GROWTH OF TWO PINUS RADIATA STOCK TYPES ON RIPPED AND RIPPED/BEDDED PLOTS AT KARIOI FOREST

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ABSTRACT

Two site preparation techniques – ripping and ripping plus bedding – were compared with an uncultivated control treatment on compacted, podsolised soils from weathered andesitic tephras at Karioi Forest. Two **Pinus radiata** D. Don seedling stock types (1/0 and 1.5/0) were used.

Ripping/bedding caused a significant improvement in height and diameter growth between ages 2 and 7 years, but the improvement was not large enough to justify the cost of cultivation on the grounds of improved growth alone. Root form and vertical extension were better in the cultivated plots than in the control, but no significant differences in stability between cultivation treatments were recorded. The 1.5/0 stock was larger at planting time than 1/0 stock, was more difficult to plant properly, and exhibited much poorer root form than 1/0 stock. It toppled almost twice as often as the 1/0 stock, despite slightly deeper planting and a larger mean root : shoot ratio. Growth was not significantly different between stock types by age 7.

Root extension was related to penetration resistance, and was severely restricted when the resistance exceeded 3 MPa.

Keywords: cultivation; root growth; penetration resistance; **Pinus radiata**.

INTRODUCTION

Cultivation prior to forest establishment has been used in New Zealand since the mid 1960s. Ripping has been a commonly used form of cultivation, and a brief outline of the development of ripping equipment has been reported previously (Mason & Cullen 1986).

Ripping has improved *Pinus radiata* growth in Northland on podsolised soils (Berg 1975), and on clay sites in Southland (Hetherington & Balneaves 1973). Improvements in root growth due to ripping have been recorded in Canterbury on gravel soils (Guild 1971; Potter & Lamb 1974; Somerville 1979) and on compacted pumice sites (Mason & Cullen 1986). However, on a low-altitude, grassed, pumice soil, ripping significantly reduced the growth of *P. radiata* (Brunsden 1980).

Bedding has been employed in New Zealand since 1974, when a bedding plough was built for use in the podsolised soils north of Auckland (Williamson 1985). In the following year, two ploughs were constructed by contractors in the central North Island. The machinery has been described by Cullen & Mason (1981).

In Northland, bedding has caused large improvements in growth compared to other cultivation practices on some sites. On a Te Kopuru sand at Waipoua, trees in ripped and bedded plots grew almost 1 m taller by age 3 years than those in ripped-only plots (Williamson 1985). Cullen & Mason (in prep.) found that the type of cultivation used can have a major influence on the results, and that ripping and bedding can improve height growth in the first 5 years by as much as 2 m compared to ripping alone or ripping/mounding. Hunter & Skinner (1986) reported that, on some Northland podsols, the growth rate in control plots was showing no signs of improvement 10 years after establishment whereas there was no evidence that that in well-cultivated plots would slow down. In the central North Island, bedding has been employed as part of an establishment regime for frost-prone sites (Menzies 1976; Washbourne 1978; Menzies & Chavasse 1982). Cultivation with discs exposed mineral soil, lowering the albedo, and reduced frost severity by as much as 4°C (Menzies & Chavasse 1982). It was also felt that ripping and bedding may improve initial growth, allowing trees to grow above the levels of severe frost, but effects on growth have not been quantified. On pumice sites, ripping is generally combined with bedding treatments in one pass. Because of impenetrable subsoils on some sites (Mason & Cullen 1986), bedding without ripping is likely to result in horizontal plate-like root systems.

The experiment described here is the oldest of several which were designed to quantify the effects of ripping and bedding pumice soils on the survival and growth of *P. radiata.*

METHOD

Plot Layout

A gently sloping (2–3°) 0.6-ha site was chosen in Cpt 61, Karioi Forest, at 960 m a.s.l. The soil (Appendix 1) was a strongly leached, podsolised, yellow-brown loam formed from mostly weathered andesitic tephra deposited during eruptions from Mt Ruapehu, Mt Ngauruhoe, and Mt Tongariro. Downward movement and deposition of iron oxides had compacted some of the andesitic lapilli layers, restricting root development in the soil profile.

The site had supported tussock (*Chionochloa rubra* Zotov/*Festuca novae-zelandiae* (Hack.) Ckn.) and a few scattered *P. contorta* Dougl., which had been recently crushed and burned.

Twelve blocks of the following cultivation treatments were laid out in paired lines, with 4 m between lines:

1. Control – uncultivated

2. Ripped – the operation was performed to a nominal depth of 60 cm with an unwinged rock ripper. The prime mover was a D8.

3. Ripped and bedded – ripping was performed as above, and a bedding plough constructed by Egmont Land Development Co. Ltd was pulled over the rip lines

in a second pass (ripping and bedding are now routinely done in one pass – Cullen & Mason 1981).

Prior to bedding, two depth measurements per rip line per block were taken with a 1-m rule, and three rip profile measurements were taken from the walls of 1-m-deep holes dug across the line of the rips.

In September 1977, two stock types of *P. radiata* were planted at 2-m spacing within lines; 1.5/0 stock from Bulls nursery and 1/0 stock from FRI nursery were randomly allocated, one to each of the two lines within each cultivation plot. The two stocks were grown from different seedlots. One 10-tree permanent sample plot was established in each line per plot. FRI staff planted the trees, with only one planter working within each block. The Bulls stock had much larger root systems and stems than the FRI stock and were difficult to plant properly. During remeasurements at ages 2, 4, and 6, tree stability and stem form were assessed.

Root Development

Large roots

At age 2, one tree was randomly selected from each plot for root assessment. Measurements were made of Menzies' taproot score (Mason 1985), the number of sinker roots greater than 2 mm, and the depth of the first lateral root (an index of planting depth).

At age 4, one tree was randomly selected from each plot in the first eight blocks and the roots were excavated to within 50 cm of the tree. Measurements were made of Menzies' lateral score (Mason 1985), the depth of the root system, and Mason's core distribution score (Mason & Cullen 1986).

Fine root development

At age 7, and during the tenth growing season, one trench was dug across each cultivation treatment, and profile wall studies of root development and soil penetration resistance were made, as has been described in detail by Mason & Cullen (1986).

RESULTS

Rip Depth

The average depth of rip line was 53 cm. Some individual rip lines were significantly different from one another, and ranged from 42 to 66 cm deep. Whilst the rip depths between some treatments were significantly different from one another, the range was small, from 50 cm (ripped, planted with FRI stock) to 55 cm (ripped/bedded, planted with Bulls stock).

Survival

There were no significant differences in survival between cultivation treatments or tree stocks. Average survival was 91.8%. Forty-eight percent of the mortality occurred during the first year after planting, 18% during Year 2, 24% during Year 3 (the trees averaged 1 m in height by this stage), and 10% between ages 3 and 9.

Growth

Growth in height and diameter during the first 9 years is summarised in Fig. 1 and 2. After age 6, diameter measurements were taken at breast height rather than at 5 cm above ground-level. Tree height in the ripped/bedded treatment was significantly different from the other two treatments by age 3, and diameter of trees in the ripped/bedded treatment was significantly different from the ripped and control treatments by age 2 ($p<0.05$).

Differences remained statistically significant until the experiment was thinned. Measurements at age 9, after thinning, showed that the difference in diameter was still significant ($p<0.05$), but the height difference was not quite significant.

After planting, the FRI stock averaged 23 cm in height and 4.7 mm in basal diameter. The Bulls stock measured 39 cm in height and 6.9 mm in diameter. By age 7 the FRI stock was slightly taller than the Bulls stock, but there were no statistically significant growth differences between the stock types.

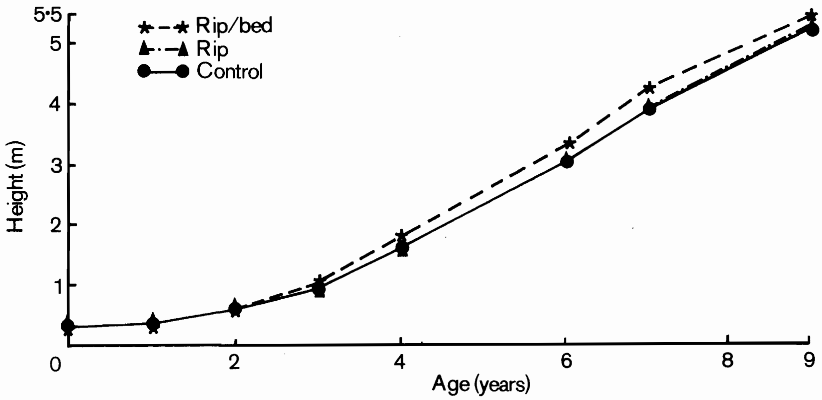

FIG. 1—Height v. age and cultivation treatment.

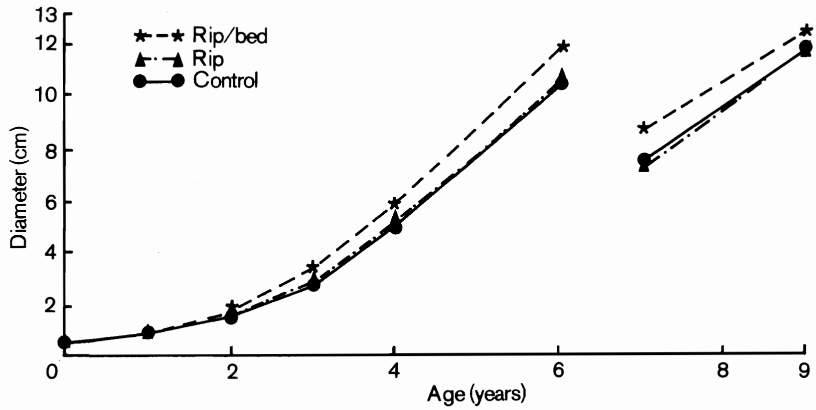

FIG. 2—Diameter v. age and cultivation treatment.

Large Root Development

Measurements at age 2 revealed that trees had been planted 1 cm deeper on average in the ripped treatments than in the other two treatments, and that Bulls stock had been planted 1 cm deeper than FRI stock. Both these differences were significant ($p<0.01$), and the interaction between the two was not significant.

The two stocks had markedly different topple indices (Mason 1985) – 1.57 for the FRI stock and 1.44 for the Bulls stock. The index ranges from 1.2 (unstable trees) to 1.8 (stable trees). The cultivation treatments did not vary significantly in topple index at age 2.

By age 4, trees in the control treatment had much poorer vertical root development than those in the ripped and ripped/bedded treatments. Menzies' taproot score (0 = no distortion, 10 = badly distorted) averaged 7.7 in the control treatment and 3.4 in the cultivated treatments. The mean root depths were 28 cm for the control treatment and 50 cm for the ripped and the ripped/bedded treatments.

The core distortion score (Mason & Cullen 1986) may be related to the frequency of stem fracture (Mason 1985). The score measures the extent to which lateral roots are wrapped around the bole of the tree, and ranges from 0 (no distortion) to 4 (roots wrapped completely around the stem). The mean scores at age 4 were 1.9 for ripped and bedded, 2.6 for ripped, and 3.5 for control. Bulls stock had a mean score of 3.1 and FRI stock had a mean score of 2.2. These differences were statistically significant ($p<0.01$). In addition to these main effects, the interaction was significant (the residual mean square was exceptionally small). Distortion in the control compared to other treatments was not as great in the FRI stock as it was in the Bulls stock. The smallest mean distortion was measured on FRI stock in the ripped/bedded treatment (1.4) and the largest was on Bulls stock from the control treatment (3.6).

Fine Root Development

Data from year 7 and year 9.5 were combined. Although there were more fine roots at age 7 (August) than at age 9.5 (March), relative differences between treatments were the same at each measurement.

Mean soil penetration resistance is shown in Fig. 3a and numbers of roots per 15 × 15-cm square *v.* depth in Fig. 3b. The percentage of squares without roots *v.* penetration resistance is shown in Fig. 3c. The number of squares without roots rises sharply above 3 MPa penetration resistance. For the two ripped treatments, only data from the central four columns of 15 × 15-cm squares were used to show roots *v.* depth. The profile walls at age 9.5 for each treatment are shown in Fig. 4. There was a tendency for roots to grow in a mass along the bottom of the rip shatter zone.

Stability

By age 4, 45% of the trees in the experiment had toppled (that is, they had a lean greater than 15° from vertical). Differences between cultivation treatments were not significant although the mean toppling rate was lower in the control treatment. The difference between the stocks was highly significant ($p<0.01$) – 57% of the Bulls stock were toppled, and 33% of the FRI stock.

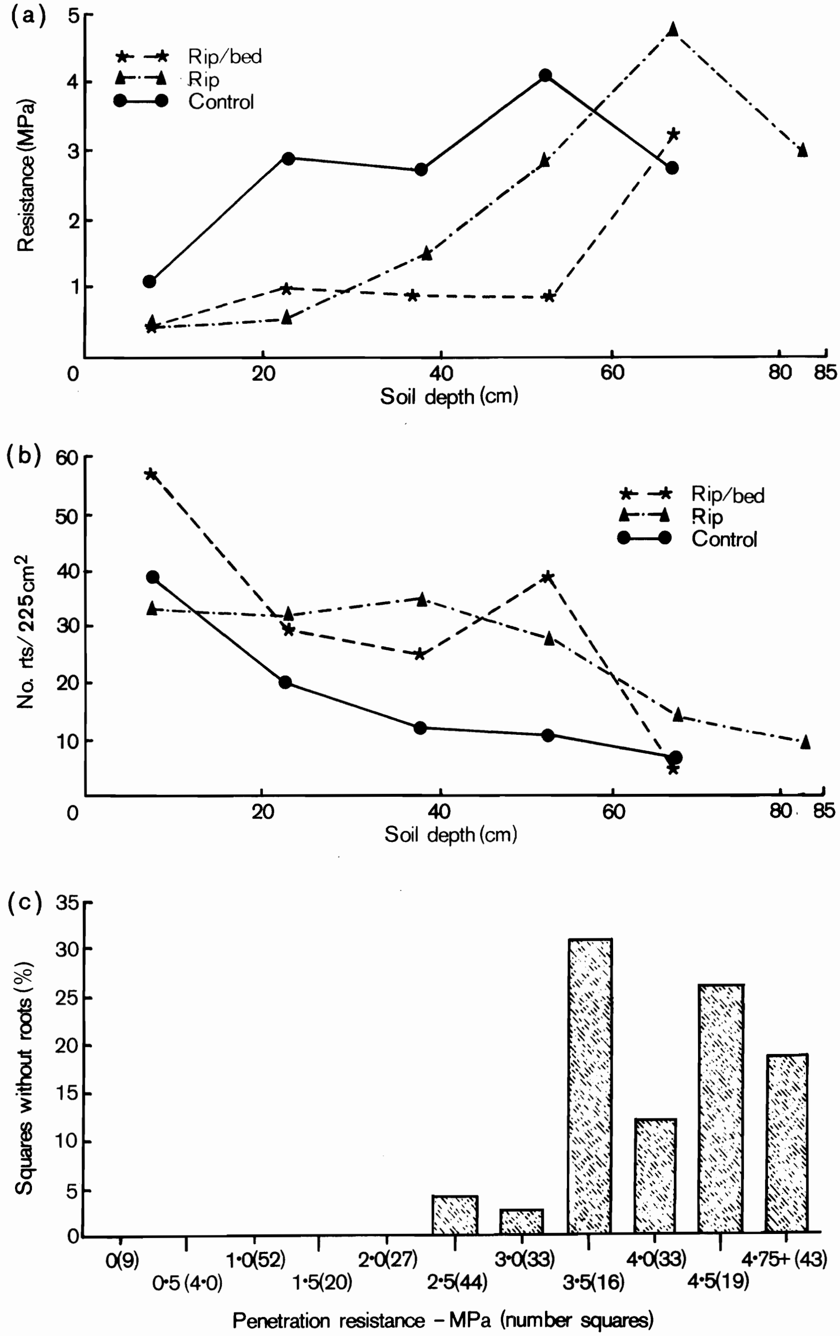

FIG. 3—(a) Penetration resistance v. depth and cultivation treatment (in (a) and (b) only the middle 30-cm cross-section of the cultivated line was measured).
(b) Number of roots v. soil depth and cultivation treatment.
(c) Root presence v. penetration resistance.

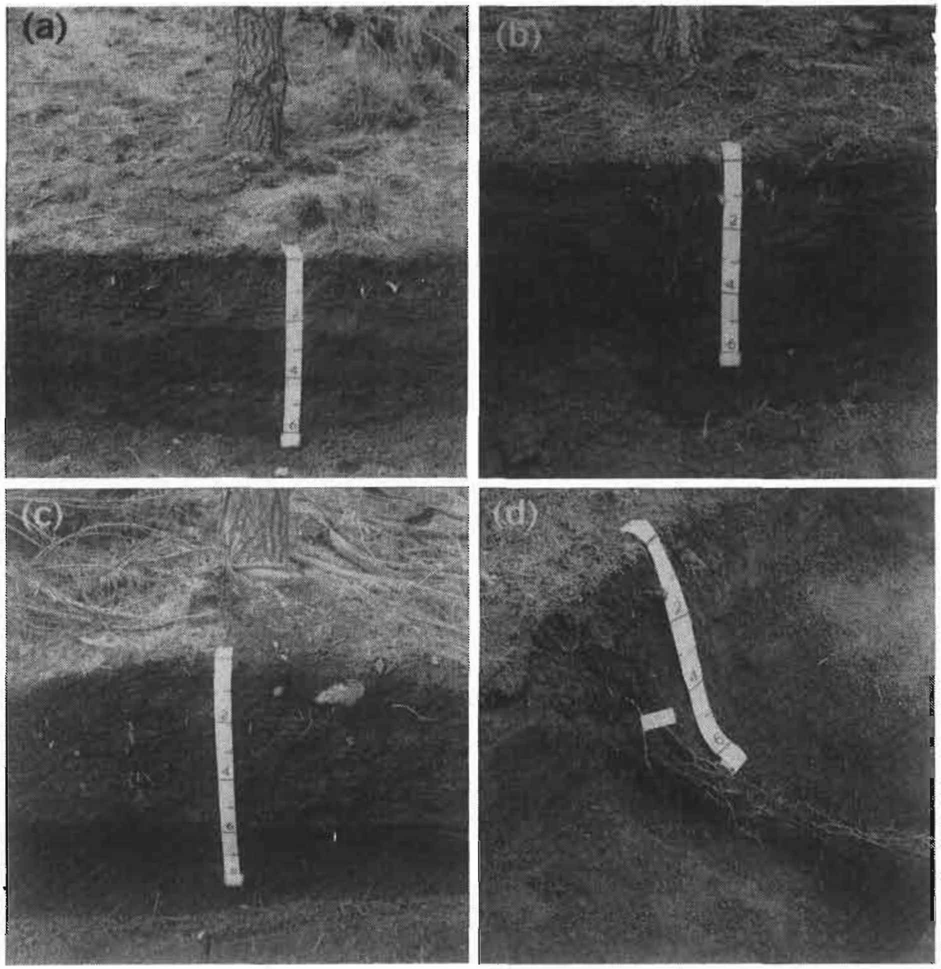

FIG. 4—(a) Profile wall of control plot at age 9.5 years
(b) Profile wall of ripped plot at age 9.5 years
(c) Profile wall of ripped and bedded plot at age 9.5 years
(d) Mat of roots growing along the base of the ripline at age 9.5 years.

Crop Selection and Thinning

At age 6, 60% of the FRI stock and 50% of the Bulls stock were suitable for selection as crop trees (significantly different at $p<0.05$). The major factor affecting these percentages was the extent to which trees exhibited butt sweep and/or sinuous stems because of toppling. The interaction between cultivation treatment and stock was significant ($p<0.05$). There was little difference between cultivation treatments planted with FRI stock, but the ripped treatment planted with Bulls stock had significantly fewer acceptable stems than the control treatment planted with Bulls stock.

DISCUSSION AND CONCLUSIONS

Growth

This experiment shows that the type of cultivation used can be important on some sites. There was no difference in above-ground growth between the ripped treatment and the control, whilst the ripped/bedded treatment grew considerably faster than the other two cultivation treatments between ages 2 and 7.

There is an indication that the growth trajectories of the bedded and control treatments may be parallel after age 7, as occurred with similar treatments (but after a different age) in Florida (Wilhite & Jones 1981). If so, then bedding would reduce the rotation length by half a growing season, and the cost of ripping/bedding (c. $175/ha) would not be recovered on the basis of increased growth at an interest rate of 10% unless growing costs discounted to time of establishment exceeded $3500.

It is not known why ripping/bedding produced an improvement in growth while ripping alone did not. On Kaingaroa gravelly sand, winged ripping improved growth without bedding (Mason & Cullen 1986). The soil in the experiment described here is higher in allophane than Kaingaroa gravelly sand, and might be prone to poor aeration. Bedding would have created more macropores, improving aeration. It may also be significant that the rock ripper used in this experiment created a slot. Immediately after cultivation, it was clear that the critical depth of the ripper (Page 1977) was close to the surface on this soil type and that soil was compressed sideways rather than shattered.

Potential Advantages of Cultivation Other than Growth

Vertical root development was much improved by ripping both for large and for fine roots. There may be a reduction in the risk of windthrow as a consequence, but this cannot be quantified yet. There was no significant difference in toppling rate due to cultivation, unlike Kaingaroa where ripping reduced toppling frequency and severity (Mason & Cullen 1986).

The control plots were difficult to plant properly, resulting in root distortion. In Kaingaroa, a proportion of the investment in cultivation is recovered at planting time, because planting is easier in loose cultivated soil (D. Kelly pers. comm.). Recent measurements of this effect showed that the saving amounted to approximately $25/ha when the planting was done with due care, whilst the cultivation cost was approximately $78/ha (P. Hall pers. comm.). At Kaingaroa, cultivation also resulted in improvements in survival and crop uniformity (Mason & Cullen 1986). No such effects were found at Karioi.

Weed growth was poor during the first few years on this site, and bedding probably had an insignificant effect on frost levels.

Stock Types

Large 1.5/0 stock was clearly inferior to the smaller 1/0 stock on this site. Large root systems made the Bulls stock difficult to plant properly at any reasonable rate and the result was severe root distortion, causing large amounts of toppling, and consequently low numbers of acceptable stems at the time of first thinning. Growth was similar for the two stocks, and the FRI stock had caught up with the Bulls stock by year 7.

Root Growth

The root assessments provided confirmation of two models derived from earlier studies. The topple indices (Mason 1985) of the two stocks at age 2 predicted that there would be more toppling of Bulls stock than of FRI stock. This occurred even though the Bulls stock had a higher shoot : root ratio and was planted slightly deeper than the FRI stock.

The penetration resistance study confirmed that soil penetration resistances above 3MPa limit the growth of *P. radiata* roots, as reported by Mason & Cullen (1986). As at Kaingaroa (Mason & Cullen 1986), some squares with high resistance readings had areas of soft soil containing roots. No high readings were recorded in the immediate vicinity of roots.

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APPENDIX 1

SOIL PROFILE DESCRIPTION

Classification: strongly leached podsolised yellow-brown loam. US: Andic Haplorthod, andesitic, sandy, mesic

Location: Karioi Forest

Parent material: Andesitic tephra consisting of Ngauruhoe tephra formation, Papakai tephra, Pouto lapilli, Wharepu tephra member, Oturere lapilli, Te Rato lapilli, and Okupata tephra formation

Landform: Undulating upland plain

Vegetation: *Pinus radiata,* tussock

Drainage: Well drained

Profile

A	0–7 cm	Very dark brown (10YR 2/2) and dark brown (10YR 3/3) gritty loamy sand; friable; weakly developed fine granular structure; many fine roots, distinct smooth boundary (Ngauruhoe tephra formation)
2Bs	7–22 cm	Dark yellowish brown (10YR 4/4) gritty greasy silt loam; friable; weakly developed medium nut structure to massive; few medium roots; many fine dark red (2YR 3/6) mottles; many fine dark grey and dark red andesitic lapilli; distinct smooth boundary (Papakai tephra)
3Bs	22–23 cm	Dark red (2.5YR 3/6) pumice gravel; firm in situ, loose; single grain; few fine roots; sharp smooth boundary (Poutu lapilli)
4Bsx	33–44 cm	Greyish brown (2.5YR 5/2) fine loamy sand; very firm; massive breaking to medium and coarse blocky structure; few distinct medium and coarse dark reddish brown (5YR 3/4) and dark red (2.54YR 3/6) stained old root channels; few fine live roots; sharp smooth boundary (Wharepu tephra member)
5CB	44–48 cm	Very dark grey (10YR 3/1) and dark brown (7.5YR 3/4) fine gravel; loose; single grain; few fine live roots; sharp smooth boundary (Oturere lapilli)
6AB	48–50 cm	Dark greyish brown (2.5Y 4/2) gritty loamy sand; firm; massive structure breaking to single grain; sharp smooth boundary (Te Rato lapilli)
6BC	50–91 cm	Brown (10YR 4/3) gravelly fine sandy loam; friable; massive structure breaking to weakly developed fine nut and single grain structure; many medium and fine andesitic lapilli; few fine roots; distinct smooth boundary (Te Rato lapilli)
7BC	91–110 cm	Dark greyish brown (2.5Y 4/2) greasy fine sandy loam; firm; massive structure breaking to weakly developed coarse blocky structure; distinct smooth boundary (Okupata tephra formation)
8BC	on	Dark greyish brown (2.5Y 4/2) sandy gravel; (very wet) friable; single grain structure