ROOT DEVELOPMENT OF RADIATA PINE IN THE GRAVEL SOILS OF EYREWELL FOREST, CANTERBURY

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SYNOPSIS

Because of the importance of tree stability against strong north-west winds at Eyrewell Forest, Canterbury, a study was carried out to assess comparative root development of two- to four-year-old Pinus radiata trees grown from natural regeneration, direct seeding, hand-planted nursery stock, and machine-planted nursery stock. Ground ripping was carried out before sowing and planting because the compacted nature of the gravel soils was thought to inhibit root development. Analysis of root growth showed root alignment along the ripped lines. This alignment was most pronounced in the machine-planted trees and less pronounced in those hand planted and those grown from direct seeding.

INTRODUCTION

Eyrewell Forest stands on a gravel plain which rises uniformly from 66 m above sea level in the east, to 210 m in the west and, apart from a few low terraces and minor surface undulations, is markedly devoid of relief. The underlying material consists of beds of recent greywacke gravels and stones mixed with sand or silt to a depth of at least 60 m. The soils, which are yellow-grey earths, mainly Lismore with small areas of Eyre, are very stony silt loams, affording only a meagre roothold for trees, whilst the compacted gravels beneath form a barrier to root development.

A feature of the spring and summer weather in the area is the dry north-west winds followed by a south-west change accompanied by rain and again followed by north-west winds, often with high temperatures.

Much has been written about wind damage to forests in Canterbury and methods of minimizing it have been put forward. Prior (1959) advocated the use of species less susceptible than Pinus radiata to windthrow, such as Pseudotsuga menziesii, Pinus nigra (laricio) and P. ponderosa, and strict silvicultural tending and carefully planned clearfelling. Wendelken (1955) came to the conclusion that, because of the superficial rooting systems, no degree of standing stability could be achieved through current silvicultural methods of pruning and thinning. He considered that a measure of stability could be brought about by the development of a group

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structure in stands which would lead to interlocking root systems. The trees would then, in effect, hold each other up.

Papesch (1969) has found that there is a high degree of correlation between stem volume and resisting bending moment. Age also has a significant effect on the resistance of the tree. The ideal, therefore, would be to grow a relatively short tree with a big diameter in as short a time as possible.

DEFINITION OF A WIND-FIRM TREE

A wind-firm tree should be one that will stand up to the strong north-west and south-west winds experienced in Eyrewell Forest, especially in spring. It is clear that, for achieving wind firmness, it is necessary for the tree to produce a well-balanced root system, and because of distortion at time of planting it may not be possible for planted trees to do so. Papesch also found that there appeared to be little difference in resistance between wet and dry soils. The holding power of a tree seems to lie in the number and size of the roots. In the compacted soils the sinkers do not appear to have much effect as they almost invariably lift out whole, along with the gravel and stones bound up with them. The long laterals, stretching along the ground close to the surface, are the main anchors of the tree. Another fact brought to light by Papesch’s investigations was that once the maximum load was achieved the tension roots failed either by shearing with the soil or fracturing as a pure tensile failure, after which the resistance of the tree to wind forces was seriously reduced.

BLOWDOWN AND RE-ESTABLISHMENT AT EYREWELL FOREST

In 1964, gales resulted in the virtual destruction of Eyrewell Forest, and a large operation had to be mounted to recover the estimated 1 200 000 m³ of windblown timber before it deteriorated.

Wendelken’s (1966) paper on the early history and management of the forest described root development and stand structure and outlined proposals for future management, including ripping of the gravel soils to increase root penetration and improve tree stability.

By 1966 a large enough area had been salvaged and clear-felled to make it possible to start re-estabishment on the completely new layout advocated by Wilson (1966) in the working plan for the five-year period 1966-1971. This plan was the basis for some of the ideas set out in Wendelken’s 1966 paper, modified to fit in with financial and other considerations. Two of the long-term proposals in the working plan were:

(1) Development of a productive forest designed to minimize risk of damage by wind or fire.

(2) Re-estabishment of the forest with a normal age-class distribution and maximum dispersion of areas of similar age class.
To accomplish these it was necessary to abandon the established compartment layout and road pattern. The system prescribed in the working plan required establishment to be carried out in strips 120 m wide, oriented with the long axes approximately at right-angles to the north-west winds. It was possible to do this because, in the course of site preparation, all logging slash was heaped into straight windrows 60 m apart and not more than 10 m wide, aligned from north-east to south-west.

During windrowing all stumps were removed. Before planting was carried out the ground was shallow ripped parallel to the windrows to a minimum depth of 30 cm at intervals of 2.4 or 2.7 m corresponding to the planting spacing. In addition to this a proportion of the area was ripped to a depth of 1.2 m at right-angles to the windrows and at a spacing of about 10 m. This deep ripping was purely experimental. Windrows are usually burned in the autumn before planting.

The trees were then planted in the rips, either by hand or by machine, using 1½/0 nursery stock, a task made comparatively cheap and easy because of the high standard of site preparation.

**NEED FOR RIPPING**

Shallow ripping—*i.e.* to a minimum depth of 30 cm—is credited with helping to achieve high survival of planted stock (never below 90%). Generally the ripping is to a depth of about 45 to 50 cm, and its effects are:

— Disturbance of the compacted gravel layers.
— Collection of moisture from rain and dew and its direction into the soil.
— Prevention of evaporation of moisture from soil.
— Possible shelter from wind in the first year.

The effects of deep ripping are as yet unknown. The zone of shattering of the compacted gravels extends to about 40 cm on either side of the shallow rip and to about 80 cm on either side of the deep rip.

After moderate spring gales in 1971 small numbers of two-, three-, and four-year-old trees were found to have toppled to some degree. The toppling was confined to individual trees and, although widespread, conformed to no obvious pattern. This discovery raised questions concerning the methods of establishment, and doubts as to the wisdom of ripping the ground, which tends to promote root growth in one plane. Detailed investigation of root systems was started in the summer of 1971-2.

Trials conducted in 1966 and 1967 into restocking by direct seeding showed that acceptable germination and survival could be obtained, so in 1968 an area of 58 ha was established by hand-sowing three or four seeds in spots at intervals of 1.8 m in the ripped lines. The seedlings were thinned in 1970 to one per spot. By late 1971 the 1968 direct-seeded trees compared favourably in height with the 1969 planted nursery stock.
Several areas throughout the forest carry natural regeneration of comparable height, which came up after site preparation.

METHOD OF INVESTIGATION

Sample trees for the investigation were taken from: the area sown in 1968; 1½/0 stock, both hand planted and machine planted in 1969; and natural regeneration two to three years old.

Twelve trees of each class from the central five rows within a 30 m wide windrowed strip were selected at random. Shelter and ashbed effects were thus avoided by taking trees from the middle of the strip.

For each tree the height and diameter over bark (d.o.b.) at 15 cm above ground level were recorded and then the north point and ground level were marked on the stem. The soil was washed away from the trees by high pressure water jet, and after all soil had been removed the roots were measured and recorded, according to their distribution in four sectors.

They were then photographed from two positions to show geographic distribution and depth of penetration (Fig. 1).

The first sector, as can be seen in Fig. 1, is 45° either side of the ripped line and is labelled the north sector. The remaining sectors are south, east and west. (Note that E and W are reversed on the photograph, because the root system is being looked at from below.) Measurements recorded for each sector were:

Taproots—presence or absence of taproot. Total length to 2 mm o.b. (over bark); length to 5 mm o.b.; diameter at half length (i.e., from the point of origin to the point where diameter was 2 mm o.b.).

Lateral roots—number of laterals and length to 2 mm o.b.

Sikers—length of largest sinker to 2 mm diameter o.b. Diameter o.b. midway between origin and 2 mm diameter o.b.

Five of the twelve trees of each category were then oven-dried at 80°C for 48 hours and weighed to find the root to shoot ratios. The roots in each sector were weighed separately.

Examples of root systems from the different methods of establishment are shown in Figs. 1 to 4. The arrow on the figures showing the profile of the tree points to the depth of the taproot. The scales are in centimetres.

ANALYSIS OF RESULTS

The measurements were analysed on the University of Canterbury computer.

Alignment of Roots

The results of the analysis show fairly clearly that establishment method affects root alignment.

Machine planting produces considerable alignment of lateral roots along the direction of rip. Direct seeding and hand planting tend to give some alignment. A two-way analysis of variance gives a highly significant difference for alignment.
Number of Laterals

A one-way analysis of variance showed no difference in the numbers of lateral roots for the planting method. Duncan’s Multiple Range test gives a marginal range difference between machine and hand planting for N-S alignment only (range difference 1.97).

Total Length of Laterals

The total length of laterals was analysed, a t-test being used, and the conclusion drawn was that growth, and therefore penetration of laterals, was not affected significantly for direct seeding and hand planting.

Taproot Numbers

The numbers of taproots for the four establishment methods were:

<table>
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<th>Direct Seeded</th>
<th>Natural Regeneration</th>
<th>Machine Planted</th>
<th>Hand Planted</th>
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<tr>
<td>Taproot</td>
<td>12</td>
<td>12</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>No taproot</td>
<td></td>
<td></td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

Taproot Length

The effect of planting method on taproot development was also analysed. In a one-way analysis of variance there was a significant difference in taproot development with planting method, when zero taproot lengths were ignored. When zero taproot lengths are included, the difference is significantly higher.

Development of Taproots

From an analysis to determine whether taproots would develop from all treatments, using the \( \chi^2 \) test, the conclusion is that direct seeding will give better taproot development than either hand or machine planting.

EXTENSION OF THE INVESTIGATION

Since only one age group was sampled in the investigation, further studies were made in the summer of 1972-3. Sample trees were taken from the area planted in 1966 after the following site preparation:

1. Deep ripping, with deep rips in two directions at right-angles to each other.
2. Deep ripping at right-angles to the windrows—i.e., in a north-west to south-east direction.
3. No ripping, but close to lines of shallow ripping.
4. Shallow ripping parallel to windows.
5. Deep ripping parallel to windrows.
6. No ripping.
Fig. 1: Direct seeded, shallow ripped. Distribution of roots seen from below (top) and depth of root penetration (bottom).
Fig. 2: Natural regeneration, no site preparation. Distribution of roots seen from below (top) and depth of root penetration (bottom).
Fig. 3: Hand planted, shallow ripped. Distribution of roots seen from below (top) and depth of root penetration (bottom).
Fig. 4: Machine planted, shallow ripped. Distribution of roots seen from below (top) and depth of root penetration (bottom).
In treatments 1, 2, 4 and 5 the 2/0 stock was machine planted, and in 3 and 6 hand planted 1/0 stock was used. Twelve trees were taken from each treatment and measured in the same way as in the previous investigation. The excavation was a slow and laborious process.

The analysis has not added much to the information gained from the first trial, partly because there were no direct-seeded trees with which to compare the planted trees. There was a significant alignment of roots in a north-south direction (at 5% level only) in treatments 3 and 4. In the east-west direction treatment 1 had the least tendency to alignment and treatment 4 had the highest. There was no significant alignment in treatments 3 and 4.

Only in treatment 1 was there any significant difference in numbers of lateral roots for root alignment, but at the 5% level only.

Ripping treatments did not affect sinker development, but the depth of sinker penetration showed significant differences between treatments, treatment 4 having least penetration and 5 the greatest.

Taproot development was rare.

**DISCUSSION**

The practical significance of the analyses is that direct seeding gives a tree with a well developed taproot and a moderately well distributed lateral root system. If natural regeneration is ignored, direct seeding gives the least weight of oven-dry material, but the best root to shoot ratio. There is a degree of alignment of the lateral roots along the rip in all treatments, but in no instance did it appear that the periphery of the ripped area had been reached. Machine planting gives the greatest oven-dry weight of material, an adverse root to shoot ratio and a lateral root system aligned along the rip. Hand planting results in a product midway between direct seeding and machine planting. Natural regeneration has not been fully analysed, but it seems that, although root development is fair, growth is slower than in the other methods.

It would be reasonable to assume that ranking for wind firmness would be, in descending order:

Direct seeded—because of taproot and spread of laterals.

Hand planted—because of slightly better alignment of laterals than machine planted and lower shoot to root ratio.

Machine planted—because of poor alignment of laterals, lack of taproot and high shoot to root ratio.

The limitations of this study are:

1. It was conducted on very young stock, equivalent to 3 to 3½ years from germination.
2. Only one direction of ripping was tested.
3. Trees planted in unripped ground were not represented.
4. No deep ripped areas were tested.
Visual assessment of the trees showed there was a considerable similarity between the root systems of direct seeding and natural regeneration and between hand and machine planting, in direction and form. The two former produced well balanced systems with laterals developing along the full length of the taproots, whilst the latter two gave clubbed systems with the roots bunched up and crisscrossed. Often they were lacking in taproots. The machine planting produced an alignment of roots along the rip markedly in excess of other methods. The forward movement of the planting machine appears to have resulted in the whole root system being swept back. When the trees are planted too deeply there is a tendency for a hockey stick root to develop, as shown in Fig. 5.

All the direct seeding and natural regeneration had well developed taproots, but 66% of that natural regeneration showed some form of distortion of these roots, either kinking as they were forced past large stones or being compressed between stones. On the other hand, all roots on the direct-seeded stock showed little or no compression, and taproots were generally vertical, since soil compaction following ripping is slow enough to allow good root penetration and development.

FURTHER INVESTIGATION

Future work will seek to follow the development of root systems of older trees and of trees planted in deep rips. It will be possible to make comparisons of systems developed by trees planted in unripped ground, on shallow and deep ripped ground, and on ground that has been ripped in both directions. Speed of machine planting has been reduced in an effort to improve root distribution of the trees.
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REFERENCES