Coarse root system characteristics and toppling of clonal and seedling trees of *Pinus radiata* on Canterbury Plains

Madan GAUTAM, Don J. MEAD, Chris FRAMPTON and Scott X. CHANG

Abstract

Qualitative characteristics of coarse root components, i.e., core distortion, lateral root distribution and dominance of vertical roots, and the relationship between tree root characteristics and toppling were studied using Mason's root core, Menzies' lateral root, and modified Menzies' vertical root scoring methods on three planting material types. Two of the planting material types, i.e., clonal tissue cultured plantlets (clone 3, Set 11/8, and clone 4, Set 38/9) and the other seedling (a GF 14 seedlot of "850" selections) trees of *Pinus radiata* D. Don. The trees were grown with either lucerne, ryegrass/clover or no understory in the Lincoln University agroforestry experiment on the Canterbury Plains.

Understorey competition had no significant effect on any of the coarse root characteristics studied. Core distortion was least severe with clone 3 trees compared with clone 4 and seedling trees. Clonal trees had more straight and dominant vertical roots whereas seedling trees had more forked and weakly developed vertical roots. The topped trees frequently had moderately distorted root cores and weakly developed vertical roots; however, analysis using the cumulative logit model showed that tree stability was significantly related to planting material type but, within each planting material type, was not related to core distortion or dominance of vertical root. Therefore, in addition to coarse root characteristics, other factors specific to each of the planting material types not tested in this study have affected the tendency of the trees to topple.

Key words: Mason's core distortion; Menzies' lateral root score; modified Menzies' vertical root score

Introduction

In New Zealand, more than 20% of radiata pine (*Pinus radiata* D. Don) trees topple in the first five years after planted (Anonymous, 1987). The strong winds of Canterbury make newly established radiata pine trees in plantations and agroforestry blocks very prone to toppling. Toppling appears to be associated with poor tap root development, such as distorted vertical roots, or bent or hooked tap roots and lateral root distribution in radiata pine (Wendelken, 1955; Chavasse, 1978; Mason, 1985; Mason, 1992); the most stable trees have a straight, undistorted taproot and sinker roots (Mason, 1985). The stability of trees decreases as spiralling of lateral roots around the root core (core distortion) increases. Toppling may be associated with genetic variation in coarse root characteristics as coarse root development was found to be genetically controlled in other tree species (Heilman, 1993). Toppling may also be associated with planting techniques (Mason, 1985), site fertility and initial growth rates (Chavasse, 1969), soil moisture content (Chavasse, 1978), weed competition (Mason, 1992), wind speed, and crown architecture (crown porosity) of the trees. Improved stability of rooted cuttings over seedlings against toppling has also been reported (Coxe, 1998; Menzies *et al.*, 1991).

The incidence of toppling of two-year-old radiata pine trees in the Lincoln University agroforestry experiment, established on a fertile and wind-prone site, was assessed by Mead *et al.* (1993) after the strong southwest gale in 1991. The percentage of trees topped was influenced by both understory treatments and planting material types (Mead *et al.*, 1993). Trees of one of the clones (clone 3) in ryegrass/clover and lucerne treatments had less than 5% topped whereas 56% to 68% of seedling trees were topped in the first two years. Likewise, less than 10% of clone 3 and 87% of seedling trees were topped in the no understorey treatments. However, the mechanisms for these differences between the clonal and seedling trees were not reported. The objectives of this study were to investigate: (a) whether tissue-cultured clonal and seedling trees have different coarse root characteristics, (b) whether understory pasture treatments alter the coarse root system structure of trees, and (c) whether tree root system characteristics are related to toppling.

Site and Methods

The overall design of the Lincoln University agroforestry experiment has been described in detail by Mead *et al.* (1993). Briefly, the experiment is a split-plot design with understory treatments in the main plots and planting material types in the sub-plots. Within the six main plot treatments bare ground (no understorey), yatsyn perennial ryegrass mixed with clovers, and WL320 lucerne were used for this study. Of the five planting material types used in the experiment two tissue cultured clones, clone 3 (Set 11/8, full sib of "875" clones 7 x 292) and clone 4 (Set 38/9, half sib of "850" clone 55), and seedlings ("850" open pollinated seed of GF 14) were selected as they cover the range in toppling (Mead *et al.*, 1993). The tissue-cultured plantlets of the clonal material and the seedlings were all bare-rooted. The main plots were replicated in three blocks.

The plots were established in 1990 with an initial stocking of 1000 stems per hectare (sp). Before planting the tree rows were ripped to a depth of 60 cm. Care was taken in planting to reduce the effects of planter differences by blocking out this factor. No pruning had been carried out before this study was completed and the stand density was 800 sp h after one thinning in 1992. The area is subject to strong moist S.W. winds in the
winter and spring and dry N.W. winds in the equinoaxes. Fifty-four trees (two trees per replication block) from each planting material type by understory treatment combination were destructively sampled in July 1993. The randomly selected trees for destructive sampling covered the range of diameters in the plot. The mean height and diameter at breast height of the sampled trees were 2.82 and 0.051 meters, respectively. The 54 trees were identified as topped or non-topped at age 2 using plot records. Before the destructive sampling, the east-west orientation of the trees was marked on the stump, and then the trees were excavated to study the characteristics of their coarse root components (i.e., root core distortion and lateral and vertical root distribution) in relation to topping incidence. The root system was excavated as much as possible; often the lateral roots were traced out more than 1 meter from the main root core.

Once the stumps were brought into the laboratory they were placed upside down in the hole of a cardboard box's base and were oriented as in the field. The base of the box was divided into four quadrants: north, south, east and west following Balneaves and de la Mare (1989). The east-west line was the ripline of the trees on the ground.

Table 1. The modified Menzies' tap root scoring system

<table>
<thead>
<tr>
<th>Case</th>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>Strong, dominant, single leading vertical tap root which originates from the root core.</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>As above in case (1), but where there are 2 to 3 leading vertical roots each of these not forked or hooked</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>As above in case (1) or (2) but the leading vertical roots distinctly forked</td>
</tr>
<tr>
<td>4</td>
<td>6</td>
<td>As above in case (1) or (2) but the leading vertical roots hooked</td>
</tr>
<tr>
<td>5</td>
<td>8</td>
<td>As above in case (1) or (2) but the leading vertical roots both forked and hooked</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>Vertical roots which do not originate from the root core and are weak, not well developed, may be many in numbers, generally more than 2.</td>
</tr>
</tbody>
</table>

Table 2. The effect of planting material types on coarse root characteristics, together with the probability (p value) of a significant difference between planting material types.

<table>
<thead>
<tr>
<th>Planting Material Type</th>
<th>Clone 3</th>
<th>Clone 4</th>
<th>Seedlings</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Menzies' lateral root score</td>
<td>2.0 (0, 4)</td>
<td>4.0 (2, 6)</td>
<td>2.0 (1, 4)</td>
<td>0.319</td>
</tr>
<tr>
<td>Modified Menzies' VR** score</td>
<td>2.0 (2, 4)</td>
<td>4.5 (2, 10)</td>
<td>10.0 (4, 10)</td>
<td>0.015</td>
</tr>
<tr>
<td>Mason's root core distortion</td>
<td>0.0 (0, 0)</td>
<td>1.0 (1, 1)</td>
<td>2.0 (1, 2)</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

*: The numbers in brackets are the first and third quartiles of the respective median. Menzies' lateral root scores range from 0 to 10 and Mason's root core distortion scores range from 0 to 4 for good to poor root systems, respectively. **: VR = vertical root

Menzies' lateral root score, modified Menzies' vertical root score, or Mason's root core distortion score (data not shown). Menzies' lateral root score was also affected by planting material types (p = 0.319, Table 2), however, the median of the modified Menzies' vertical root score was significantly different (p = 0.015) between the planting material types (Table 2). Pair-wise tests showed that the difference was only between clone 3 and seedlings (p<0.001). The median of Mason's root core distortion score was significantly different (p<0.001) between the planting material types (Table 2). Pair-wise tests indicated that the seedling and clone 4 trees had their coarse root systems more severely distorted than that of clone 3 (p<0.001). The root core of clone 3 trees virtually showed no distortion.

Table 3. The relationship between coarse root system character score and topping, together with the probability (p value) of a significant difference between topped and non-topped trees.

<table>
<thead>
<tr>
<th>Scoring Type</th>
<th>Median score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topped (n = 20)</td>
<td>Non-topped (n = 34)</td>
</tr>
<tr>
<td>Menzies' lateral root score</td>
<td>3.0 (2, 4)*</td>
</tr>
<tr>
<td>Modified Menzies' VR** score</td>
<td>10.0 (2, 10)</td>
</tr>
<tr>
<td>Mason's root core distortion</td>
<td>1.0 (1, 2)</td>
</tr>
</tbody>
</table>

* and **: See Table 2.

Results
The Kruskal-Wallis test showed that understory treatments had no significant effect on the median of
and Menzies’ vertical root score as predictors were not significant (p > 0.05) in the model, whereas the planting material variables were significant (p < 0.05, Table 4). This seemed to indicate that the frequency of topping is related to the genetic characteristics, stock type and physiological age of the planting material rather than the coarse root characteristics per se.

Discussion

This study showed that the degree of spiraling of lateral roots and the straightness, forking and dominance of vertical roots were significantly influenced by planting material types. Fewer clonal trees had distorted cores or weakly developed vertical roots than the seedling trees. In this respect, the tendency for the seedling trees to topple seemed to be explained by the characteristics of the coarse root systems. This statement is, of course, based on unstratified (between topped and non-topped trees) data for each planting material type and the result was different based on stratified data (discussed elsewhere in this paper). Similar results were found by Mason (1985) and is being confirmed by on-going studies by Ingleby Coxie in Northland (I. Coxie, pers. comm.).

The lateral roots predominantly spread into three adjacent, i.e., the east, west, and south, quadrants from the tree stem. This pattern could have been influenced by the rippin on the east-west direction before the trees were planted (Mead et al., 1993), and the south side being cooler and moister than the north side (Yunusa et al., 1995).

The vertical and lateral root characteristics and core distortion of the trees studied were not altered by understorey treatments (data not shown). This did not explain the findings of Mead et al. (1993) where they found that, in the same trial at age two, a significantly greater percentage of the trees were topped in the bare ground plots than in the plots sown with pasture species. It is likely that the effect of understorey treatment on topping at age two was through the effect of pasture competition on tree size (Mason, 1985) and shoot/root ratio. Trees in the bare ground plots were larger and tended to have a greater shoot/root ratio than those in the plots with pasture understorey; thus trees in the bare ground plots were more prone to topping.

We found that the topped trees had significantly higher core distortion and less developed vertical roots than the non-topped trees (Table 3); elsewhere, it has also been demonstrated that the arrangement of lateral and vertical roots played a significant role in tree stability against topping (Burdett, 1979; Mason, 1985; Mason and Cullen, 1986). However, the difference in the core distortion median values of 0 (non-topped) and 1 (toppled) is very small. This weak association probably led to the lack of strong associations between coarse root characteristics and topping occurrence rate within each planting material type, as discussed below.

The strong association between the planting material type and topping rate indicates that it is necessary to evaluate coarse root characteristic and topping for each planting material type. However, due to unbalanced data, it was not possible to use normal tests to explain the relationship between core distortion or dominance of vertical roots of a particular planting material type in relation to topping indices. Instead, a cumulative logit model was constructed for the data. It showed that topping was not (p > 0.05) associated with root core distortion or dominance of vertical roots within each planting material type (Table 4) but was strongly related to planting material types. This result was somewhat contradictory with those of Mason (1985). Further studies using larger sample sizes are needed to confirm these results.

Table 4. Parameters for the cumulative logit model that relates planting material types, Mason’s root core distortion score and the modified Menzies’ vertical root score to tree stability against topping. The model was highly significant (p < 0.001). A p value of less than 0.05 indicates a significant contribution of the predictor to the logit model.

<table>
<thead>
<tr>
<th>Predictor used in models</th>
<th>Coefficient</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.2568</td>
<td>0.807</td>
</tr>
<tr>
<td>Core distortion score</td>
<td>-0.0191</td>
<td>0.341</td>
</tr>
<tr>
<td>Vertical score</td>
<td>-0.0191</td>
<td>0.850</td>
</tr>
<tr>
<td>Clone 3</td>
<td>3.7387</td>
<td>0.010</td>
</tr>
<tr>
<td>Clone 4</td>
<td>1.9387</td>
<td>0.019</td>
</tr>
</tbody>
</table>

The strong association of topping with the planting material types may also be explained by the differences in crown architecture of the trees established from the different planting material types which were not directly tested in this study. Another study in this agroforestry experiment using the same sample trees has shown that foliage density was significantly lower in clone 3 than in seedlings and clone 3 had longer internodes than the seedlings (Bandara, 1997). Aerial photographic images of the agroforestry site showed a higher porosity in clonal tree crowns than in the seedling trees (E. Mason, 1998, pers. comm.). Wind or other forces acting on the aerial portion of a tree will impart less tendency for the trees to oscillate or rotate on their axis by allowing more wind to pass through the canopy of porous crowns than that of dense ones (Burdett, 1979).

In summary, results from this study showed that the main differences in coarse root characteristics were between the clonal and seedling trees. Understorey pasture species had little effect on root system properties.
evaluated 3 years after planting, and within each planting material type, root system characteristics were not related to toppling. The selection of planting material types with a stable character against toppling is important for areas prone to strong winds.

Acknowledgements

The authors would like to thank Dr. Peter Clinton, Forest Research, Christchurch and Dr. Euan Mason, School of Forestry, Canterbury University, for discussion on topics related to this study. Two anonymous reviewers provided very helpful comments.

References


---

New Zealand Journal of Forestry

Compelling Reasons to Read New Zealand Journal of Forestry

PREMIER PUBLICATION
As the publication of the New Zealand Institute of Forestry, the New Zealand Journal of Forestry is the premier publication of professional forestry in New Zealand.

BROAD LINKS
Membership of the New Zealand Institute of Forestry spans a broad range of corporate, government and private forestry professionals who are active in all aspects of the forest sector, from forest establishment, management and marketing to wood product development and trade.

PROFESSIONAL DEVELOPMENT
Readers of the Journal are able to keep up-to-date with key debates and the latest technology developments in forestry, in turn aiding their professional development.

PEER REVIEW
Have your papers published under internationally accepted conditions of "peer review" by respected members of the NZ Institute of Forestry.

FORESTRY TRADE ON OFFER
The Foretrade section offers suppliers an opportunity to make services and equipment available in a classified advertising section.

---

NZ JOURNAL OF FORESTRY, MAY 1999

18