FRI/INDUSTRY RESEARCH CO-OPERATIVE

NATIONAL FOREST FERTILISING CO-OPERATIVE RESEARCH PROGRAMME

FOREST MANAGEMENT AND RESOURCES DIVISION
FOREST RESEARCH INSTITUTE
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Results of some experiments involving cultivation, fertilisation and/or weed control as factors, examining the growth of young radiata pine

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FRI/INDUSTRY RESEARCH COOPERATIVES

EXECUTIVE SUMMARY

Seven experiments planted over a range of soil types, altitudes and regions examined interactions between the effects of cultivation, fertilisation, and/or weed control on young radiata pine growth over the first four to six years.

Application of chemical herbicides after establishment increased growth in every experiment where it was tested, and survival in some experiments.

Fertilisation improved growth and survival markedly on a clay soil in Northland, modestly on two gravel soils in Canterbury, and minimally on a Yellow-Brown Earth in Southland and on a pumice site in the central North Island.

Cultivation improved growth on a Northland clay site, a Southland Yellow-Brown Earth, and a Pumice site in the Central North Island. In Canterbury growth improved when 2, 4, or 6 discs were employed after ripping, but not with other cultivation methods. In several experiments using discs after ripping improved growth more than ripping alone.

In two Canterbury experiments fertiliser increased growth more in the presence of weed control than in the absence of weed control.

On one of the pumice sites weed control was more beneficial in uncultivated plots because bracken was partly controlled by the cultivation.

Fertilisation, weed control, and cultivation all influenced tree stability on some sites. It appeared that cultivation treatments which produced a mound of soil over an uncultivated subsoil resulted in more toppling and windthrow. Weed control increased the likelihood of toppling.

These results indicate that response to either fertilisation, weed control, or cultivation can be markedly affected by the presence or absence of the other two treatments. Because the effects of interactions of these treatments have been very different on different sites, we do not have enough information to accurately predict the effect of combining these treatments on early tree growth.

TABULAR SUMMARY OF RESULTS

Experiment Location	Expt Age	Soil	Cult (C)	Wd ctl (W)	Fert (F)	C*W	C*F	W*F	C*W*F
Southland (Glendhu)	4	Clay	***	**	--	--	#	--	--
			C	--	--	--	--	--	--
			S+	S+	S-	--	--	--	--
			T+	--	--	--	--	--	--
Canterbury (Eyrewell)	4	Gravel	*	**	--	--	--	#	--
			--	C	--	--	--	--	--
			--	S+	--	--	--	--	--
Canterbury (Balmoral)	4	Gravel	--	--	--	--	--	#	--
			--	C	--	--	--	--	--
			--	S-	-	--	--	--	--
Central N.I. (Kaingaroa)	6	Pumice	--		--		--		
			--		C		--		
			S+		--		--		
			W+		T-		--		
Central N.I. (Ohakuri)	6	Pumice	***	****		#			
			C	C		C			
			S+	--		--			
			T+	T+		--			
Central N.I. (Wainui)	6	Pumice	--	***	--	--	--	--	--
			--	C	--	--	--	--	--
			--	S+	--	--	--	--	--
			--	T+	T+	--	--	--	--
Northland (Karikari)	5	Clay	****		****		#		
			C		C		--		
			--		S+		--		
			T+		T+		--		

--	= NO EFFECT (MAY BE INTERACTIVE)
*	= 0-25 CM INCR. IN HT
**	= 25-50 CM INCR. IN HT
***	= 50-100 CM INCR. IN HT
****	= >100 CM INCR. IN HT
#	= SIGN. HT INTERACTION
C	= REDUCTION IN CROP VARIABILITY DETECTED
S	= EFFECT ON SURVIVAL
T	= EFFECT ON TOPPLING FREQUENCY
W	= EFFECT ON WINDTHROW

FOREST RESEARCH INSTITUTE PROJECT RECORD NO.: 1846

DIVISION: FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD: PROPAGATION AND EARLY GROWTH

PROJECT NO.: FE 32 SUBPROJECT NO.: RF ID: 437

WORK PLAN NO.: 556 FIELD EXPERIMENT(S): SD 615

TITLE: ESTABLISHMENT REGIMES FOR RADIATA PINE ON YELLOW-BROWN EARTHS IN SOUTHLAND - 4TH YEAR RESULTS

AUTHOR/S: E.G. MASON, P. MILNE & A.W.J. CULLEN DATE: FEB 1988

KEYWORDS: CULTIVATION, WEED CONTROL, FERTILISATION

SUMMARY

An analysis of four years' growth in a factorial experiment is described. The experiment consisted of three factors: cultivation, fertilisation, and weed control.

The overall average height was 245 centimetres, and the average diameter at breast height was 35 millimetres.

Cultivation significantly improved both height and diameter growth, and treatments involving discs were better than those involving only a ripper. The best cultivation treatment improved height growth by 65 cms over the control treatment, and cultivation dramatically improved crop uniformity.

Weed control improved height growth by 28 cms.

Fertilisation was interactive with cultivation. It increased diameter and height within the best cultivation treatments, and decreased both parameters within the worst treatments. The overall effect of this interaction was small, however.

The incidence of multiboling varied between 7% and 20%, and was significantly correlated with the weed control x fertiliser interaction.

Toppling affected between 4% and 22% of the crop, depending on cultivation treatment. Treatments with larger trees tended to be more affected.

INTRODUCTION

As part of the experimental cultivation rig programme (see work plan FE32/437) a factorial experiment (SD 615) was established in Glendhu Forest in 1983. It forms part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

Cultivation is a very effective site preparation technique on yellow-brown earths in Southland, but techniques tested to date have probably not maximised the site potential.

The topsoil of yellow-brown earths is often exceptionally 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. The resistance to penetration of yellow-brown earths probably increases as soil moisture decreases. The soil was reasonably wet when measurements were taken.

When this soil is ripped, the topsoil is pushed upwards as two hinges, but does not fracture. In some cases a hole remains where the base of the ripper passed, because the fractured subsoil is slightly compressed upwards and the two topsoil hinges do not fall back into place. The trees benefit both from the improved drainage, and the increase in soil volume, but growth could be better.

SD 542 in Berwick (Appendix 1) showed an enormous improvement in the crop brought about by blading and ripping. Blading probably removed much of the puggy topsoil, and ripping increased the subsoil volume available to the trees. The expected loss in growth due to topsoil removal was more than offset by the improved aeration of the remaining soil.

If topsoil could be retained, but its structure improved the trees should respond with even better growth and more uniformity. SD 615 was a first attempt to do this.

METHOD

Treatments tried in SD 615 were as follows:

1 Control (C)

2 Ripping (R)

3 Rippping / flat roller (RR)

4 Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)

5 Ripping / 4 inverted discs (R4)

6 Ripping / 6 inverted discs (R6)

7 Ripping / 2 inverted discs / hourglass roller (R2R)

8 Ripping / 4 inverted discs / hourglass roller (R4R)

9 Ripping / 6 inverted discs / hourglass roller (R6R)

10 Ripping / 6 inverted discs / hourglass roller (wet soil) (R6RW)

Spot weed control and fertilisation were incorporated within the above treatments, to form a three way factorial, split-plot design within five blocks. Plots were 80 metres long, and contained 3 lines of cultivation. The distance between lines was 4 metres.

Each line was planted with 1/0 stock from Edendale Nursery. The stock was lifted and trimmed in bundles of ten and transported in cardboard boxes of the type recommended by FRI. The 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 so that at older ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

The 80 metre plots were then divided into 4 subplots with random treatments of weed control (2 kgs of Velpar/hectare applied manually) and fertiliser (R. Fitzgerald, complete mix) in a factorial design.

The survival, height, and basal diameter were reassessed after the second, third and, excepting basal diameter, the fourth years. Diameter at breast height was measured in the fourth year. By the end of the third year, significant amounts of toppling had occured. The stem condition of each tree was recorded after the third and fourth years.

In addition, multiboling of trees 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.

RESULTS

A Survival

Average survivals were 88% for the control treatment, 90% for the two ripped treatments and 95% for the ripped and disced treatments.

When fertiliser was applied without weed control, survival averaged 87%, while the other three treatments defined by the weed control x fertiliser interaction had a mean survival of 95%.

B Growth

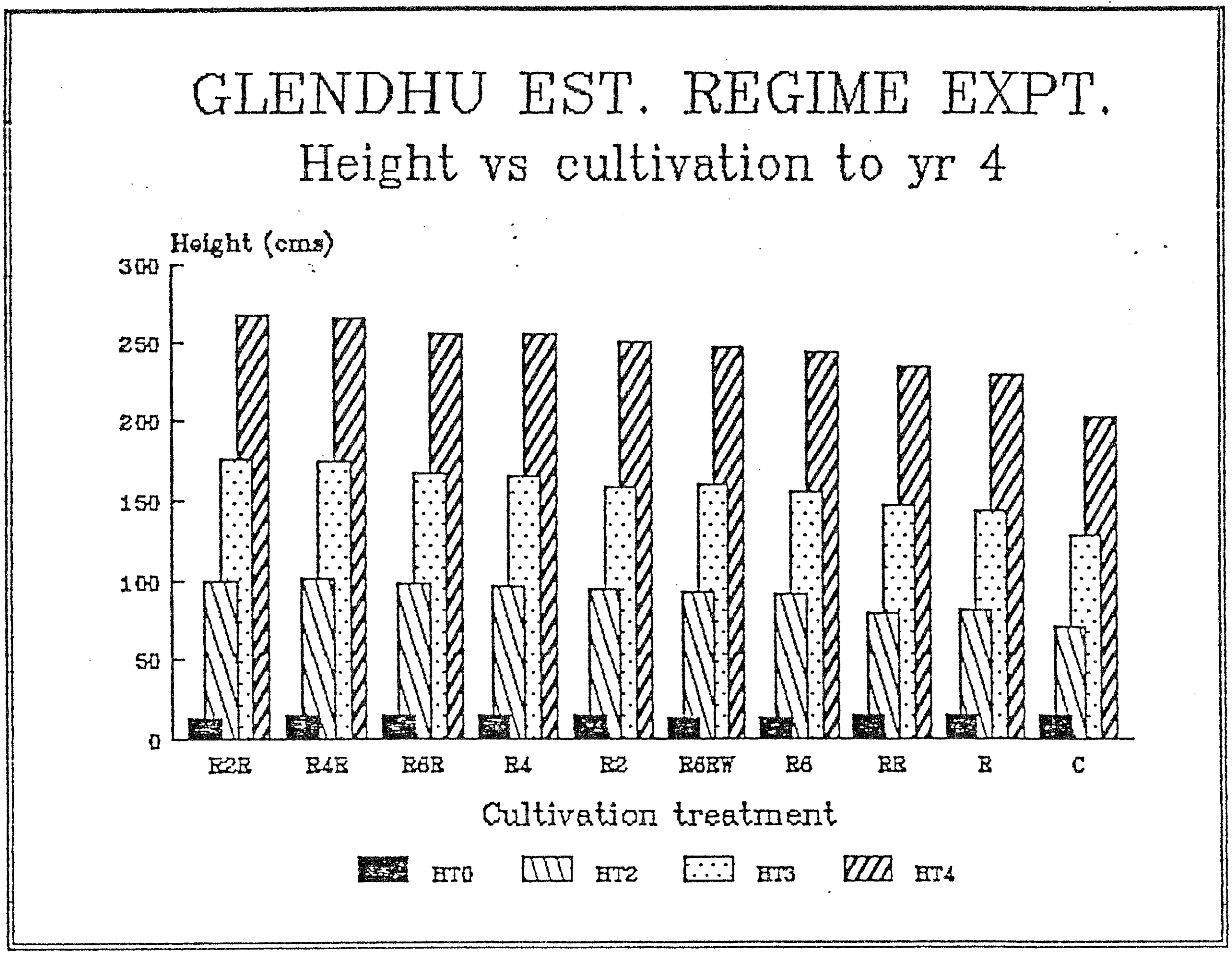
Average height after four years was 245 centimetres, and the average diameter was 35 millimetres. Height growth during the fourth year was 90 cms.

Figures 1 and 2 show height and diameter growth during the first four years. There was a continuing divergence in growth betwen the best and worst treatments. Growth in the control plots was far more variable than in the cultivated plots (Figure 3).

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 ($P<0.001$). Those treatments with discs averaged 255 cm in height and 38 mm in diameter, while the ripped only treatments averaged 231 cm and 30 mm respectively.

Employing a roller with the discs brought about an improvement of 13 cm in height, and 4 mm in diameter after year three. While small, this main effect was statistically significant ($P<0.01$). While still present, the effect was not quite significant ($P<0.05$) after year four. The contrast does not include rip/6 discs/roll for wet soil, since there was no corresponding treatment without a roller.

FIGURE 1



1 Control (C)

2 Ripping (R)

3 Rippping / flat roller (RR)

4 Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)

5 Ripping / 4 inverted discs (R4)

6 Ripping / 6 inverted discs (R6)

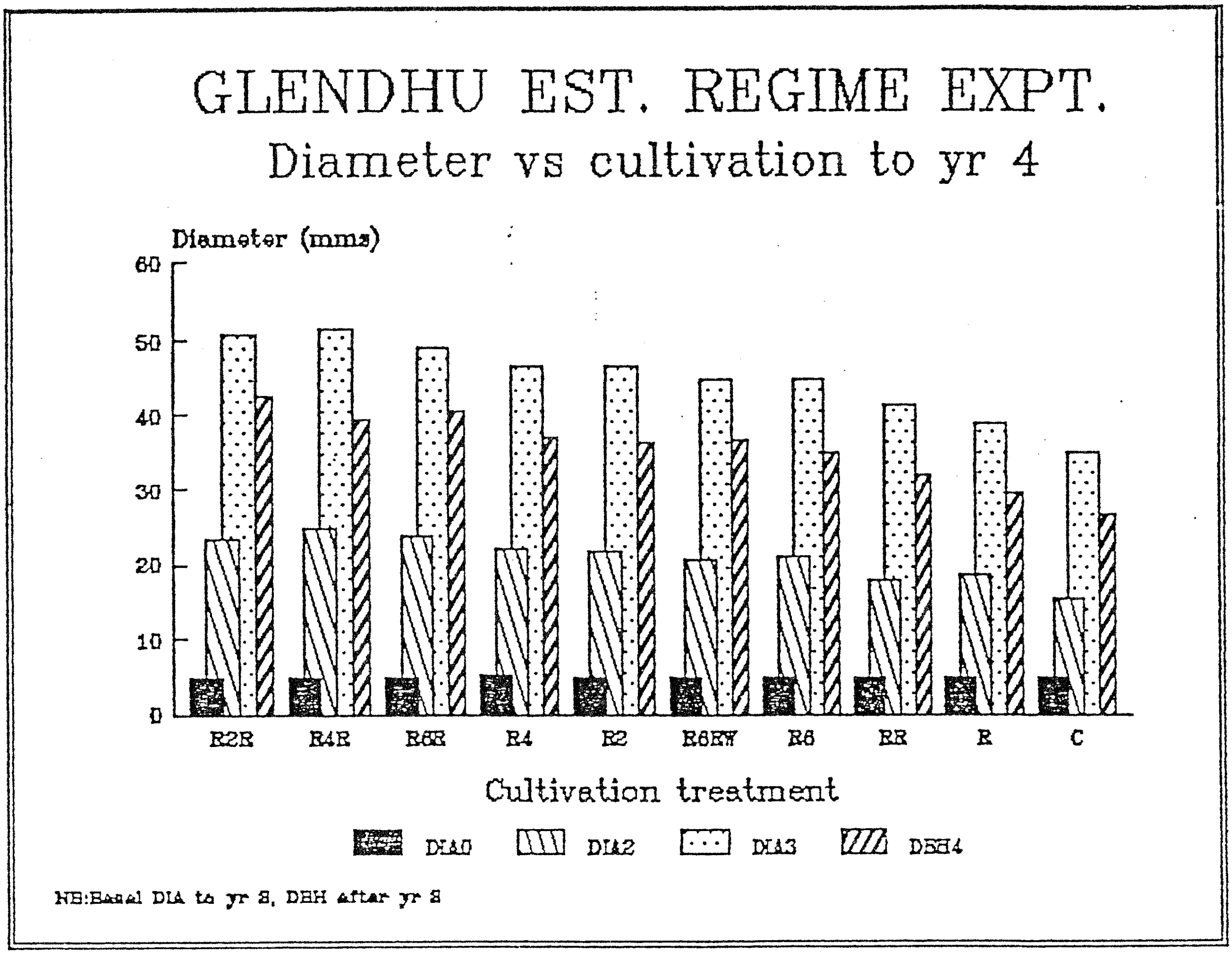
7 Ripping / 2 inverted discs / hourglass roller (R2R)

8 Ripping / 4 inverted discs / hourglass roller (R4R)

9 Ripping / 6 inverted discs / hourglass roller (R6R)

10 Ripping / 6 inverted discs / hourglass roller (wet soil) (R6RW)

FIGURE 2



1 Control (C)

2 Ripping (R)

3 Rippping / flat roller (RR)

4 Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)

5 Ripping / 4 inverted discs (R4)

6 Ripping / 6 inverted discs (R6)

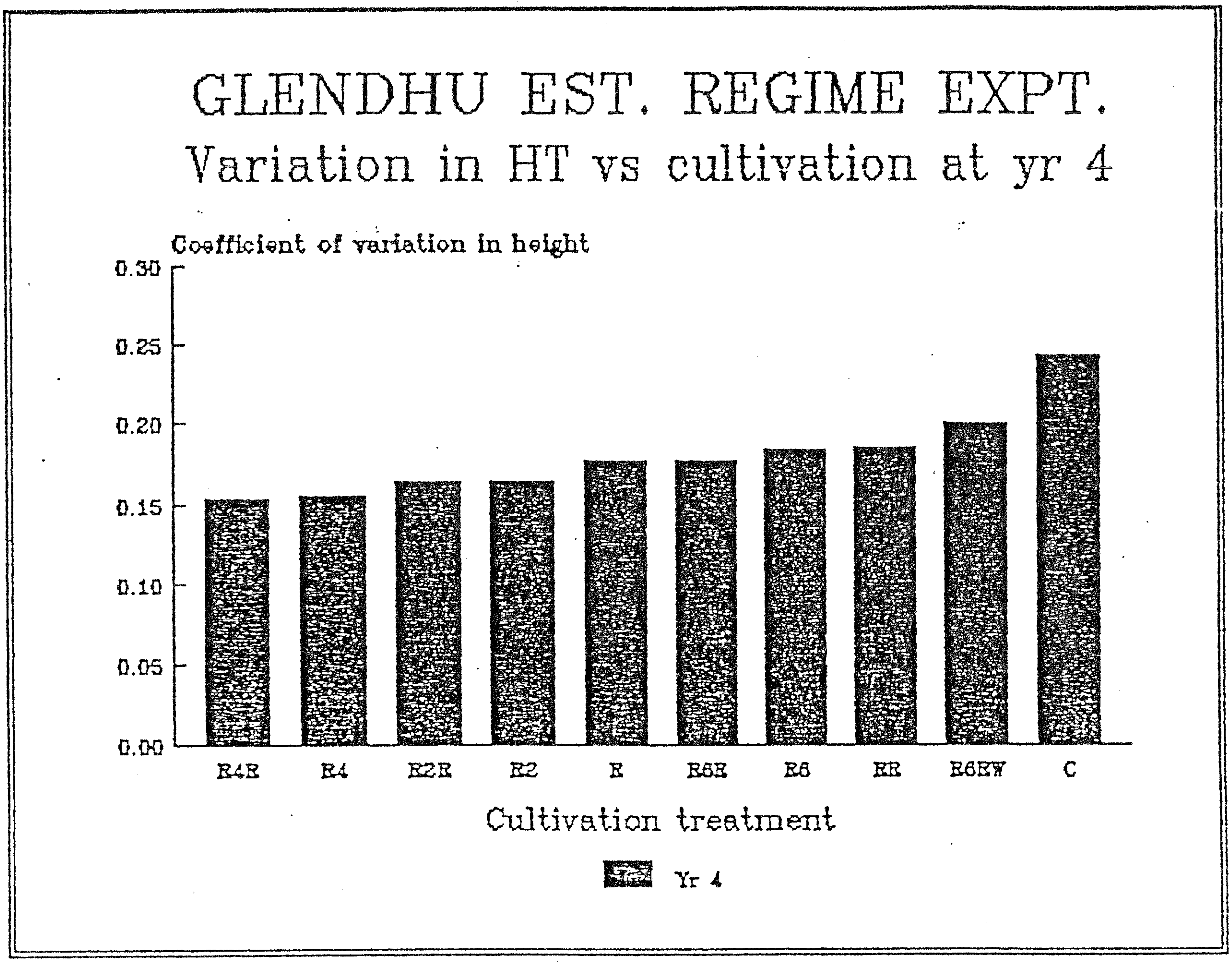
7 Ripping / 2 inverted discs / hourglass roller (R2R)

8 Ripping / 4 inverted discs / hourglass roller (R4R)

9 Ripping / 6 inverted discs / hourglass roller (R6R)

10 Ripping / 6 inverted discs / hourglass roller (wet soil) (R6RW)

FIGURE 3



1 Control (C)

2 Ripping (R)

3 Rippping / flat roller (RR)

4 Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)

5 Ripping / 4 inverted discs (R4)

6 Ripping / 6 inverted discs (R6)

7 Ripping / 2 inverted discs / hourglass roller (R2R)

8 Ripping / 4 inverted discs / hourglass roller (R4R)

9 Ripping / 6 inverted discs / hourglass roller (R6R)

10 Ripping / 6 inverted discs / hourglass roller (wet soil) (R6RW)

Weed control added 28 cms in height, and 6 mm in diameter. This reflects a continuing divergence of the growth trajectories of the weed control and no weed control treatments.

Fertiliser was interactive with cultivation adding growth with the best treatments, and reducing growth with the poorer treatments. The effect of fertiliser on growth was less than 10 cm growth in all cases except ripping and rolling, where it decreased growth by 30 cms.

C <u>Toppling</u>

Toppling was significantly more frequent on the top of the hill than lower down (Figure 4). Block 1 was at the highest altitude and block 5 was at the lowest.

Figure 5 shows an analysis of toppling frequency by cultivation treatment. In the control and ripped plots, where growth was slower, toppling was less frequent than in the other plots ($P<0.03$). Fertiliser and weed control made no difference to toppling frequency.

D <u>Multiboling</u>

Multiboled trees had smaller main stems than the other trees in the experiment at age four (Figure 6). An analysis of initial measurements demonstrated that there were no differences in height and diameter immediately after planting between those trees which subsequently became multileadered, and those which didn't. The diameter difference was 9 mm at age 3, and was 5 mm at age 4.

Frequency of multiboles was significantly affected by the interaction between fertiliser and weed control (Figure 7). In the absence of weed control, fertiliser reduced the incidence of multiboles When weed control was included, fertiliser had no impact on the frequency of multiboles. Weed control significantly increased the amount of multiboles.

Cultivation with a ripping tine but no discs caused a slight increase in multibole frequency (Figure 8).

DISCUSSION

A <u>Survival</u>

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

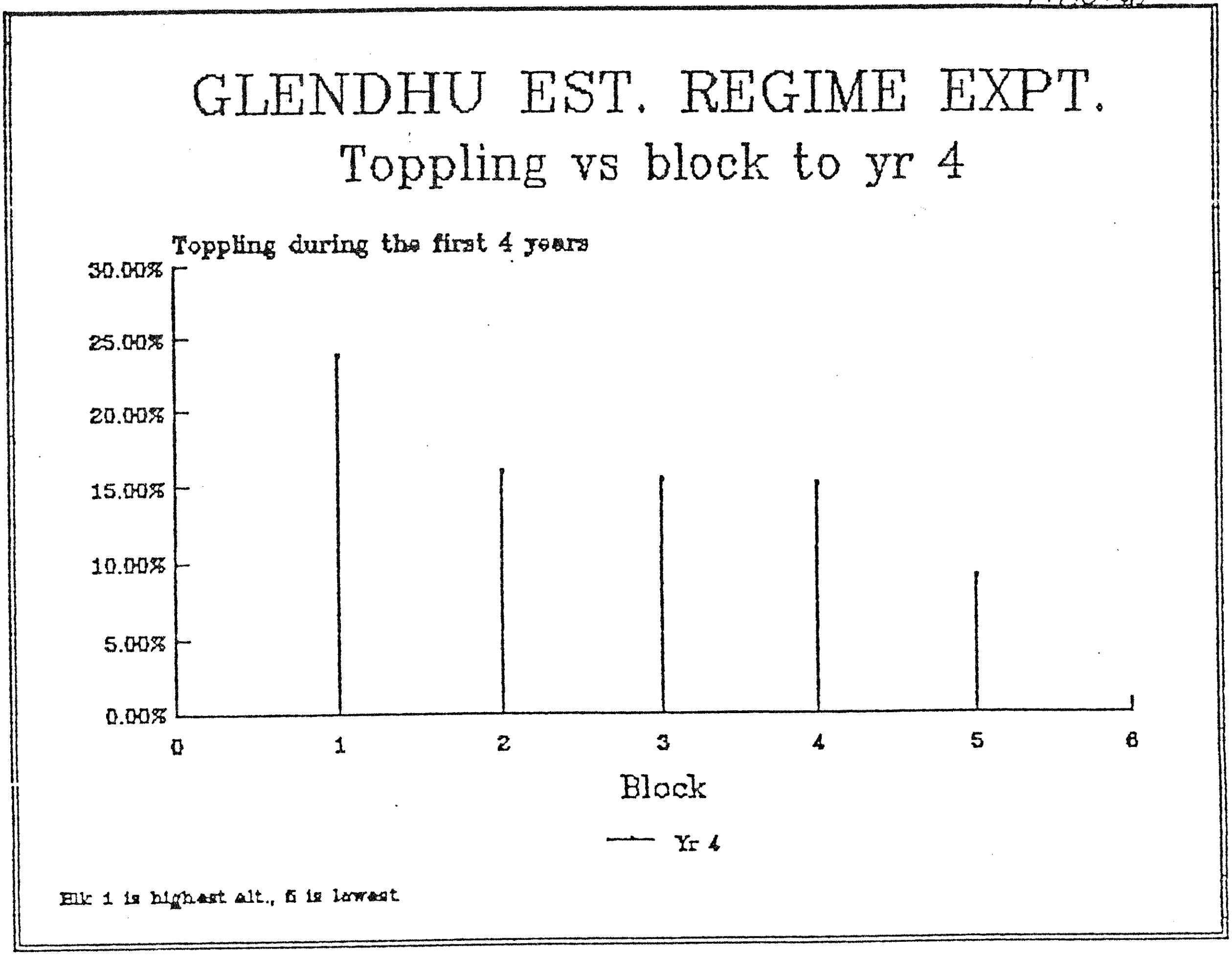
As usual, adding fertiliser without weed control encouraged weed growth around the trees, and survival was depressed.

B <u>Growth</u>

The improvement in growth brought about by cultivation was quite dramatic. Not only did cultivation improved average growth, but the resulting crops were significantly more uniform.

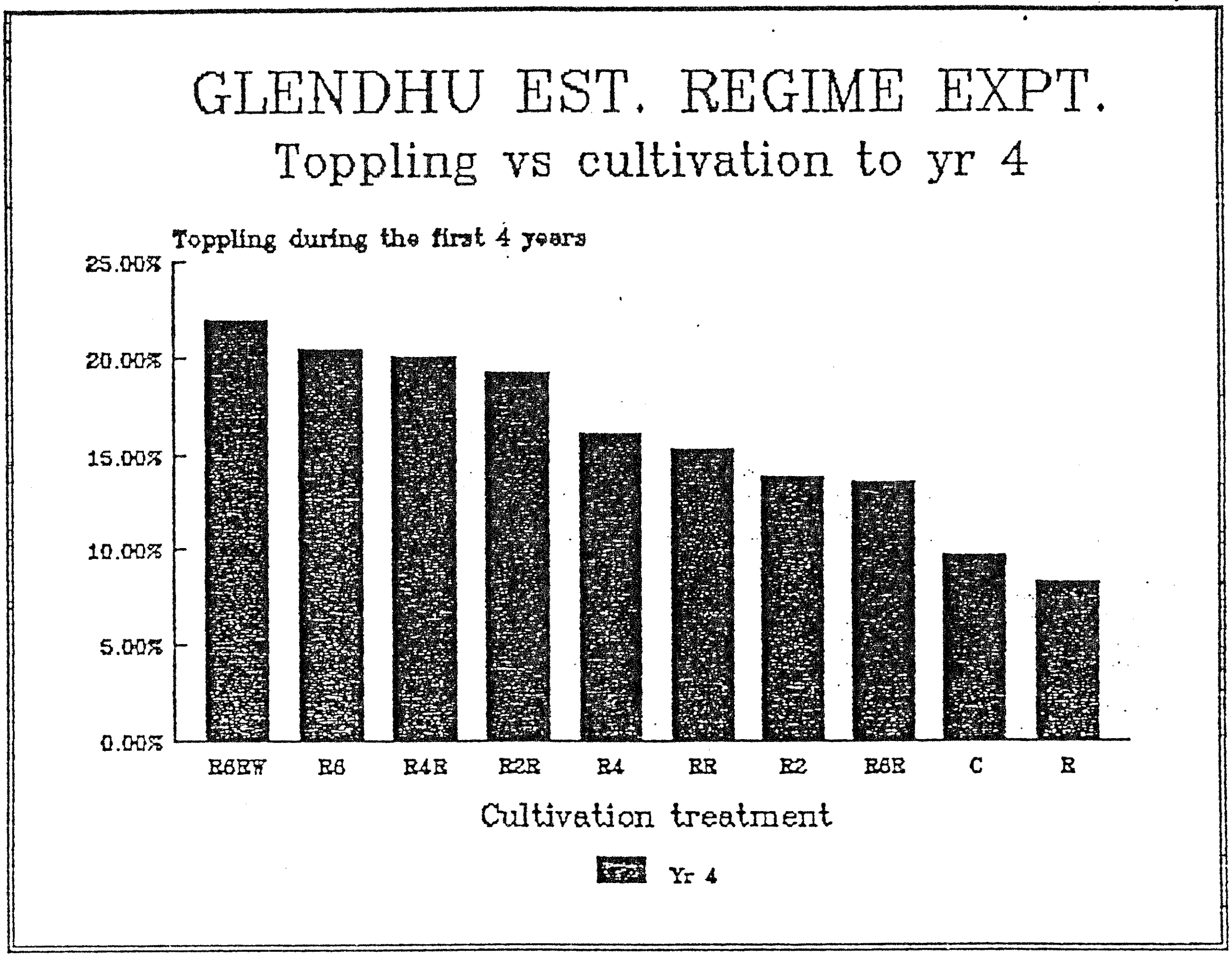
It is likely that the effect of cultivation was brought about by an improvement in drainage of the topsoil. Yellow-brown earths in Southland have exceedingly wet surface horizons. This would help to explain the difference in response between trees growing on ripped lines and those on ripped and disced lines. A wet pumice soil with a high clay content at Karioi was improved more by ripping and bedding than by ripping alone (Mason, Cullen & Rijkse, in prep).

FIGURE 4



GLENDHU EST. REGIME EXPT.
Toppling vs block to yr 4
Toppling during the first 4 years
30.00%
25.00%
20.00%
15.00%
10.00%
5.00%
0.00%
0
1
2
3
4
5
6
Block
Yr 4
Blk 1 is highest alt., 5 is lowest

FIGURE 5



1 Control (C)

2 Ripping (R)

3 Rippping / flat roller (RR)

4 Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)

5 Ripping / 4 inverted discs (R4)

6 Ripping / 6 inverted discs (R6)

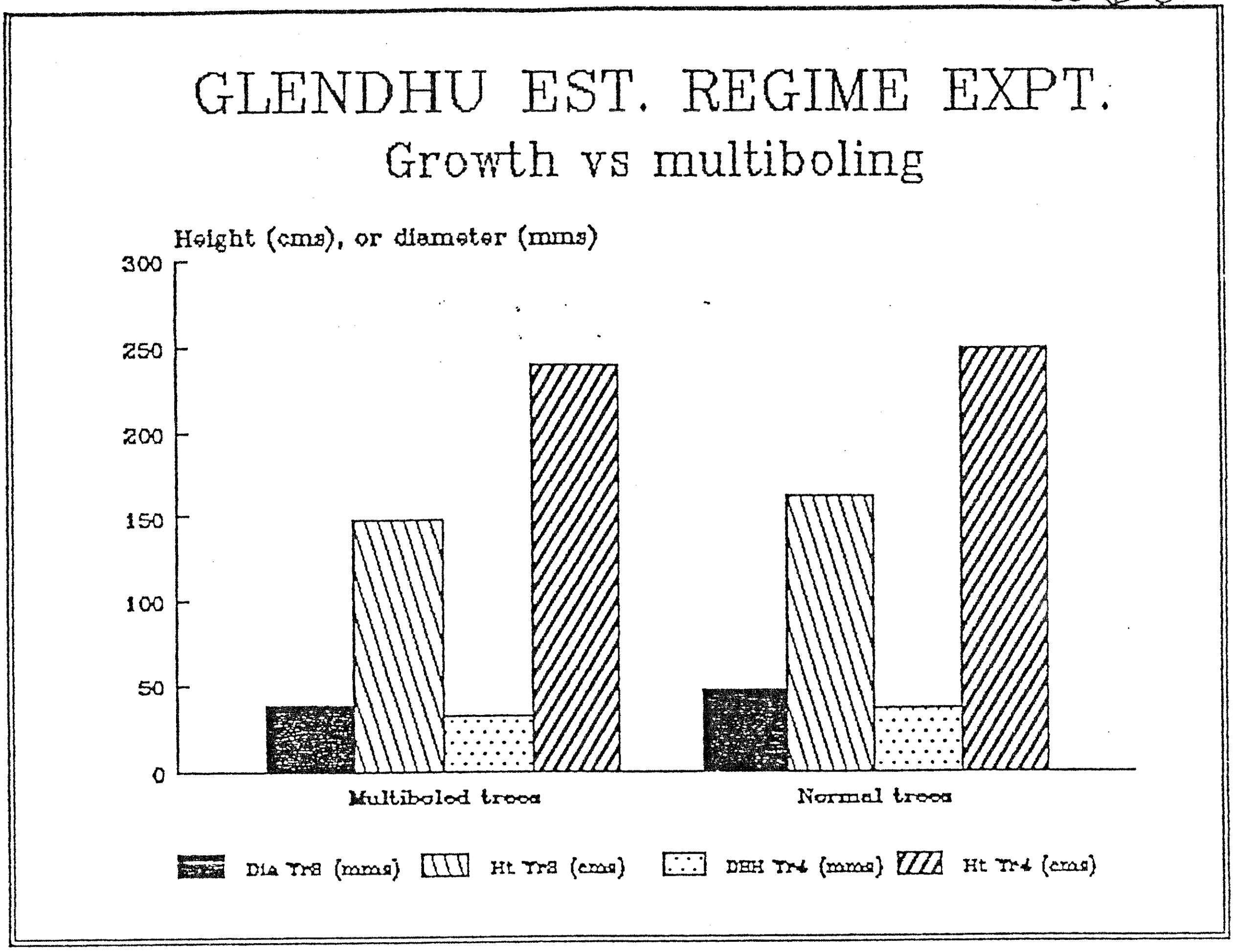
7 Ripping / 2 inverted discs / hourglass roller (R2R)

8 Ripping / 4 inverted discs / hourglass roller (R4R)

9 Ripping / 6 inverted discs / hourglass roller (R6R)

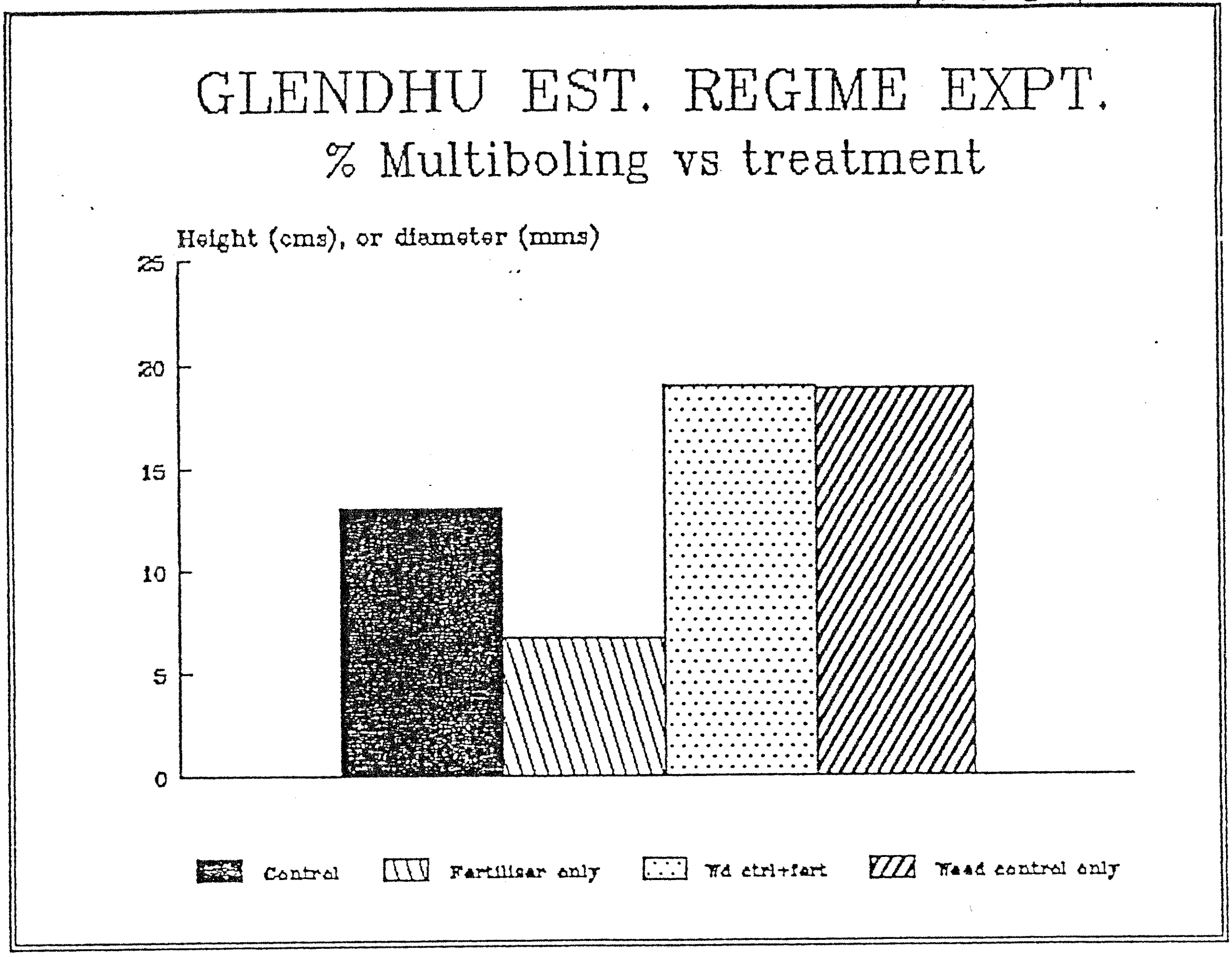
10 Ripping / 6 inverted discs / hourglass roller (wet soil) (R6RW)

FIGURE 6



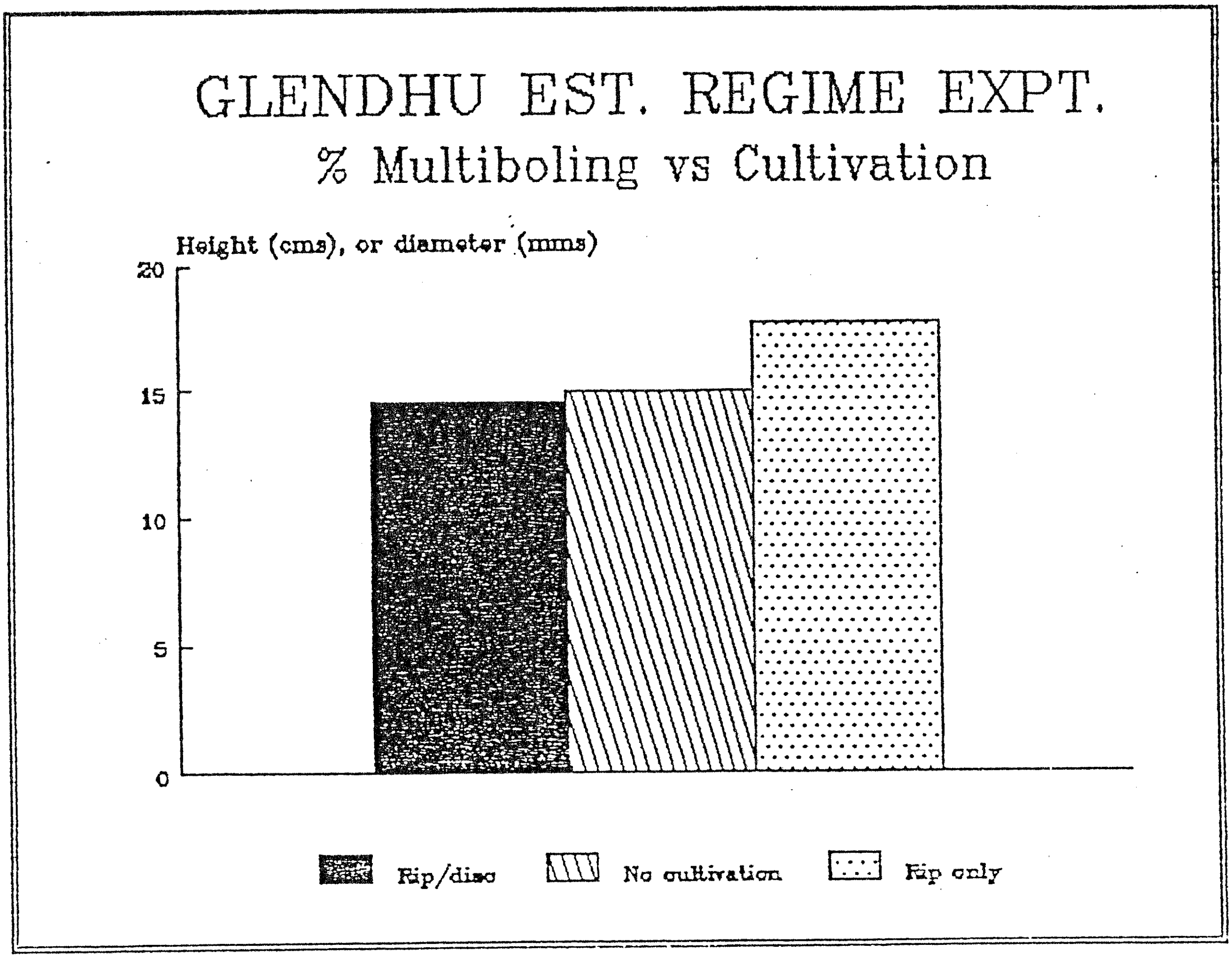
GLENDHU EST. REGIME EXPT.
Growth vs multiboling
Height (cms), or diameter (mms)
300
250
200
150
100
50
0
Multiboled trees
Normal trees
Dia Tr3 (mms)
Ht Tr3 (cms)
DBH Tr4 (mms)
Ht Tr4 (cms)

FIGURE 7



GLENDHU EST. REGIME EXPT.
% Multiboling vs treatment
Height (cms), or diameter (mms)
25
20
15
10
5
0
Control
Fertiliser only
Wd ctrl+fert
Weed control only

FIGURE 8



GLENDHU EST. REGIME EXPT.
% Multiboling vs Cultivation
Height (cms), or diameter (mms)
20
15
10
5
0
Rip/disc
No cultivation
Rip only

Ripping may have increased the useable soil volume, but this was probably less important during the first 3 years than it may be subsequently. In Kaingaroa Forest, soil volume was not a significant factor until after age 3 (Mason & Cullen, 1986).

It is also clear that ripping and discing provided a better growing medium than simply ripping on these soils. Improved drainage and aeration of the topsoil may be one of the prime reasons why this was so.

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 an real increase in growth, then this could be because the soil clods were further fractured as the roller passed over them. Further improvement of the topsoil structure may have resulted in even better growth.

Future research should concentrate on improving the structure of the topsoil, in conjunction with ripping of the subsoil. An experiment should be implemented to see how much extra growth can be achieved with well cultivated topsoil, even if this involves several passes of various disc or harrow combinations. If the extra growth warrants it, machinery could be developed to do the job in one pass.

The interaction between cultivation and fertiliser is not easy to explain. It is clear, however, that fertiliser had a minimal impact on growth in the experiment, compared with other factors.

C <u>Toppling</u>

Toppling increased in frequency with increasing tree size. This correlation has been observed in several other trials at ages 2 and 3 (Mason, 1985).

In addition, cultivation with discs increased the toppling rate within tree size classes. This is also identical to results from other experiments (Mason, 1985). The loose soil created by discing may provide less support for trees as they sway in the wind, increasing the likelihood of toppling. It is also possible that the toppled trees had inferior root systems.

Research has already shown that nursery and planting practices can have a large impact on toppling frequency, and, since most trees in the experiment were stable, it would be wise to look at improvements in other areas rather than use toppling as a reason not to cultivate.

D <u>Multiboling</u>

Multiboling occured more frequently in this experiment than in any other experiment we have measured in New Zealand. Comments by Dennys Guild (pers. comm.) suggeset that the problem is widespread in the Otago region.

The growth of the largest stem within multiboles trees was significantly less than that of normal trees, and with average diameters reduced by 5 mm, some multiboles trees may never contribute much to the crop, even if the other boles were cut out at age 3 or four. The difference in growth is reducing, however.

The results have also provided indications about the process of multiboling. Weed control significantly increased the frequency of multiboles. When fertiliser was applied with weed control, it had no effect, whilst adding fertiliser in the absence of weed control reduced multiboling by more than half. Since adding fertiliser stimulates weed growth, it appears that thick weeds around the base of a tree can suppress the development of multiboles. While no-one would suggest that weeds should be retained for this purpose, the result adds weight to the view held by those who planted the experiment, that multiboles develop 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 multileadering frequency. Some useful work could be done retrospectively at relatively low cost if required.

Conclusions

Cultivation and weed control have the potential to dramatically improve initial growth of trees growing on yellow-brown earths in Southland. Survival, growth and crop uniformity can all be significantly improved, and managers may be able to contemplate further reductions in initial stocking if the techniques are implemented on a large scale.

Both treatments can also have detrimental effects on tree form, however. Cultivating with ripper/discs increased the incidence of toppling, whilst weed control increased the frequency of multiboling. These phenomena may significantly reduce the overall advantages of the two treatments.

Further research into both phenomena may suggest ways for managers to enjoy the benefits of intensive site preparation without detrimental side effects.

It is also clear that proper cultivation and weed control can reduce the length of the rotation. These two treatments together have already added more than a year's growth in both height and diameter, compared to the control treatment.

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APPENDIX

Results from S 542, year 5, first two blocks.

Treatment	Survival (%)	Height (cm)	Variability (C.O.V. Ht)
Blading and ripping	95 a	2.07 a	0.157 a
Blading	94 a	1.95 ab	0.158 a
Ripping	83 ab	1.82 b	0.217 ab
Ripping and bedding	74 ab	2.02 ab	0.233 ab
Bedding	80 ab	1.87 ab	0.259 b
Control	64 b	1.37 c	0.283 b
Weed control	85 a	1.99 a	0.202 a
No weed control	78 b	1.71 b	0.234 b

FOREST RESEARCH INSTITUTE PROJECT RECORD NO. 1848

DIVISION FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD PROPAGATION AND EARLY GROWTH

PROJECT NO. FE 32 SUBPROJECT NO. R.F. ID.

WORK PLAN NO. 437 FIELD EXPERIMENT(S) C573/1

TITLE EXPERIMENTAL CULTIVATION RIG TRIAL AT EYREWELL - RESULTS AFTER YEAR 4

AUTHOR/S E.G. MASON, P. MILNE & A.W.J. CULLEN DATE Feb 1988

KEYWORDS CULTIVATION, WEED CONTROL, FERTILISATION

SUMMARY

An analysis of four years' growth in a factorial experiment is described. The experiment consisted of three factors: cultivation, fertilisation, and weed control.

On average, the trees in the experiment were 278 cms tall, and 41 mm in diameter at breast height.

The cultivation effect was significant after four years. Those treatments which employed discs but no roller were taller than those with discs and a roller. Ripping alone was the poorest treatment.

The effect of weed control was significant on its own, while the effect of fertiliser was interactive with weed control. Weed control increased height growth by 43 centimetres and diameter growth by 11 millimetres. Fertilisation did not increase diameter growth in the absence of weed control and increased it by 3 millimetres in the presence of weed control.

INTRODUCTION

As part of the experimental cultivation rig programme (see work plan FE32/437) a factorial experiment was established in Eyrewell Forest in 1983. It formed part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

METHOD

A windrowed portion of Eyrewell Forest was cultivated with three blocks of ten treatments. The treatment plots were 80 metres long, and contained 3 cultivated lines . The distance between lines was 4 m. Cultivation treatments consisted of:

1.	Rip/6 discs/hourglass roller	(R6R)
2.	Rip/4 discs/hourglass roller	(R4R)
3.	Rip/2 discs/hourglass roller	(R2R)
4.	Rip/6 discs	(R6)
5.	Rip/4 discs	(R4)
6.	Rip/2 discs	(R2)
7.	Rip/flat roller	(RR)
8.	Rip	(R)
9.	Control	(C)
10.	Rip/drag log over rip (current treatment at Eyrewell, at the time of plot establishment). (RLOG)	

Each line was planted with 1/0 stock from Rangiora nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type employed by NZ Forest Products Ltd. The spacing within lines was 2 metres. The initial height and diameter (5 cms above ground level) of each tree in the centre line of each plot was recorded. The two outer lines were employed as buffer lines so that at older stand ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

The 80 metre plots were then divided into 4 subplots with treatments of weed control (2 kg velpar/hectare applied manually) and fertiliser (R. Fitzgerald, complete mix) randomly allocated to the sub plots in a factorial design. The main weeds present were grasses.

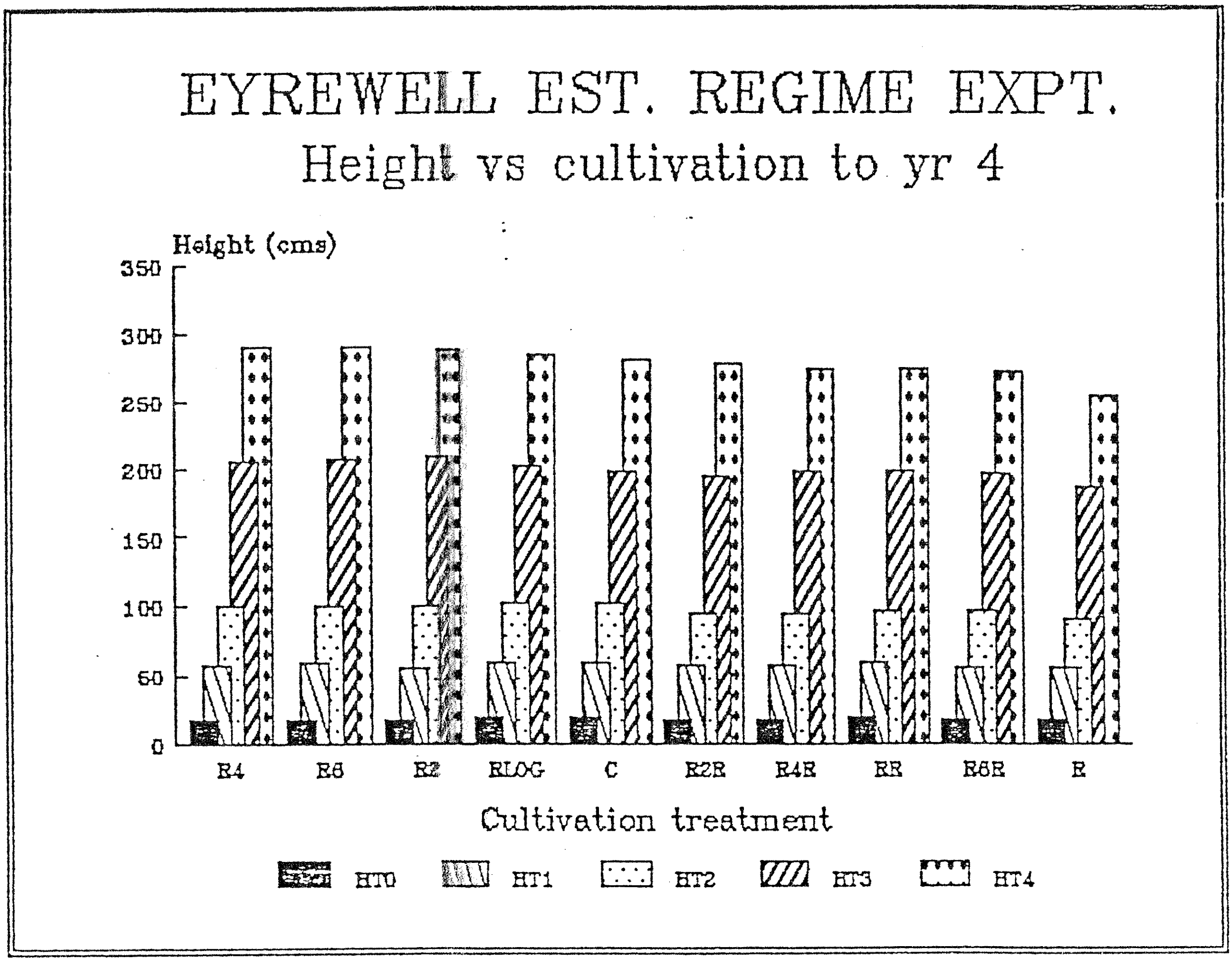
The survival, height, and basal diameter were assessed after each of the first four years, except for basal diameter which was abandoned in favour of diameter at breast height in year four.

RESULTS

Average height after four years was 278 cm, and the average diameter at breast height was 41 mm. The average survival was 96.3%.

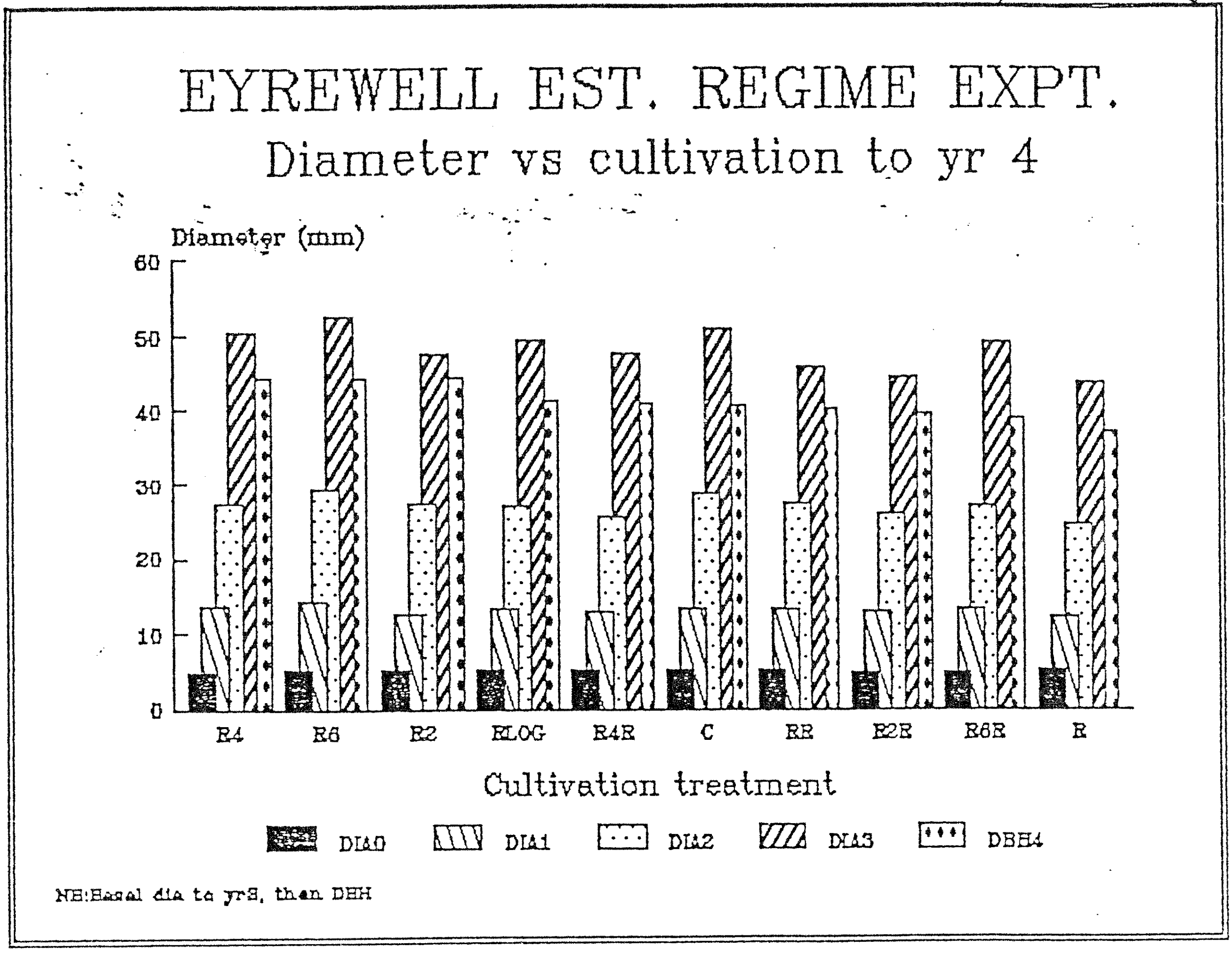
Cultivation significantly ($P<0.02$) affected both height and diameter growth. Ripping followed by 6, 4, or 2 discs were the best treatments, and ripping only was the worst. Differences in height and diameter growth are shown in Figures 1 and 2 respectively. Linear contrasts showed that growth on ripped, and disced treatments was significantly better than growth on ripped disced and rolled treatments.

FIGURE 1



1.	Rip/6 discs/hourglass roller	(R6R)
2.	Rip/4 discs/hourglass roller	(R4R)
3.	Rip/2 discs/hourglass roller	(R2R)
4.	Rip/6 discs	(R6)
5.	Rip/4 discs	(R4)
6.	Rip/2 discs	(R2)
7.	Rip/flat roller	(RR)
8.	Rip	(R)
9.	Control	(C)
10.	Rip/drag log over rip (current treatment at Eyrewell, at the time of plot establishment). (RLOG)	

FIGURE 2



1. Rip/6 discs/hourglass roller (R6R)
2. Rip/4 discs/hourglass roller (R4R)
3. Rip/2 discs/hourglass roller (R2R)
4. Rip/6 discs (R6)
5. Rip/4 discs (R4)
6. Rip/2 discs (R2)
7. Rip/flat roller (RR)
8. Rip (R)
9. Control (C)
10. Rip/drag log over rip (current treatment at Eyrewell, at the time of plot establishment). (RLOG)

Although growth was poorest in the ripped treatment, the height and diameter of this treatment were not significantly different from those in the control treatment. Height and diameter in the ripped treatment were significantly different ($P<0.05$) from height and diameter in the ripped and disced treatments, however.

The effect of weed control was significant when compared with the largest interaction mean square. It improved height growth by 44 cm and dbh growth by 11 mm. There was a significant interaction between fertiliser and weed control for diameter growth. In the presence of weed control, fertiliser improved tree diameter by 3 mm in diameter, and when weed control was excluded fertiliser gave in no increase in diameter. (Figure 3).

Weed control also brought about a significant improvement in crop uniformity. The coefficient of variation (COV) in height was reduced from 0.160 to 0.135, and the COV in diameter was reduced from 0.273 to 0.200.

DISCUSSION AND CONCLUSIONS

As in central North Island pumice sites (Mason & Cullen 1986), the effects of cultivation only began to emerge after the fourth year on this site. The improvement in growth due to ripping and discing was only 10 cm in height and 4 mm in dbh, and would not justify this operation on the basis of growth alone. However, an earlier study showed that trees growing in ripped soil at Eyrewell were more firmly anchored than those in unripped soil (Somerville 1979), and the results from the experiment described here imply that discs should be used to pull soil back over the rip-line if ripping is to be undertaken.

The effect of weed control was important on this site. It may prove to be worth adopting as a standard practice.

As usual, the effect of fertiliser was suppressed when it was not applied in conjunction with weed control. The overall effect of adding fertiliser was relatively minor, and the operation would probably be uneconomic.

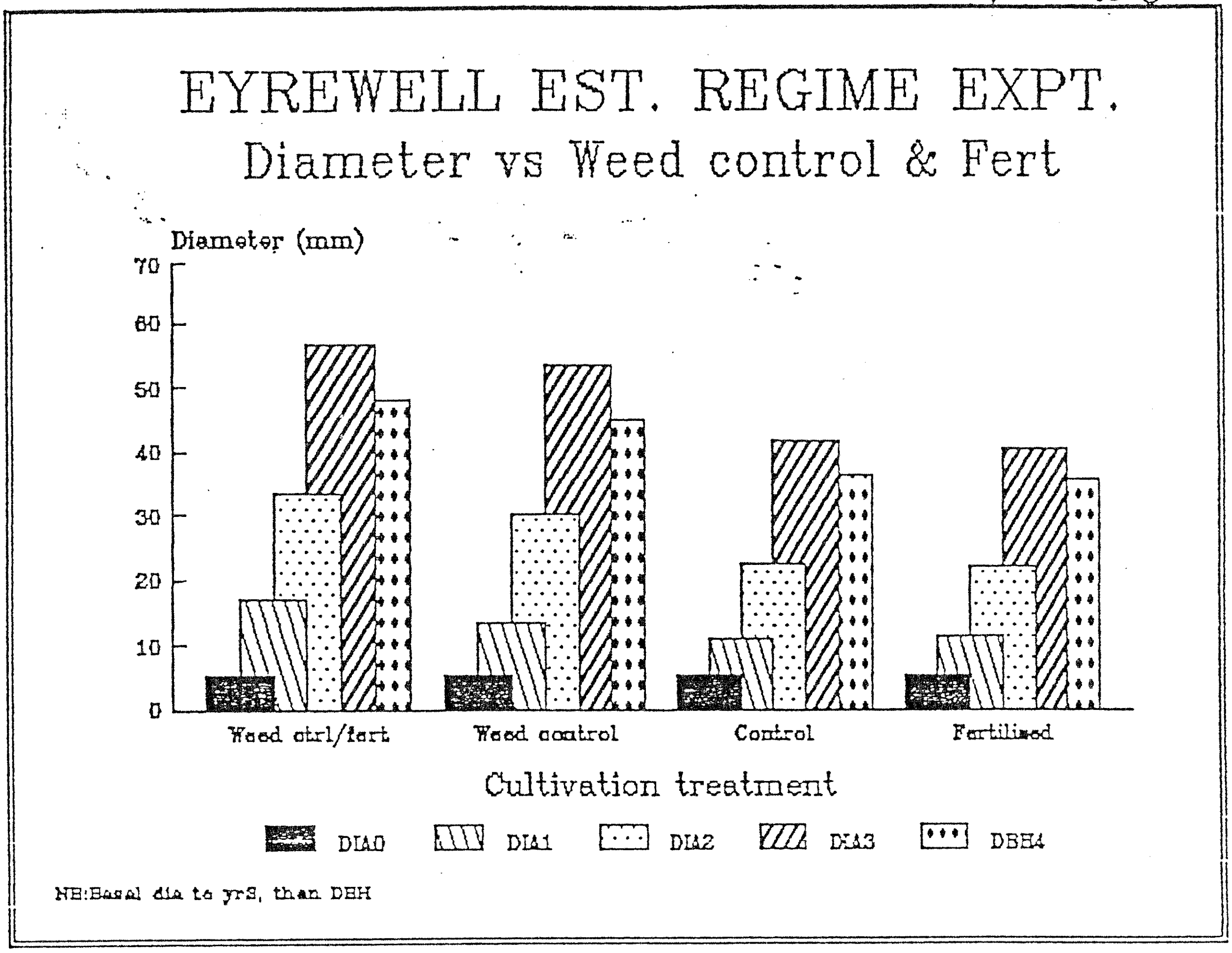
Further monitoring of the trial will reveal the long-term impact of these effects on the crop.

REFERENCES

Mason, E.G., & A.W.J. Cullen. 1986, Growth of *Pinus radiata* on ripped and unripped Taupo pumice soil, *New Zealand Journal of Forestry Science* 16(1): 3-18.

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.

FIGURE 3


EYREWELL EST. REGIME EXPT.
Diameter vs Weed control & Fert
Diameter (mm)
70
60
50
40
30
20
10
0
Weed ctrl/fert
Weed control
Control
Fertilised
Cultivation treatment
DIA0
DIA1
DIA2
DIA3
DBH4
NB:Basal dia to yr3, then DBH

FOREST RESEARCH INSTITUTE PROJECT RECORD NO.: 184

DIVISION': FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD: PROPAGATION AND EARLY GROWTH

PROJECT NO. : FE 32 SUBPROJECT NO. : RF ID :

WORK PLAN NO. : 437 FIELD EXPERIMENT(S) : C573/2

TITLE : EXPERIMENTAL CULTIVATION RIG TRIAL AT BALMORAL : RESULTS AFTER YEAR 4

AUTHOR/S : E.G. MASON, P. MILNE & A.W.J. CULLEN DATE : FEBRUARY 1988

KEYWORDS : CULTIVATION, WEED CONTROL, FERTILISATION

SUMMARY

The results after four years of a factorial establishment trial at Balmoral Forest, involving cultivation, fertilisation, and weed control are described.

The overall average height after four years was 261 centimetres, and average diameter at breast height was 37 millimetres.

Cultivation made no detectable difference to growth during the year. There was a significant interaction between weed control and fertilisation. In terms of growth, fertilisation was more effective in combination with weed control than it was without weed control.

The plots treated with Velpar had a survival rate of only 86%, while those untreated had a survival rate of over 99%. Some cultivation treatments were more affected by the Velpar than others.

INTRODUCTION

As part of the experimental cultivation rig programme (see work plan FE32/327) a factorial experiment was established in Balmoral Forest in 1983. It forms part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

METHOD

A windrowed portion of Balmoral Forest was cultivated with four blocks of ten treatments. The treatment plots were 80 metres long, and contained 3 lines of cultivation. The distance between lines was 4 metres. Cultivation treatments were as follows:

1. Rip/6 discs/roll
2. Rip/4 discs/roll
3. Rip/2 discs/roll
4. Rip/flat roll
5. Rip/2 discs
6. Rip/4 discs
7. Rip/6 discs
8. Rip
9. Rip/machine plant
10. Control

Each line was planted with 1/0 stock from Rangiora Nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type employed by NZ Forest Products Ltd. The spacing within lines was 2 metres. Planting was carried out over two days. By the second day a dry northwest wind was blowing, and some of the trees may have suffered from drying. 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 rows so that after competition between adjacent trees began the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

The 80 metre plots were then divided into 4 subplots with random treatments of weed control (2 kgs of Velpar/hectare applied manually) and fertiliser (R. Fitzgerald, complete mix) in a factorial design. The main weed present was fireweed.

The survival, height, and basal diameter were reassessed after the first, second, and third years. After four years the height and diameter at breast height were recorded.

RESULTS

Average height after year four was 261 cm, and the average diameter at breast height was 37 mm.

Cultivation did not significantly affect growth.

There was a significant interaction between fertiliser and weed control. Trees given weed control and fertilizer grew 33 cm taller than Control trees, and trees given no weed control, but given fertilizer grew only 18 cm taller than Control trees. This effect is shown graphically in Figures 1 and 2.

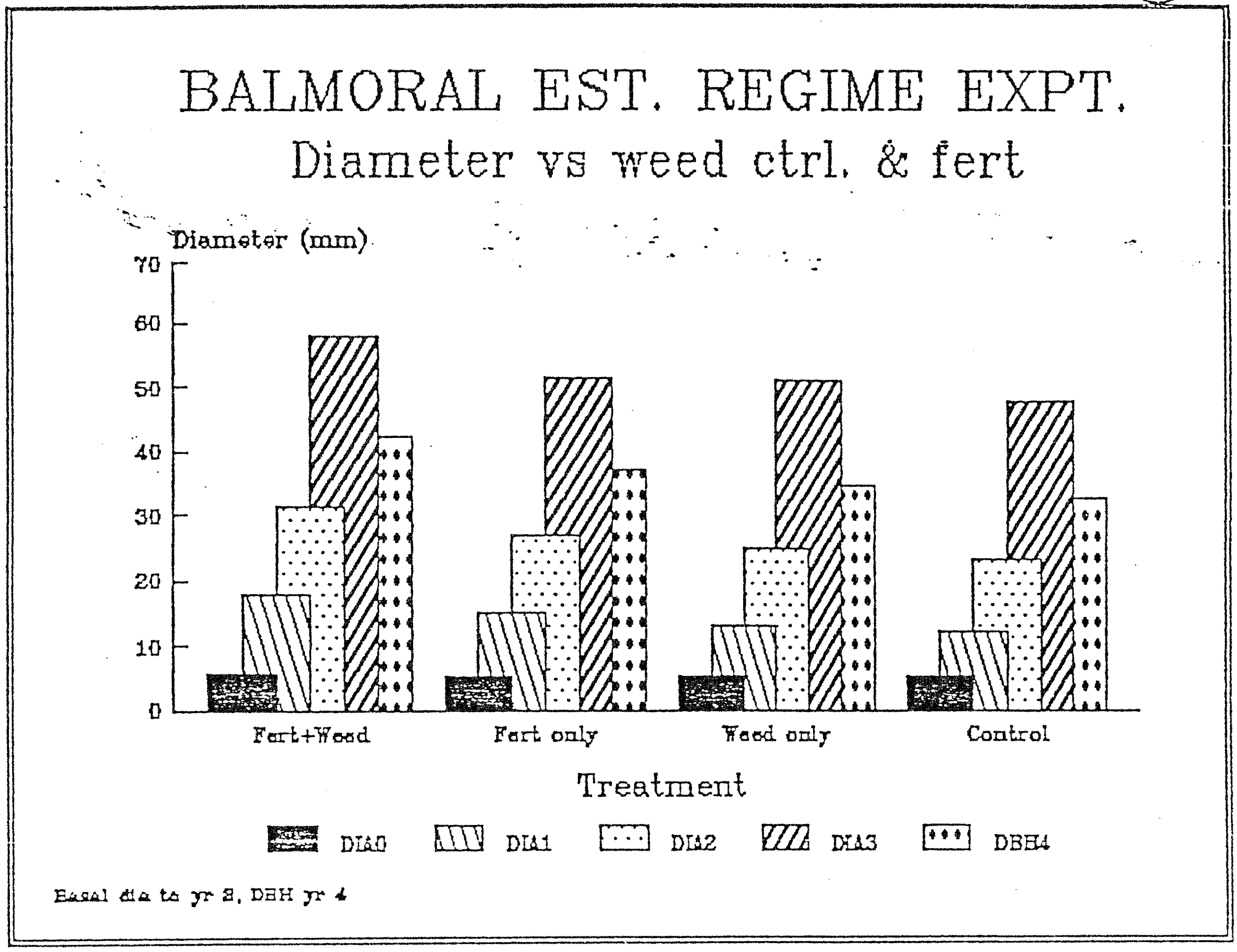
Survival in the plots treated with Velpar was only 86%, while the survival in the rest of the trial was above 99%. In addition, the Velpar-treated plots were significantly more variable than the untreated plots (height coeficient of variation 0.176 and 0.146 respectively). The interaction between weed control and cultivation was significant with respect to survival, but there was no consistent pattern with cultivation treatments.

DISCUSSION AND CONCLUSIONS

Cultivation did not improve height or diameter growth on this site up to age 4. Other experiments on this soil type have suggested that trees growing on ripped sites should develop a deeper root system than those on unripped sites, and this may eventually result in some improvement in above ground growth.

As usual, the effect of fertiliser was somewhat suppressed when it was not applied in conjunction with weed control. The effect of adding both fertiliser and weed control was to increase height by 44 cms (or 18%) and diameter by 10 mm (or 30%) at age four.

FIGURE 2



BALMORAL EST. REGIME EXPT.
Diameter vs weed ctrl. & fert
Diameter (mm)
70
60
50
40
30
20
10
0
Fert+Weed
Fert only
Weed only
Control
Treatment
DIA0
DIA1
DIA2
DIA3
DBH4
Basal dia to yr 3, DBH yr 4

FOREST RESEARCH INSTITUTE PROJECT RECORD NO.: 1845

DIVISION: FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD: PROPAGATION AND EARLY GROWTH

PROJECT NO.: FE 32 SUBPROJECT NO.: R.F. ID.: 437

WORK PLAN NO.: 556 FIELD EXPERIMENT(S): R1835

TITLE: EFFECTS OF SITE MODIFICATION ON THE GROWTH OF RADIATA PINE AT KAINGAROA FOREST - RESULTS AFTER YEAR 6

AUTHOR(S): E.G. MASON & A.W.J. CULLEN DATE: MARCH 1988

KEYWORDS: CULTIVATION, WEED CONTROL, FERTILISATION

ABSTRACT

An analysis of six years' growth in a factorial experiment is described. The experiment consisted of two factors: cultivation and fertilisation.

Cultivation significantly improved survival from 91.7% to 99.5%.

The overall average height was 696 cm, and average diameter at breast height 126 mm.

Cultivation caused no significant differences in above-ground growth during the six years, but there was more windthrow after thinning at age five in those treatments which did not include subsoil cultivation.

Fertilisation caused significant differences in growth initially, but the growth trajectories did not diverge after age 3, and by age six the improvement in growth due to fertilisation was negligible as a proportion of total growth.

Toppling was significantly less frequent during the first five years in those plots which had received fertiliser.

INTRODUCTION

As part of the experimental cultivation rig programme (see Work Plan FE32/437) a factorial experiment was established in Kaingaroa Forest in 1981. It formed part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

Cultivation has increased root growth on pumice sites elsewhere (Mason & Cullen 1986, Mason *et al.* (in prep)), but effects on above ground growth are variable. In some instances growth differences do not appear for several years after planting.

METHOD

A site in central Kaingaroa, Compartment 436, was chosen. The area had not supported a crop during the first rotation because although the area had been stocked with Ponderosa pine, the area chosen was a slight depression, and frost had killed the Ponderosa pine seedlings soon after planting.

The soil type was Kaingaroa gravelly sand.

Treatments tried in RO1835 were as follows:

1. Control (C)
2. Ripping (R)
3. Ripping / 4 inverted discs (Pulling the topsoil in over the rip) (R4)
4. Ripping / 6 inverted discs (R6)
5. Ripping / 4 inverted discs / hourglass roller (R4R)
6. Ripping / 6 inverted discs / hourglass roller (R6R)
7. 6 discs only (6D)
8. Hand cultivation (to a spade's depth, 30x30 cms) (HC)

Cultivation plots were 40 m long, and contained 3 lines. The distance between lines was 3 m.

Blocks were divided in half, and a half was randomly selected for fertilisation. 80 gm of diammonium phosphate was placed in a slit 10 cm from the base of each tree.

Each line was planted with 1/0 stock from Kaingaroa Nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type recommended by FRI. The spacing within lines was 2 m. 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 so that at older ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

The depth of the topsoil was measured on either side of each tree.

Broadcast weed control was applied to the entire experiment in each of the first two years.

The survival, height, and basal diameter were re-assessed after the second, third, and, excepting basal diameter, the fourth, fifth, and sixth years. Diameter at breast height was measured after year four. The stem condition of each tree was recorded at each re-measurement.

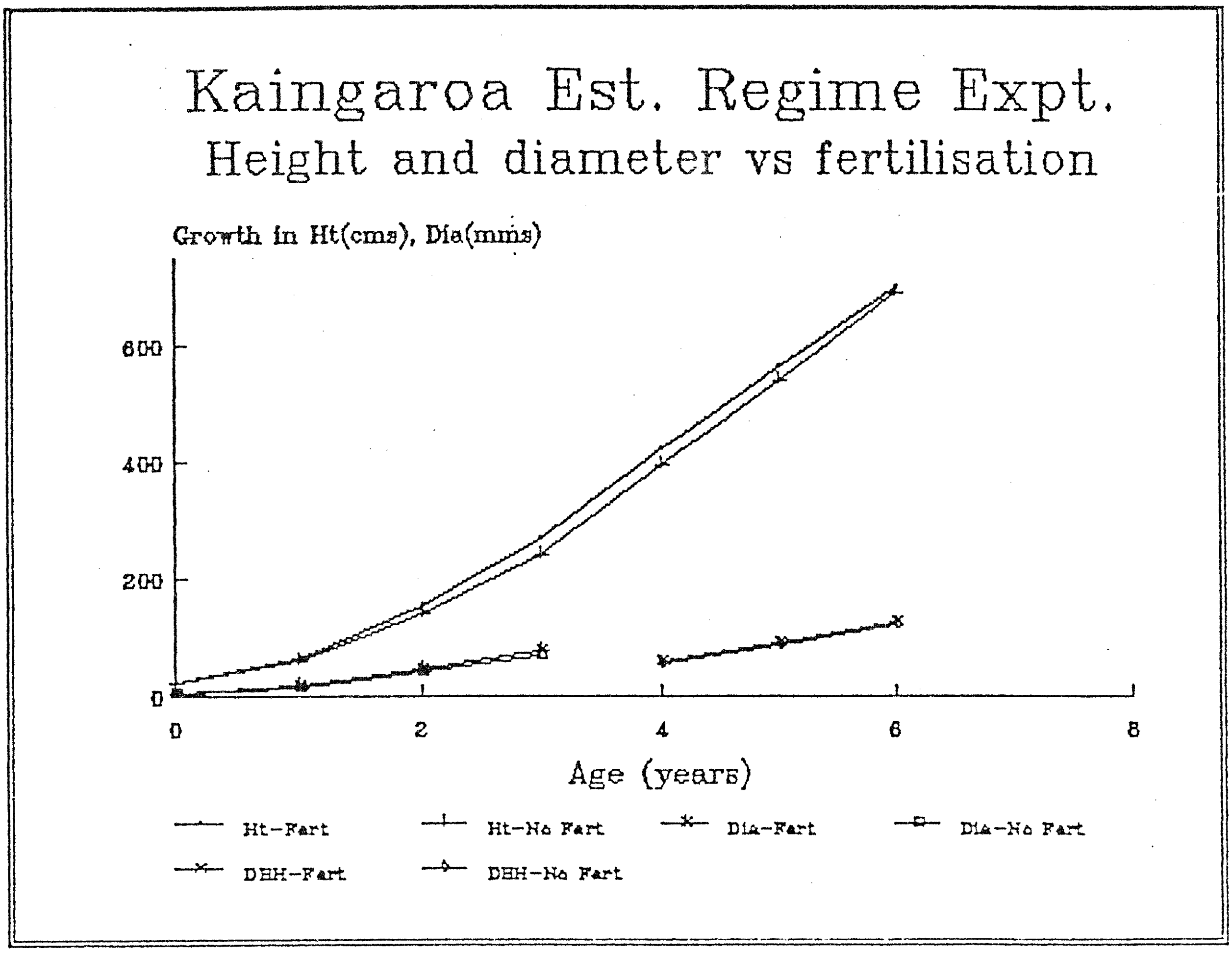
After year five, four crop trees in each plot, and three in each buffer line, were carefully selected and pruned. The remaining trees were thinned out.

RESULTS

A. Survival

Survival was significantly related to cultivation ($P<0.03$). Average survival in the cultivated plots was 99.5%, whilst that in the control plots was 91.7%.

FIGURE 1


Kaingaroa Est. Regime Expt.
Height and diameter vs fertilisation
Growth in Ht(cms), Dia(mms)
600
400
200
0
0
2
4
6
8
Age (years)
Ht-Fert
Ht-No Fert
Dia-Fert
Dia-No Fert
DBH-Fert
DBH-No Fert

B. **Growth**

Average height after year six was 696 cm, and the average diameter at breast height was 126 mm.

Fertilisation caused an increase in growth during the first three years, but not thereafter (Figure 1). It also brought about a slight but significant ($P<0.05$) decrease in variation within plots. The coefficient of variation in DBH at age 5 was reduced from 0.21 to 0.18.

Cultivation did not significantly affect above-ground growth.

Topsoil depth was not significant as a covariate. The average depth of topsoil (and depth to hardpan) was 16 cms.

C. **Toppling**

On average, 27% of the trees in the experiment toppled during the first five years. Fertilisation significantly affected toppling frequency, with 21% of the fertilised trees toppling, compared to 33% of unfertilised trees.

Cultivation did not significantly affect the amount of toppling.

D. **Windthrow**

After thinning and pruning at age 5, windthrow occurred in the experiment. In order to make an assessment from a larger sample of trees, buffer lines were included in the tally.

Windthrow was significantly more frequent in the 6 disc only and uncultivated treatments ($P<0.002$). The average windthrow in each cultivation treatment is shown in Figure 2.

Fertilisation also affected windthrow significantly ($P<0.02$). 4.6% of fertilised trees were windthrown compared with 1.7% of unfertilised trees.

E. **Crop quality**

The treatments caused no significant differences in the number of crop quality trees prior to thinning. 52% of the surviving trees were suitable for selection as crop trees. Figure 3 shows the percentage of crop trees, runts, and those with multiboles, multileaders (competing stems emerging below ground), basket whorls, and toppling related deformities.

DISCUSSION AND CONCLUSIONS

A. **Survival**

The improvement in survival due to cultivation is similar in magnitude to that detected by Mason & Cullen (1986) on the same soil type.

B. **Growth**

The initial improvement in growth due to fertilisation lends support to the view (I.R. Hunter pers. comm.) that on fertile sites fertiliser can help trees grow new roots rapidly so that the trees can access a large enough volume of soil to extract nutrients from.

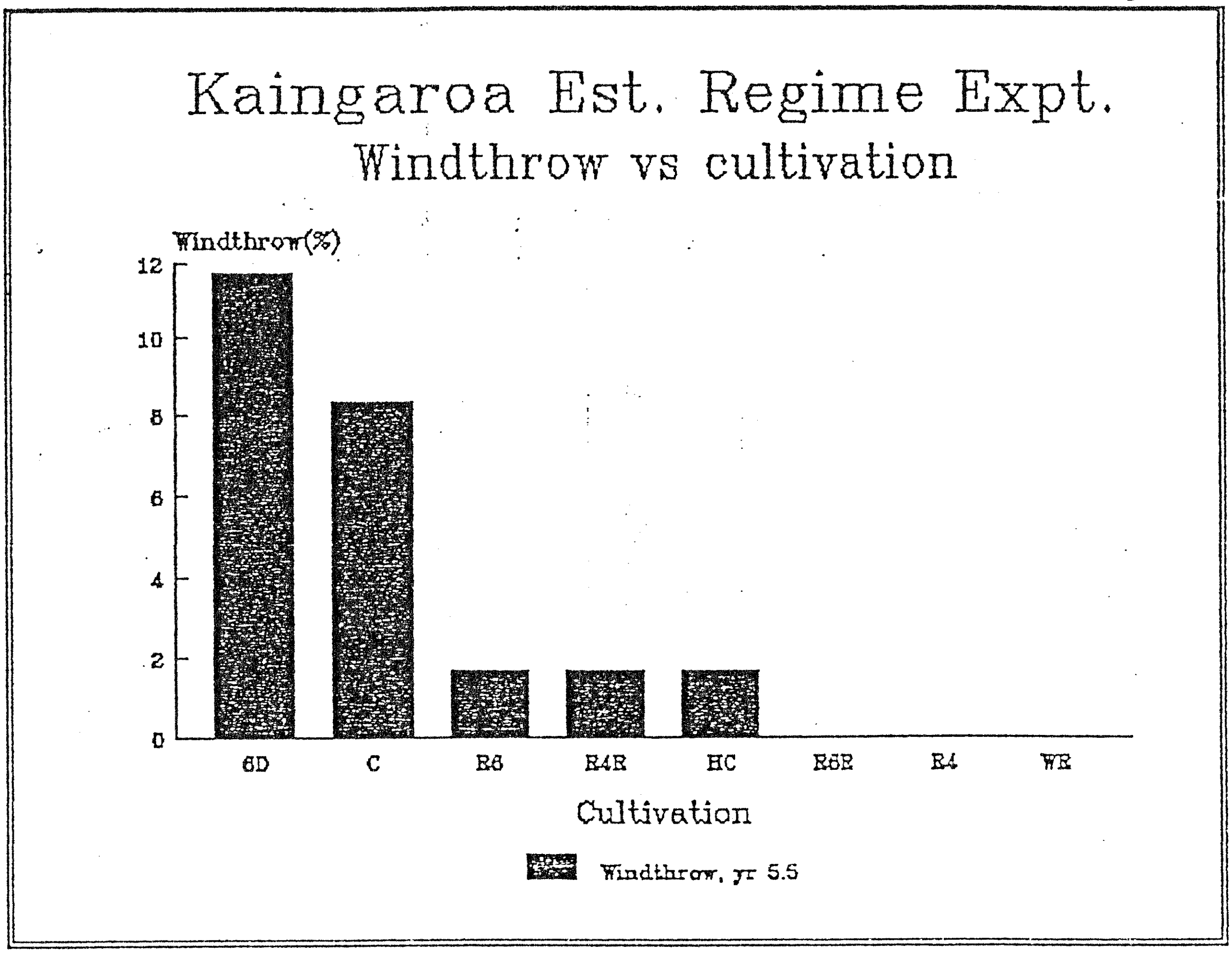
The experiment showed that the extra cost of fertilisation was not justified on this site.

C. **Toppling**

Toppling is recognised as a different phenomenon from windthrow (Mason 1986).

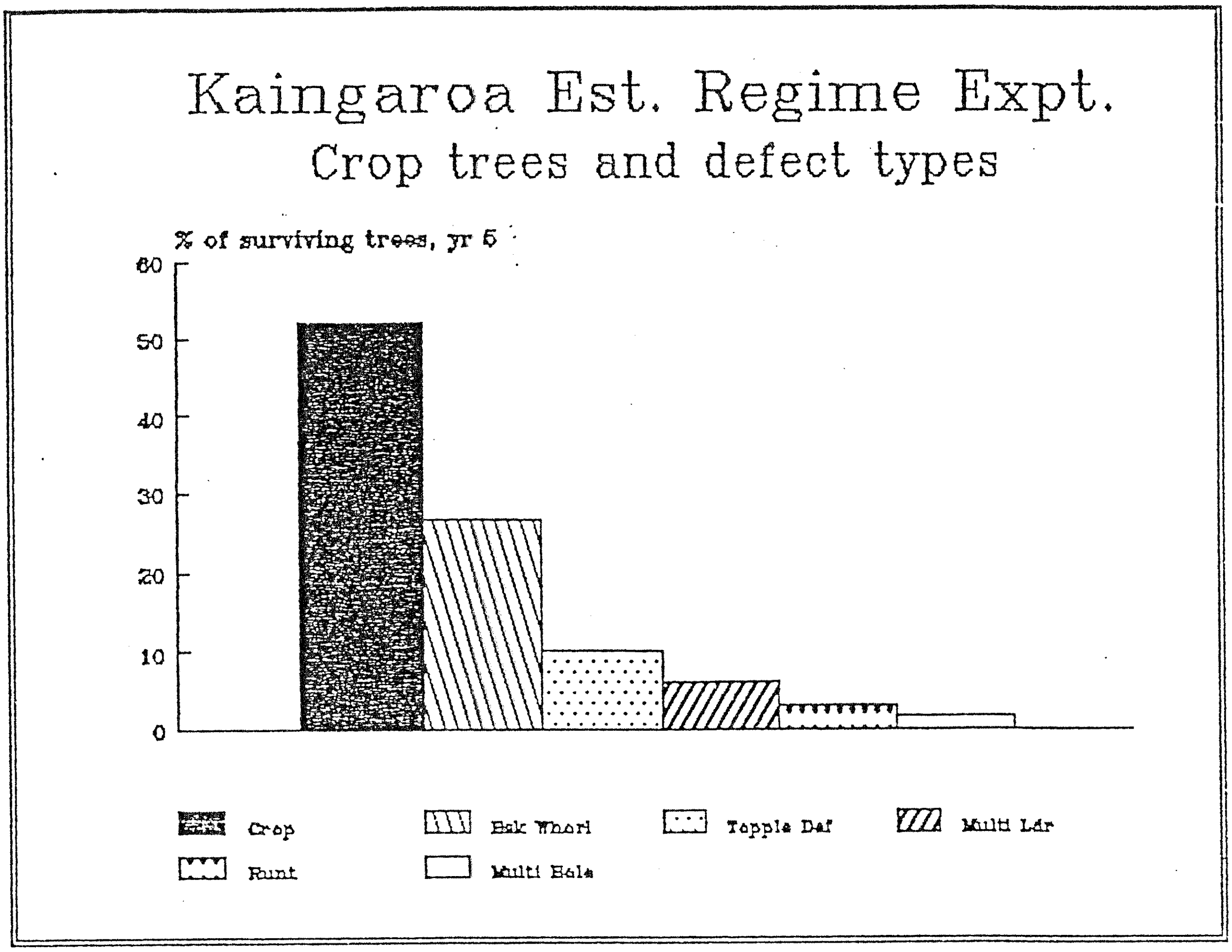
The effect of fertilisation on toppling propensity in this experiment was the reverse of the effect noted at Wainui in the same series of trials. Although small, the reasons for this difference are unknown.

FIGURE 2



1. Control (C)
2. Ripping (R)
3. Ripping / 4 inverted discs (Pulling the topsoil in over the rip) (R4)
4. Ripping / 6 inverted discs (R6)
5. Ripping / 4 inverted discs / hourglass roller (R4R)
6. Ripping / 6 inverted discs / hourglass roller (R6R)
7. 6 discs only (6D)
8. Hand cultivation (to a spade's depth, 30x30 cms) (HC)

FIGURE 3


Kaingaroa Est. Regime Expt.
Crop trees and defect types
% of surviving trees, yr 5
60
50
40
30
20
10
0
Crop
Bsk Whorl
Topple Def
Multi Ldr
Runt
Multi Bole

D. Windthrow

The 6 disc only treatment was included in the experiment in an attempt to simulate the effects of V-blading, a treatment which is now widely used at Kaingaroa. To the extent that both treatments create a loose mound of soil on top of uncultivated soil, the simulation is valid. It is of some real concern, then, that windthrow was so much more frequent in this and the control treatments than on treatments which included subsoil cultivation.

Windthrow is a random process, and one experiment may not accurately reflect the risk of windthrow due to V-blading compact soils in Kaingaroa. However, the experiment shows that windthrow risk after V-blading may be higher *relative* to the risk of windthrow after subsoil cultivaton on these sites. The absolute risk probably varies from location to location.

An assessment of windthrow risk should be conducted as soon as other V-bladed sites in Kaingaroa are old enough so that the true costs and benefits of V-blading Kaingaroa Gravelly Sand can be determined.

The increase in windthrow due to fertilisation may have been caused by the slightly larger trees in these plots. It is likely that frequency of windthrow was to some extent correlated with timing of thinning. Since they contained larger trees, the fertilised plots were effectively thinned slightly later than the unfertilised plots.

It would be advisable that , thinning is done on schedule where V-blading has been employed on compact soils (especially Kaingaroa Gravelly Sand).

E. Crop quality

Whilst 27% of the experiment toppled to at least 15 degrees from vertical during the first 5 years, only 10% of the surviving trees were rejected due to toppling-related defects. There were two reasons for this. Firstly, the defect due to any given degree of toppling varies with the size of the tree when the toppling occurs (Mason in prep.). Some of the toppling occurred when the trees were small and the effects on stem form were minor. Secondly, trees were rejected on the basis of the most significant defect. In some cases, trees rejected for other reasons exhibited toppling-related defects as well.

REFERENCES

Mason, E.G. 1985: Causes of Juvenile Instability of *Pinus radiata* in New Zealand, *NZ Journal of Forestry Science* 15(3) : 263-280.

Mason, E.G., & Cullen, A.W.J. 1986: Growth of *Pinus radiata* on ripped and unripped Taupo Pumice soil, *NZ Journal of Forestry Science* 16(1) : 3-18.

1850

FOREST RESEARCH INSTITUTE PROJECT RECORD NO.

DIVISION FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD PROPAGATION AND EARLY GROWTH

PROJECT NO. FE 32 SUBPROJECT NO. R.F. ID. 437

WORK PLAN NO. 556 FIELD EXPERIMENT(S) R1835/2

TITLE EFFECTS OF SITE MODIFICATION ON THE GROWTH OF RADIATA PINE AT OHAKURI FOREST - RESULTS AFTER YEAR 5

AUTHOR/S E.G. MASON & A.W.J. CULLEN DATE MARCH 1988

KEYWORDS CULTIVATION, WEED CONTROL

SUMMARY

The results after five years growth of a factorial establishment trial at Ohakuri Forest, involving cultivation and weed control are described.

Cultivation treatments which provided a large volume of loose earth significantly improved survival from 84.2% to 95.7%.

The overall average height was 590 cm, and average diameter at breast height was 93 mm.

Cultivation and weed control caused significant differences in above-ground growth during the five years, and the interaction between the two factors was significant. Weed control significantly improved growth even when compared to the interaction mean square, adding 1 m in height and 2 cm in diameter.

Toppling was significantly more frequent during the first five years in those plots which were V-bladed without ripping.

INTRODUCTION

As part of the experimental cultivation rig programme (see Work Plan FE32/437) a factorial experiment was established in Ohakuri Forest in 1981. It formed part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

Cultivation has increased root growth on pumice sites elsewhere (Mason & Cullen 1986; Mason *et al.* (in prep)), but effects on above-ground growth are variable. In some instances growth differences do not appear for several years after planting.

METHOD

An abandoned farm site above Lake Ohakuri was cleared of scattered pine trees. Following desiccation of the weeds, the area was burnt. The area was prone to bracken and cape broom infestation, and it was an ideal site on which to test the effectiveness of cultivation and weed control during forest establishment of a low-altitude pumice site.

Treatments tried in RO1835/2 were as follows:

1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
8. Ripping / 6 inverted discs / hourglass roller (R6R)
9. 6 discs only
10. Hand cultivation (to a spade's depth, 30x30 cms) (HC)
11. Ripping / flat roller (RR)
12. V-blading and planting in the bladed mounds (VB)
13. V-blading, double pass (on either side of the bladed mound) (VB2)
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

Cultivation plots were 40 m long, and contained 3 lines. The distance between lines was 3 m.

Each line was planted with 1/0 stock from Athol nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type recommended by FRI. The spacing within lines was 2 m. The initial height and diameter (5 cm above ground level) of each tree in the centre line of each plot were recorded. The two outer lines were employed as buffer lines so that at older ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

Blocks were divided in half, and a half was randomly selected for weed control. 8 kg of Velpar in 400 l of water were sprayed over each selected line. After years 2, 3 and 4, the weed control plots were slashed by hand.

The survival, height, and basal diameter were re-assessed after the first, second, third, and, excepting basal diameter, the fourth and fifth years. Diameter at breast height was measured after year four. The stem condition of each tree was recorded at each re-measurement.

RESULTS

A. Survival

Survival was significantly related to cultivation ($P<0.005$). Ripping/flat rolling, hand cultivation, and the control were the three worst treatments. They averaged 84.2% survival whilst the other treatments averaged 95.7%. Since this comparison was performed after the data were examined, Scheffe's test was employed, and the difference was statistically significant ($P<0.05$).

B. Growth

Average height after Year 5 was 590 cms, and the average diameter at breast height was 93 mm.

Cultivation increased both height and diameter growth (Figures 1 and 2). These differences were significant when compared to the cultivation x weed control mean square ($P<0.02$). General contrasts showed that ripping was significantly better than doing nothing, increasing height growth by 90 cm ($P<0.05$) and dbh growth by 19 mm ($P<0.04$). Using discs as well further improved height growth by 67 cm ($P<0.05$) and diameter growth by 12 mm ($P<0.03$).

Weed control was also significant compared to the interaction mean square, improving height growth by 103 cm ($P<0.001$) and dbh growth by 32 mm ($P<0.001$).

Growth in height and dbh were significantly affected by the interaction between cultivation and weed control (Figures 3 and 4). Weed control had the biggest impact in the control, hand cultivated, and rip/6 disc/rolled treatments. It was clear that in machine cultivated treatments without chemical weed control, there was a lower weed infestation than in those treatments with neither machine cultivation nor chemical weed control.

C. Toppling

Toppling was more frequent in plots where weed growth was controlled than in those without weed control ($P<0.0001$). 27% of the crop toppled in the presence of weed control, whilst 13% toppled where weed control was absent.

Cultivation technique had a major impact on the frequency of toppling during the first five years ($P<0.001$ see Figure 5). Toppling was most frequent (43% incidence) in the double v-bladed treatment. This was significantly different from all other treatments except the rip/6 discs treatment ($P<0.05$).

DISCUSSION AND CONCLUSIONS

A. Survival

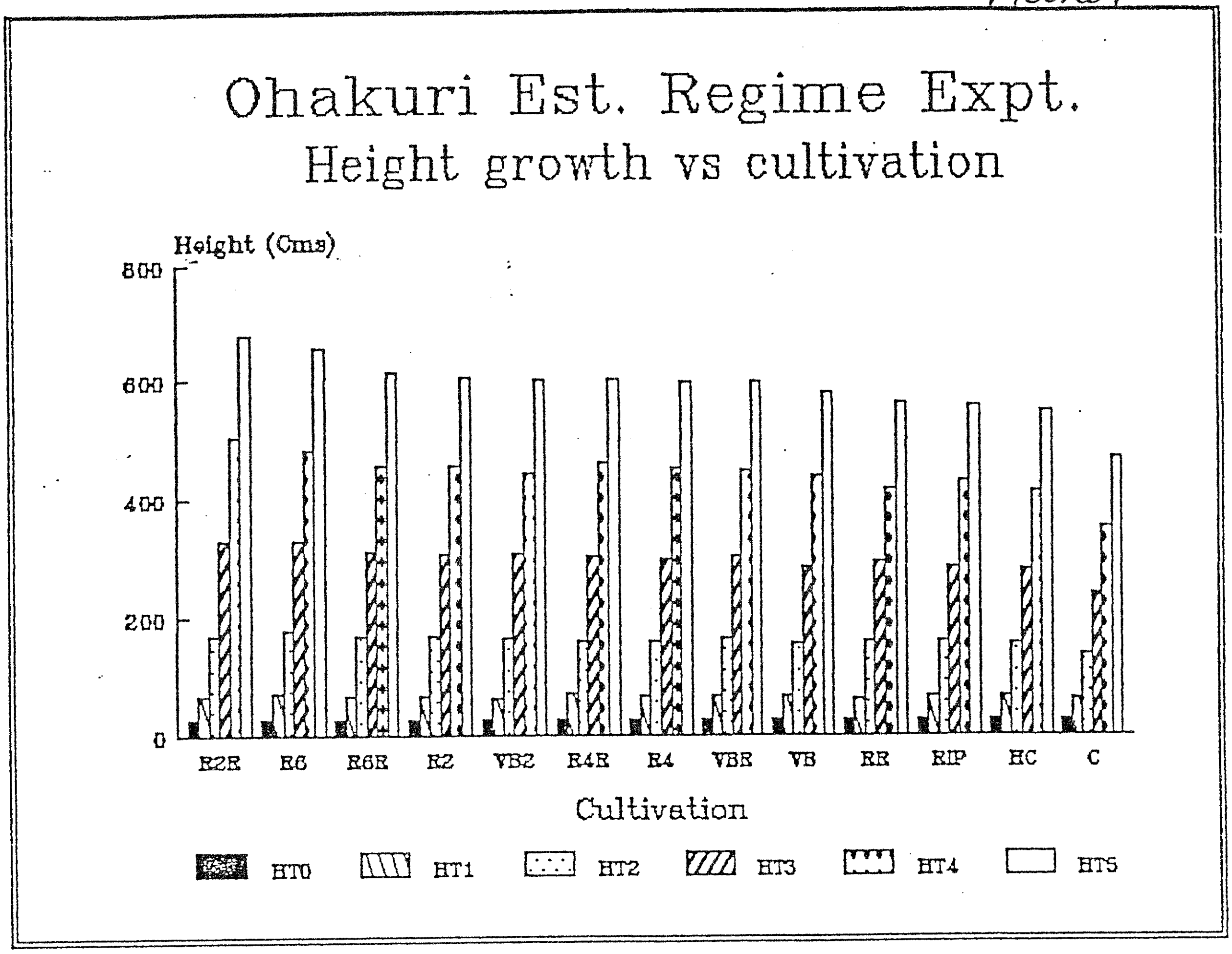
The improvement in survival due to cultivation is similar in magnitude to that detected by Mason & Cullen (1986, 1988a) at Kaingaroa, and it is clear that this improvement is a relatively consistent feature of cultivation in the central North Island.

B. Growth

The improvement in growth due to chemical weed control was entirely expected on this weed-prone site.

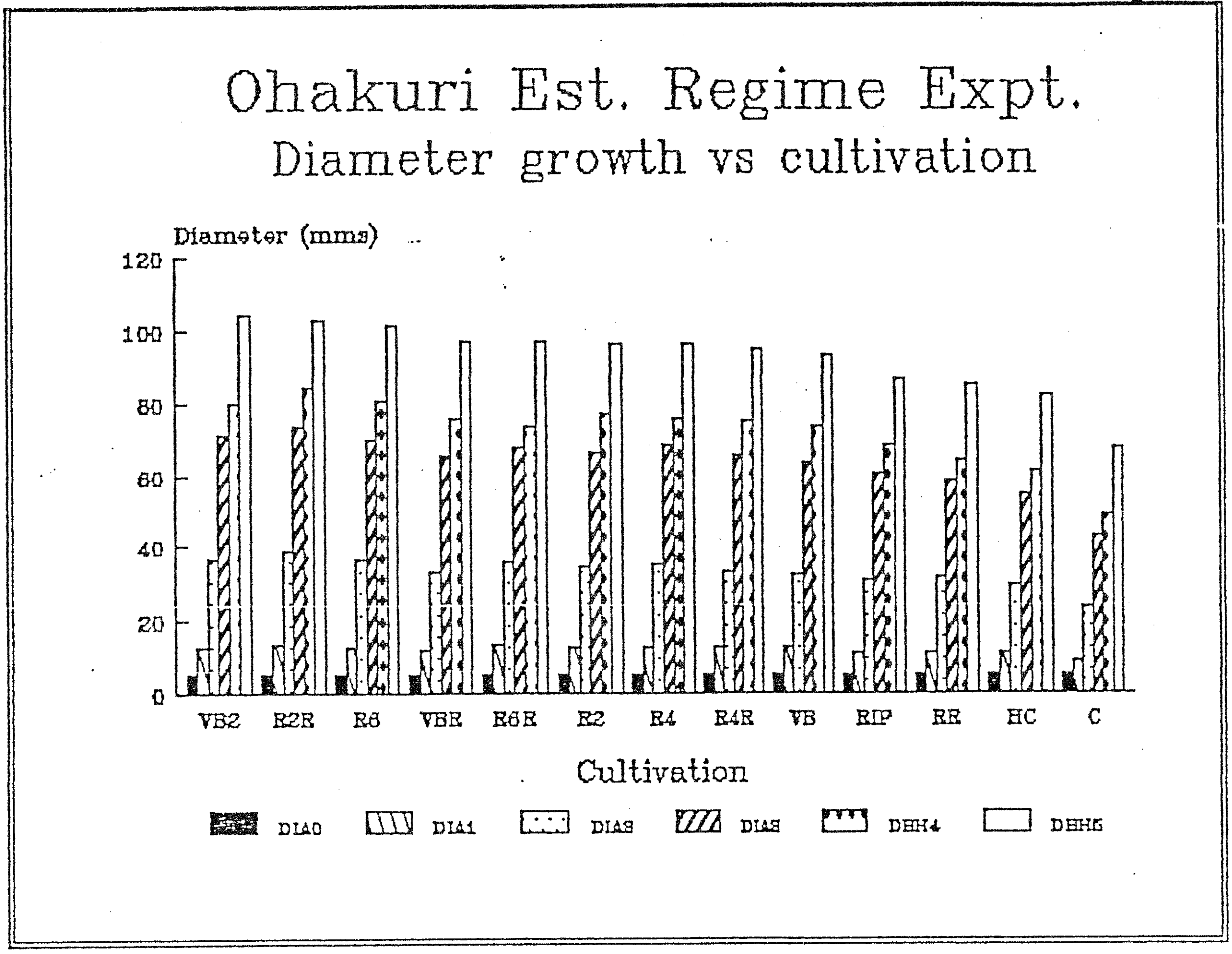
The improvement due to cultivation, however, was far larger than that detected in other central North Island pumice sites (Mason & Cullen 1986, 1988a, 1988b; Mason *et al.* in

FIGURE 1



1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
8. Ripping / 6 inverted discs / hourglass roller (R6R)
9. 6 discs only
10. Hand cultivation (to a spade's depth, 30x30 cms) (HC)
11. Ripping / flat roller (RR)
12. V-blading and planting in the bladed mounds (VB)
13. V-blading, double pass (on either side of the bladed mound) (VB2)
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

FIGURE 2



1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
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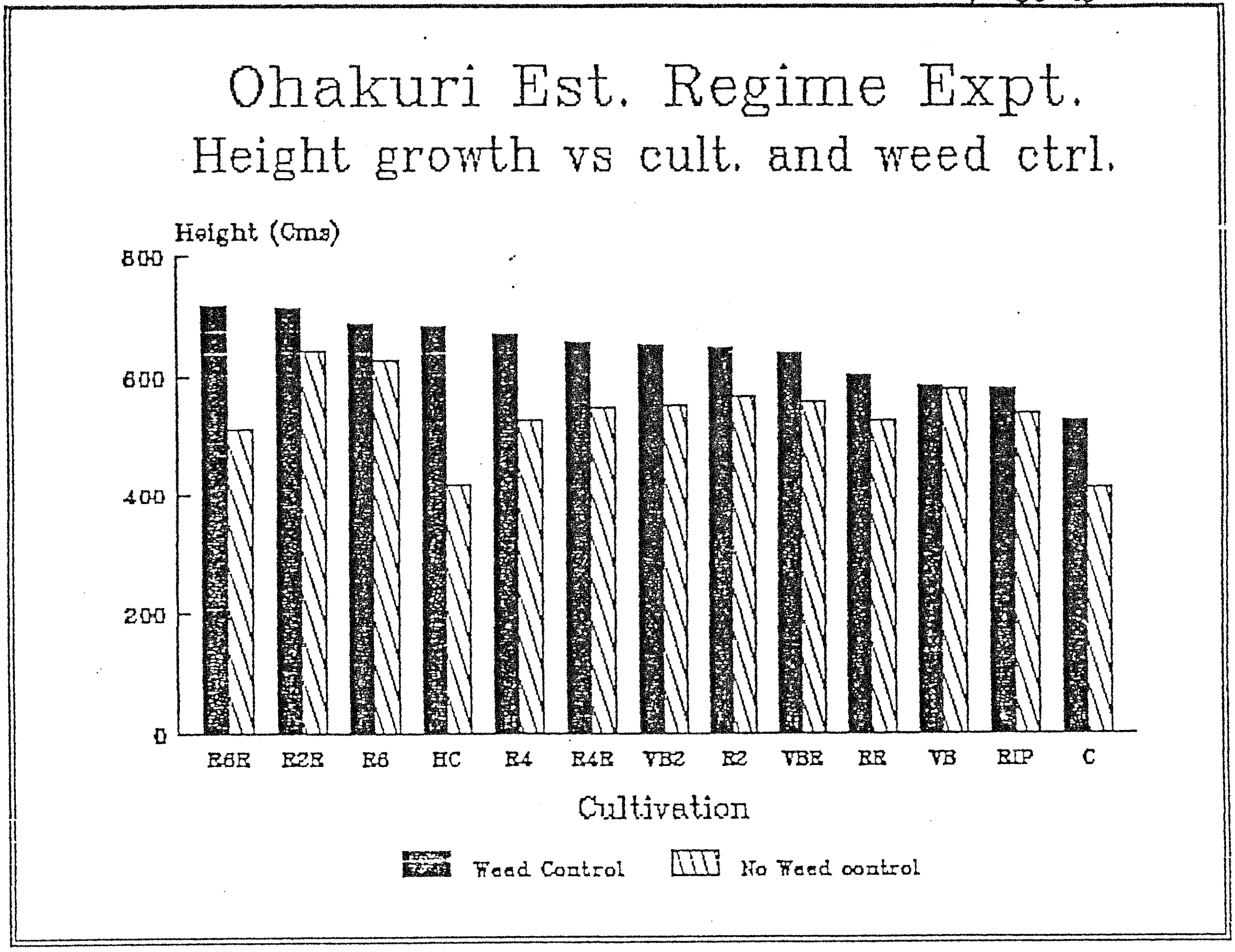
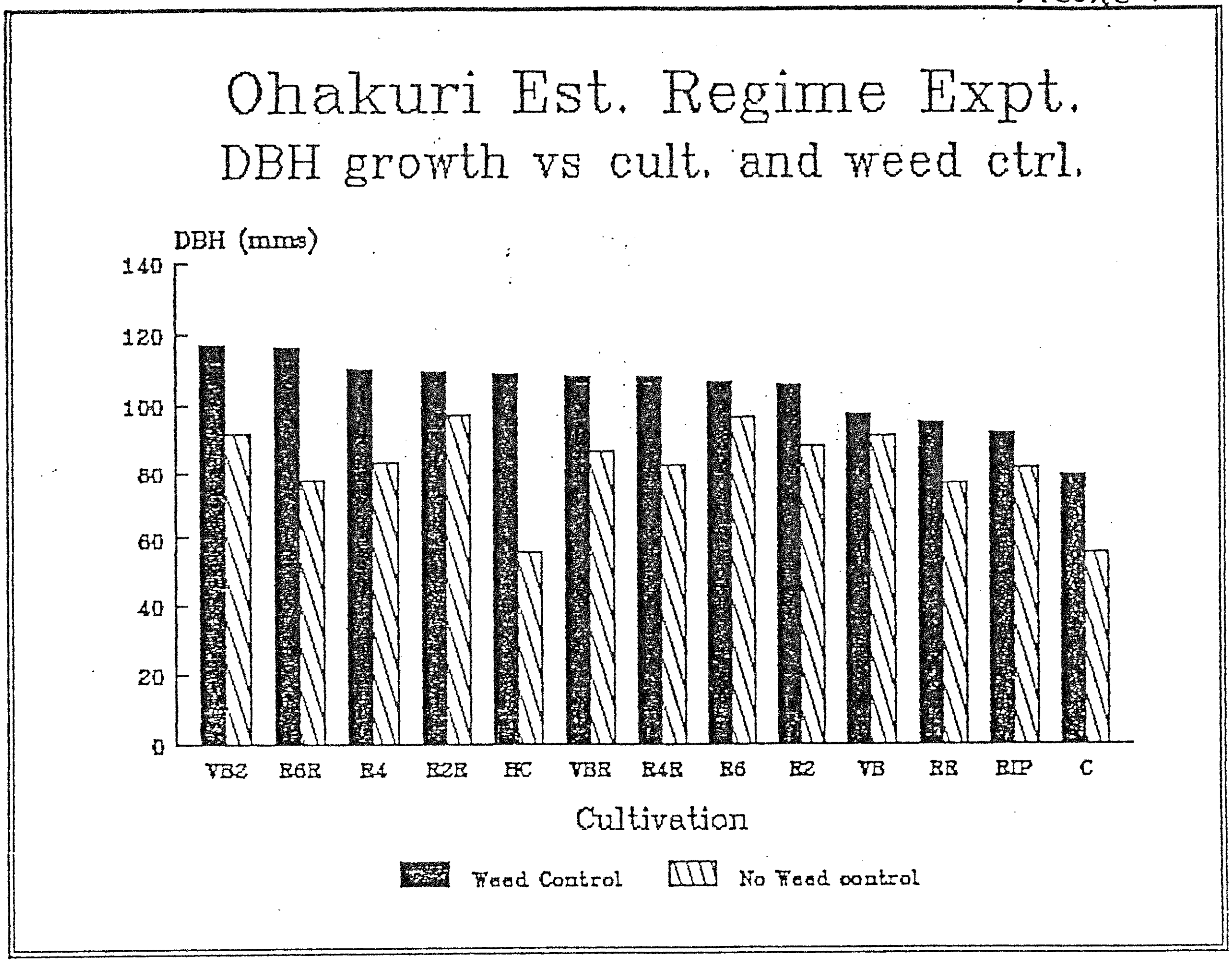
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

FIGURE 3



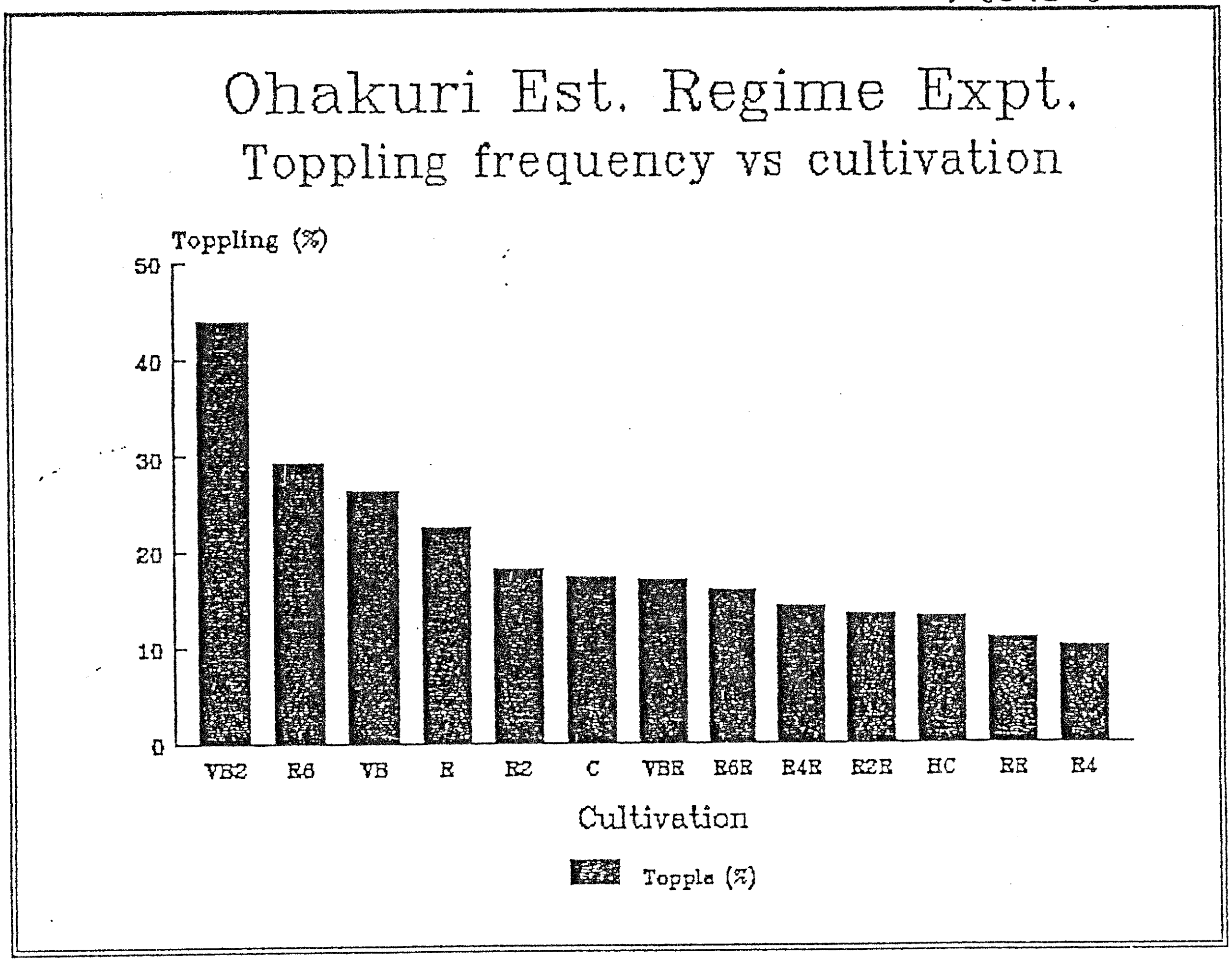
1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
8. Ripping / 6 inverted discs / hourglass roller (R6R)
9. 6 discs only
10. Hand cultivation (to a spade's depth, 30x30 cms) (HC)
11. Ripping / flat roller (RR)
12. V-blading and planting in the bladed mounds (VB)
13. V-blading, double pass (on either side of the bladed mound) (VB2)
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

FIGURE 4



1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
8. Ripping / 6 inverted discs / hourglass roller (R6R)
9. 6 discs only
10. Hand cultivation (to a spade's depth, 30x30 cms) (HC)
11. Ripping / flat roller (RR)
12. V-blading and planting in the bladed mounds (VB)
13. V-blading, double pass (on either side of the bladed mound) (VB2)
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

FIGURE 5



1. Control (C)
2. Ripping (R)
3. Ripping / 2 inverted discs (Pulling the topsoil in over the rip) (R2)
4. Ripping / 4 inverted discs (R4)
5. Ripping / 6 inverted discs (R6)
6. Ripping / 2 inverted discs / hourglass roller (R2R)
7. Ripping / 4 inverted discs / hourglass roller (R4R)
8. Ripping / 6 inverted discs / hourglass roller (R6R)
9. 6 discs only
10. Hand cultivation (to a spade's depth, 30x30 cms) (HC)
11. Ripping / flat roller (RR)
12. V-blading and planting in the bladed mounds (VB)
13. V-blading, double pass (on either side of the bladed mound) (VB2)
14. V-blading followed by ripping down either side of the bladed lanes (VBR)

prep.). The soil at Ohakuri was relatively easily penetrated by roots, and the topsoil was dark and deep (except for Block 1 which had a hardpan at a depth of 30 cm). Some hint of why cultivation improved growth was provided by the interaction between cultivation and chemical weed control. Weed control was more effective in the control and hand cultivated plots than in almost all the other cultivation plots. This suggests that part of the improvement in growth after cultivation was due to weed control.

Cultivation improved growth in the presence of weed control, however. This could be due in part to the fact that weed control was not total, but it none-the-less highlights the need for more study of why cultivation is more effective at promoting growth on some soils than on others.

The improvement in growth after discing may have resulted from both more effective weed control, and from a greater improvement in the structure of the topsoil after this treatment. The fact that hand cultivation was effective only in the presence of weed control suggests that there was room for soil structure improvement.

C. Toppling

Toppling was more frequent in those treatments which incorporated weed control. There were two possible reasons for this. Firstly, trees were larger in the weed control plots. Generally the larger trees in a stand topple more frequently than the smaller ones (Mason 1985). Secondly, trees competing with bracken would have had smaller crowns and been less exposed than those in plots where the weeds were controlled.

The effect of cultivation may be related to the height of the mounds on which the trees were growing. The double V-blading treatment produced a significantly higher mound than any of the other treatments, and the rip/6 discs treatment produced a higher mound than all the other discing treatments. At Kaingaroa (Mason & Cullen 1988a), trees on loose mounds with no ripping were less wind-firm than those on other treatments. This may also partly explain the frequency of toppling on the unripped, V-bladed treatments at Ohakuri.

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Mason, E.G., & Cullen, A.W.J. 1988a. Effects of site modification on the growth of radiata pine at Kaingaroa Forest - results after year 6. *MOF, FRI Project Record*

Mason, E.G., & Cullen, A.W.J. 1988b. Effects of site modification on the growth of radiata pine at Wainui Forest - results after year 6. *MOF, FRI Project Record*

Mason, E.G., A.W.J. Cullen, & W.C. Rijkse, (in prep), Growth of two stock types on uncultivated, ripped, and ripped and bedded soil at Karioi Forest

FOREST RESEARCH INSTITUTE | PROJECT RECORD NO.: 1844

DIVISION: FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD: PROPAGATION AND EARLY GROWTH

PROJECT NO.: FE 32 | SUBPROJECT NO.: | R.F. ID.: 437

WORK PLAN NO.: 556 | FIELD EXPERIMENT(S): R 1846

TITLE: EFFECTS OF SITE MODIFICATION ON THE GROWTH OF RADIATA PINE AT WAINUI FOREST - RESULTS AFTER YEAR 6

AUTHOR(S): E.G. MASON & A.W.J. CULLEN DATE: MARCH 1988

KEYWORDS: CULTIVATION, WEED CONTROL, FERTILISATION

ABSTRACT*

An analysis of six years' growth in a factorial experiment is described. The experiment consisted of three factors: cultivation, fertilisation, and weed control.

The overall average height was 464 cm, and average diameter at breast height was 83 mm.

The effect of cultivation was significant in the Analyses of Variance, but treatment differences were affected by the serious frost damage over parts of the experiment. Those treatments which by chance occupied benign microsites performed far better than those which occupied microsites subject to frost. There were no consistent differences between groups of cultivation treatments.

Weed control was the most important factor in the experiment. It brought about major improvements in both survival and growth, and there is little doubt that on such sites weed control is essential.

The effect of fertilisation on tree growth was not detected by the experiment. Fertiliser clearly improved grass growth, and, if anything, the effect of fertiliser was to enhance the damaging effect of frost, although this could not be shown in the variable conditions of the experiment.

Toppling was significantly more frequent in those plots which had received fertiliser or weed control treatments.

Note: This material is unpublished and must not be cited as a literature reference

INTRODUCTION

As part of the experimental cultivation rig programme (see work plan FE32/437) a factorial experiment was established in Wainui Forest in 1981. It formed part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

Cultivation has increased root growth on pumice sites elsewhere (Mason & Cullen 1986; Mason *et al.* (in prep)), but effects on above ground growth are variable. In some instances growth differences do not appear for several years after planting.

On high-altitude sites in the central North Island, frost can have a major impact on establishment. It was therefore important to assess the impact of weed control and its interactions with other site modification techniques.

METHOD

Treatments tried in RO1846 were as follows:

1. Control
2. Ripping
3. Ripping / flat roller
4. Ripping / 4 inverted discs (pulling the topsoil in over the rip)
5. Ripping / 6 inverted discs
6. Ripping / 4 inverted discs / hourglass roller
7. Ripping / 6 inverted discs / hourglass roller
8. 6 discs only
9. Hand cultivation (to a spade's depth, 30 x 30 cms)

Cultivation plots were 40 metres long, and contained 3 lines. The distance between lines was 3 metres.

Blocks were divided in half, and a half was randomly selected for weed control treatment. The herbicide used was Velpar, broadcast at a rate of 5 kg per hectare. Weed control was renewed at age 2.5 as a spot 1 metre square around each tree. The site had been a farm, and grasses were the principal weeds.

Fertilisation was incorporated within the above treatments, to form a three way factorial, split-plot design within four blocks. 80 gms of diammonium phosphate was placed in a slit 10 cm from the base of each tree.

Each line was planted with 1/0 stock from Pakipaki Nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type recommended by FRI. The 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 so that at older ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

It was clear that the site was likely to be variable, with shallow gullies running across the experiment. These gullies were plotted on a map of the experiment, and each tree was classified according to whether it was in the base of the gully, on the sideslope, or out of a gully.

The survival, height, and basal diameter were re-assessed annually for six years, except diameter at breast height was measured in year six rather than basal diameter. Tree topple was recorded at each re-measurement.

RESULTS

A. Survival

Survival was significantly related to weed control and microsite, and the interaction between the two factors was significant (P<0.05). The effects are shown graphically in Figure 1.

B. Growth

Average height after year six was 464 cm, and the average diameter at breast height was 83 mm.

Weed control was the most significant factor in the experiment, improving tree growth by 69 cm in height, and 15 mm in dbh (P<0.001).

Although cultivation was significant in the Analysis of Variance, similar treatments had quite different effects on growth, and there was doubt that the differences reflected real effects of cultivation. Figure 2 shows the mean height of each cultivation plot plotted against the number of the plot within each block, going west (1) to east (9). It is very likely that there was a site gradient from west to east in the experiment. Unfortunately the blocks ran north to south. In some cases plots of cultivation treatments tended to be mostly easterly or mostly westerly. Those which were mostly westerly had significantly larger means than those which were mostly easterly.

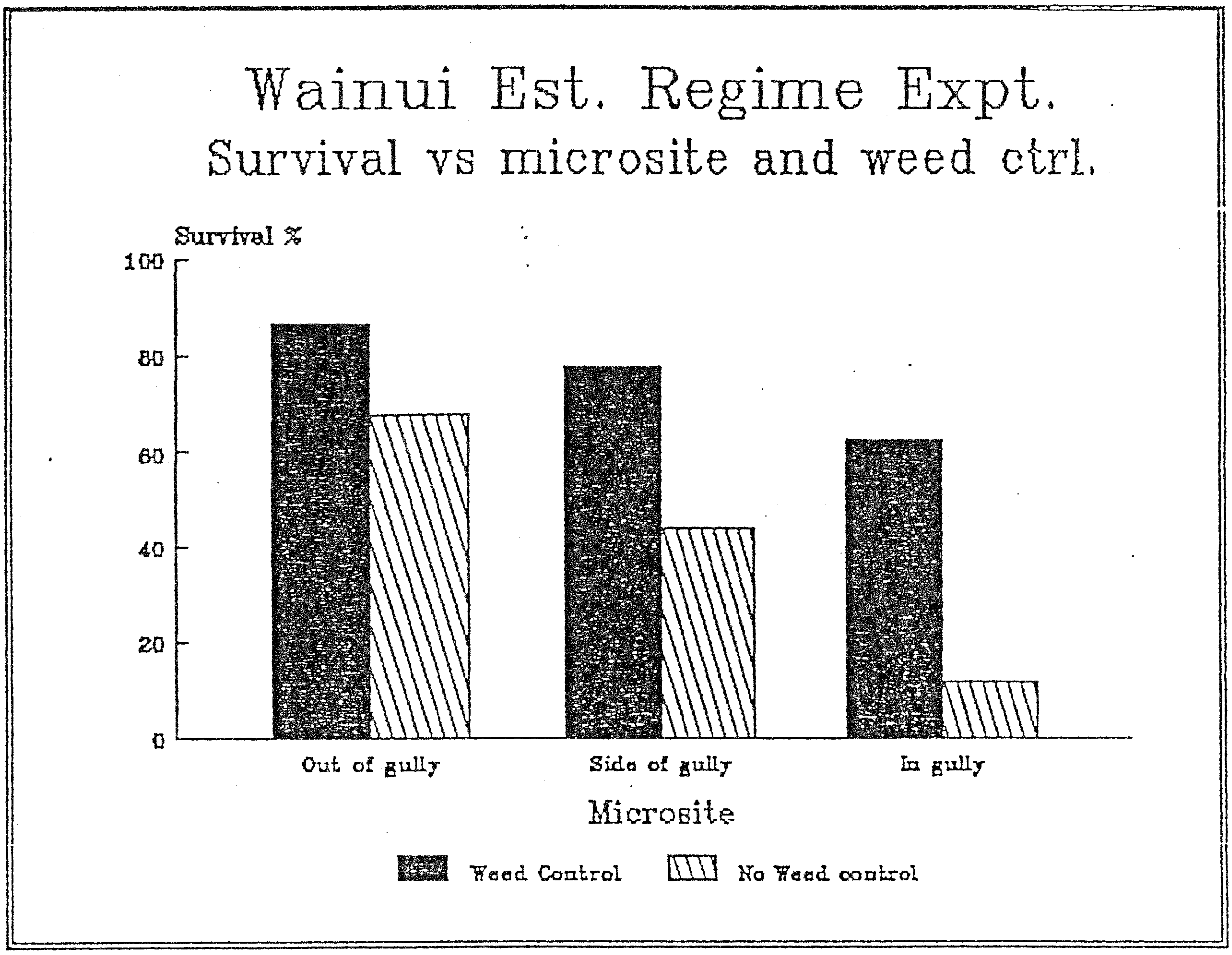
An analysis of covariance, using east-west position as a covariate, was conducted. The cultivation effect was not quite significant (P<0.06), whilst the position covariate was highly significant (P<0.0001).

C. Toppling

On average, 55% of the surviving trees in the experiment had toppled to at least 15 degrees from vertical by age 6. Most of the toppling occurred between ages 3 and 6.

The amount of toppling was significantly related to block, fertilisation, and weed control (P<0.003). There was more toppling in Block 5 than in the other blocks, perhaps reflecting differences in planting quality. The effects of weed control and fertilisation on toppling are shown in Figure 3. Interactions between the two were not significant.

FIGURE 1


Wainui Est. Regime Expt.
Survival vs microsite and weed ctrl.
Survival %
100
80
60
40
20
0
Out of gully
Side of gully
In gully
Microsite
Weed Control
No Weed control

DISCUSSION AND CONCLUSIONS

A. Survival

It is clear that weed control was absolutely essential on this site. It may also have been a good idea for managers to avoid planting in the small gullies. Such a practice would have raised survival from 51 to 87 percent. The gullies were rarely more than 4 metres across, and the area would have been adequately stocked if they were left unplanted.

B. Growth

Weed control increased growth markedly. There is little doubt that it would be a cost-effective operation on such frost-prone, weed-infested sites.

It is unfortunate that the site quality gradient did not coincide with the blocking of the experiment. None-the-less, no major impacts of cultivation were detectable, even when microsite was included as a covariate. This finding was similar to those from other experiments in the central North Island pumice region, where cultivation did not consistently result in above-ground improvement in growth.

The fertilisation and weed control treatments were much less confounded with the site gradient, since they were replicated within each cultivation line.

C. Toppling

Weed control produced faster growing trees which toppled more frequently than those which did not have the benefit of weed control. This increase in toppling could have been due to rapid initial growth, but it could equally have been due to the increased exposure and larger crowns of the trees in the weed control plots.

It is unknown why fertiliser increased toppling without increasing growth. It is possible that fertilisation produced a smaller root:shoot ratio. Nambiar (1980) concluded that more fertile sites produced trees with smaller root:shoot ratios. However, an increase in above ground growth could be expected on a more fertile site, and this was not found after fertilisation at Wainui. Also, Mason (1985) found no significant correlation between root:shoot ratio and toppling propensity.

The high incidence of toppling stresses the need for more research to reduce this problem.

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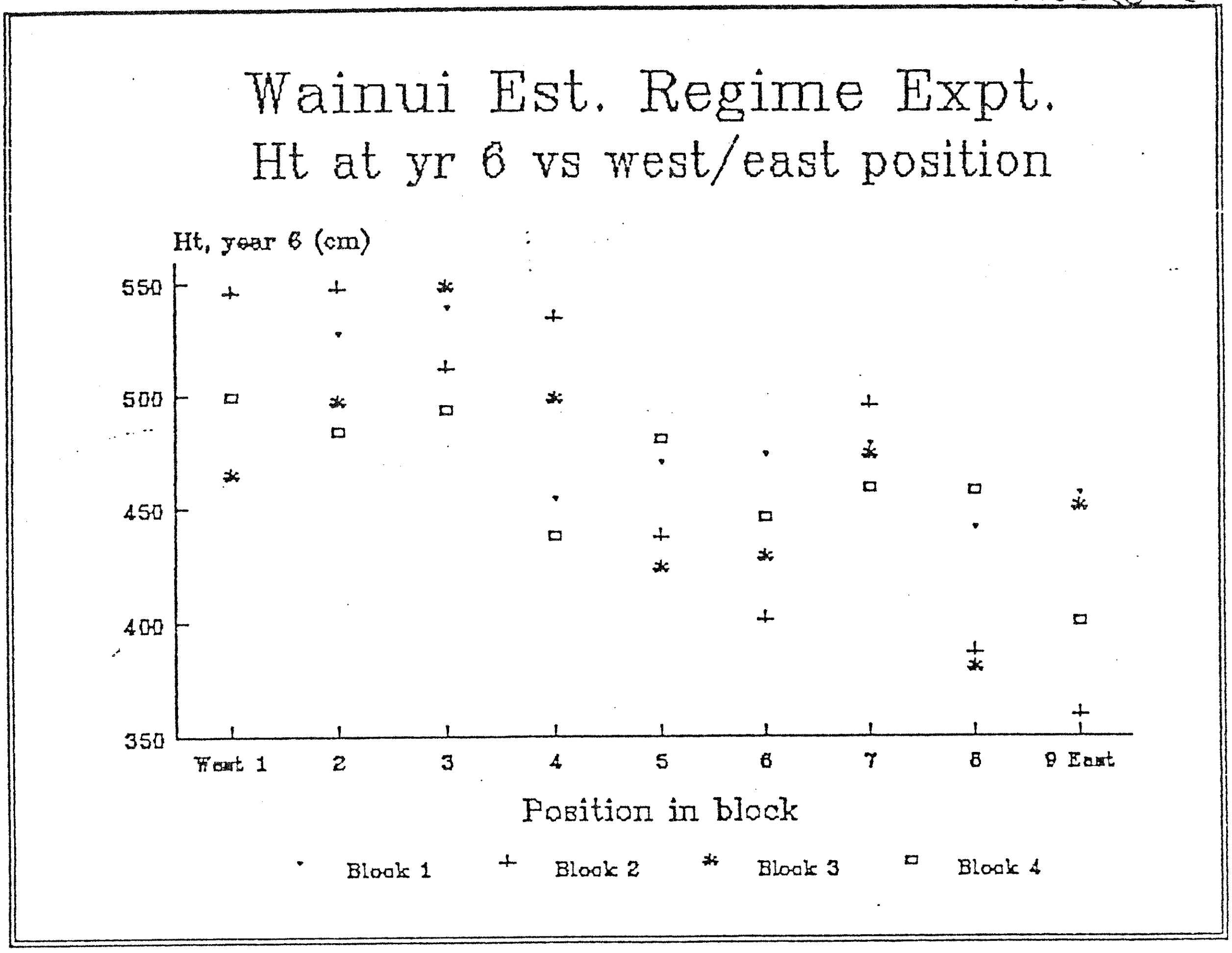
Mason, E.G. & Cullen, A.W.J. 1986. Growth of *Pinus radiata* on ripped and unripped Taupo Pumice soil. *NZ Journal of Forestry Science 16(1)*: 3-18.

Mason, E.G.; Cullen, A.W.J. & Rijkse, W.J. (in prep). Growth of *Pinus radiata* on compact, high-allophane, pumice soil after three different cultivation treatments.

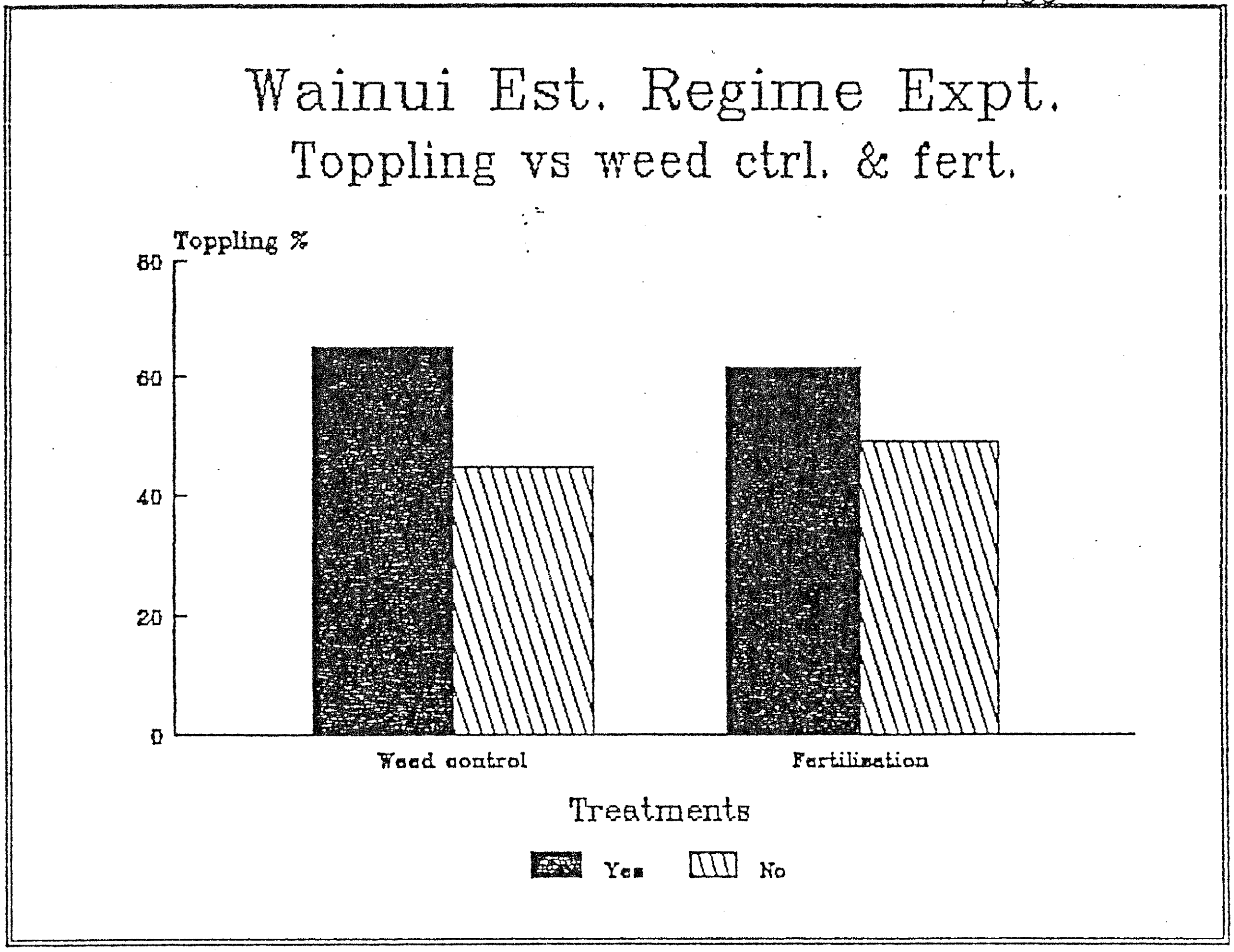
Nambiar, E.K.S. 1980. Root configuration and root regeneration in *Pinus radiata* seedlings. *NZ Journal of Forestry Science 10 (1)*: 249-263.

FIGURE 2



Wainui Est. Regime Expt.
Ht at yr 6 vs west/east position
Ht, year 6 (cm)
550
500
450
400
350
West 1
2
3
4
5
6
7
8
9 East
Position in block
Block 1
Block 2
Block 3
Block 4

FIGURE 3


Wainui Est. Regime Expt.
Toppling vs weed ctrl. & fert.
Toppling %
80
60
40
20
0
Weed control
Fertilization
Treatments
Yes
No

FOREST RESEARCH INSTITUTE PROJECT RECORD NO. 1849

DIVISION FOREST HEALTH AND IMPROVEMENT

RESEARCH FIELD PROPAGATION AND EARLY GROWTH

PROJECT NO. FE 32 SUBPROJECT NO. R.F. ID. 437

WORK PLAN NO. 556 FIELD EXPERIMENT(S) A912/3

TITLE EFFECTS OF SITE MODIFICATION ON THE GROWTH OF RADIATA PINE AT CAPE KARIKARI - RESULTS AFTER YEAR 4

AUTHOR/S E.G. MASON & A.W.J. CULLEN DATE MARCH 1988

KEYWORDS CULTIVATION, WEED CONTROL

SUMMARY

The results after four years growth of a factorial establishment trial at Cape Karikari, involving cultivation and fertilisation are described.

Fertilisation with rock phosphate after planting and with a mixture of Triple Superphosphate and Diammonium Phosphate after planting improved growth to age four by 3.4 metres in height and 46 millimetres in diameter. Fertilisation also improved survival from 61% to 96%.

The cultivation x fertilisation interaction was significant, as cultivation had little effect in the absence of fertiliser. In the presence of fertiliser, cultivation improved growth by 1.65 metres in height, and by 32 millimetres in diameter.

Toppling was significantly more frequent during the first four years in cultivated plots, and in fertilised plots. These effects would have been generated in part by differences in tree size and soil strength.

INTRODUCTION

As part of the experimental cultivation rig programme (see Work Plan FE32/437) a factorial experiment was established at Cape Karikari in 1983. It formed part of a nationwide series designed to quantify the effects of site modification at establishment on crop performance.

METHOD

The soil on the trial site was Pukenamu clay. It was poorly drained, and changed colour midway across the trial site. The experiment was blocked so that the soil type was as uniform as possible within each of the four blocks.

Cultivation treatments tried in A912/3 were as follows:

1. Control (C)
2. Ripping (R)
3. Ripping / 6 inverted discs (Pulling the topsoil in over the rip) (R6)
4. Ripping with three tines / 6 inverted discs (3R6D)
5. Ripping / 6 inverted discs / hourglass roller (R6R)

Cultivation plots were 40 m long, and contained 4 lines. The distance between lines was 3 m.

Each line was planted with 1/0 stock from Sweetwater Nursery. The seedlings were lifted and trimmed in bundles of ten and transported in cardboard boxes of the type recommended by FRI. The spacing within lines was 2 m. The initial height and diameter (5 cm above ground level) of each tree in the two centre lines of each plot was recorded. The two outer lines were employed as buffer lines so that at older ages the centre line would more accurately represent the growth of an entire stand with the same treatment as the plot.

Cultivated plots were divided in half, and a half of each was randomly selected for fertilisation. 100 kg/hectare of rock phosphate was spread by hand immediately after planting, and 50 gm each of triple superphosphate and diammonium phosphate was applied around each tree after Year 1.

The survival, height, and basal diameter were re-assessed after the first, second, third, and, excepting basal diameter, the fourth years. Diameter at breast height was measured after Year 4. The stem condition of each tree was recorded at each re-measurement.

RESULTS

A. Survival

Survival was significantly related to fertilisation ($P<0.0001$), but not to cultivation. Of the trees planted within fertilised plots 96% survived, whilst only 61% of those in the unfertilised plots survived.

B. Growth

Fertilisation significantly improved both height growth ($P<0.0001$) and diameter growth ($P<0.0001$) after Year 4 (Figures 1 & 2). This effect was very highly significant when compared to the fertilisation x cultivation interaction.

FIGURE 1

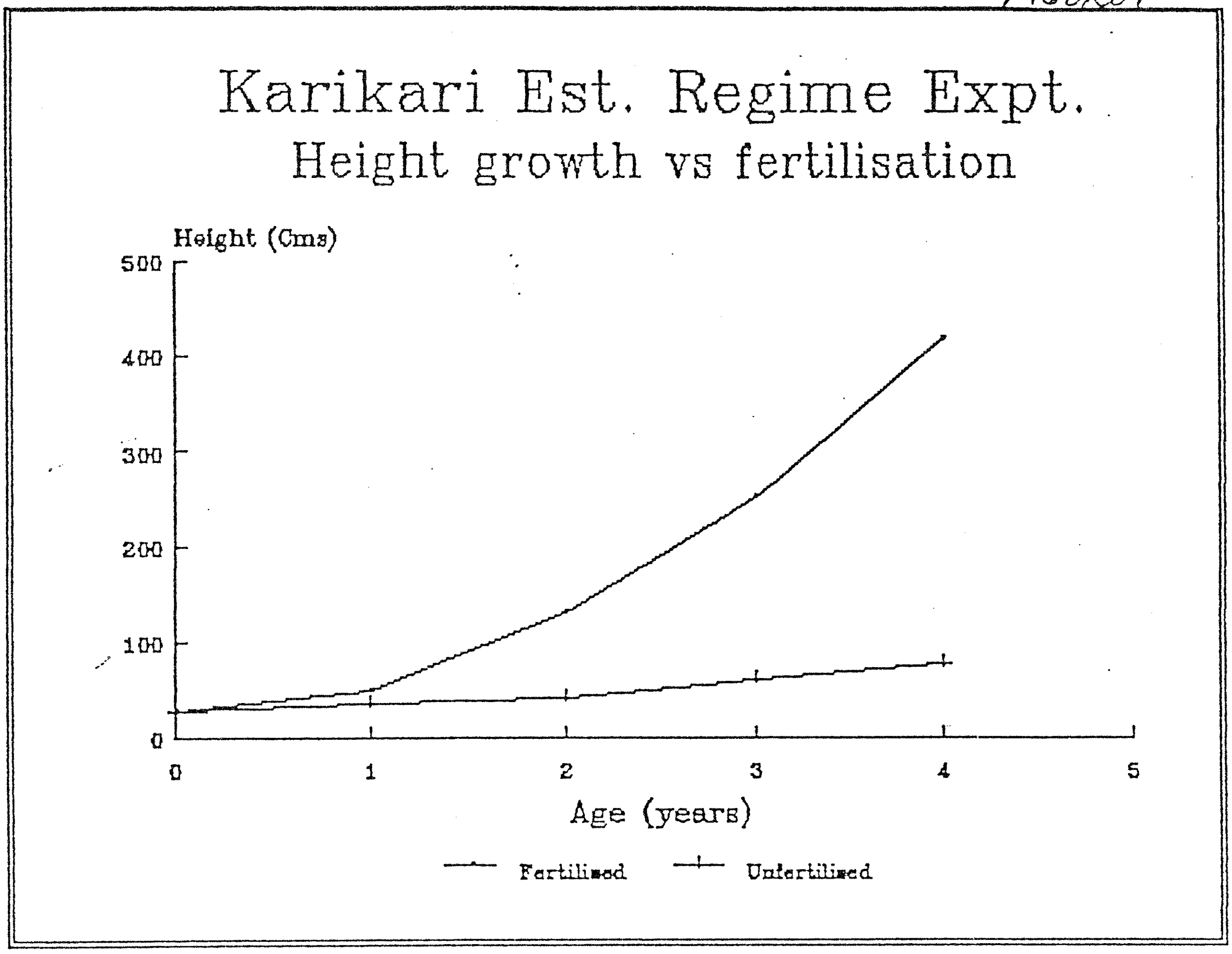
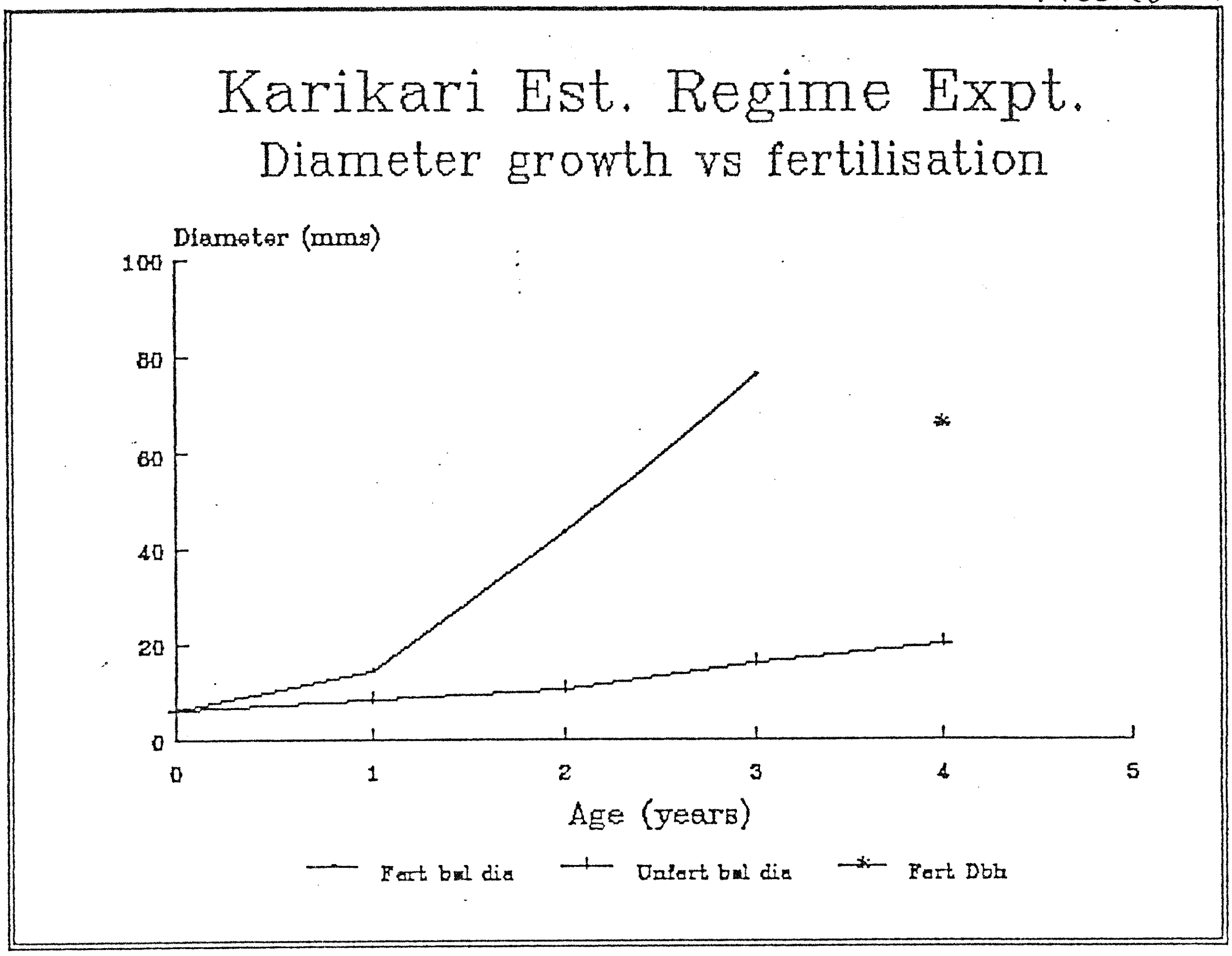

Karikari Est. Regime Expt.
Height growth vs fertilisation
Height (Cms)
500
400
300
200
100
0
0
1
2
3
4
5
Age (years)
Fertilised
Unfertilised

FIGURE 2


Karikari Est. Regime Expt.
Diameter growth vs fertilisation
Diameter (mms)
100
80
60
40
20
0
0
1
2
3
4
5
Age (years)
Fert bsl dia
Unfert bsl dia
Fert Dbh

The fertilisation x cultivation interaction was significant ($P<0.0003$). Cultivation was relatively ineffective in the absence of fertiliser.

An analysis of variance was performed using only the fertilised component of the trial. Cultivation significantly improved growth in both height growth ($P<0.0001$) and diameter growth ($P<0.0002$). The effects are shown in Figures 3 & 4. There were no significant differences between types of cultivation treatments, although diameter growth was improved with discing as well as ripping (treatment R6, R6R, and SR60).

C. **Toppling**

Toppling frequency was significantly affected by both cultivation ($P<0.04$) and fertilisation ($P<0.02$). The interaction term was not significant. The effect of cultivation is shown in Figure 5. 22% of the fertilised trees toppled by age four, compared to 13% of the unfertilised trees.

DISCUSSION AND CONCLUSIONS

A. **Survival**

The improvement in survival due to fertilisation highlights the extreme nutrient deficiency experienced by the unfertilised trees on this site.

B. **Growth**

The poor growth of unfertilised trees, and the fact that they did not respond to cultivation, suggests that this site was unusually nutrient deficient, even for Northland.

At least part of the cultivation effect was due to improved drainage. Reeds growing in control plots survived during the first year after planting, whilst those in adjacent ripped and ripped/disced plots died.

There were no differences in growth between types of cultivation, unlike experiences elsewhere (Mason *et al.* in prep, Mason *et. al.* 1988; Mason & Cullen 1988). This highlights the need for more research into the effects of cultivation on soil physical properties.

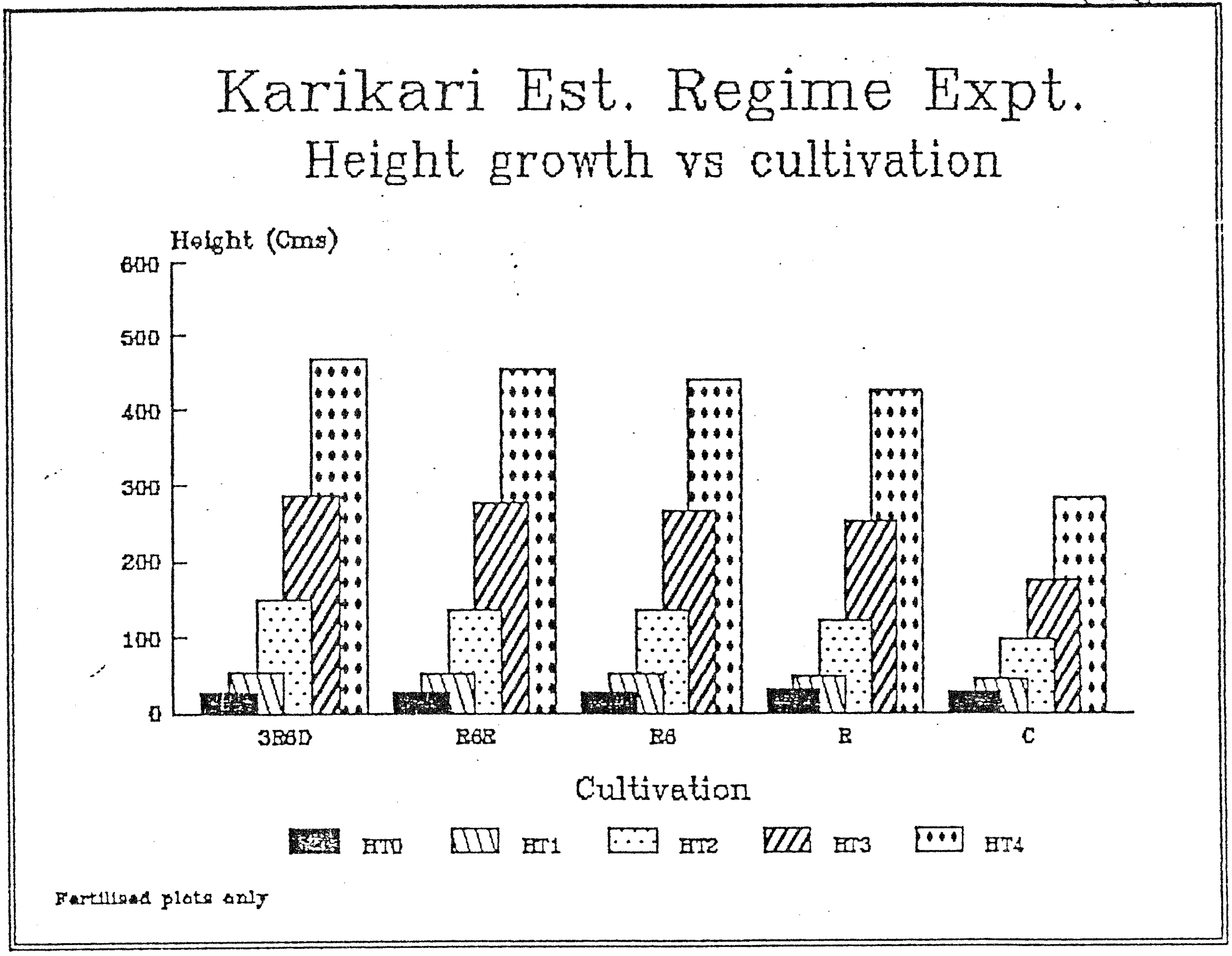
C. **Toppling**

The effect of fertilisation on toppling frequency can be explained by the difference in tree size. Trees smaller than 1 m in height do not usually topple as frequently as larger trees (Mason 1985).

The fact that toppling was affected by cultivation but was unaffected by the fertilisation x cultivation interaction suggests that soil strength rather than tree size was the main cause of the differences between cultivation treatments. Toppling is usually preceded by "socketing", and is a result of root failure after a period of tree sway. If the soil around the base of the stem is firm, as in a control treatment, toppling can be less likely (Mason 1985).

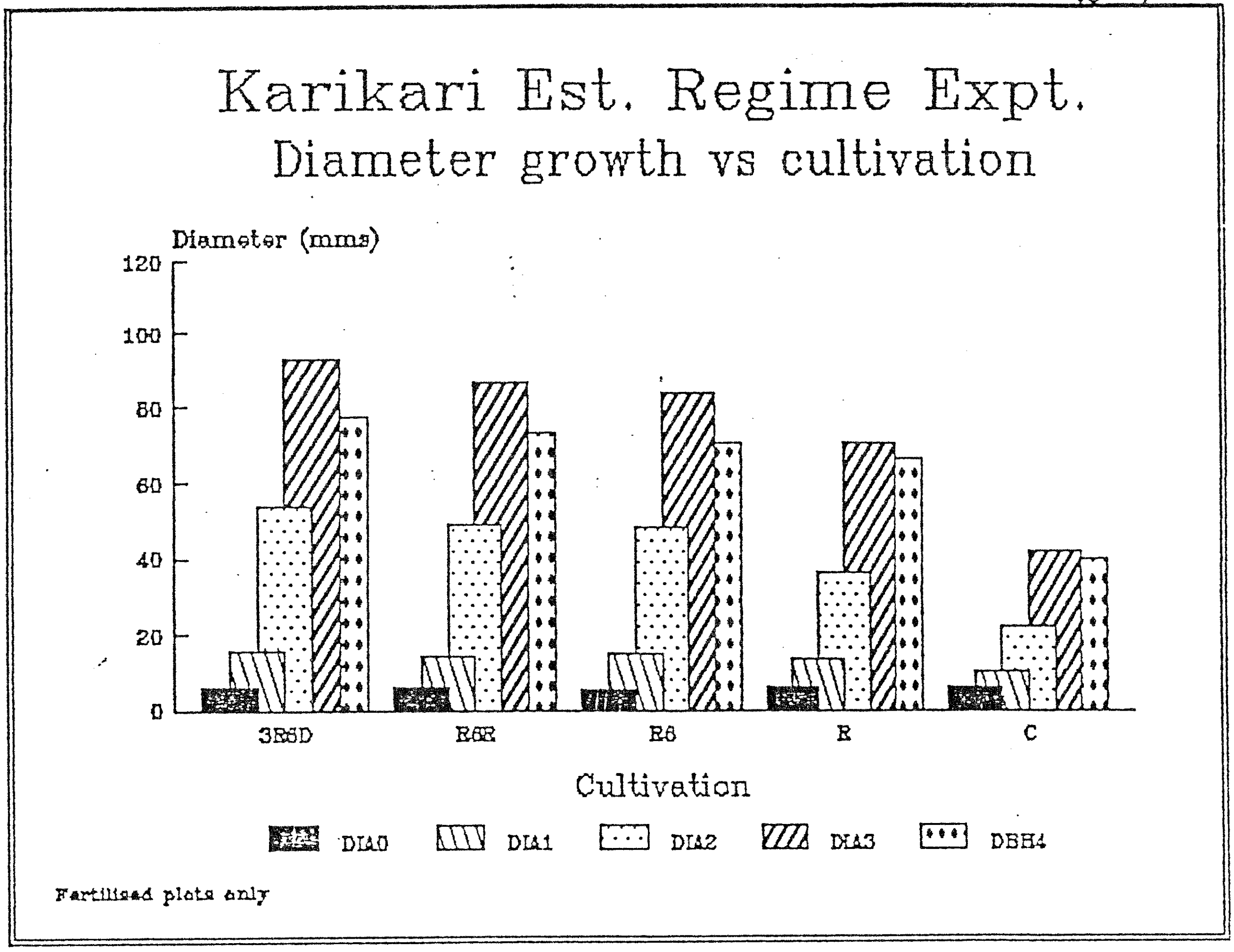
Cultivation with inverted discs has been shown to increase the likelihood of toppling elsewhere (Mason 1985). Observations of toppling frequency at Karikari are consistent with this finding.

FIGURE 3



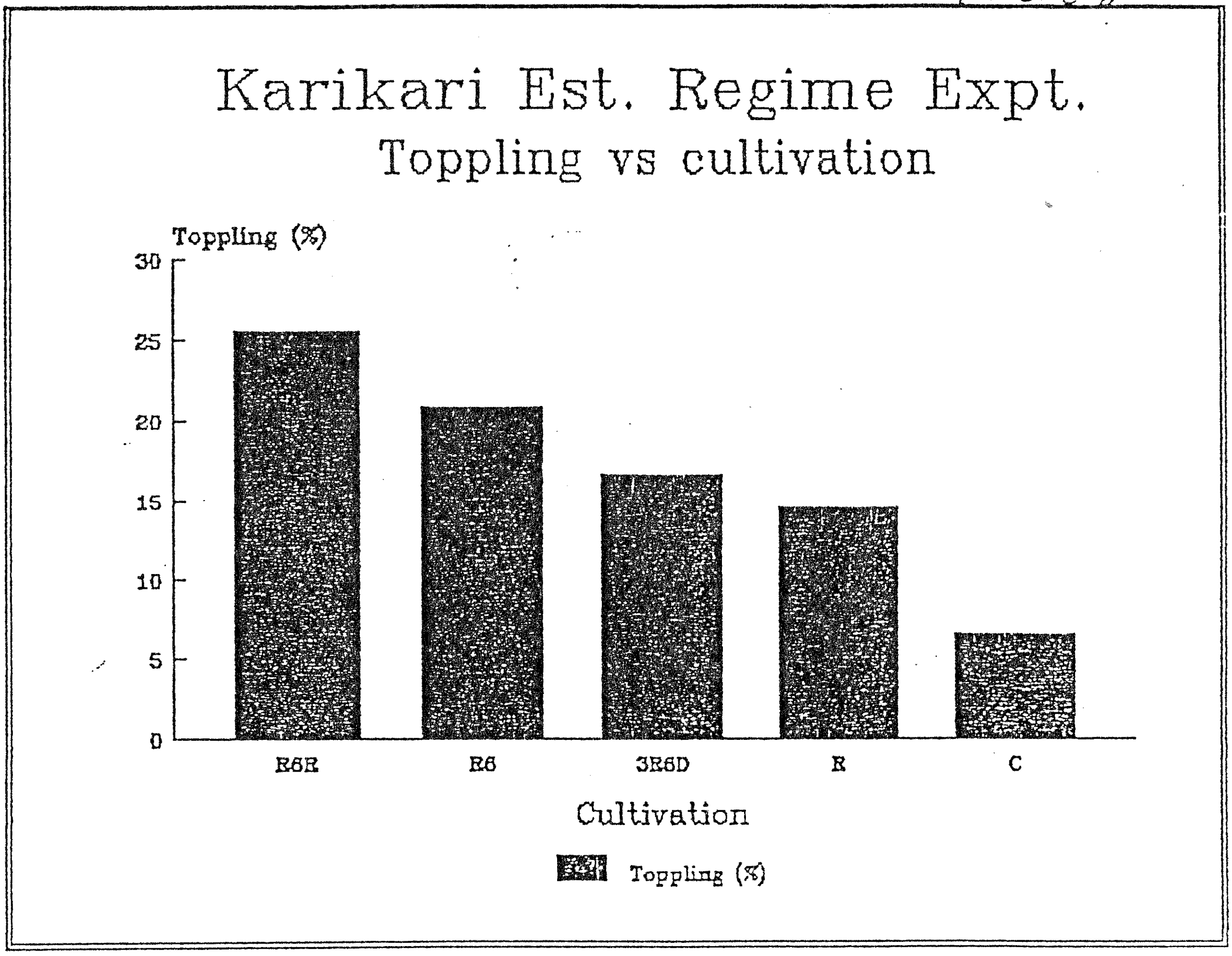
1. Control (C)
2. Ripping (R)
3. Ripping / 6 inverted discs (Pulling the topsoil in over the rip) (R6)
4. Ripping with three tines / 6 inverted discs (3R6D)
5. Ripping / 6 inverted discs / hourglass roller (R6R)

FIGURE 4



1. Control (C)
2. Ripping (R)
3. Ripping / 6 inverted discs (Pulling the topsoil in over the rip) (R6)
4. Ripping with three tines / 6 inverted discs (3R6D)
5. Ripping / 6 inverted discs / hourglass roller (R6R)

FIGURE 5



1. Control (C)
2. Ripping (R)
3. Ripping / 6 inverted discs (Pulling the topsoil in over the rip) (R6)
4. Ripping with three tines / 6 inverted discs (3R6D)
5. Ripping / 6 inverted discs / hourglass roller (R6R)

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