ROOT PATTERNS OF PINUS RADIATA ON FIVE RIPPING TREATMENTS IN A CANTERBURY FOREST

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(Received for publication 20 March 1989)

ABSTRACT

Eight years after planting, root systems were compared for 30 **Pinus radiata** D. Don trees excavated from each of five different ripping treatments and an unripped control. Taproots of trees from deep-ripped (100 cm) treatments penetrated to a far greater depth (153 cm) than those from the shallow-ripped treatment (60 cm). Taproots of trees planted on the unripped site penetrated to a maximum depth of 48 cm because of the presence of a hard pan.

A single line rip (deep or shallow) resulted in some orientation of primary lateral roots. This orientation became more pronounced in the secondary lateral roots, which were confined along the line of the rip. Although lateral roots were more evenly distributed in the unripped and cross-ripped treatments, least development was in the north-east quadrant and greatest development in the south-west.

The number of butt-swept trees was not significantly affected by treatment, but the severity of stem deviation and sinuosity resulting from initial butt sweep was related to treatment. The straighter the taproot and the deeper its penetration, the less stem deviation.

It is suggested that all sites with a shallow hard pan be deep-ripped, using winged rippers, to maximise soil disturbance, and that forests on the Canterbury Plains have rows orientated south-west to north-east.

Keywords: growth; root systems; establishment; **Pinus radiata.**

INTRODUCTION

Since Potter & Lamb (1974) showed that the compacted drought-prone gravel soils of the Canterbury Plains inhibited root development and that ripping to 45 cm improved taproot and lateral root penetration, the relative merits of ripping have been debated (T. Brummer, unpubl. data; Somerville 1979). Because root development in deep rips (120 cm) increased anchorage on these sites a tendency has developed towards stem failure rather than uprooting in the frequent north-west gales experienced (Somerville 1979). Therefore the benefits of ripping for stability have to be weighed against the problems caused by increased stem failure.

A trial was established at Eyrewell Forest in 1975 to investigate the influence of five ripping treatments on early growth, volume production, root development, and stand stability. Root development in the stand 8½ years after planting is outlined in this paper.

METHOD

The trial site was burnt in 1967 after windrowing of slash and stumps left from harvesting the previous crop. The area remained fallow until it was ripped in 1975, using a Komatsu 155 (135 kW) tracked machine fitted with a single-tine rock ripper.

An unreplicated trial was laid out to test six ripping treatments. All single rips were orientated north-west to south-east. In Treatments (4)–(6), the second rip was orientated north-east to south-west, at right angles to the first rip.

(1) Control (no rip)
(2) Shallow rip (45 cm)
(3) Deep rip (120 cm)
(4) Deep rip (north-west to south-east), shallow rip (north-east to south-west)
(5) Shallow rip (north-west to south-east), shallow rip (north-east to south-west)
(6) Deep rip (north-west to south-east), deep rip (north-east to south-west)

Ripping depth was tested with a soil probe. Sampling of the deep rips indicated that ripping had broken the gravel soils to a depth of at least 100 cm. Similarly, probing of all the shallow-ripped areas indicated shattering of the soil structure to a depth of 47 cm. The width of shatter differed according to depth. In the top 30-cm layer of soil, disturbance extended 45 cm either side of the ripped line on the deep-ripped treatments and 30 cm either side on the shallow-ripped treatments.

Each block of approximately 150 × 60 m was ripped in lines 4 m apart. In 1975 all six blocks were hand-planted at 4 × 4-m spacing (625 stems/ha). Stock was 1½/0 *Pinus radiata* seedlings raised from Amberley Seed Orchard seed at Rangiora Nursery. Before planting, seedling lateral roots were trimmed to a radial length of 10 cm and taproots to 10 cm. Each planter planted one row per block, randomly allocated to avoid planter bias in subsequent assessments of the trial.

In 1983, 180 trees (30 from each treatment) were randomly selected before excavation, and stem diameter (dbh) and height were measured. Where butt sweep was apparent, the horizontal deviation from the vertical stem mid-point was measured at the point of maximum deflection. Any stem malformation was recorded, the most common being stem sinuosity. The north-west quadrant on each tree was identified by an aluminium tag. The trees were then excavated with a tractor-mounted winch. During excavation excess soil and stones were washed off the roots. Stumps were then severed at ground level.

Qualitative Assessment of Roots

The "Menzies Scoring System" (Chavasse 1978; Mason 1985) (Appendix 1) was used to give a subjective appraisal of taproot distortion, lateral root arrangement, and root tangle.

Taproot Assessments

Taproot length (ground level to tip) and diameter at 30 cm below ground level were measured (Fig. 1). The number of sinkers over 20 cm in length were counted, distinguishing between those originating from the central root axis and those originating from laterals.

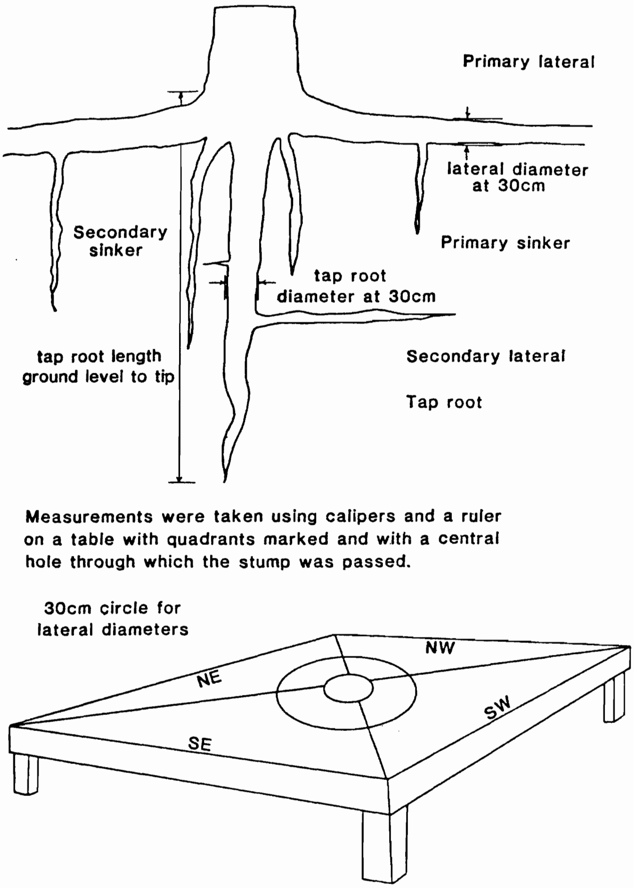

FIG. 1—Methods used for taking measurements.

Lateral Root Assessments

Primary lateral roots with diameters greater than 1 cm were measured at 30 cm from the centre of the root system for each of four quadrants (north-west, south-east, north-east, and south-west; *see* Fig. 1). Laterals with diameters less than 1 cm were counted only. Secondary laterals, i.e., laterals originating from the taproot or sinkers, that exceeded 1 cm in diameter at 15 cm from their point of origin were measured. Secondary laterals under this size were not counted since there were too many, particularly on roots of trees excavated from the deep-ripped treatments.

Means and standard deviations were calculated for most of the parameters measured. Differences between treatments, and within treatments where appropriate, were tested by unpaired t-tests.

RESULTS

Stem Growth

Heights and diameters did not differ significantly between treatments, but basal area and volumes were lower for the deep-ripped Treatment (3) than for other treatments (Table 1). There appeared to be a gradient of increasing basal area and volume from the north corner through to the southern end of the block, which probably reflected site differences rather than differences between treatments.

TABLE 1–Mean height, diameter, basal area, and volume of 30 trees sampled from each ripping treatment

Treatment	Height (m)	dbh (cm)	Basal area (cm^2)	Volume (dm^3)
1*	7.5 a†	10.4 a	108 a	35 a
2	7.8 a	10.5 a	110 a	36 a
3	7.9 a	9.8 a	96 b	30 b
4	7.9 a	10.4 a	108 a	35 a
5	7.8 a	10.6 a	112 a	37 a
6	7.7 a	10.2 a	104 ab	35 a

* Treatment 1 = Control (no rip)
2 = Shallow rip (45 cm) in north-west to south-east direction
3 = Deep rip (120 cm) in north-west to south-east direction
4 = Deep rip (north-west to south-east); shallow rip (north-east to south-west)
5 = Shallow rip (north-west to south-east); shallow rip (north-east to south-west)
6 = Deep rip (north-west to south-east); deep rip (north-east to south-west)

† Within each factor, means with the same letter are not significantly different (t-test, $p \leq 0.05$).

Stem Malformation

The unripped treatment had fewer trees with sinuosity, and deflection was less severe than those from any of the ripped treatments (Table 2). However, butt sweep alone was prevalent in the unripped plot. In the ripped treatments, butt sweep and stem sinuosity most often occurred together. Stems from the single-ripped Treatments (2) and (3) had the worst stem deviation.

TABLE 2–Number of trees per treatment with butt sweep, sinuosity, or both defects, and the mean stem deflection caused by butt sweep

Treatment	Butt sweep	Sinuosity	Butt sweep/ sinuosity	No defect	Mean stem defection (cm)
1*	16	2	3	9	10.8
2	8	3	16	3	13.7
3	12	3	11	4	14.9
4	12	0	14	4	11.6
5	8	2	15	5	11.9
6	4	1	17	8	10.4

* *See* Table 1 for explanation of treatments.

Root Development

Menzies' scoring system

Taproot distortion was worst on the unripped treatment, affecting 28 (93%) of the 30 trees examined (Fig. 2). The taproots from the deep-ripped treatments showed little sign of distortion, with 72 (82%) of the 90 trees having a perfect score (0). Taproot development was not as good on the shallow-ripped treatments, and some deformation was apparent on all but 11 (20%) of the 60 trees.

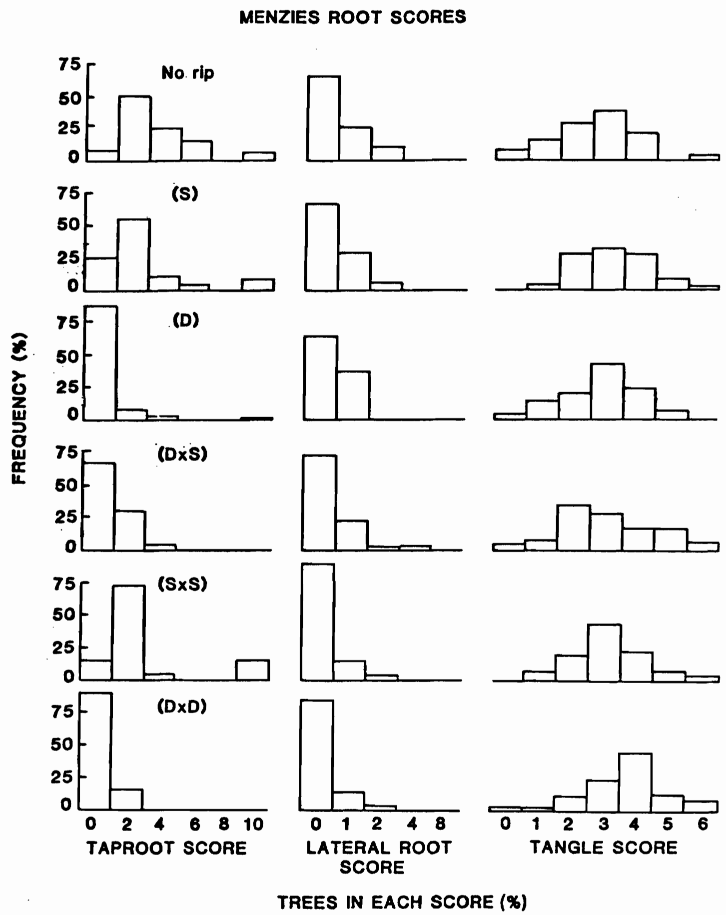

FIG. 2—Root scores on Menzies' scoring systems; (S) = shallow-ripped, (D) = deep-ripped.

Although lateral roots were distributed in all quadrants in all treatments, root tangle was prevalent. The severity of tangle constricted the main taproot(s) or sinkers, leading to potential fracture zones (*see* Fig. 3). Only five out of the 180 trees had no tangle at all; six trees had the maximum score of 6.

FIG. 3—Dissected root system, showing effect of root tangle at planting.

Quantitative assessment of taproots

Although trees from the shallow-ripped Treatments (2) and (5) had taproot lengths significantly longer than those from the unripped treatment, the differences were only of the order of 10–16 cm (Table 3). Taproots from the deep-ripped treatments were 50–60 cm longer than those from the shallow-ripped treatment. The pattern of taproot diameter closely followed that of taproot length, with taproots from the unripped treatment having the smallest diameter and those from the deep-ripped treatments the largest.

TABLE 3–Mean length and diameter (± s.d.) of taproots for the 30 trees in each treatment

Treatment	Length (cm)	Diameter (cm)
1*	48 (± 12) a†	4.0 (± 1.2) a
2	59 (± 11) b	4.8 (± 1.7) bc
3	107 (± 13) d	5.5 (± 1.8) c
4	99 (± 18) c	5.4 (± 1.3) bc
5	63 (± 8) b	4.7 (± 1.3) ab
6	112 (± 15) d	5.3 (± 1.3) bc

* *See* Table 1 for explanation of treatments.

† For each factor, means with the same alphabetical letter are not significantly different($p<0.05$).

Primary sinkers were analysed separately from secondary sinkers. The number of primary sinkers did not differ significantly between treatments. However, roots from the shallow-ripped Treatments (2) and (5) had more secondary sinkers (six and five respectively) than those from unripped ground (three) ($p \leq 0.05$).

Quantitative assessment of lateral roots

Numbers of large lateral roots ($\geq$ 1 cm diameter) were significantly different for treatments in the north-west, north-east, and south-west quadrants, but not for treatments in the south-east quadrant (Table 4). Numbers of roots within each treatment were similar for the north-west, south-east, and south-west quadrants, but roots were fewer in the north-east quadrant. These differences were most marked in the single-ripped Treatments (2) and (3). In each quadrant, the greatest number of lateral roots were found on trees from the unripped Treatment (1).

Lateral root diameters were generally greater on trees planted in the shallow-ripped treatments, with generally smaller roots on trees planted in the deep-ripped and unripped treatments (Table 4). However, because of the greater number of roots on trees in the unripped treatment, total cross-sectional area of lateral roots was generally greater in Treatment (1) than for any other treatment.

With the exception of Treatments (2) and (3), differences in lateral root diameter between quadrants were small but significant ($p \leq 0.05$). In all treatments the larger roots (diameter and total cross-sectional area) were in the south-east quadrant in the lee of the north-west wind, and the smallest were in the north-east quadrant.

There were few secondary laterals (< 1 cm) on roots from the unripped treatment (Table 5), and numbers were similar in all quadrants. Root alignment occurred along the ripped zone in Treatments (2) and (3), but secondary laterals were more evenly distributed in the cross-ripped Treatments (4), (5), and (6). Total cross-sectional area of secondary lateral roots (< 1 cm) was generally least in the north-east quadrant, irrespective of site treatment, and greatest in the south-west quadrant in the cross-ripped treatments.

Relationship Between Root Development, Incidence of Butt Sweep, and Severity of Stem Deflection

The severity of root deformation, as expressed by the Menzies' Taproot Score, decreased significantly as taproot length increased for all treatments ($r^2 = 0.87$). Further regressions were determined for taproot length on incidence of butt sweep and severity of stem deviation. Although regression values were weak ($r^2 = 0.18$ and $r^2 = 0.28$, respectively) both were significant.

DISCUSSION

Earlier studies in Canterbury showed clearly that most root development was confined to the ripped zone. Therefore it was argued convincingly that ripping should be aligned into the north-west wind to improve root development in the windward zone. The added advantage of improving permeability to enhance airflow through the stand during north-west storms was also seen as good justification for aligning the rows of trees into the north-west. However, in more recent times it has been well documented that early stand stability is mostly determined by good taproot development (Mason 1985). This is not dependent on rip orientation but on ripping to an appropriate depth and on using quality seedlings capable of taproot regeneration after planting (Washbourn 1984).

In our study shallow ripping to a nominal depth of 45 cm increased taproot length by only 10–15 cm over unripped treatments. Deep ripping allowed the taproot to develop to far greater depths (up to 153 cm). Shallow ripping failed to penetrate the

TABLE 4–Mean numbers, diameters, and total cross-sectional areas of primary laterals

Treatment	Quadrant											
	NW			SE			NE			SW		
	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)
1*	3.9 b†	27.4 ab	53.3 a	4.0 a	31.4 a	71.9 a	3.1 a	29.9 cd	38.3 a	3.9 bc	27.9 b	60.7 a
2	4.4 c	30.5 c	56.7 a	3.7 b	30.7 ab	52.8 c	2.8 b	28.9 ac	38.4 a	4.2 b	29.2 a	53.7 c
3	3.4 a	29.2 c	41.8 c	3.9 ab	29.2 b	46.0 d	2.3 c	27.1 c	27.9 c	3.7 c	29.2 a	44.3 e
4	3.4 a	28.9 bc	46.8 b	4.1 a	32.3 a	61.5 b	2.9 ab	27.9 bc	31.1 d	3.7 c	30.4 a	53.6 c
5	4.0 bc	28.3 bc	46.4 b	4.1 a	31.9 a	59.0 b	3.0 a	27.2 c	34.8 b	5.0 a	28.2 b	56.5 b
6	4.1 bc	26.3 a	40.1 c	3.9 ab	29.9 ab	51.8 c	3.0 a	26.5 d	33.7 c	4.0 b	27.8 b	47.9 d

**See* Table 1 for explanation of treatments.
† Within each quadrant, means with the same letter are not significantly different (t-test, $p < 0.05$).

TABLE 5–Mean numbers, diameters, and total cross-sectional areas of secondary laterals

Treatment	Quadrant											
	NW			SE			NE			SW		
	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)	No.	Diam. (cm)	Area (cm^2)
1*	6 c†	15.7 c	14.8 d	8 c	19.0 a	28.9 c	6 d	15.3 a	14.0 e	7 c	17.5 b	21.4 d
2	21 a	17.4 b	63.6 a	21 a	18.1 a	61.8 a	14 ab	15.5 a	33.6 a	14 b	15.9 c	35.4 c
3	23 a	16.3 c	61.1 a	22 a	16.7 bc	61.4 a	10 c	15.9 a	25.3 c	13 b	16.5 bc	35.4 c
4	13 b	13.7 d	17.8 d	14 b	14.0 d	27.4 c	10 c	14.4 b	20.7 d	13 b	16.3 c	34.5 c
5	13 b	18.5 a	44.5 bc	17 ab	16.9 b	48.6 b	13 b	15.0 ab	29.2 b	14 b	20.8 a	60.6 a
6	16 b	17.3 b	47.9 b	18 ab	15.9 c	45.5 b	15 a	15.5 a	36.0 a	18 a	16.8 bc	50.8 b

* *See* Table 1 for explanation of treatments.
† Within each quadrant, means with the same letter are not significantly different (t-test, $p < 0.05$).

full depth of the hard pan of tightly packed gravel, and it appeared that the taproots could not penetrate any further. Soil probing of the deep-ripped areas indicated soil disturbance to a depth of at least 100 cm. Average taproot length exceeded this depth, suggesting that the hard pan had been penetrated by ripping. The upper boundary of the pan is very distinct at about 30 cm, but its lower limit is difficult to define. Depths of 45–70 cm below the soil surface have been claimed, but the depth probably varies greatly, even over quite short distances.

Butt sweep and sinuosity were more prevalent in all the blocks receiving a ripping treatment before planting, and were greatest for trees planted in the blocks ripped in one direction only. The blocks ripped in two directions had a high incidence of butt sweep, but resultant stem deviation was no more severe than for those trees in the unripped treatment. Taproot deformation and stem deflection were both significantly correlated with depth of taproot penetration, i.e., the deeper the taproot the less its degree of deformation and the straighter the stem of the tree. This confirms previous work (Mason 1985) where the taproot deformation score was correlated with the incidence of toppling, which results in butt sweep.

Primary lateral root development was more balanced (with little tendency to follow the line of the rip) than that shown in the earlier studies at Eyrewell Forest (Potter & Lamb 1974) and at Balmoral Forest (Washbourn 1984). However, more primary lateral roots were produced in the leeward (south-east and south-west) quadrants, in contrast to Somerville's (1979) finding that heavier lateral development occurred on the windward (north-west) quadrant. The other prevailing wind at Eyrewell Forest is from the south-west, and lateral root development in this quadrant exceeded that in the leeward quadrant (north-east). It is possible that this reflects a "rain shadow". Most rain falls during south-westerly storms, and as a young stand develops a natural "rain shadow" forms on the north-east side of the tree, possibly limiting root growth there. Other investigations have shown that while fine roots may grow into such zones, they often die so that larger lateral roots never develop (Kimmins 1987; Sutton 1969). Local climatic factors at Eyrewell Forest also inhibit early vigorous root growth (Washbourn 1984). Soil temperatures at 10 cm, which can exceed 30°C, coupled with lack of adequate soil moisture, resulted in root death in the first season after planting. In subsequent years no death was recorded, but root growth and vigour decreased as soil moisture became depleted in the spring, and soil temperatures and plant moisture stress increased. More recent studies in a 4-year-old *P. radiata* stand have also noted that pasture and tree root growth is less in the north-east quadrant where soil moisture is depleted than in the south-west and south-east quadrants where soil moisture is adequate (P. Clinton, pers. comm.).

For forests on the Canterbury Plains, therefore, rows may be best orientated in a south-west to north-east direction to promote a more even moisture distribution and the development of more balanced root systems in young stands. To ensure stability and to reduce stem deviation caused by lack of taproot development, and to promote a balanced lateral root system, all sites with a shallow hard pan should be deep-ripped to maximise soil disturbance.

ACKNOWLEDGMENTS

The staff of the (then) N.Z. Forest Service at Eyrewell Forest greatly assisted with this work. Rick Denton and Jessica Hunter measured the root systems and Brian Cosslett took the photographs. M. Menzies, R. Washbourn, D. Franklin, and J. Orwin advised on the presentation of this work.

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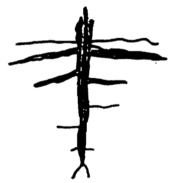
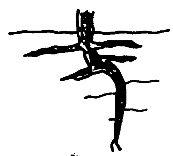
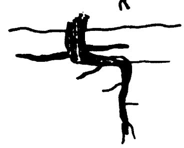
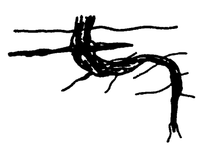
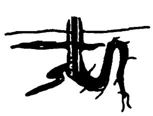
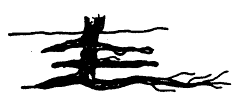
APPENDIX 1

MENZIES' SCORING SYSTEM FOR EVALUATING ROOT SYSTEMS

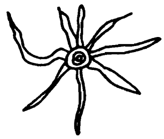
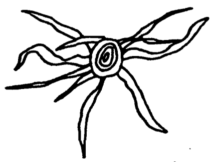
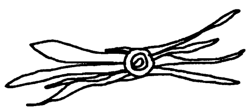
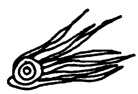
1. Menzies' Taproot Score (maximum 10)

The score ranges from 0, for a good root system, to 10, for a poor root system

SCORE	DIAGRAM	DESCRIPTION
0		Strong, dominant, well developed taproot
2		Stunted, slightly malformed, but still a definite taproot
4		Taproot distinctly hooked
6		Taproot quite badly hooked, but downward development still present
8		Taproot severely deformed into two or more fracture zones, but growth still downward
10		Taproot does not come below a horizontal plane, or no taproot at all. Subtract one point for each strong sinker present.

2. Menzies' Lateral Score (maximum 10)

The score ranges from 0, for a good root system, to 10, for a poor root system

SCORE	DIAGRAM	DESCRIPTION
0		Laterals on all four sides
2		Laterals in three quadrants
4		Laterals in two adjacent quadrants
6		Laterals in two opposite quadrants
8		Laterals in one quadrant
10		No significant laterals in any quadrant

3. Tangled roots (maximum 6)
0–6 scale subjectively assessed.