Influence of Silviculture and Seedlot on Crown Structure and Stem Wood Properties:
Shellocks FR121/11

J.C. Grace

Report No. 139 ***December 2006***

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NOTE : Confidential to participants of the Stand Growth Modelling Cooperative.
: This is an unpublished report and must not be cited as a literature reference.

EXECUTIVE SUMMARY

Twenty trees were destructively sampled in FR121/11, Shellocks, to provide a dataset for the Stand Growth Modelling Cooperative's Internal Stem Modelling theme. The theme objective is: "To develop and refine a tree-level model of internal wood properties with respect to stem shape, and crown architecture as well as site, stocking and planting stock".

Two trees of average DBH were selected from each of 10 plots that covered both a multinodal and a long internode seedlot, and a range of silvicultural treatments. In total there were eight GF25 trees and twelve long internode trees.

Branching characteristics were measured in the field, and wood samples measured using SilviScan.

The crown structure of the GF25 seedlot compared to the GF13 (LI25) seedlot can be summarised as follows:

- More branch clusters in total
- More clusters per annual shoot
- Less branches per cluster
- More stem cones per cluster
- Similar amount of foliage on a branch in relation to its diameter
- Similar amount of branch basal area in a tree (for a given silvicultural treatment)

Discs were cut immediately below selected branch clusters and images taken. Qualitatively, it appeared that compression wood was more likely to be visible on discs immediately below clusters with large branches.

SilviScan data were available from a bark-bark strip (2 pith-bark strips) through any obvious compression wood for 5 different positions within a tree. These data were examined for general trends within a tree, and for differences between the two pith-bark strips.

The wood properties available from SilviScan were density, microfibril angle and modulus of elasticity.

- For a given stem position, density tends to increase with increasing tree age
- For a given tree age density tends to be higher near the base of the tree
- For a given stem position MFA tends to decrease with increasing tree age
- For a given tree age MFA tends to be higher near the base of the tree
- MOE tends to increase with increasing stem age
- There are no obvious trends with stem position

Differences between trees with respect to either seedlot or silvicultural treatment were minor.

Differences between wood properties for the two samples from a given growth ring were examined. There was little variation in the values of the differences between the two seedlots, however there was an indication that the differences in density were more variable at lower stockings.

FR121/11 was on a poor quality site. This study should be repeated using other trials from the FR121 series to determine whether the above results are consistent across sites.

Influence of silviculture and seedlot on crown structure and stem wood properties: Shellocks FR121/11

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INTRODUCTION

Stand Growth Modelling Cooperative Trial FR121/11 was planted at Shellocks (Canterbury Plains) in 1991, and the establishment of the trial is described in SGMC Report No. 84. The trial was considered to represent a "low site index" in the Canterbury Region. The treatments and seedlots present are summarised in Table 1. The trial layout is shown in Appendix 1.

Table 1. Treatments in Trial FR121/11.

	Silviculture					Planting stock				
Trt	Pruning	Stocking (stems/ha)		Thinning		Seedlings				
	Crown remaining	Initial	Final	MCH (m)	Ratio	GF6 (88/102)	GF14 (88/105)	GF16 (88/201)	GF25 (90/294)	GF13 (LI25) (89/15)
1	4m	250	100	6.2	2.5:1	•			•	•
2	"	500	200	6.2	2.5:1	•	•	•	•	•
3	"	1000	400	6.2	2.5:1	•			•	•
4	Unpruned	500	200	6.2	2.5:1	•			•	•
5	"	1000	400	6.2	2.5:1	•			•	•
6	"	1000	600	6.2	1.7:1	•			•	•
7	"	1000	1000	-	1:1	•	•	•	•	•

Of particular note is that the trial contained *Acacia dealbata* regeneration. These were removed at same time as the PSPs were established and thinned (at age 8 years).

At the July 2005 Stand Growth Modelling Cooperative meeting, approval was given to destructively sample 20 trees (10 trees from each of the GF25 and GF13/LI25 seedlots) to examine the influence of silviculture and seedlot on crown structure and stem wood properties. Specific aims of the data collection were to address the following questions:

- Do GF25 and GF13 (LI25) seedlots have a different crown structure?
- Do branch diameters within a cluster visually influence the variability of wood properties both circumferentially around a disc, and with distance from cluster within the internode below?
- Can 'average' radial growth and wood properties be predicted from crown structure?
- Are the above relationships additionally influenced by stocking and or seedlot?

In addition this dataset will contribute to the data pool for the internal stem modelling theme, which has the objective:

> To develop and refine a tree-level model of internal wood properties with respect to stem shape, and crown architecture as well as site, stocking and planting stock.

SAMPLE TREE SELECTION

The initial plan was to sample 2 trees from the GF25 seedlot and 2 trees from the GF13 (LI25) seedlot for each of treatments 1, 2, 3, 5 and 6 (see Table 1). An initial examination of tree DBH data indicated that the GF25 plot in treatment 3 (Plot 11/13) had been influenced by its position at the end of the row (see Appendix 1). This plot was replaced by the GF13 (LI25) plot from treatment 4, giving 4 GF25 plots and 6 GF13 (LI25) plots.

The two trees from each plot were selected in the following manner:

The plot mean DBH was calculated from the 2004 PSP remeasurement. All trees within 1 cm of the respective plot mean DBH were listed. In August 2005 all trees were assessed for their suitability for destructive sampling (i.e. no damage, broken top etc). Two trees of acceptable stem form were selected from each plot, such that the mean DBH for these two trees retained the order of plot mean DBH across the selected plots (see Table 2). It had been considered whether the sample trees should be selected on the basis of a third variable as well (e.g. position of the tree in the plot; standing tree sonics). This idea was abandoned, since there were only a very limited number of trees that satisfied the DBH and stem form criteria.

Table 2. List of selected sample trees

Treatment	Plot Number	Seedlot	Plot: mean DBH (cm) 2004	Sample Trees: mean DBH (cm) 2004	Plot minus Sample mean DBH (cm)	DBH (cm) Tree 1	DBH (cm) Tree 2	PSP Number Tree1	PSP Number Tree2
1	2	LI	24.7	24.6	0.1	24.2	25.0	40	8
1	3	GF25	25.7	25.8	-0.1	25.7	25.9	34	30
2	7	LI	24.9	24.8	0.1	24.7	24.8	2	13
2	8	GF25	23.5	23.2	0.3	23.1	23.3	3	18
3	10	LI	21.2	21.1	0.1	21.0	21.1	25	62
4	14	LI	25.9	26.3	-0.4	25.8	26.8	9	20
5	16	LI	25.2	25.1	0.1	25.1	25.1	5	70
5	17	GF25	25	24.9	0.1	24.7	25.1	16	5
6	18	LI	22	22.1	-0.1	22.0	22.1	23	42
6	19	GF25	21.3	21.6	-0.3	21.6	21.6	18	49

SUMMARY OF DATA COLLECTION

For each tree, the aim was to collect the following data:

- TreeD image to provide a permanent record of stem form.
- Data on location and weight of foliage for 6 branches per tree. These were a large and a small diameter branch from each of the lower, middle and upper third of the crown. These data are needed for modelling the relationship between crown structure and stem radial growth and wood density.

- Position (height) of each branch cluster, and number of stem growth rings below and above the cluster. These data are needed for estimating and modelling the number of branch clusters in an annual shoot.
- Diameter and azimuth location of each branch and stem cone in each cluster. These data are needed for modelling crown structure.
- Discs were cut immediately below branch clusters, imaged and then saved for SilviScan analysis at the following positions:
  - One third way down live crown (below sample branches from upper third of crown)
  - Two thirds way down live crown (below sample branch samples from middle third of crown)
  - Base of live crown (varies between 1.0 and 4.0 m)
  - DBH (approx. 1.4 m)
  - Base of tree (approx. 0.5 m)
- Additional discs were cut immediately below the branch clusters closest to 4 m, 6 m, 8 m etc to top of tree, and imaged.
- Discs were cut at approx. 5 cm intervals and imaged for two internodes per tree. These internodes were selected to be below the small-sized and the large-sized branch cluster containing the foliage sample branches in the lower third of the crown.
- Data on growth of the branches that were measured for foliage amount.

DATA ANALYSIS – BRANCHING CHARACTERISTICS

a. Foliage relationships

The branches were cut from the stem leaving a stub of approximately 1 cm. The stub was to enable branch growth to be measured retrospectively from planed samples. The ability to collect these data is compromised if the branch is cut flush with the stem.

The variables recorded were:

- Diameter of the branch at end closest to the stem
- Distance to the balance point of the branch with foliage present
- Weight of the branch with foliage present
- Distance to the balance point of the branch with foliage removed
- Weight of the branch with foliage removed

The weights were obtained using a 25kg balance that measured to 100 gm accuracy.

These data will be used in a separate study to investigate whether ring width and ring average wood density can be predicted from crown structure.

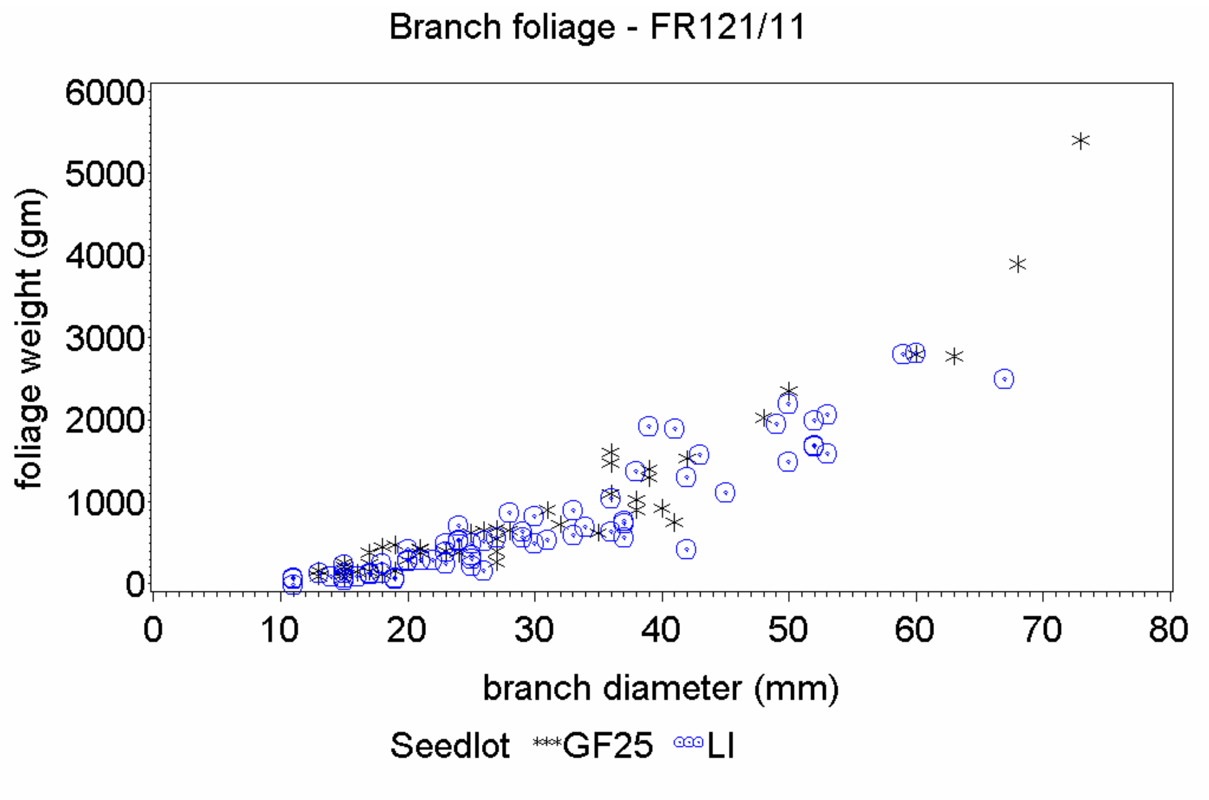
The relationship between foliage weight and branch diameter (Figure 1) was examined to investigate whether it was influenced by treatment or seedlot. Visually there is little difference between the two seedlots. Equation 1 was fitted to the data using the SAS NLIN procedure; and then the residuals were examined using the SAS GLM procedure. This analysis indicated that the relationship was not influenced by treatment, but that the relationship varied slightly with seedlot. When the analysis was repeating using only branches with diameters smaller than 47 mm, the relationship was not influenced by seedlot.

$$fw = a \times (bd)^b \quad (1)$$

where:

fw is the weight of foliage on the branch
bd is the branch diameter
a, b are model parameters

Figure 1. Relationship between foliage weight and branch diameter.



b. Number of branch clusters

The variables recorded were:

- Height of base of branch cluster
- Height to top of branch cluster
- Number of stem growth rings below the branch cluster
- Number of stem growth rings above the branch cluster

Counting the stem growth rings at this site was very difficult due to the presence of false rings. To minimise errors, one person was assigned the task of counting rings.

The number of branch clusters on a tree did not vary with final crop stocking, however, on average, trees from the GF25 seedlot had 11 more branch clusters than the long internode seedlot (Figure 2).

The difference between the two seedlots results from the fact that the GF25 seedlot tended to form more branch clusters in a given year compared to the long internode seedlot (Figure 3).

Figure 3 also shows that the number of branch clusters in an annual shoot tended to increase with increasing tree age, as has been observed in other branching datasets.

Figure 2. Number of branch clusters on individual trees

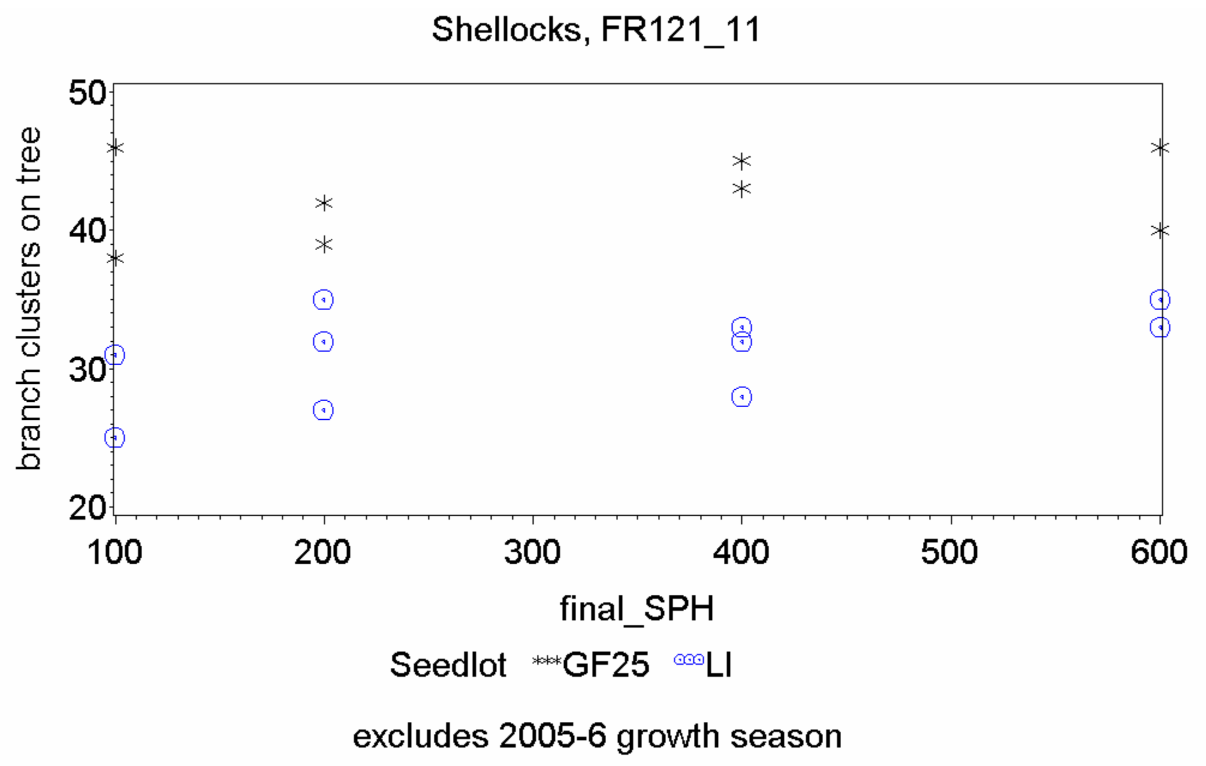
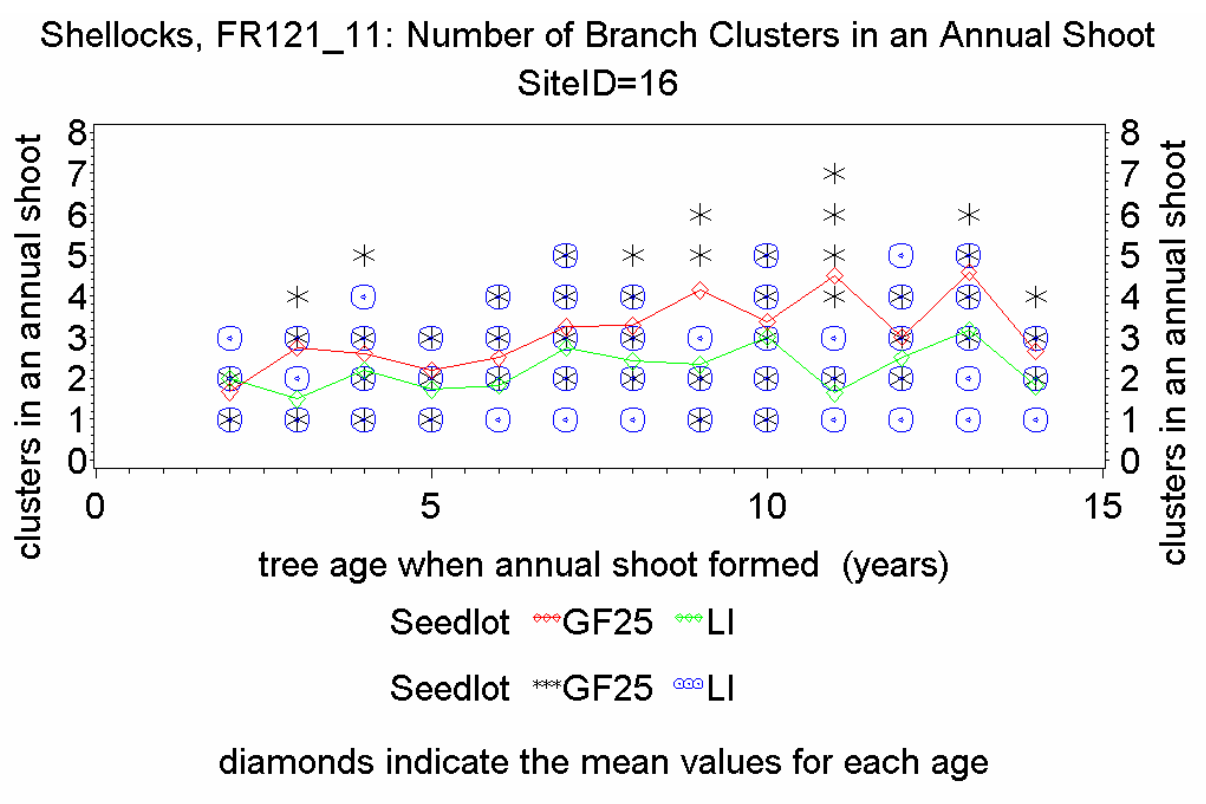


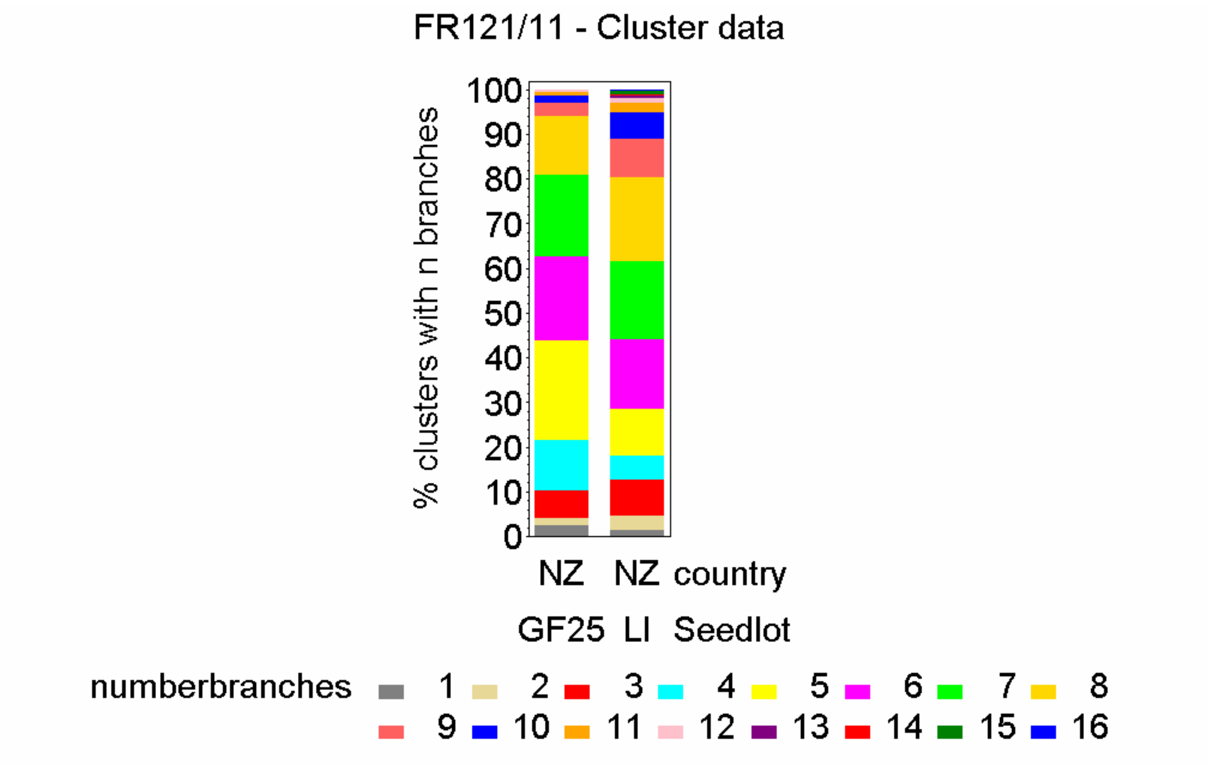
Figure 3. Number of branch clusters in an annual shoot.



c. Number of branches in a cluster

The number of branches in a cluster varied between the GF25 and Long Internode seedlots (Figure 4). Approximately 20% of the Long Internode clusters measured had 9 or more branches whereas only approximately 5% of the GF25 clusters had 9 or more branches.

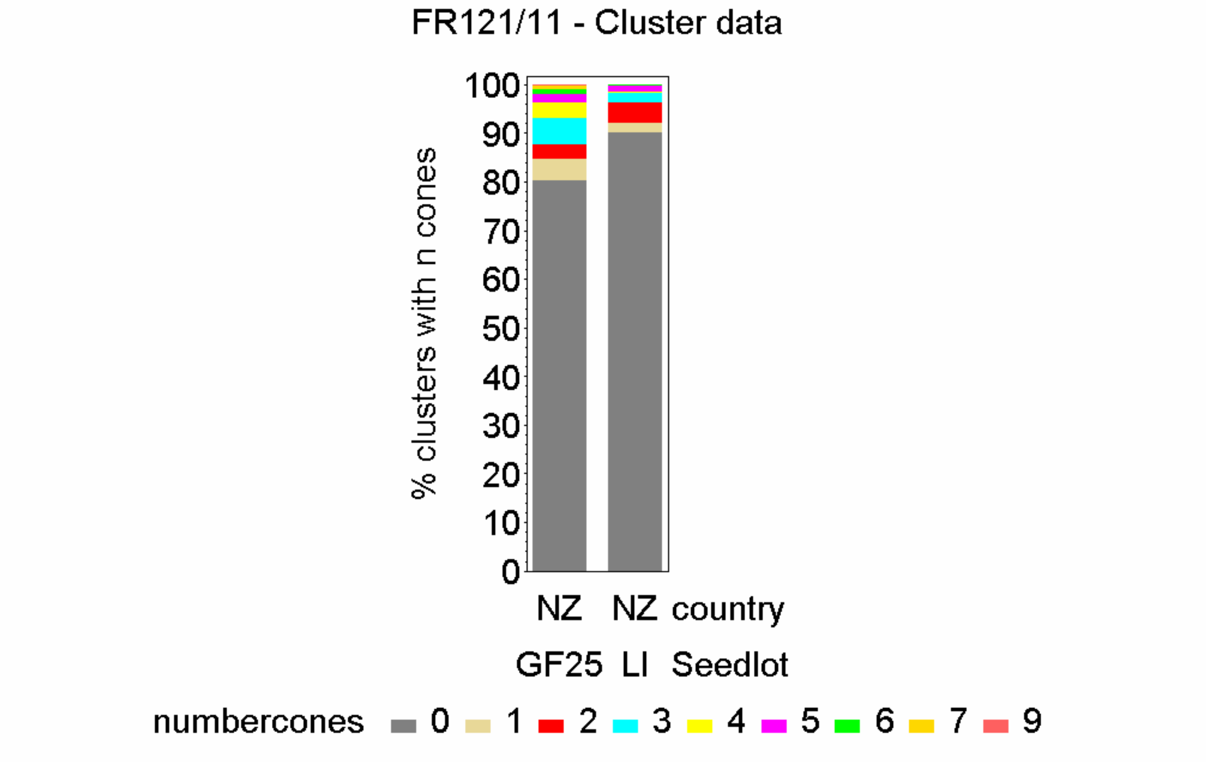
Figure 4. Variation in the number of branches in a cluster with seedlot.



d. Number of stem cones in a cluster

Approximately 20% of the GF25 clusters measured contained stem cones, whereas only approximately 10% of the Long Internode clusters contained stem cones (Figure 5). A possible reason for the difference is the variation in the number of branch clusters in an annual shoot. Stem cones are unlikely to be formed in the last cluster of an annual shoot.

Figure 5. Variation in number of stem cones in a branch cluster with seedlot



e. Branch diameter

The diameter of the largest branch in each cluster was retained. For each tree the mean (Figure 6) and the maximum (Figure 7) of these diameters was calculated. These figures illustrate that for a common treatment, branches from the GF25 seedlot may be slightly smaller than those from the long internode seedlot.

Figure 6. Mean branch diameter (averaged over largest branch in each cluster).

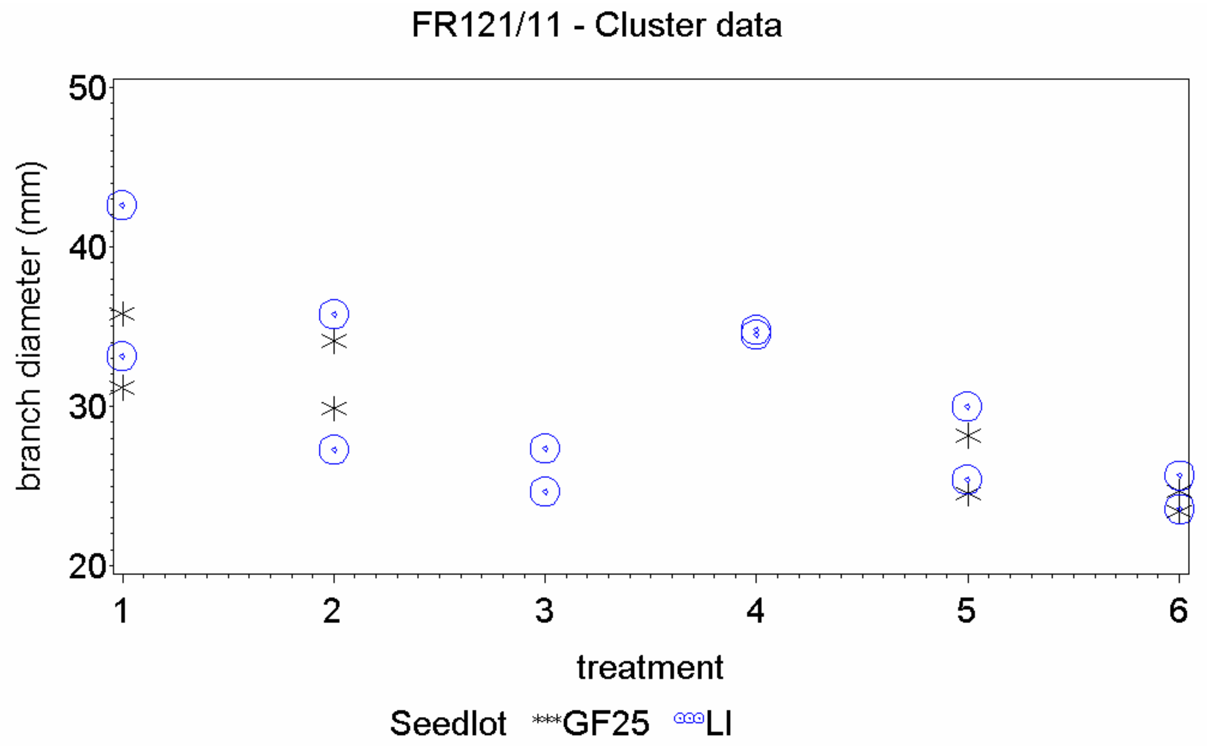
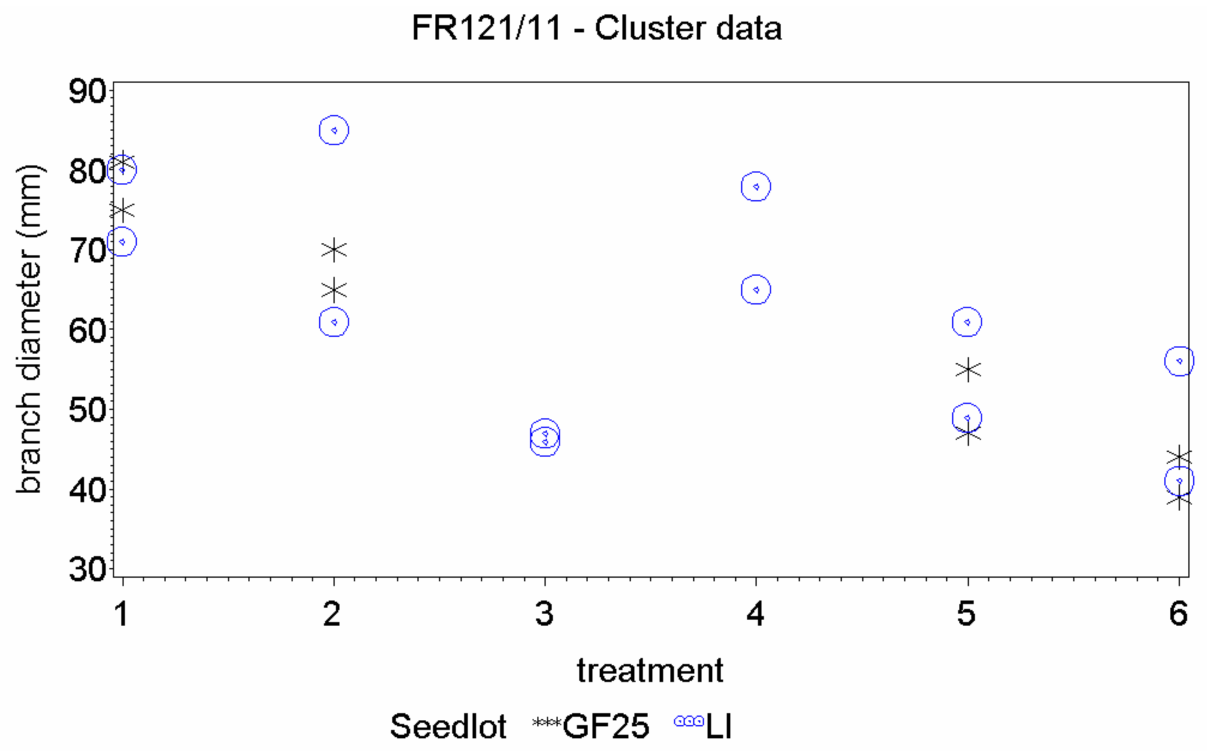


Figure 7. Maximum branch diameter for each tree.



f. Branch basal area for individual trees

The basal area for an individual branch was calculated as:

$$\pi \times d^2 / 4.0$$

where:

d is the measured branch diameter

These values were summed to give the branch basal area for each tree.

Individual tree branch basal area was lower for trees at higher final crop stockings (Figure 8). At final crop stocking of 200 and 400 stems/ha, the unpruned trees (treatments 4 and 5) had a higher branch basal area than the pruned trees (treatments 2 and 3). For a given final crop stocking and treatment, there were no consistent trends between the two seedlots (Figure 9). Much of the differences between individual trees, could be attributed to tree DBH (Figure 10). This is not surprising since it is branches that support the foliage required for tree growth. Interestingly there were no obvious differences between the two seedlots.

Figure 8. Variation in branch basal area for individual trees with respect to final crop stocking and treatment.

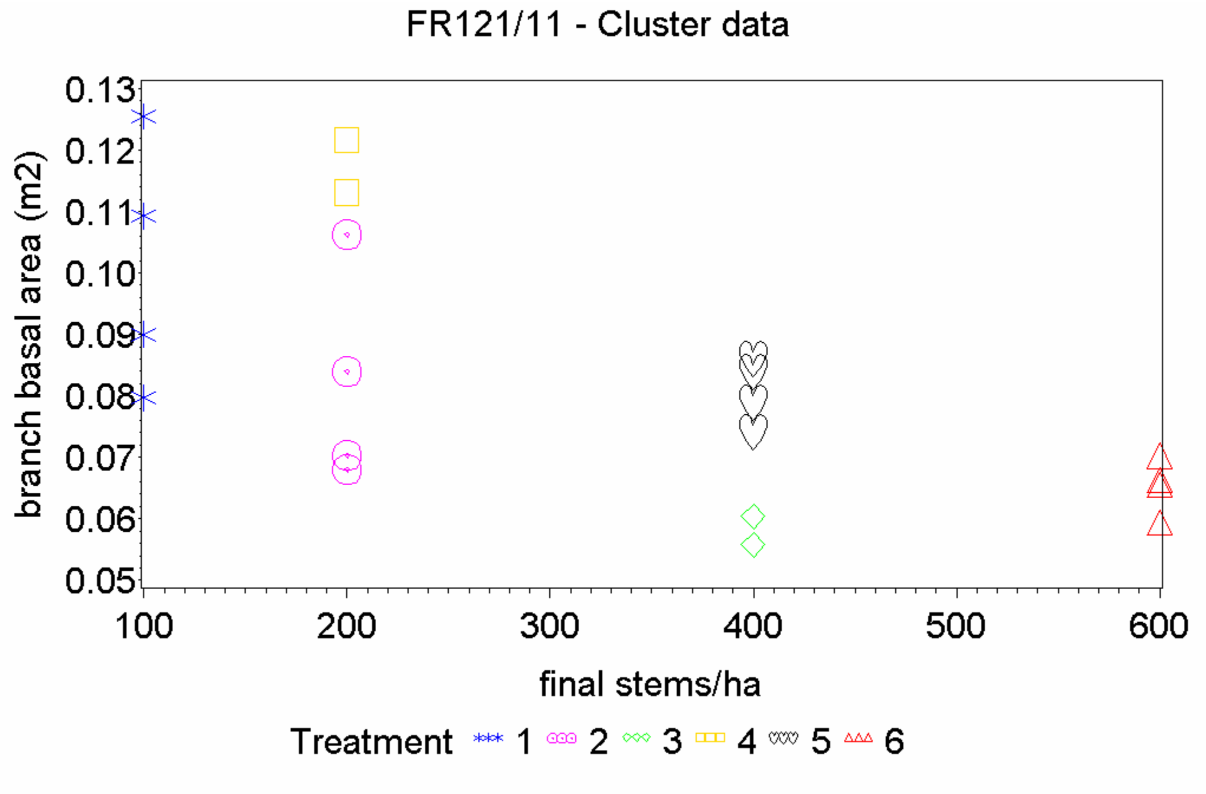


Figure 9. Variation in branch basal area for individual trees with respect to final crop stocking and seedlot.

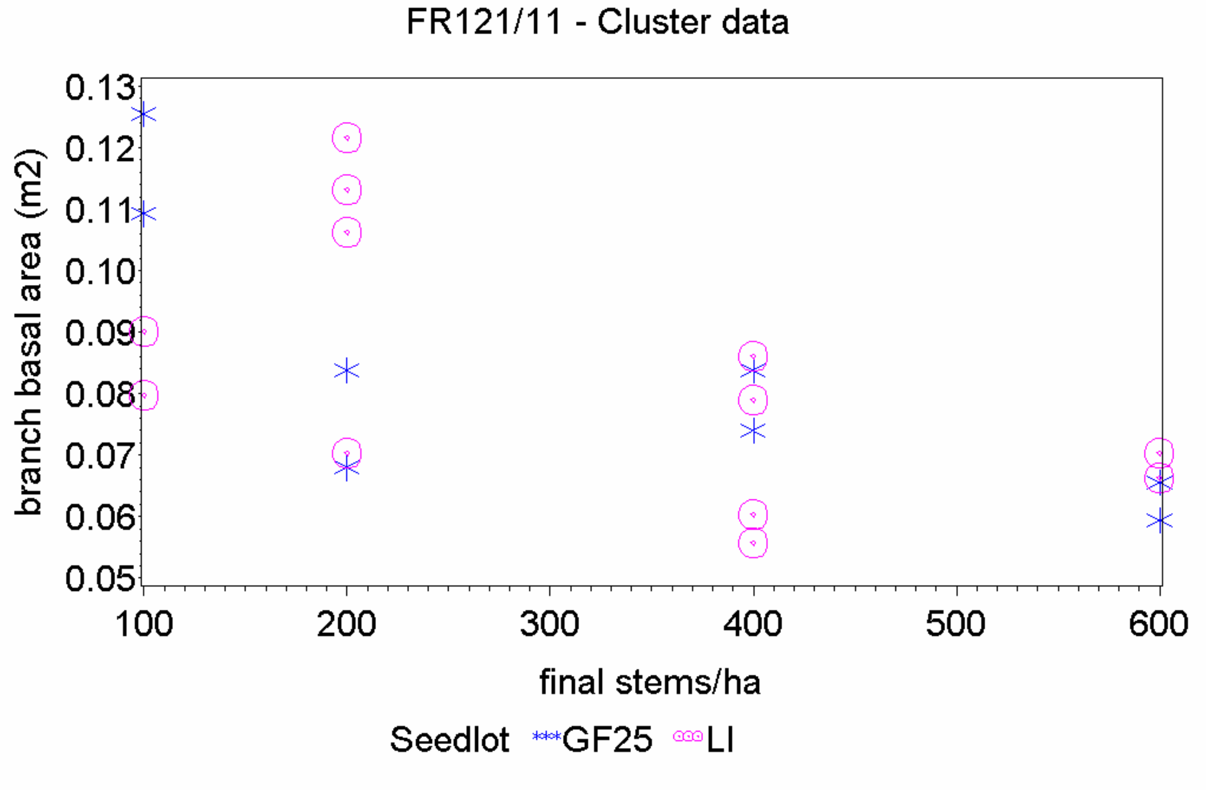
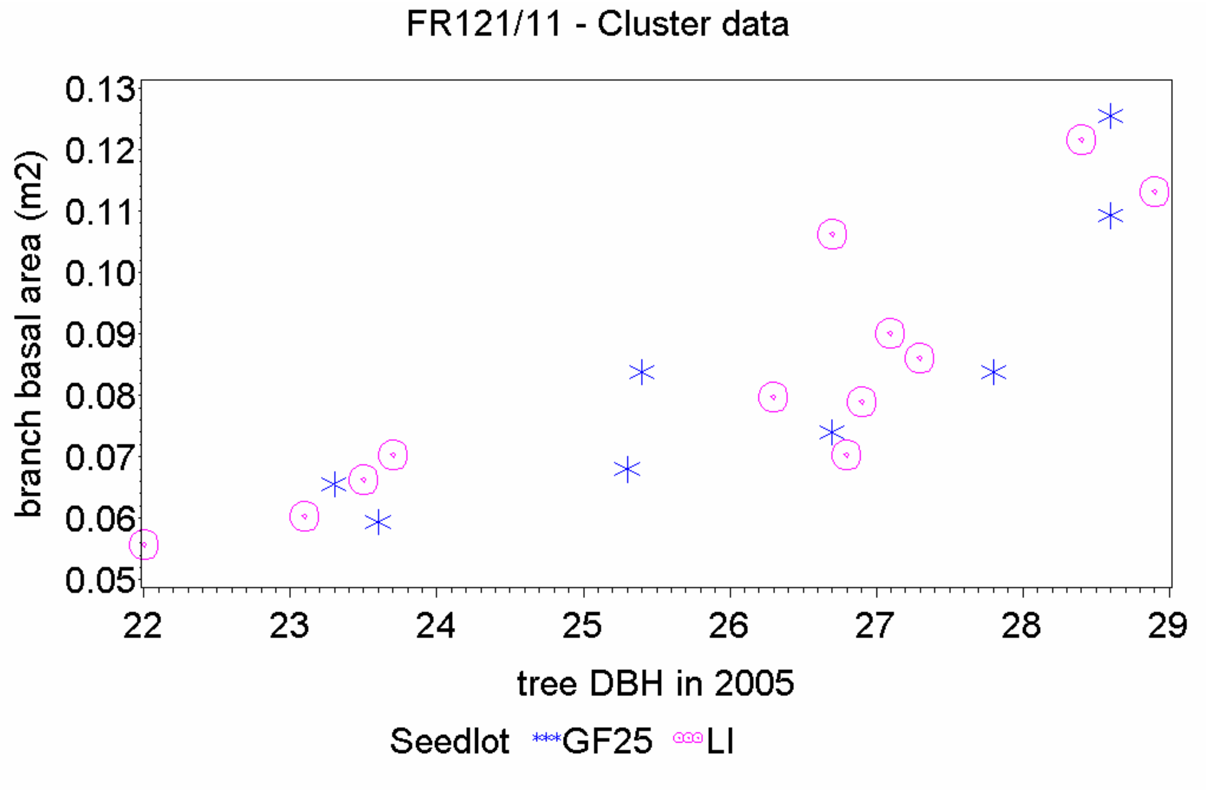


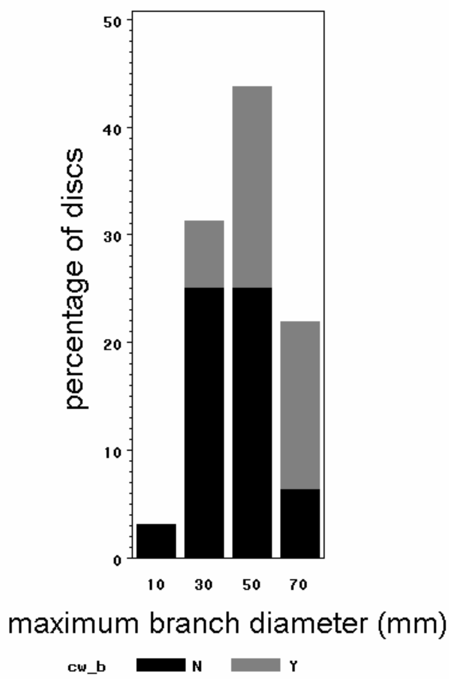
Figure 10. Variation in individual tree branch basal area with DBH.



g. Branch Dimensions and Compression Wood

In order to gain better understand how branches might influence wood properties, images were taken of selected discs. Discs were orientated with respect to each other and the corresponding branch cluster by means of a reference line, painted along the length of the felled stem. The data included 32 images of discs cut immediately below branch clusters. These 32 images were examined and the position of the branches in the cluster overlaid. The maximum branch diameter in cluster above ranged from 13 mm to 74 mm. Thirteen of the images showed signs of compression wood that appeared to be related to branch position whereas the others showed no obvious signs compression wood. Qualitatively, it appeared that compression wood was more likely to be visible on discs immediately below clusters with large branches (Figure 11).

Figure 11. Percentage of discs below branch clusters that showed (cw_b = Y) or did not show (cw_b = N) signs of compression wood in relation to the diameter of the largest branch in the cluster immediately above the disc.



DATA ANALYSIS - SilviScan DATA

For each wood strip sent to SilviScan, a data file was generated containing:

- density measurements at 25 micron resolution
- microfibril angle measurements at 5 mm resolution
- estimated modulus of elasticity at 5 mm resolution

The first task was to estimate where the growth ring boundaries occurred. Several pieces of information were combined to achieve this objective:

- a graph of the density profile produced by the G2Ring software (developed by David Pont)
- the field count of the number of rings that should be in the sample
- 18 mm wide block of wood that was immediately above/below the sample set for SilviScan analysis.

Once ring boundaries had been assigned to each strip, average values for each ring in each strip were calculated and examined. Graphs of the individual tree data for density, microfibril angle (MFA) and modulus of elasticity (MOE) were plotted (Figure 12 to Figure 29). Each set of four graphs contrasts either two GF25 and two long internode trees from the same silvicultural treatment, or four long internode trees with the same stocking treatment where two trees have received pruning and two trees have remained unpruned.

There are two observations for each stem position and tree age when the ring was formed. In some instances there are noticeable differences between these two observations. This is because the bark-bark strip was cut to pass through any obvious compression wood.
On an individual tree basis the graphs illustrate known trends:

- For a given stem position, density tends to increase with increasing tree age
- For a given tree age density tends to be higher near the base of the tree (stem position 1)
- For a given stem position MFA tends to decrease with increasing tree age
- For a given tree age MFA tends to be higher near the base of the tree (stem position 1)
- MOE tends to increase with increasing stem age
- There are no obvious trends with stem position

Within each block of 4 graphs, there are no obvious major differences between trees.

Differences between the two estimates of wood properties for each growth ring have been examined to see whether there are any obvious differences with respect to the different silvicultural treatments and seedlots (Figure 30 to Figure 34). There was little difference between the two seedlots (Figure 31). There were more obvious differences with stocking with samples from lower stockings showing more variability (Figure 32).

From examining the bar charts for individual trees (Figure 30):

- Trees 11 and 4 stand out as having more variation in density,
- Tree 20 stands out as having more variation in MFA,
- Trees 7 and 8 stands out as having more variation in MOE
- MOE is not that variable for trees 4, 11 and 20.

The TreeD images of the sample trees were examined to see whether there were any features that might be associated with the above observations.

- Tree 4 had noticeable butt sweep
- Tree 11 had a very slight lean
- Tree 20 visually had an eccentric crown
- Tree 7 appeared to be straight
- Tree 8 had noticeable lean
- Trees 12 and 14 also had noticeable lean

DISCUSSION

Twenty trees were felled in experiment FR121/11 (Shellocks). Two trees of average DBH were selected from each of 10 plots that covered a range of multinodal and long internode seedlots, and a range of silvicultural treatments. Branching characteristics were measured in the field, and wood samples measured using SilviScan.

The number of trees sampled was small, because many different characteristics were measured on each tree, in order to begin to understand the influence of stem form and crown structure on wood property formation.

The crown structure of the GF25 seedlot compared to the GF13 (LI25) seedlot can be summarised as follows:

- More branch clusters in total
- More clusters per annual shoot
- Less branches per cluster
- More stem cones per cluster
- Similar amount of foliage on a branch in relation to its diameter
- Similar amount of branch basal area in a tree (for a given silvicultural treatment)

The amount of foliage for trees of the same DBH is considered to be similar for the two different seedlots. However, the difference in branch arrangement may influence the amount of light intercepted by the tree crowns. Also we do not know whether other physiological processes such as photosynthesis, respiration, and allocation patterns would vary between the two seedlots.

Wood property data were available from a bark-bark strip (2 pith-bark strips) through any obvious compression wood for 5 different positions within a tree. These data were examined for general trends within a tree, and for differences between the two pith-bark strips. Within a tree, wood properties obviously varied with age of wood formation and position within the crown. Differences between trees with respect to either seedlot or silvicultural treatment were minor.

Examination of the difference in wood properties for a given growth ring between the two pith-bark strips indicated that there were only minor differences between the two seedlots. However there was more variability in density at lower stockings. Trees at lower stockings tend to have larger branches, and discs with larger branches in the cluster above were more likely to have compression wood distributions related to branch position. These results suggest that crown structure may be contributing to the within-stem variability in wood properties.

FUTURE RESEARCH

These data will also be used to investigate whether 'average' radial growth and wood properties be predicted from crown structure using the model developed by Pont (2003).

A further study is planned for the Internal Stem Modelling Theme in February 2007. Data will be collected from the 1978 Genetic Gain Trial in Mohaka (WN377). In particular data collection will concentrate on crown structure (for revising TreeBLOSSIM) and using imaging to understand 3-d variability in compression wood, especially around branch clusters. This new dataset will complement that collected in the 1978 Genetic Gain Trial at Golden Downs (NN530/2) and provide a contrast between sites for trees from the same seedlot.

This trial, FR121/11 was on a poor quality site, and few differences were found between trees from the GF25 and long internode seedlots. This study should be repeated using other trials from the FR121 series to determine whether these results are consistent across sites.

ACKNOWLEDGEMENTS

Thanks to the Selwyn Plantation Board, and in particular Hugh Stevenson, for allowing us to use this trial, and for clearing the understory vegetation around the sample trees.
Thanks to Richard Beamish-White, Lisa Blomquist, Rod Brownlie, Blake Christianson, Jeremy Cox, Tony Evanson, Dave Henley, Pat Hodgkiss, and Emmanuel Lepine for their contribution to the field work.

REFERENCES

Pont, D. 2003: A model of secondary growth for radiate pine. M.F.Sc. thesis. University of Canterbury, Christchurch. 183pp.

Figure 12. SilviScan estimates of density for individual growth rings for trees with a final crop stocking of 100 stems/ha.

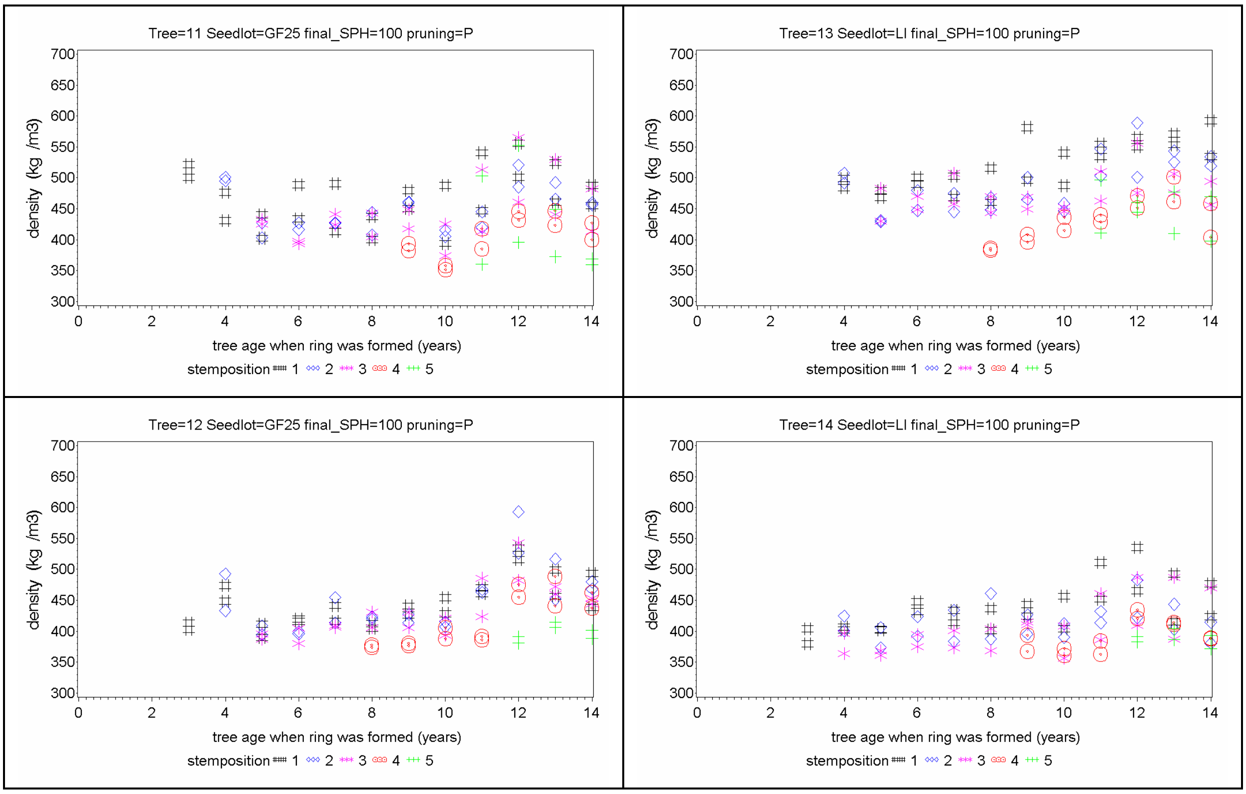


Figure 13. SilviScan estimates of density for individual growth rings for trees with a final crop stocking of 200 stems/ha.

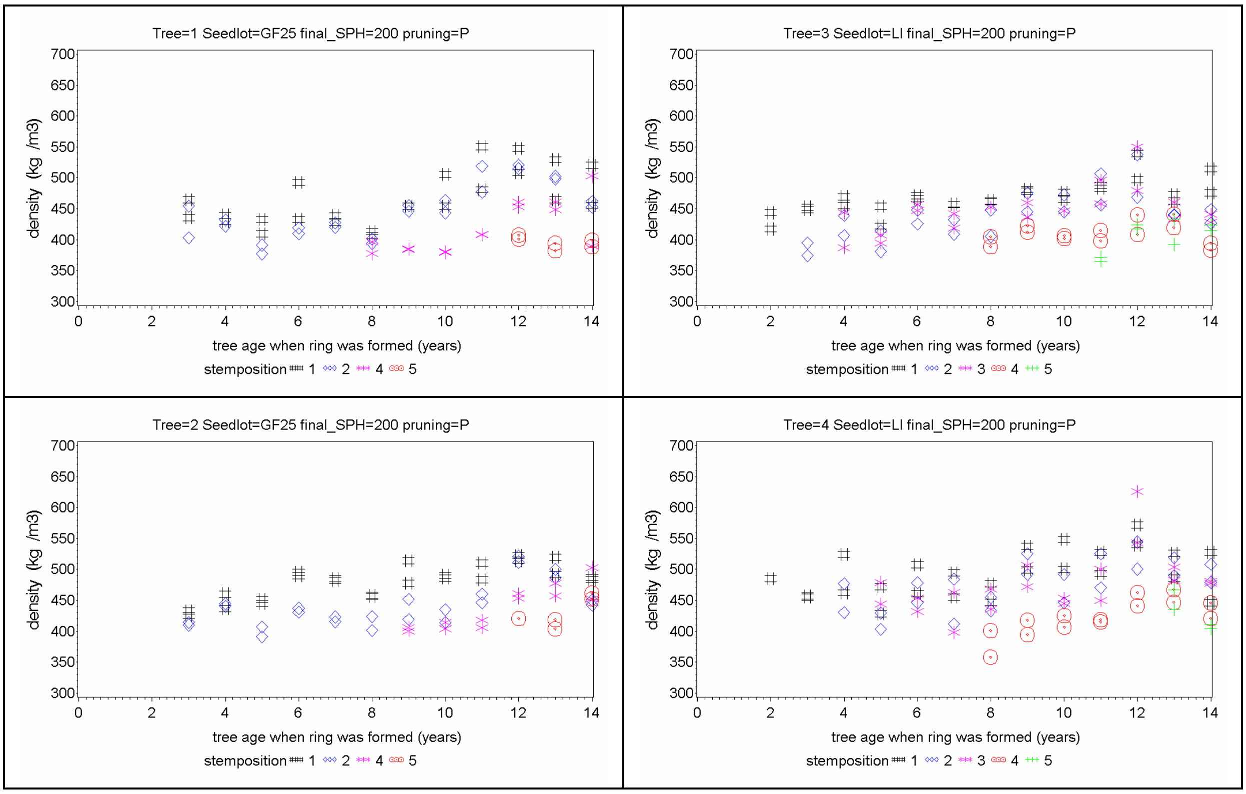


Figure 14. SilviScan estimates of density for individual growth rings for trees with a final crop stocking of 400 stems/ha.

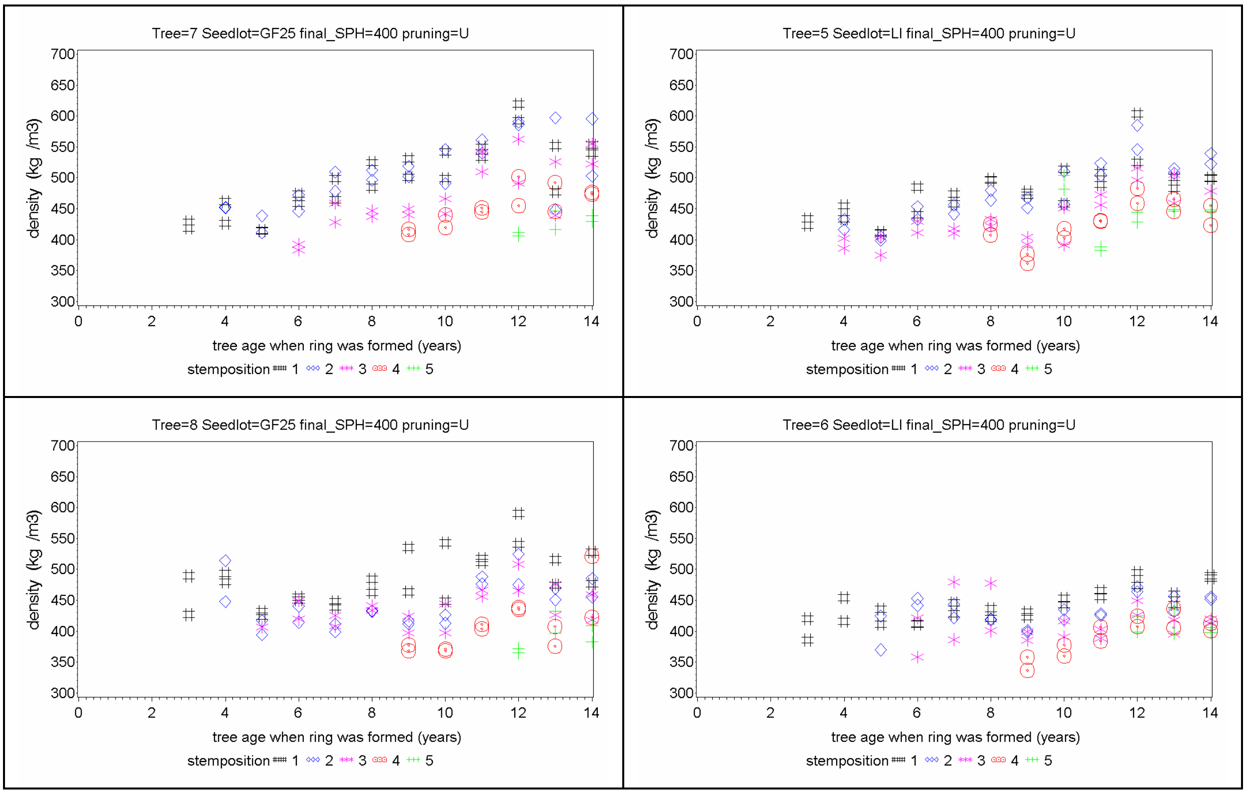


Figure 15. SilviScan estimates of density for individual growth rings for trees with a final crop stocking of 600 stems/ha.

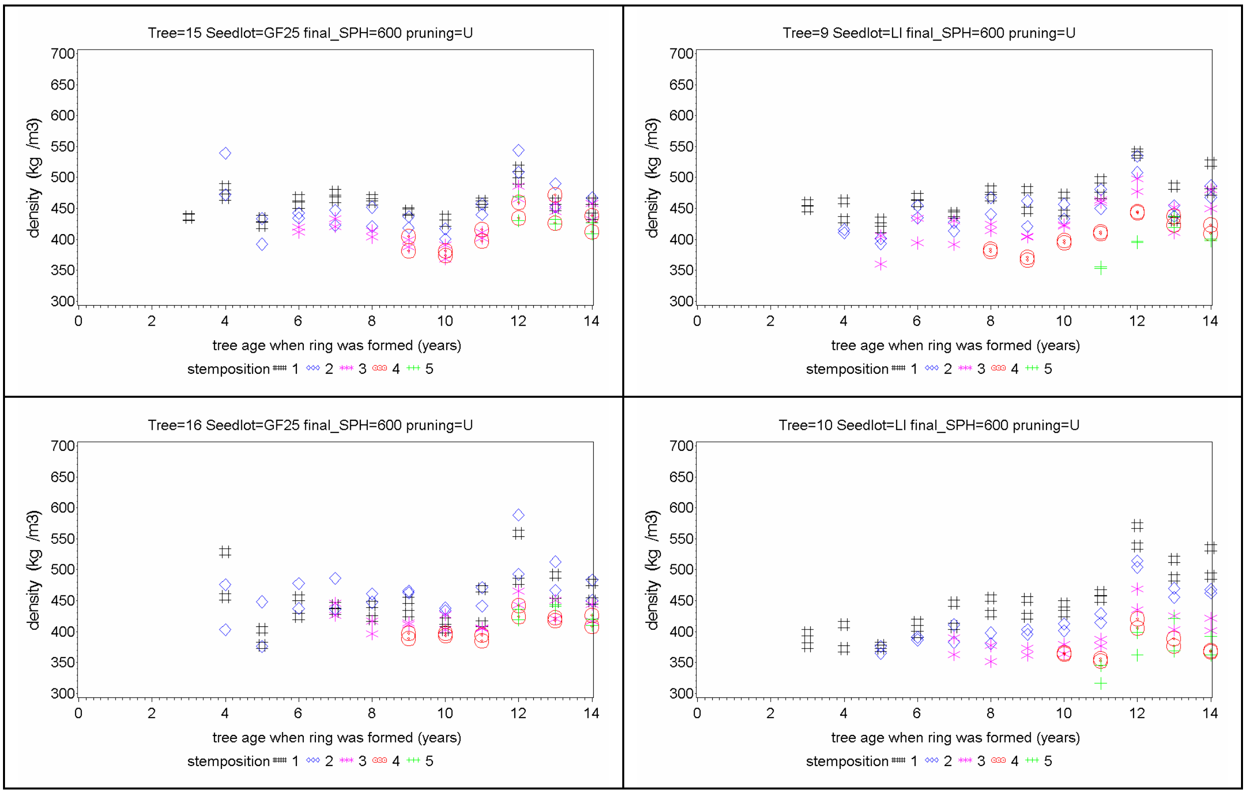


Figure 16. SilviScan estimates of density for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 200 stems/ha.

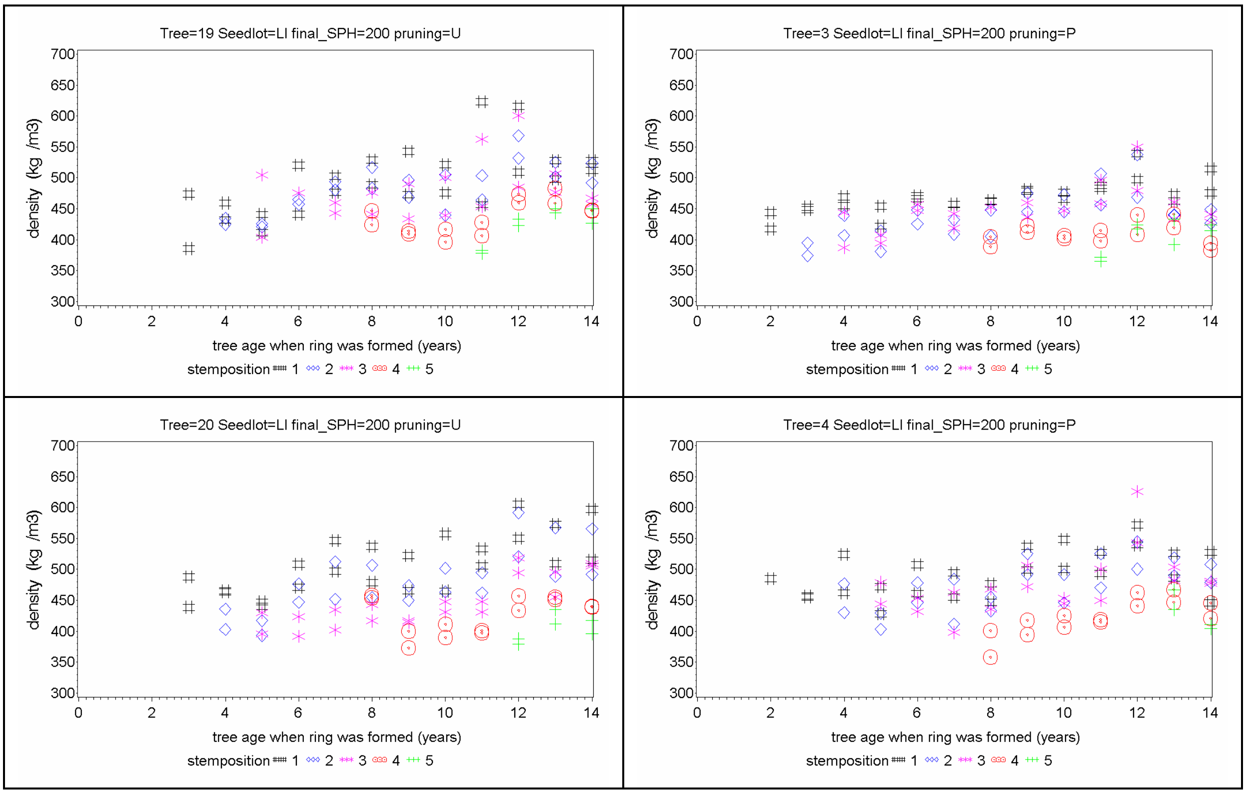


Figure 17. SilviScan estimates of density for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 400 stems/ha.

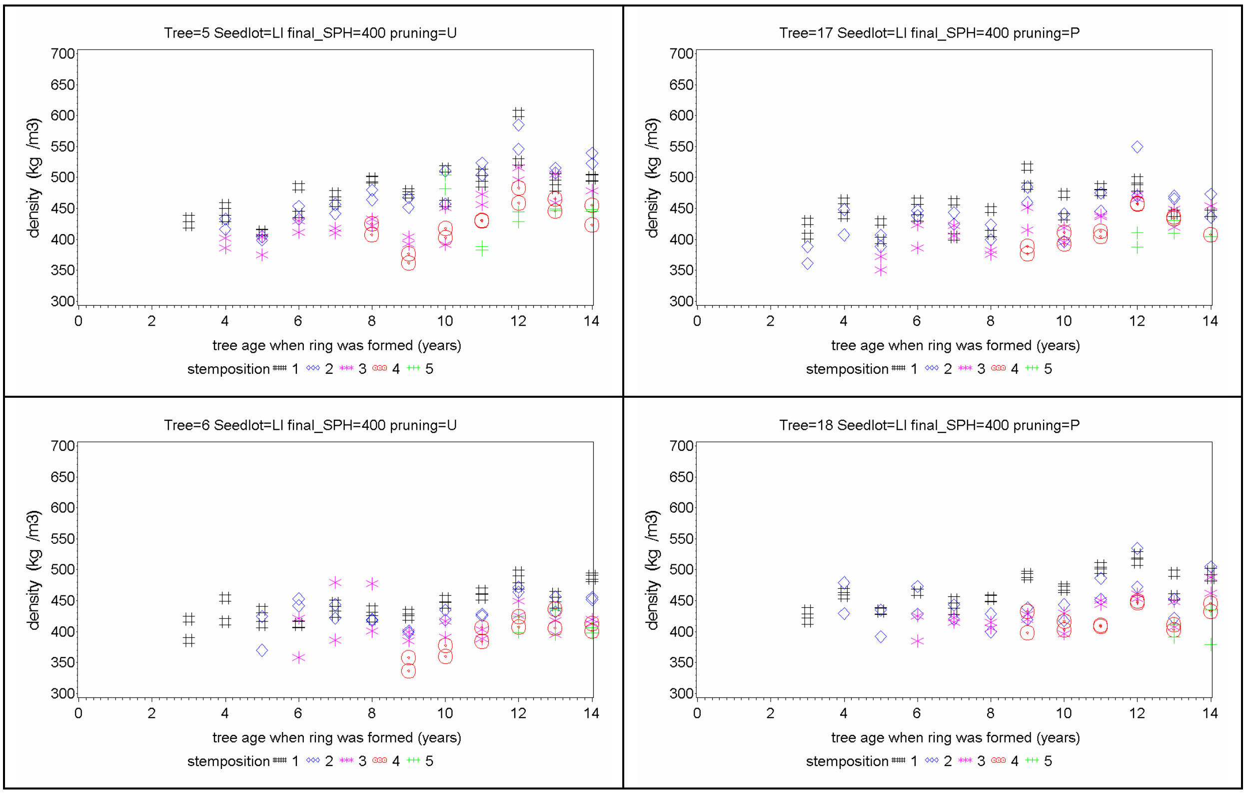


Figure 18. SilviScan estimates of microfibril angle (MFA) for individual growth rings for trees with a final crop stocking of 100 stems/ha.

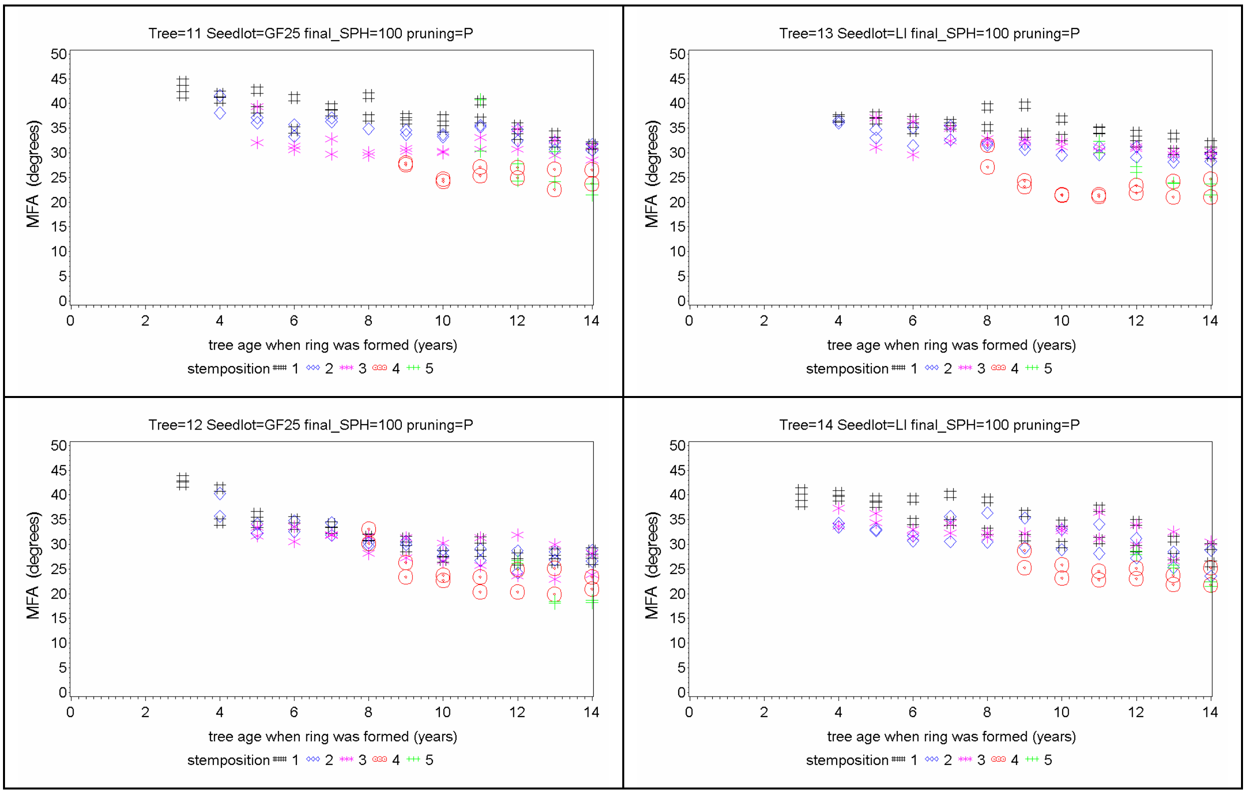


Figure 19. SilviScan estimates of microfibril angle (MFA) for individual growth rings for trees with a final crop stocking of 200 stems/ha.

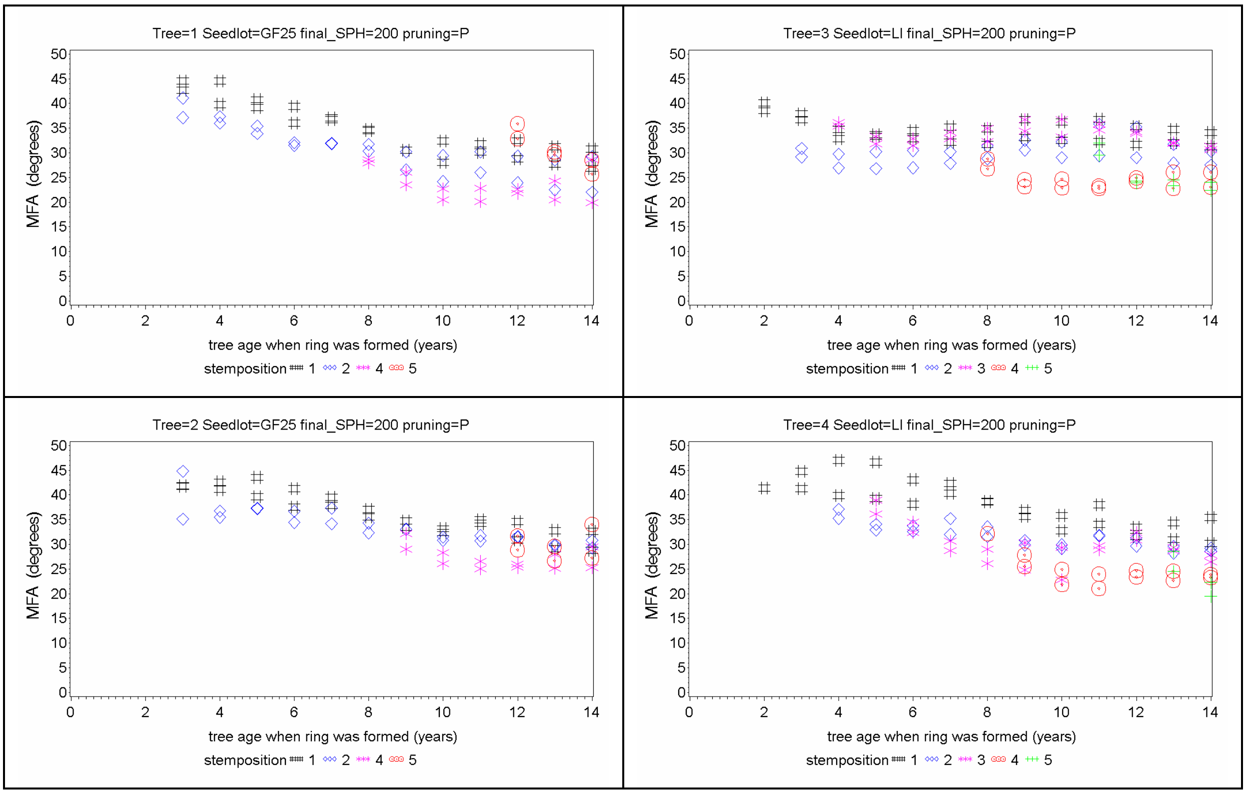


Figure 20. **SilviScan estimates of microfibril angle (MFA) for individual growth rings for trees with a final crop stocking of 400 stems/ha.**

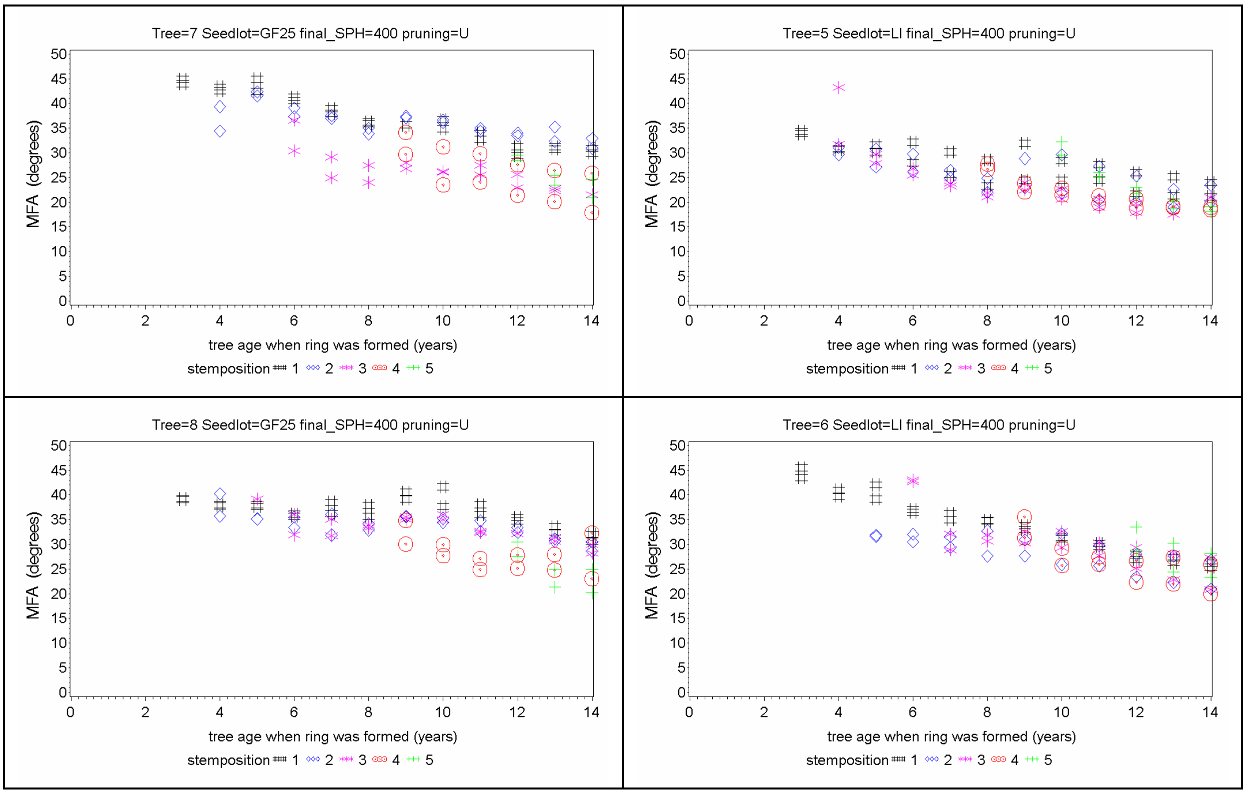


Figure 21. **SilviScan estimates of microfibril angle (MFA) for individual growth rings for trees with a final crop stocking of 600 stems/ha.**

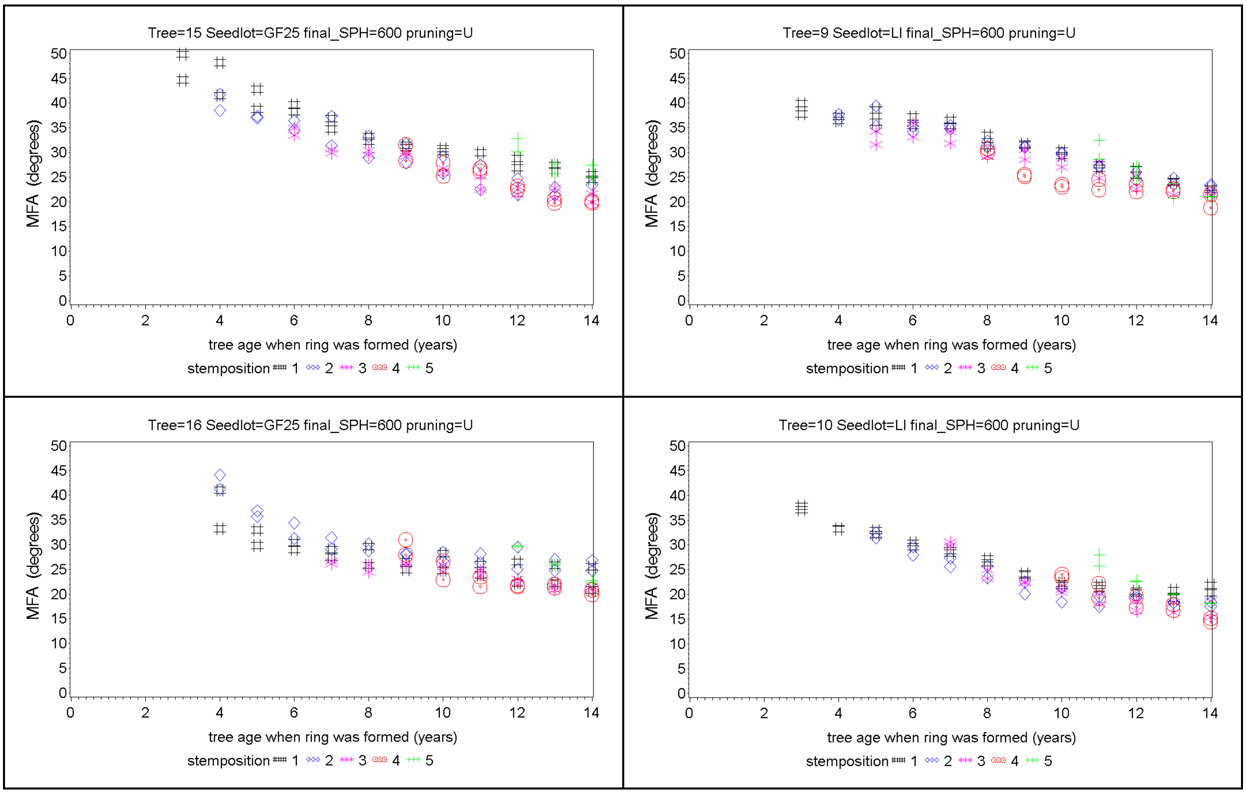


Figure 22. **SilviScan estimates of MFA for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 200 stems/ha.**

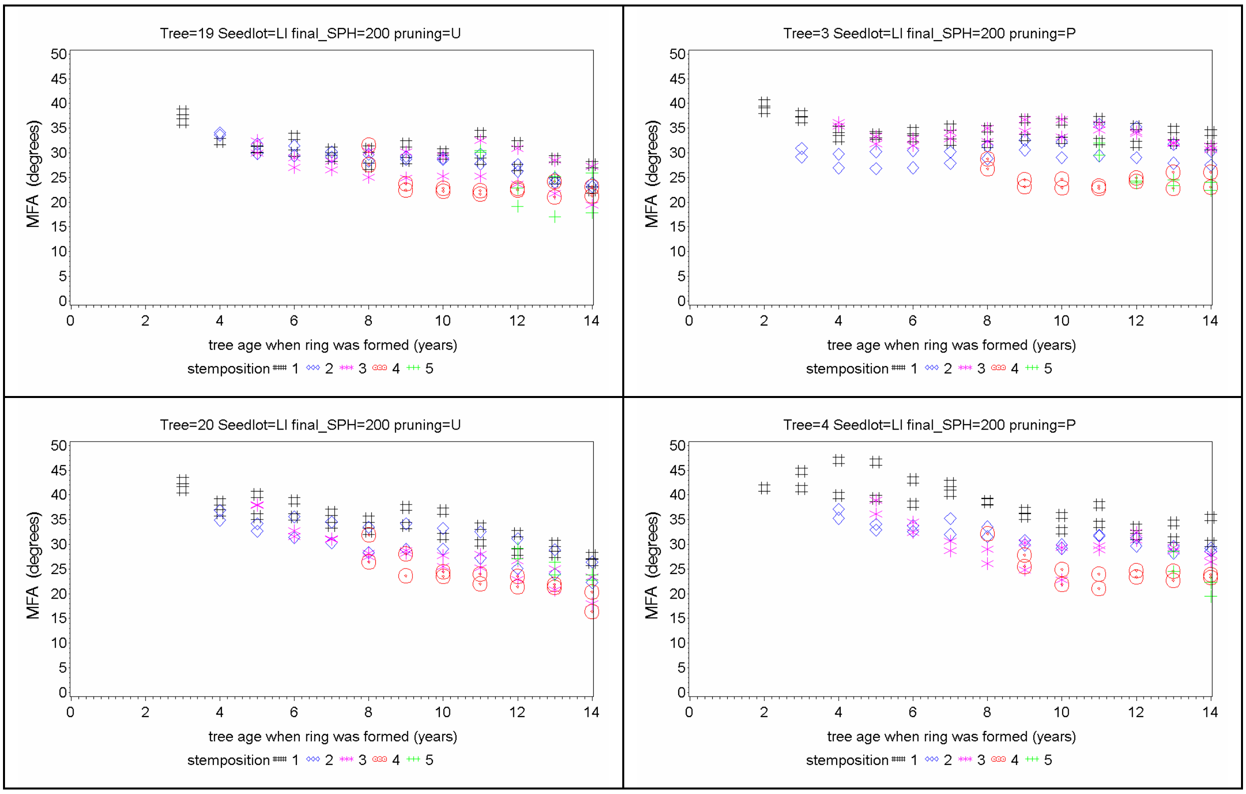


Figure 23. **SilviScan estimates of MFA for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 400 stems/ha.**

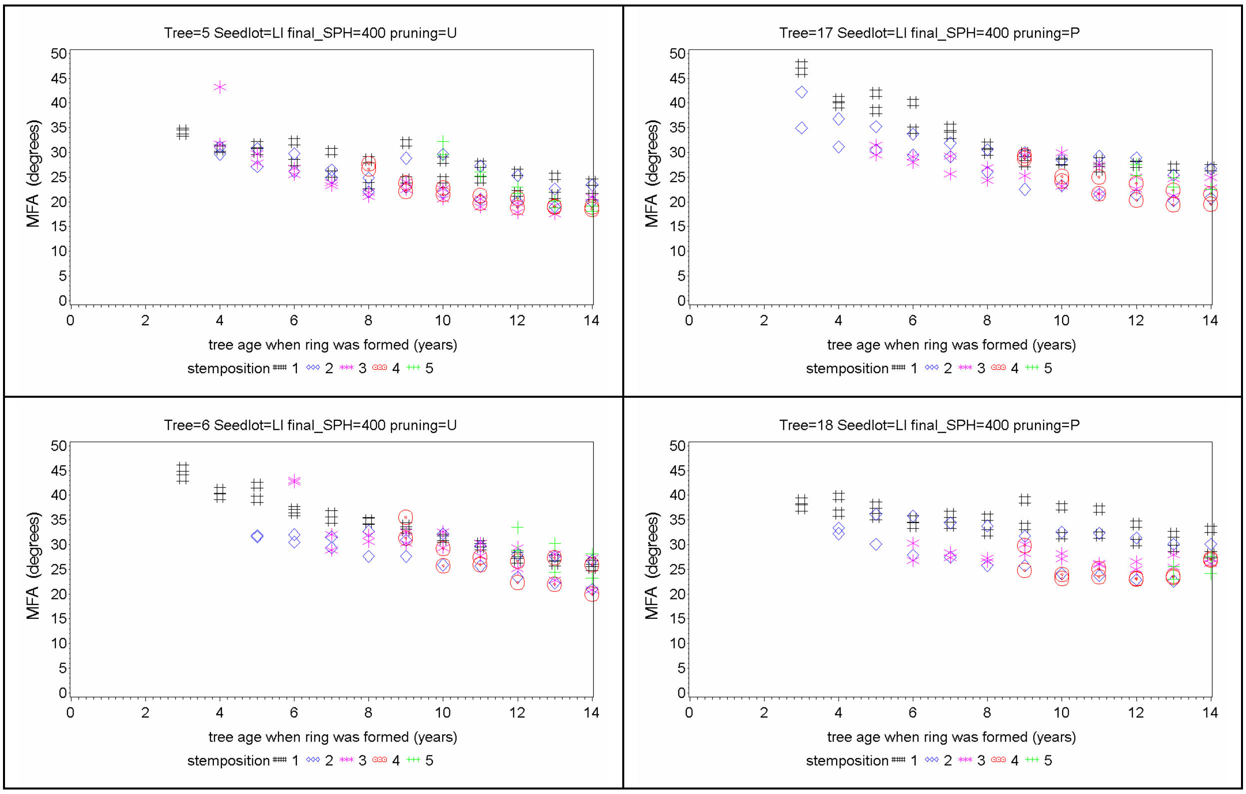


Figure 24. SilviScan estimates of modulus of elasticity (MOE) for individual growth rings for trees with a final crop stocking of 100 stems/ha.

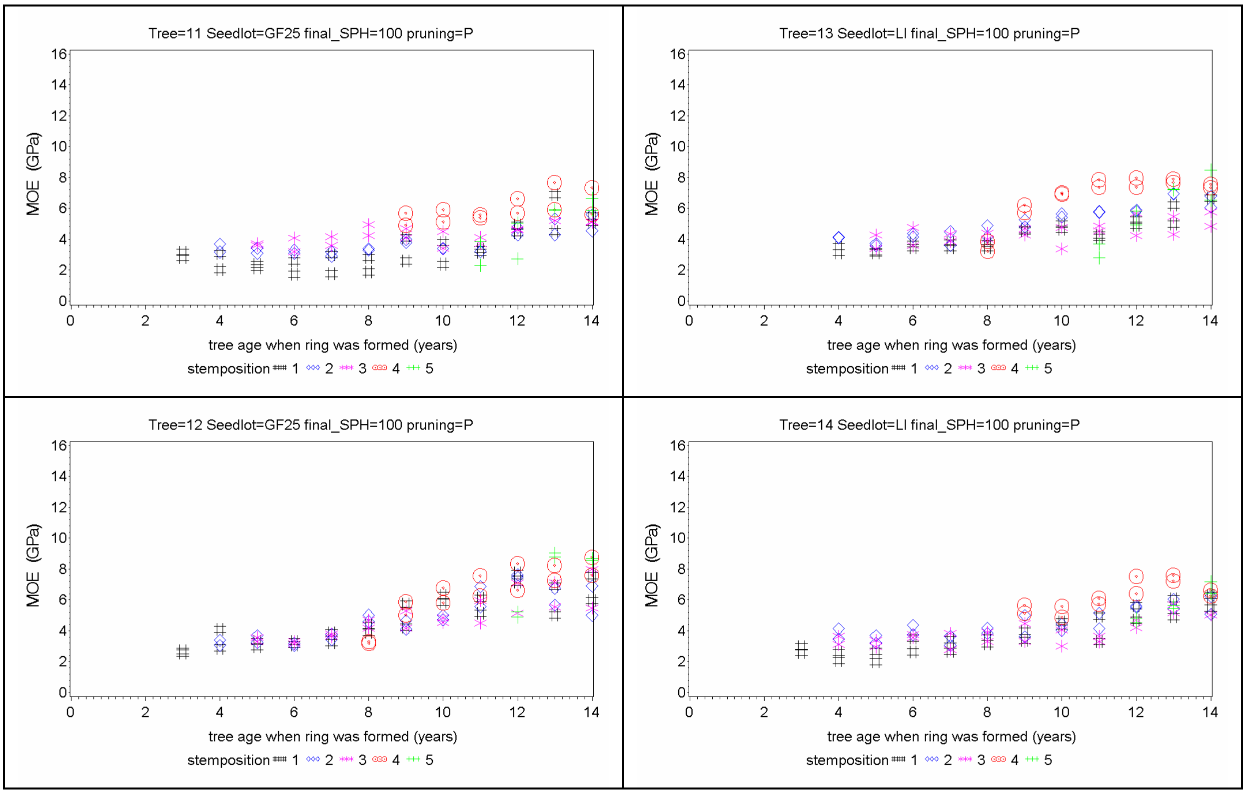


Figure 25. SilviScan estimates of modulus of elasticity (MOE) for individual growth rings for trees with a final crop stocking of 200 stems/ha.

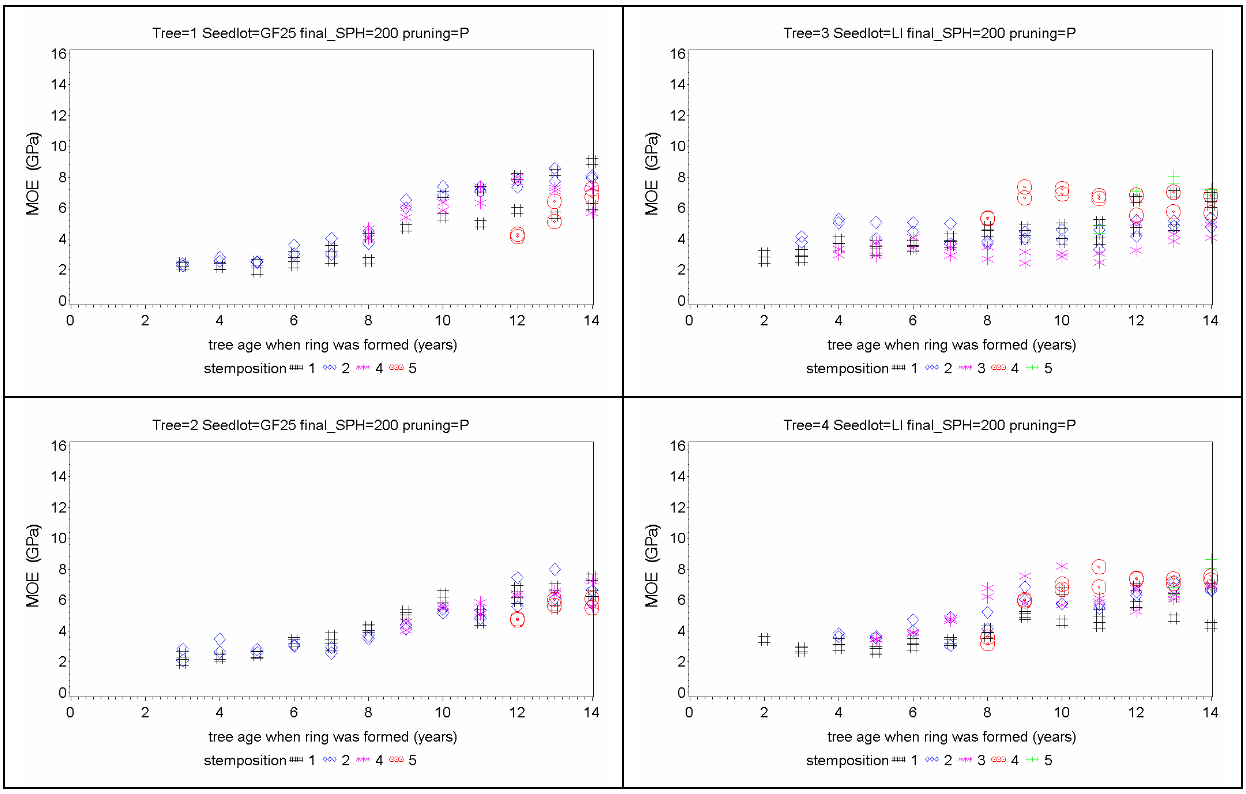


Figure 26. SilviScan estimates of modulus of elasticity (MOE) for individual growth rings for trees with a final crop stocking of 400 stems/ha.

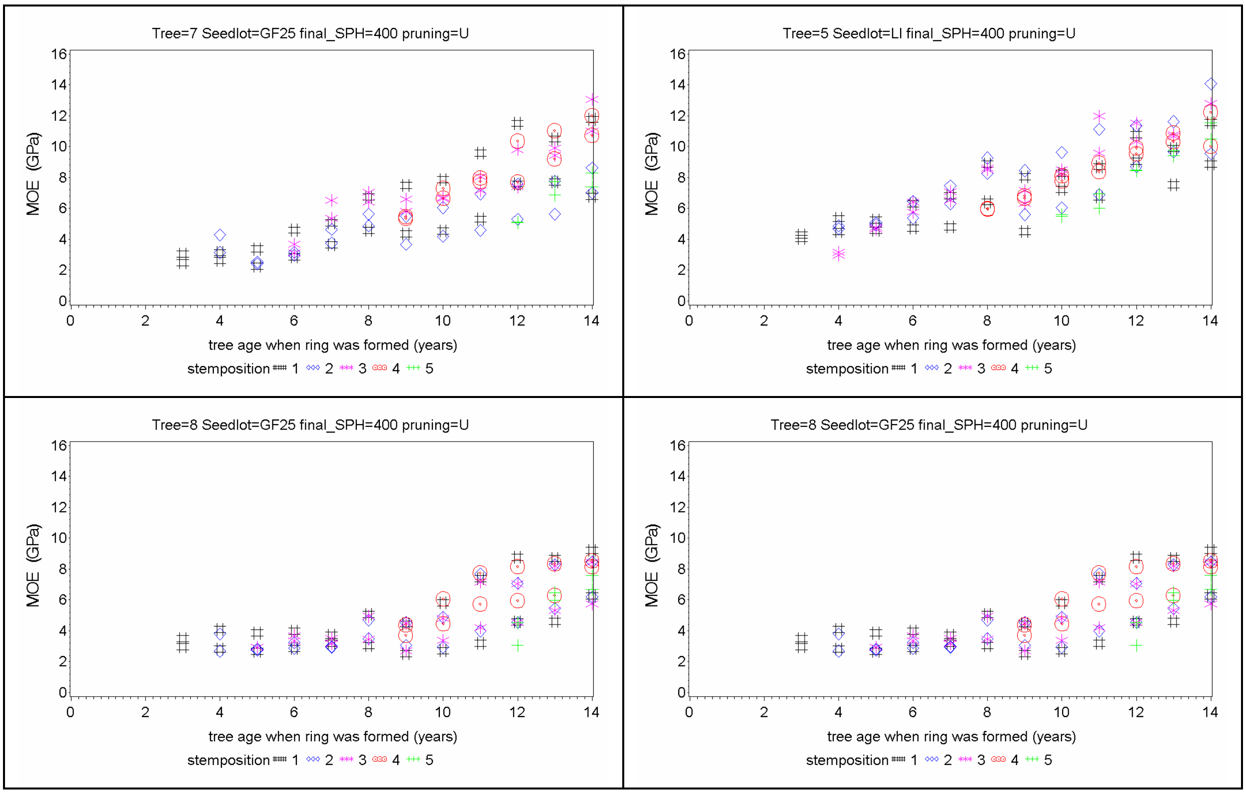


Figure 27. SilviScan estimates of modulus of elasticity (MOE) for individual growth rings for trees with a final crop stocking of 600 stems/ha.

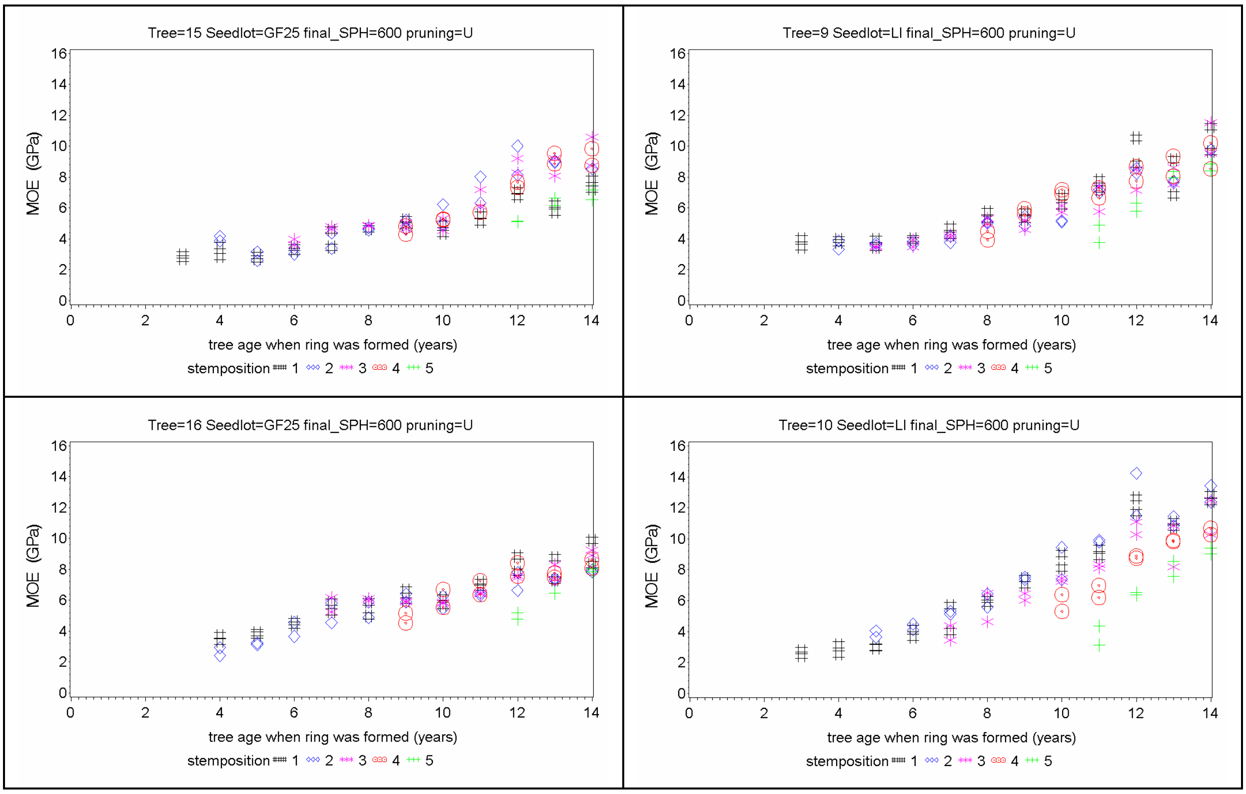


Figure 28. SilviScan estimates of MOE for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 200 stems/ha.

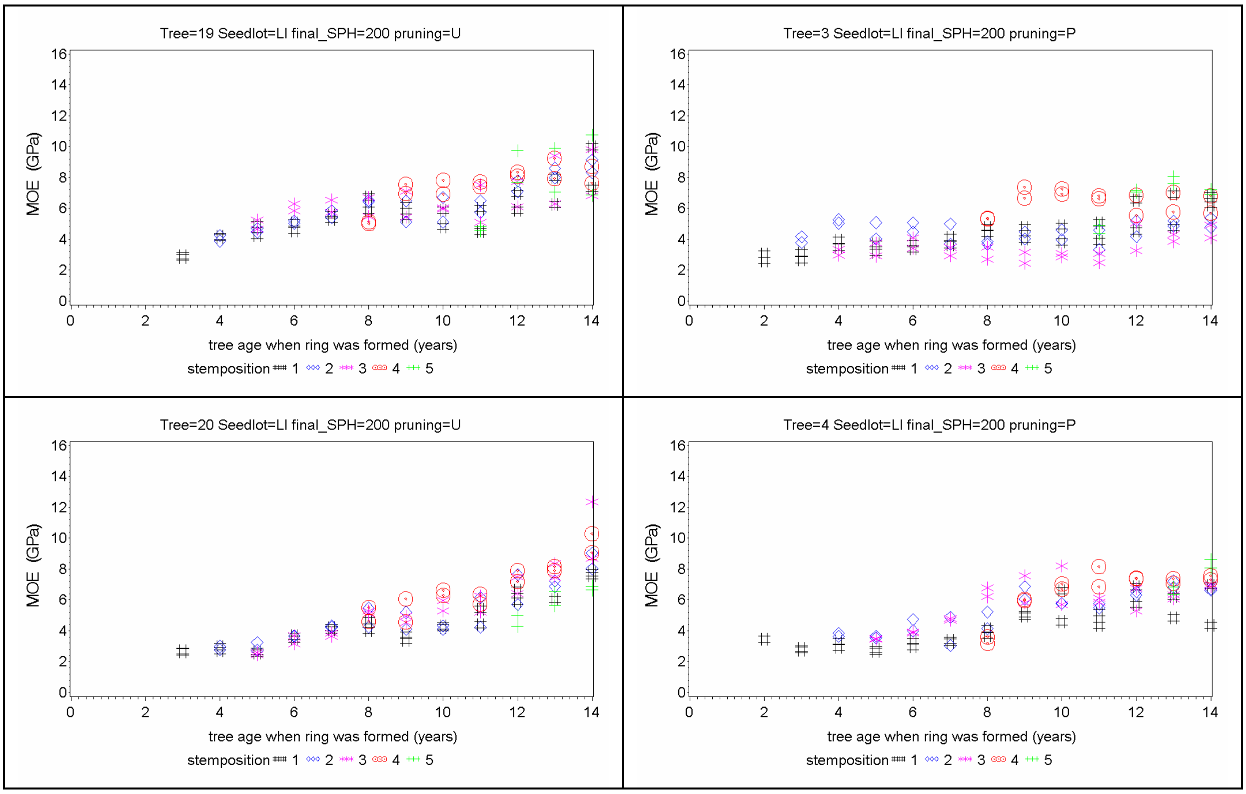


Figure 29. SilviScan estimates of MOE for individual growth rings for unpruned /pruned long internodes trees with a final crop stocking of 400 stems/ha.

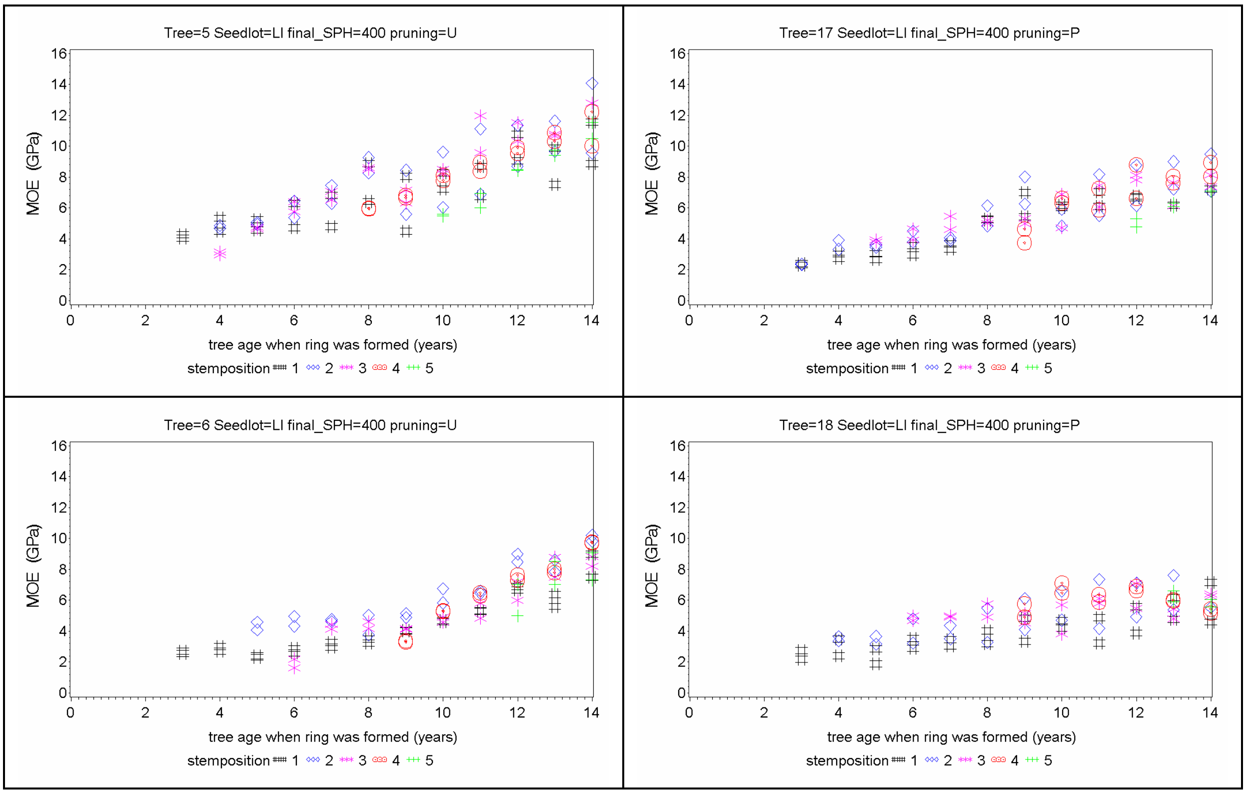


Figure 30. **Bar graph showing differences in density, MFA and MOE between the two samples from a growth ring for each tree.**

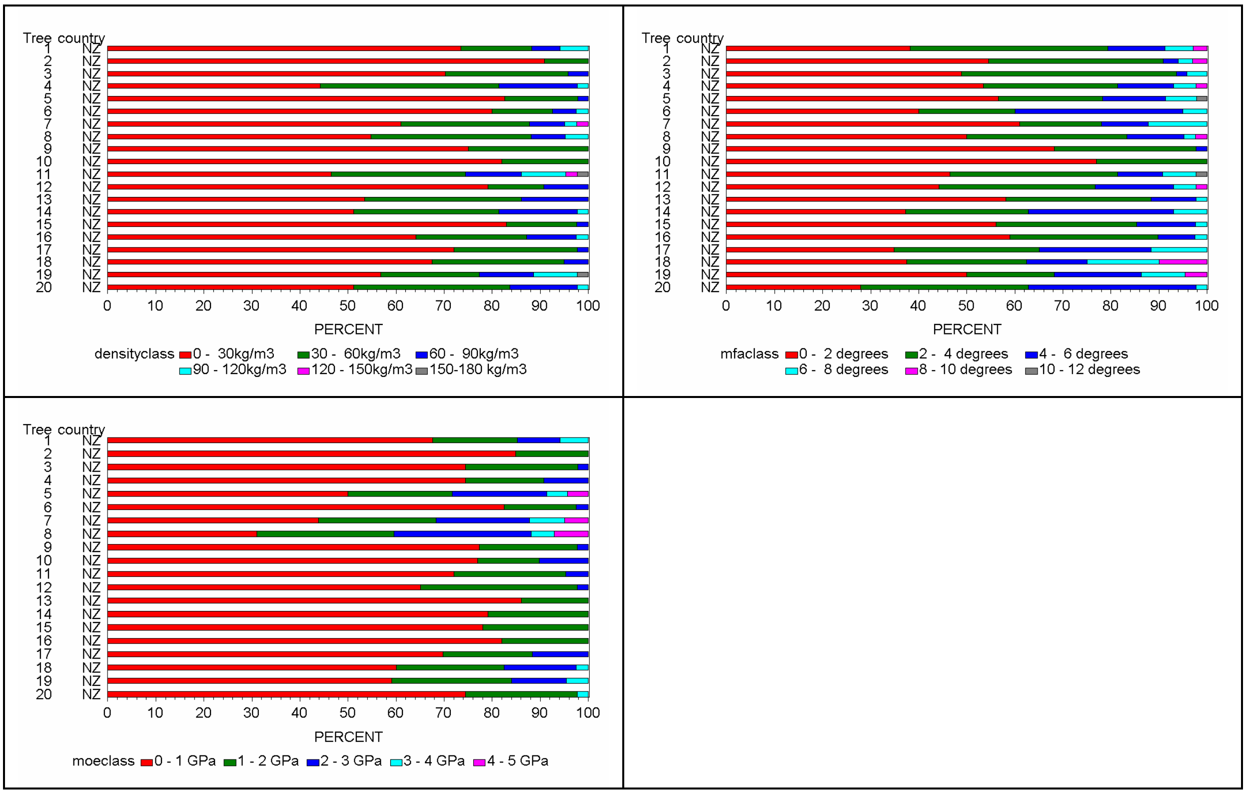


Figure 31. **Bar graph showing differences in density, MFA and MOE between the two samples from a growth ring for each seedlot.**

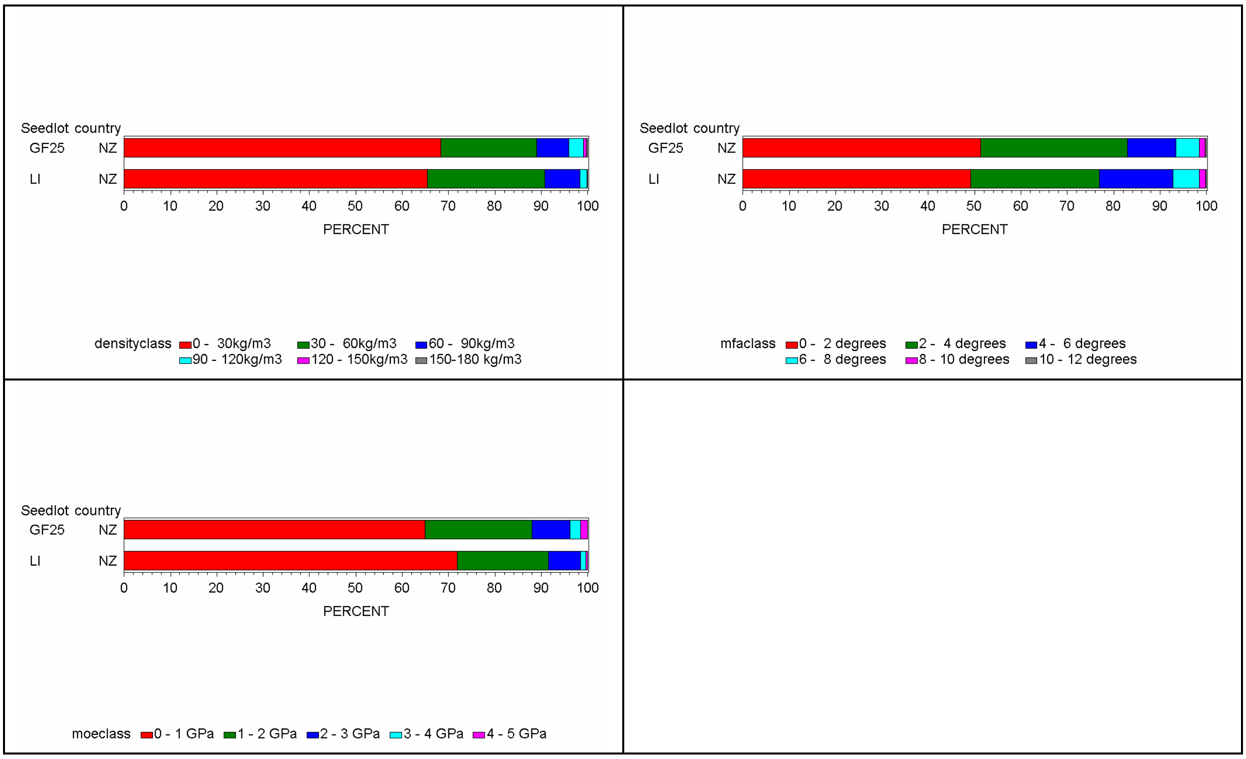


Figure 32. Bar graph showing differences in density, MFA and MOE between the two samples from a growth ring for the different final crop stockings.

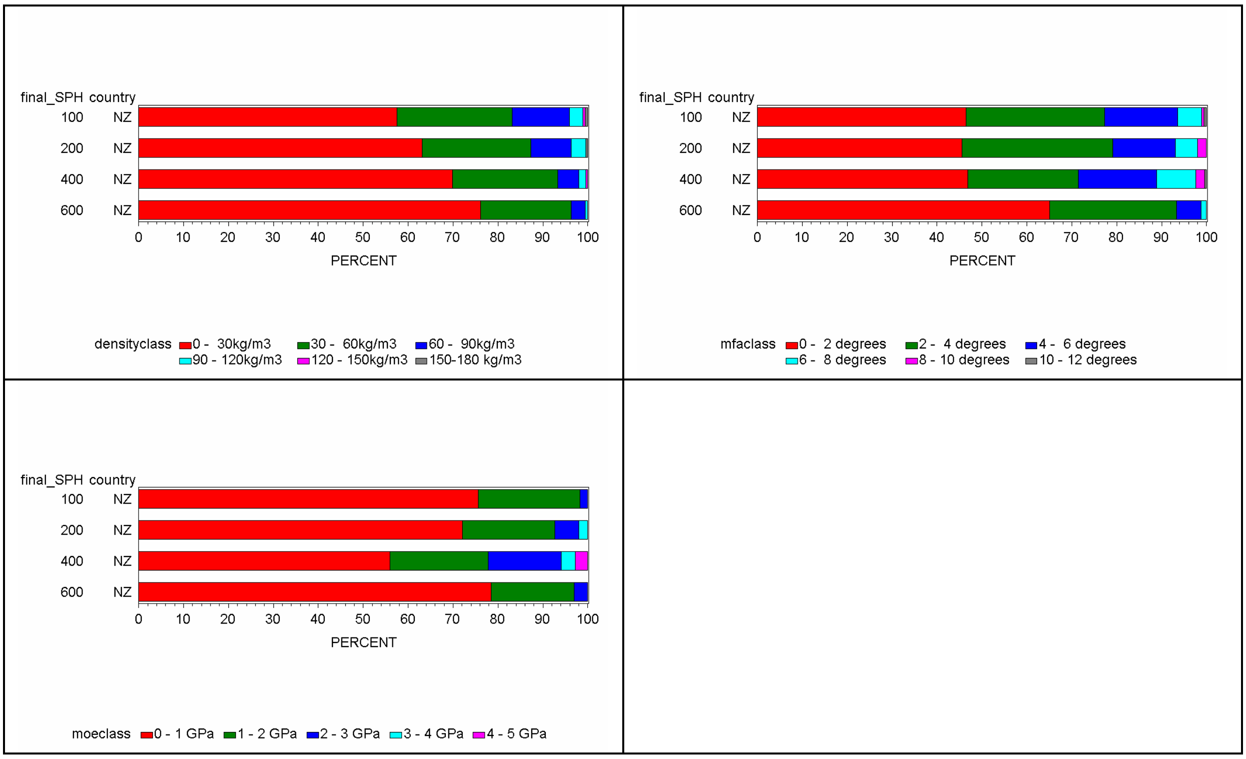


Figure 33. Bar graph showing differences in density, MFA and MOE between the two samples from a growth ring for the different treatents.

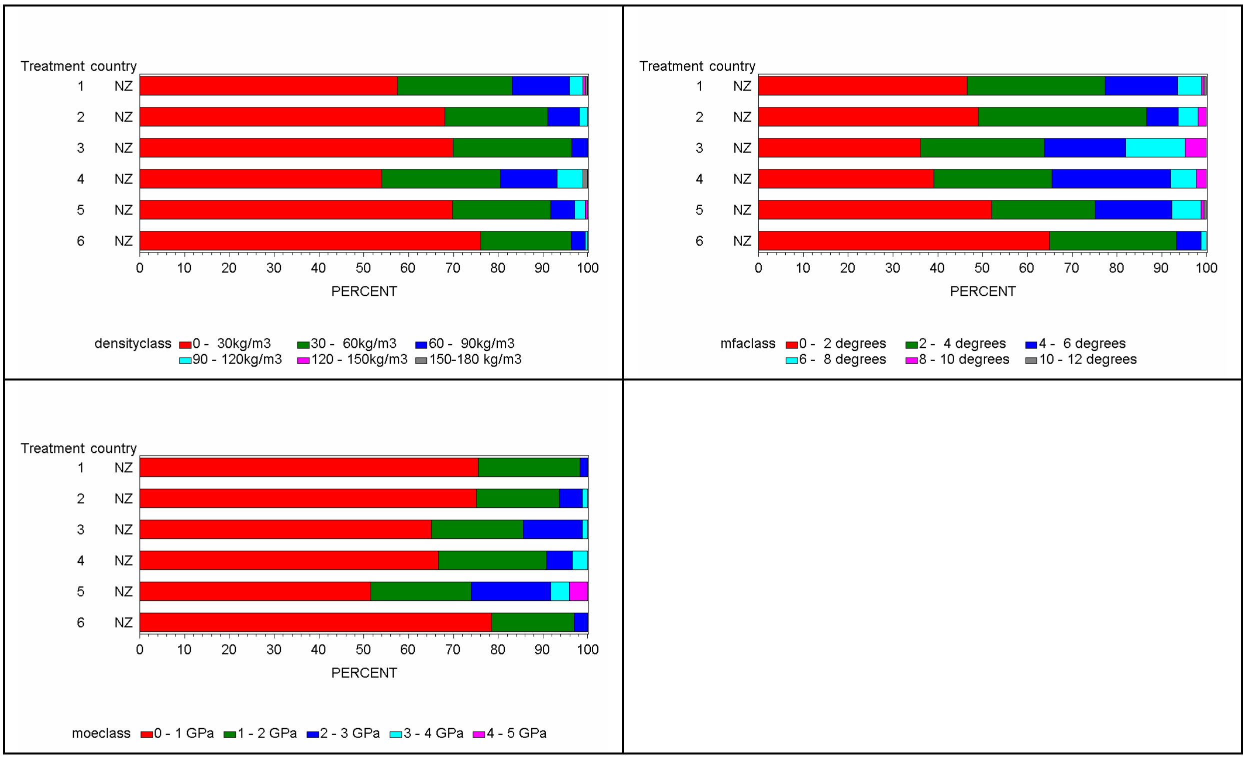
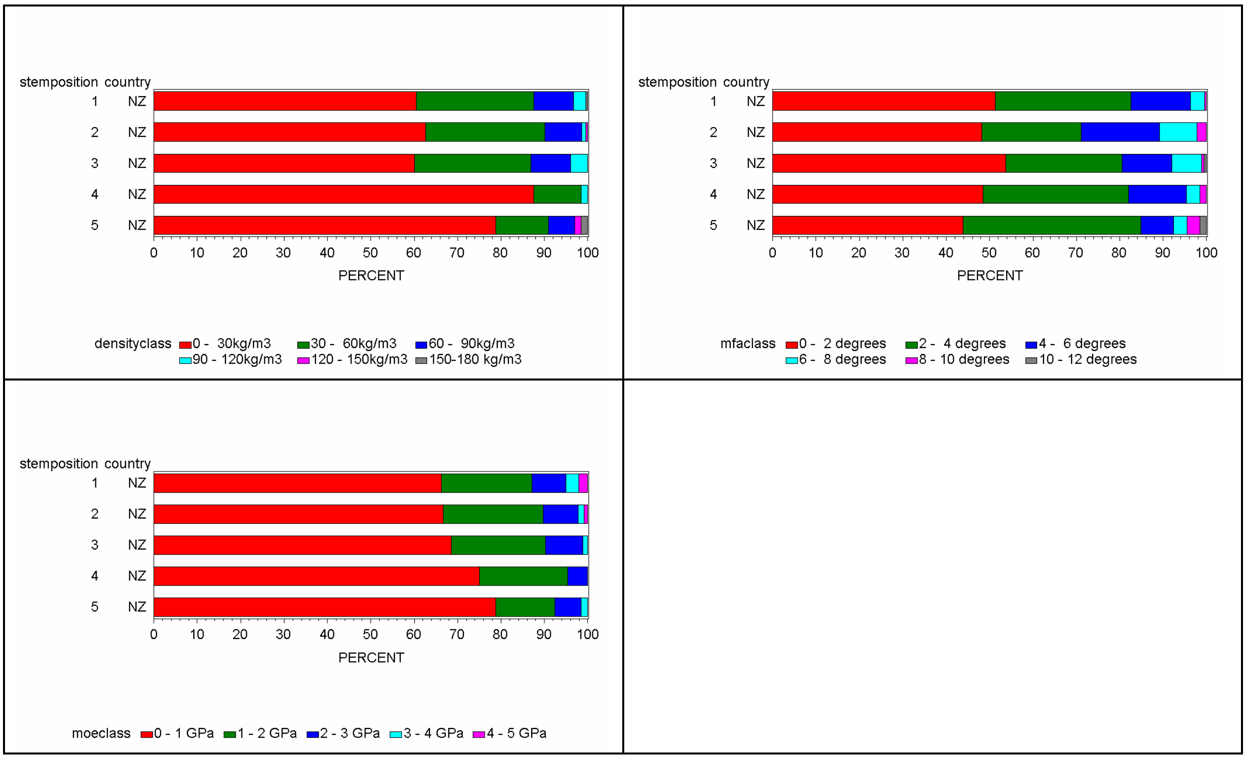


Figure 34. Bar graph showing differences in density, MFA and MOE between the two samples from a growth ring for the different stem positions.



Appendix 1. Map showing layout of Experiment FR121/11 (Shellocks).