

# ROOT DEVELOPMENT AND WIND-FIRMNESS ON THE SHALLOW GRAVEL SOILS OF THE CANTERBURY PLAINS

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## *Summary*

*Strong winds and shallow soils are the critical factors in the development of forests on the gravel plains of Canterbury. Studies of rooting systems in trees at Eyrewell Forest show that all roots are superficial and that, with employment of orthodox silvicultural systems, no degree of stand stability is likely to be achieved. Interlocking of root systems through development of a group structure in the stands does, however, offer some promise of greater wind-firmness.*

## INTRODUCTION

The plains of Canterbury were naturally treeless. Efforts to establish forests have been continuous since the date of European settlement with varying degrees of success. The principal adverse factor has been wind. There has been loss, through wind-throw, irrespective of the species planted, stand treatment, or stand structure. Wind-throw has usually been experienced whenever the canopy has reached a height of 55 ft., this being particularly true for stands planted on light grave soils, e.g., Eyrewell and Balmoral Forests. Pertinent factors of site, for Eyrewell Forest, are detailed below.

## *Climate*

Rainfall over the forest appears adequate for tree growth, varying from 25 in. in the east to over 35 in. in the west; but evaporation from a free water surface is high and may reach 75 per cent. of the total annual rainfall. At certain periods of the year, notably early summer, evaporation might even exceed precipitation. Effective precipitation is therefore considerably lower than the rainfall figures would indicate.

Prevailing winds blow from the north-west. These winds may reach gale force at any time of the year, particularly at the equinoxes. They are warm fohn-like winds, strong and gusty. Surface speeds up to 45 m.p.h. are common, velocities to 55 m.p.h. are less usual though not rare, while even greater velocities are occasionally experienced. These winds are channelled on to the plains through narrow mountain gorges, and the steeply rising foothills on either side of the gorges offer only limited and local protection to the plain-land. The merging of downward flowing winds in the lee of the foothills with the air streams issuing from the gorges gives rise to winds of great turbulence and power. Eyrewell Forest lies on the edge of such a zone of turbulence, along the north bank of the broad Waimakariri River, 12 miles from the Waimakariri Gorge.

### Soils

Soils are shallow. They may consist of almost pure gravel, though there are local superficial layers of silty sand or occasional flat lenses of admixed gravel and silty sand. All materials have been water laid and there is very considerable variation from place to place in the forest with respect to gravel size. Over the whole forest, however, sub-soils are compacted. At a depth of 18 ins. this compaction is so pronounced that downward penetration of roots is effectively prevented. Locally the larger stones are iron encrusted and the finer soil particles may be cemented into crumb-like masses, but this cementing is seldom well developed; its presence or absence makes no apparent difference with respect to root development or root penetration.

### Soil Moisture

The water table lies at considerable depth, usually at depths greater than 100 ft., and the forest crop must therefore be dependent upon that portion of the rainfall that reaches and is stored in the soil. Following rain, there is typically a steep moisture gradient from wet above to dry beneath. Even after heavy and prolonged rainfall, water does not readily penetrate to depth, but lies on or near to the surface until lost through evaporation or transpiration.

It will be appreciated that, at such times, the upper soil horizons can become saturated and the soil mass, under these conditions, offers little resistance to the movement of tree roots. With tree movement in strong winds, the roots work toward the surface. Downward trending root laterals near the tree butt are torn or sheared off, and eventually main laterals are exposed and lie along the surface. Where most of the roots are exposed in this manner, there is little development of a basal plate of soil and roots with consequent loss of windfirmness. There may even develop actual cavities beneath the principal roots where the coarser gravels do not work downward into the positions vacated by upward movement of roots through the soil. These features are aggravated by the complete absence, for *Pinus radiata* at Eyrewell, of any penetration of roots to significant depth.

### ROOTING HABIT OF *P. RADIATA* AT EYREWELL

On many soils in New Zealand, *Pinus radiata* is a deep rooting species and is windfirm; but in Eyrewell Forest deep penetration of roots is impossible consequent on the compaction of the sub-soils already mentioned.

In all even-aged stands in Eyrewell Forest, and under most conditions of stand density, root development follows the same pattern. In early life a tap root penetrates downward for 12-18 ins., one or more laterals performing this function for planted stock. The tap root tapers rapidly but becomes clubbed shaped and distorted when further downward penetration is prevented by a large stone or compacted gravel. Gross distortion follows and growth ceases. Several

series of laterals are then given off, with the principal laterals near the surface. Fewer and smaller laterals are given off near the primary root tip.

Initially, these laterals grow radially outwards; in the case of naturally regenerated stands they are disposed regularly like the spokes of a wheel. With planted stock, especially following spade planting, the radial habit may be neither so pronounced nor regular but develops over one or more growing seasons. This difference between planted and self-sown trees does not, however, appear to have any bearing upon subsequent wind-firmness. Along the length of the laterals peg-roots then extend downward, but meet the same fate as the primary roots. They become club-shaped and distorted and growth soon ceases. The overall pattern, therefore, is for development of a very shallow, wide-spread rooting system with numerous small peg-roots.

As soon as the extending tips of lateral roots from adjoining trees become opposed to one another, at distances of one to two feet, the direction of growth changes. This appears to be due to exhaustion of the soil moisture reserves of the zone of soil between the opposed root tips, this zone being drawn upon by the feeding roots of both laterals. But whatever the explanation, the mechanism operates whenever laterals become opposed after a certain stage in their development. In Eyrewell Forest, in the spacing trials set out in 1950, the phenomenon can be demonstrated in stands at 6, 8 and 10 ft. spacing. In the case of the 16 and 20 ft. spacing trials root tips of adjacent trees are not yet in opposition.

The net effect is that the radial roots continue to grow in a swinging curve, tracing out a form of ellipsoid arc. The root plate is effectively restricted; tensile stresses imposed on such curved root systems have an additional fulcrum on which to gain purchase in comparison with roots for which stresses are in line with the root axes. These factors contribute, therefore, to the weakness of the rooting system; one by reducing the extent of the root plate and the mass of the soil held by the roots, and the other by permitting failure under relatively weak loads.

Similar conditions obtain whenever a root, growing radially outwards, passes an established root lying across its path. Though the feeding tip of the larger root may be several feet distant there will usually be secondary or tertiary feeding roots disposed along its length. Deflection from a direction at right angles to the older root to a direction parallel with it, or through an even greater angle, is usual.

Roots may, however, cross under certain circumstances. A small lateral may cross over a large non-feeding prop root near the butt of a tree and, of greater importance, there may be a free interlacing of lateral roots in young dense stands. For this latter phenomenon two reasons might be advanced.

In the first place it is possible that the joint demand made by such young laterals on available soil moisture might be insufficient

for the setting up of the soil moisture gradients responsible for root deflection; and in the second place the early closure of the stand canopy must lead to greater conservation of available soil moisture. But whatever the reason, in these young dense stands the lateral roots do interlace, and it is in this that there appear possibilities for the development of greater wind-firmness. Before amplifying this statement, however, one or two other matters might be considered.

### EFFECTS OF THINNING, ESPACEMENT, ETC.

Where trees are so widely spaced that lateral roots from adjoining trees do not meet, it is obvious that root plates will be more extensive and that there should be a greater degree of wind-firmness. But with this wide espacement timber quality suffers. Considerations of timber quality would indicate that initial espacement should not exceed ten to twelve ft. At these distances the peculiarities of root plate development, already described, are pronounced. Can thinning techniques lead to development of greater wind-firmness in the stands?

With thinning, some roots are eliminated and the vacated soil is open to occupation by laterals from residual stems. But by the time thinning is undertaken these laterals will already be growing in the swinging curve already described. Thinning cannot straighten these nor overcome their inherent weakness. The vacated soil will, in time, be occupied by secondary and tertiary roots, but in the meantime the aboveground portions of the trees will be exposed to wind action to a greater extent than ever before. It would not appear, from study of thinned stands in Eyrewell Forest, that thinning has at any time imparted a greater degree of wind-firmness to the stands, irrespective of intensity of thinning or of the stage of stand development reached at the time of thinning.

There has been irregular wind-throw in all stands regardless of espacement, thinned and unthinned. As a consequence, the stands are losing their even-aged, evenly spaced character. The gaps, created by wind-throw, have been filled, to a varying degree, by regeneration. The tendency throughout the forest is, therefore, toward development of a group even aged structure. (Fig. 1.)

In the regeneration groups spacing is very variable, ranging from a few inches to several feet, the groups being separated from one another by blank areas where regeneration has failed through the presence of heavy slash, competition with grasses, and so on. It is within these young dense groups that the interlacing of roots is found. When the roots of an entire group are exposed it is found that all roots and rootlets criss-cross in bewildering fashion, and the root mass extends for considerable distances into the group surround, an entirely different root pattern to that found in the regularly spaced older stands. (Fig 2.)

### ADVANTAGES OF GROUP STRUCTURE

With this interlacing it is clear that there must be greater wind-



*Figure 1.*  
*Regeneration in groups, seven years old, central trees dominant.*



*Figure 2.*  
*Rooting system of trees in group (Fig. 1). Note interlacing.*

firmness. Before a tree can be up-rooted, its roots must be torn from the interlocking mass; or an entire group of trees must be overthrown, requiring exertion of a force many times that required for the up-rooting of a single tree.

Further study of the groups indicates that fears, commonly expressed, to the effect that growth of above-ground portions of the trees will be unsatisfactory, are ill-founded. The oldest groups studied, nine years old, show that the general rule is for one or more stems central to the group to assume dominance. One central stem, or stems, gains a lead in height growth early in the life of the group, and this lead steadily increases. In one specific case the lead at two years of age was no more than a few inches but, at eight years, this had increased to 42 ins. In general, the more stems there are in a group, the less is the chance of a branchy marginal tree assuming dominance. Fears that timber quality, with group structure, will be low therefore appear unfounded.

Conversion of even aged, regularly spaced stands to group even aged stands thus appears to be one possible solution to the problem of wind-throw for stands established on these light gravel plains. Nothing will fully overcome the inherent disabilities of the soils but, with a group even aged structure, it should be possible to grow better forests than those now on the ground. Experimental work to test the hypothesis is now under way and will be extended. This work covers tests of group size, espacement within groups (5-25 stems per group with stems spaced from 2-4ft. apart), and also admixture of species by groups (*Pinus laricio* groups planted in wind damaged *Pinus radiata* stands). Time alone will tell the full story, but the technique does offer some promise. With present techniques the wind is in full control of the forest, not the forester.