whether the difference in time when sizes of trees in alternative treatments are equivalent is increasing or remaining static. At Glendhu, the difference in time was increasing from year to year up to age five, and the gain in time from ripping/mounding followed by weed control was one year by this age.

It is recommended that managers consider adopting cultivation with ripper tines and inverted discs (to form a mound over the rip line), as well as spot weed control after planting. Cost: effectiveness of these treatments could be assessed by assuming that they resulted in improvements in survival of 5% and gains in growth equivalent to one year of a rotation. These would be the lowest estimates of gains over a rotation.

CONCLUSIONS

On moist Yellow-Brown Earths in South Otago and Southland, ripping and discing improved radiata pine growth by 0.7-0.8 m in height, and by 1.8 cm diameter at breast height by the end of the first five years after planting. The two growth trajectories continued to diverge, at least up to age five.

Ripping and discing was markedly superior to ripping alone, although it did not matter whether two, four, or six inverted discs were employed. Rolling the mound created by discing improved diameter growth slightly.

Herbicide applied in a spot surrounding the trees immediately after planting added 0.3 m in height and 0.9 cm in diameter at breast height.

Both cultivation and weed control significantly improved crop uniformity.

Fertilisation had no important effects on growth.

Those treatments which improved growth also improved survival of the out-planted seedlings. The proportion surviving in the control treatment varied between sites.

Weed control increased the number of multiboled trees, and the dominant stems of these trees grew more slowly than those of normal trees.

The overall level of toppling was unaffected by cultivation, weed control, or fertilisation, at Glendhu, although toppling occurred later in slower growing treatments. At Berwick, toppling occurred more frequently in the cultivated plots.

ACKNOWLEDGEMENTS

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REFERENCES

Balneaves, J.M. 1988: Frost damage, survival, and growth of *Pinus radiata, P. muricata*, and *P. contorta* seedlings on a frost flat, New Zealand Journal of Forestry Science 18(2) 161-165.

Cullen, A.W.J.; Mason E.G. 1981: The use of cultivation as an aid to forest establishment, New Zealand Forest Service, Forest Research Institute, Proceedings of Symposium No. 22: 115-126.

Derr, H.J.; Mann, W.F. Jnr 1970: Site preparation improves growth of planted pines, US Forest Service Research Note SO-106: 3 pp.

Haywood, J.D. 1983: Small topographic differences affect slash pine response to site preparation and fertilisation, Southern Journal of Applied Forestry 7 (3):145-148

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

Mason, E.G. 1985: Causes of juvenile instability of *Pinus radiata* in New Zealand, New Zealand Journal of Forestry Science, 15: 263-280.

Mason, E.G. 1992, Decision support systems for establishing radiata pine plantations in the Central North Island of New Zealand, PhD Thesis, University of Canterbury, New Zealand: 301 pp

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: 3-18.

Mason, E.G.; Cullen, A.W.J; Rijkse 1988: Growth of radiata pine on uncultivated, ripped, and ripped and bedded soil in Karioi Forest, New Zealand Journal of Forestry Science 18 (3): 287-296

Mead, D.J. 1990, Response of young *Pinus radiata* to cultivation and fertiliser near Motueka, New Zealand, New Zealand Journal of Forestry Science 20 (3): 268-78

Outcalt, 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.

Page, A.l. 1978: Enterprise shown on difficult Northland soil, Forest Industries review.

Snowdon, P.; Waring, H.D. 1984: Long-term nature of growth responses obtained to fertiliser and weed control applied at planting and their consequences for forest management, IN: Proceedings of the IUFRO symposium on site and site productivity of fast growing plantations, Pretoria and Petermaritzberg, South Africa: 701-711.

Trewin, A.R.D; Cullen, A.W.J., 1985: A fully integrated system for planting bare-root seedlings of radiata pine in New Zealand, Proceedings of IUFRO Symposium on Nursery Management Practices for the Southern Pines, Montgomery, Alabama, USA.

Wilhite, L.P.; Jones, E.P. Jnr. 1981: Bedding effects on maturing slash pine stands, Southern Journal of Applied Forestry 5 (1): 24-27.

Williamson, M.J. 1985: Cultivation in Northland, New Zealand Journal of Forestry 30 (2): 218-231

APPENDIX 1

Contents of fertiliser pellets used at Glendhu

1) D.A.P. 54 gm:	9.7 gm elemental N; 10.8 gm element P.
2) Potassium chloride 20 gm:	10 gm elemental K.
3) Kieserite 20 gm:	3.6 gm elemental Mg.
4) K.B. 48 (Neobor) 2 gm:	0.3 gm elemental B.
5) Copper sulphate 4 gm:	1.0 gm elemental Cu.

Total: 100.0 gm/tree

INSTITUTE NEWS

Issues on which Council have been active

Council have been active on a number of issues of interest to our membership.

1 Forest Policy

This continues to be a significant area of debate. Council have sent a draft to each of the Regional Councils. In addition, there has been discussion with MOF and Ministry of the Environment. Despite a desire by Government to have this topic handled by each region independently of central government, application of regional rules of Resource Management has shown that many aspects cannot be left to the parochial instincts of planners and some framework of policy is needed. This was apparent from the way in which indigenous policy was presented in the Forests Amendment Bill as the politicians perceived the electoral risk of leaving this solely to the provisions of the Resource Management Act. I expect to have this debated at the AGM in Napier.

2 Forest Accord

The statement of an accord between the NZ Forest Owners Association and a majority of the environmental organisations, including Maruia Society, Forest and Bird Society etc, was seen in 1991 as a good method of meeting the public's perceived desire to halt reduction of the area and quality of NZ indigenous forest. The Institute along with Greenpeace and various other interested non-signatories is considering the issue of joining the Accord. It should be noted that the aim of the Accord participants was to find common ground and aim to bind these organisations into a form of discipline of action on this topic. This had the attraction of reducing litigation and making clear that support of environmentally friendly plantation forestry could help to reduce the pressure on natural rain forest world wide. In return, participants gave up some capacity to act on this contentious issue. Foresters acting for landowners who wish to convert relict or scrub forest to production species could be uncomfortable with certain definitions in the Accord and it is this removal of ability to exercise professional judgement that the Institute has to be wary of.

Peter Olsen

Nowhere is this more evident than in the Gisborne District Council region where the Government seeks to encourage planting of production species for both protection of eroding unstable soils and to provide economic support for a regional economy suffering recession and subsequent employment and social problems. Application of Regional Rules could be at variance with rigid interpretation of the Accord where scrub species are concerned. Much of the furore could have been avoided if Government had funded adequate analysis and definition of areas of indigenous cover worthy of protection from felling where flora and fauna reserves were justified. Most of the area north of the Hikuai River is in Maori Land and much of this is reverting to manuka and kanuka.

The Ngati Porou initiatives in forest establishment have taken regard for riparian and other reserves and this is applauded by most observers. However, the environmentalists' lobby finds fault with the process of selection of these and it is difficult to avoid the conclusion that the Accord is being used as an instrument of their concern for indigenous forest protection without adequate regard for economic and social issues.

3 Mission Statement

The drafting of a Mission Statement for