Effect of clonal deployment on acoustic velocity

P. Silcock

Report No. 111, November 2007

EXECUTIVE SUMMARY

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THE PROBLEM

Clonal forestry offers the potential to deliver the benefits of the best genotypes from a controlled cross. The ability to deploy clonal radiata pine trees holds some significant advantages to the industry such as increases in productivity and quality as well as reduction in variation. However, the question of whether to deploy clones in mixed or pure blocks has until recently, been largely unanswered.

COOP INITIATIVES

In 1995 a large trial in Tarawera forest was set up by the Plantation Management Coop (PMC) to answer the question 'do clones perform better, because of reduced competition, when planted as single clonal blocks versus clonal mixtures?' The trial serves as an expansion of the two pilot trials established in 1989, located in Kawerau, New Zealand and Tumbarumba, NSW, Australia. Previous projects have reported on growth data at all three sites.

THIS PROJECT

This project was set up to obtain and analyse the standing tree acoustic velocity of different clones from the Tarawera and Kawerau trials, to determine whether the way the clones were deployed has any bearing on the wood properties, i.e. stiffness.

RESULTS

The analysis showed that the different clones develop wood of varying levels of stiffness. However there is no statistical difference in the acoustic velocity of the wood of a clone when grown in clonal mixtures or pure blocks. The variation in acoustic velocity of clones within blocks of pure clones is less than in blocks of clonal mixtures.

IMPLICATIONS FOR THE COOP

There is a growing body of evidence that the configuration of clonal forestry has little impact on the growth of trees and the quality of the logs from those trees. These results support the conclusions from the previous analysis of growth data from Tarawera, Kawerau and Tumbarumba trials which found no difference between the growth of trees in clonal mixtures and pure blocks. Continued monitoring of these trials will provide for further studies as competition increases and stands mature.

INTRODUCTION

Clonal forestry offers the potential to deliver the benefits of the best genotypes from a controlled cross. The advantage of growing forests using clones developed from particular genotypes is mature trees which are more uniform in height and diameter. The wood properties will also be more consistent and may be selected to suit particular end uses. This holds some significant advantages to the industry such as increases in productivity and quality as well as reduction in variation. However, the question of whether to deploy clones in mixed or pure blocks has until recently, been largely unanswered.

In 1995 a large trial in Tarawera forest was set up by the Plantation Management Coop (PMC) to answer the question 'do clones perform better, because of reduced competition, when planted as single clonal blocks versus clonal mixtures?' The trial serves as an expansion of the two pilot trials established in 1989, located in Kawerau, New Zealand and Tumbarumba, NSW, Australia. All three of these trials provide information on the effects of genetic uniformity on tree growth and log quality. These trials have recently been analysed for tree growth (Kimberly and Dean 2006, Marshall 2007). They showed there to be no overall advantage in terms of growth, to planting clones in pure blocks versus planting clones in mixtures. This report is an overview of an analysis on the acoustic data of the Kawerau (FR 450) and Tarawera (FR 308) trials.

TRIAL DESCRIPTION

FR 450 - Kawerau

In 1988 the trial was planted at Tui Glen near Kawerau in the Bay of Plenty region of the North Island, New Zealand. The three hectare trial comprises two replications each of the following three treatments: four single clone plots, four 4 clone mixtures and two 16 clone mixture blocks from two superior improved families. Each replication also contains two control blocks of control pollinated seedlings. The clones and seedling controls were sourced from 268 control pollinated seedlings (family 268.405). The control serves as a genetic benchmark and will also quantify the tree growth and quality of the clonal material.

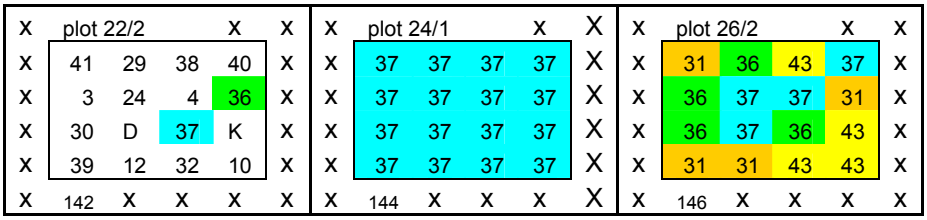

Figure 1. Block layout and composition of clones within blocks.

The trial contains 28 plots, each 0.0256 hectares in size. The trees were planted at 4x4 metre spacing (625 stems/ha), and have not been thinned due to a late prescription and subsequent risk of severe windthrow. This has resulted in severe competition; inducing mortality and potentially influencing diameter growth and acoustic velocity in recent years. The trial was pruned at ages 6 and 7 to a mean height of 6.2 metres. The site is at the upper end of productivity (300 Index – 43.2, Site Index 39.2m); the standing volume at age 18 was approximately 700m^3/ha. Refer to the establishment report (Darling and Tombleson, 1989) for a full description of the trial.

FR 308 - Tarawera

In June 1995 the trial was established as an extension of the Tui Glen pilot trial in compartment 45/1A of Tarawera forest in the Bay of Plenty region of the North Island, New Zealand. The 13 hectare trial comprises two replications of each of the following three treatments: 8 blocks of 16 clone mixture, 10 blocks of 2 clone mixture, and 10 blocks of the reciprocal of the 2 clone mix. The trial also includes 16 blocks of a single-clone. Three blocks were replicated three times. A control, comprising GF 23 seedlings, established in the four 36 tree blocks was incorporated into the trial. The control serves as a genetic benchmark and will also quantify the tree growth and quality physiological maturation effects of the clonal material.

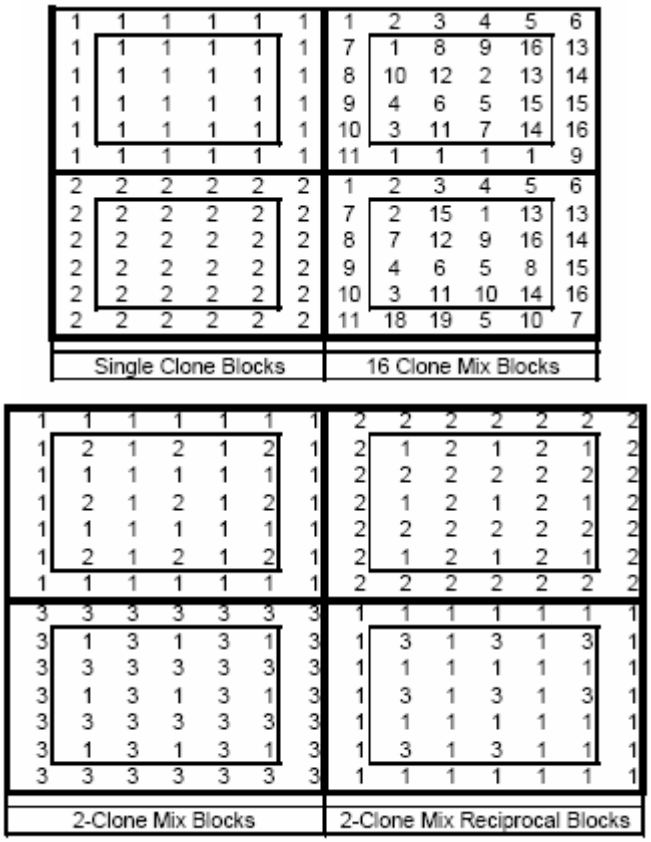

Figure 2. Examples of the layout within and between the different blocks. Each number represents a different clone.

The trial contains 112 plots that cover the 13 hectares. The two-clone mixture plots have a plot size of 0.1225 ha compared to the other treatments which have a plots size of 0.040 ha. The larger plot size was to allow for the planting pattern of the two-clone mixtures as shown in Figure 1. Sixteen different clones were planted using tissue culture plantlets. The sixteen clones were included in the single clonal block and the 16 clone mixtures, however only the first 5 clones are included in the two-clone mixtures treatment.

The trees were planted at 5x5 metre spacing (400 stems/ha). The trees were access pruned at age 6 to a height of 3 metres. The site is classified as highly productive in both terms of height and volume growth with a 300 index of 28.7 and the site index of the plots ranging between 31 -39. Refer to the establishment report (Turner et.al., 1996) for a full description of the trial.

Between July 2007 and September 2007 the compartment containing the trial was production thinned. The trial was established at final crop stocking and the experimental design does not allow for thinning. Approximately 23% of the stems were removed. There was concern over the future of the trial, however a brief analysis of those trees removed carried out to identify any potential bias in tree selection by the thinning crew showed fairly smooth distribution of residual clones. It was decided the project would continue as there would be no effect on the wood properties of the residual trees in the 2-4 weeks since production thinning. Annual re-measurement of the trial for the next three years will be necessary to capture the growth response to the thinning. The additional variation introduced by the production thinning will be accounted for by using a competition coefficient to measure the different level of competition each tree is exposed to.

DATA COLLECTION

Trees were assessed for acoustic velocity using the IML electronic hammer. This tool is a non-destructive measure of the speed of sound within wood. The speed of sound is correlated to the stiffness of lumber cut from the trees - faster sound waves indicate higher wood stiffness. A value for a single side of the tree at breast height was collected as outlined in the operators' manual (Kimberley et. al., 2004). Compression wood, large branch whorls and excessive lean was avoided. The four clone mix and pure plots and their control plots were measured in FR 450. In FR 308 the 16 clone mix and pure plots of the 16 clones and their control plots were measured; it was decided that collecting data from the 2 clone mix and their reciprocals was not necessary as the 16 clone mix was of a sufficient sample size.

ANALYSIS

The IML hammer measures acoustic velocity in km/sec. This data has not been converted to dynamic Modulus of Elasticity (MOE) for ease of interpretation. Thus the acoustic velocity is simply a means of ranking each clone, indicative of its wood quality rather than attempting to quantify the actual stiffness of the wood from each tree.

The clonal effect was analysed simply by comparing mean acoustic velocities for each of the different clones regardless of the clonal pattern that they were planted in. The mixed procedure was used in SAS to test for any significant difference in mean velocity between clones and the control pollinated seedlings.

The effect of deployment configuration was examined by comparing the acoustic velocity of the different clones planted as mixtures and as pure blocks. The mixed procedure was used to in SAS to test for any significant difference in mean velocity between mixed and pure plantings.

Within plot variation was assessed by comparing the level of variation within each plot grouped by treatment. The mixed procedure was used in SAS to test for any significant difference in the Coefficient of Variation between mixed and pure plantings.

RESULTS

Clonal Effect

There is a similar range in acoustic velocity of around 500km/sec between clones of each trial. The clones of the older trial FR 475, age 19 show higher acoustic velocity when compared to the control seedlings, however only two clones show significantly higher acoustic velocity. The clones of the younger trial FR 308, age 12 show more variation, with some performing better, some worse than the control seedlings plots. Both trials show similar levels of within-clone variation. The lower mean acoustic values of the younger stand could be attributed the selection criteria for growth and form of the more recent clonal material resulting in faster growth rates and lower wood quality (Chauhan and Walker 2006). Additionally, a higher proportion of lower stiffness juvenile core-wood could influence the measured time of flight in the outerwood of the younger stems.

FR 450 - Kawerau

Mean acoustic velocity for each of the four clones and the control seedlots in FR 450 ranged between 2599 and 3094 m/sec. Figure 3 illustrates the difference in wood quality between the four clones and the control seedlots. The acoustic velocities of clones 37 and 43 clones was significantly greater at $p<0.005$ than the poorer performing clones 31 and 36 and the control seedlings. The mean velocity of all four clones were significantly greater at $p<0.005$ than the control seedlings. The error bars show a similar level of variation in acoustic velocity within each clone and control seedling of around +/- 100km/sec.

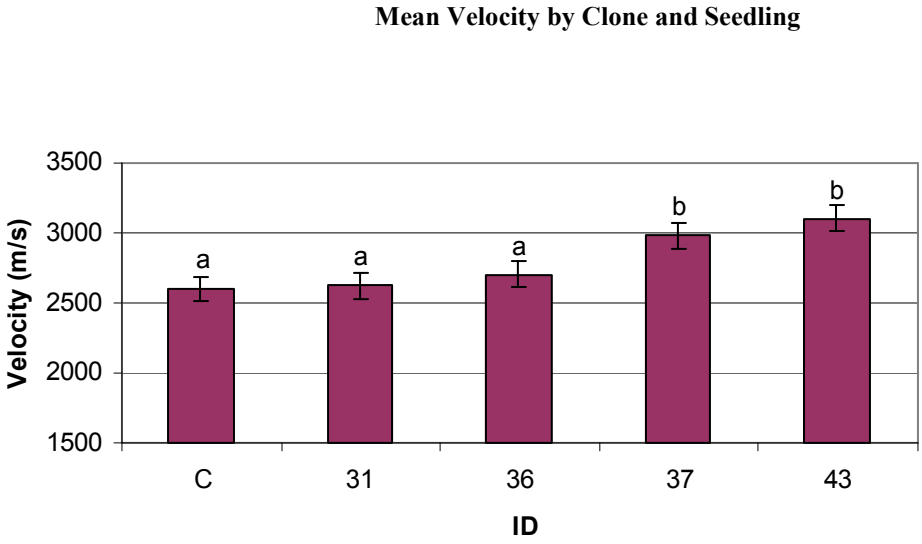

Figure 3. The mean acoustic velocity of the different clones and the control pollinated seedlings[1].

FR 308 - Tarawera

Mean acoustic velocity for each of the 16 clones and the control GF23 seedlings in FR 308 ranged between 2049 and 2587 m/sec. Figure 4 illustrate the difference in wood quality between the 16 clones and the control seedlots. The error bars show a similar level of variation in acoustic velocity within each clone and control seedling of +/- 100km/sec.

[1] Clone and seedling ID labelled with the same letter do not differ significantly (p=0.05)

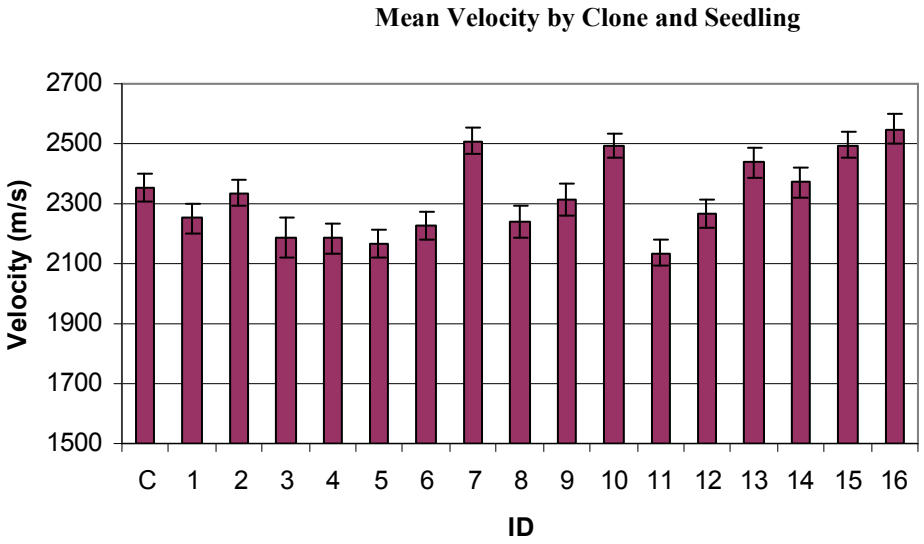

Figure 4. The mean acoustic velocity of the different clones and control pollinated seedlings.

Pure vs Clonal Mixtures

The mean acoustic velocity was plotted for each clone planted in single clone blocks and as clonal mixtures. Figure 4 shows no clear pattern in wood quality between the treatments over both sites, with some clones performing better when planted as mixtures and others when planted as pure blocks. With a site index of 29 metres and at a live stocking of 592 stems/ha full site occupancy has been achieved for many years at the Kawerau site. The consequent inter-tree competition levels will possibly be higher than encountered in most current regimes. The resulting suppression of diameter growth may have negated any potential significant differences between the clonal blocks and mixtures.

FR 450 -Kawerau

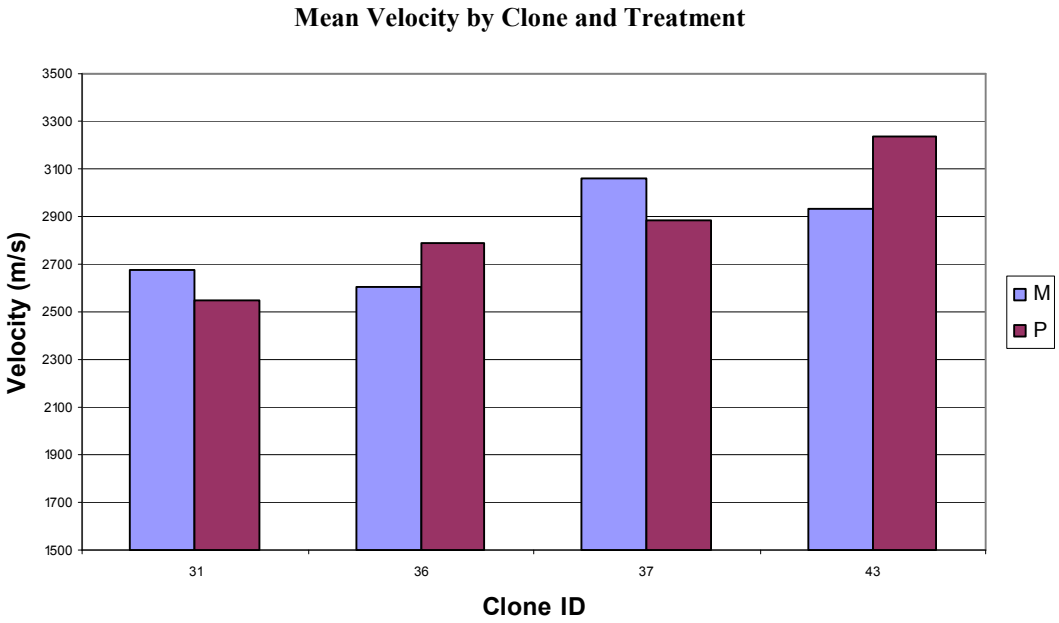

Figure 5. Mean acoustic velocity of pure clone blocks vs four mixture blocks.

Mean acoustic velocity (m/s) at age 19 of the four clones tested as pure blocks and four clone mixtures is summarised in Table 1. The mixed procedure was used to test for any difference in mean velocity between mixed and pure plantings. No significant difference at was found when clones were grouped individually or combined, between planting in pure clone blocks and mixture blocks for acoustic velocity.

Table 1. Comparison of pure versus 4-clone mixed plantings of acoustic velocity for each clone at tree age 19

Clone	Pure	Mixed	Significance of pure vs mixed planting (p=0.05)
31	2549.6	2648.6	n.s
36	2711.0	2602.1	n.s
37	2882.9	3021.3	n.s
43	3237.6	2960.8	n.s
Combined	2848.2	2834.4	n.s

FR 308 - Tarawera

The mean acoustic velocity was plotted for each clone planted in single clone blocks and as clonal mixtures. Figure 6 shows no clear pattern in wood quality between the treatments over both sites, with some clones performing better when planted as mixtures and others when planted as pure blocks.

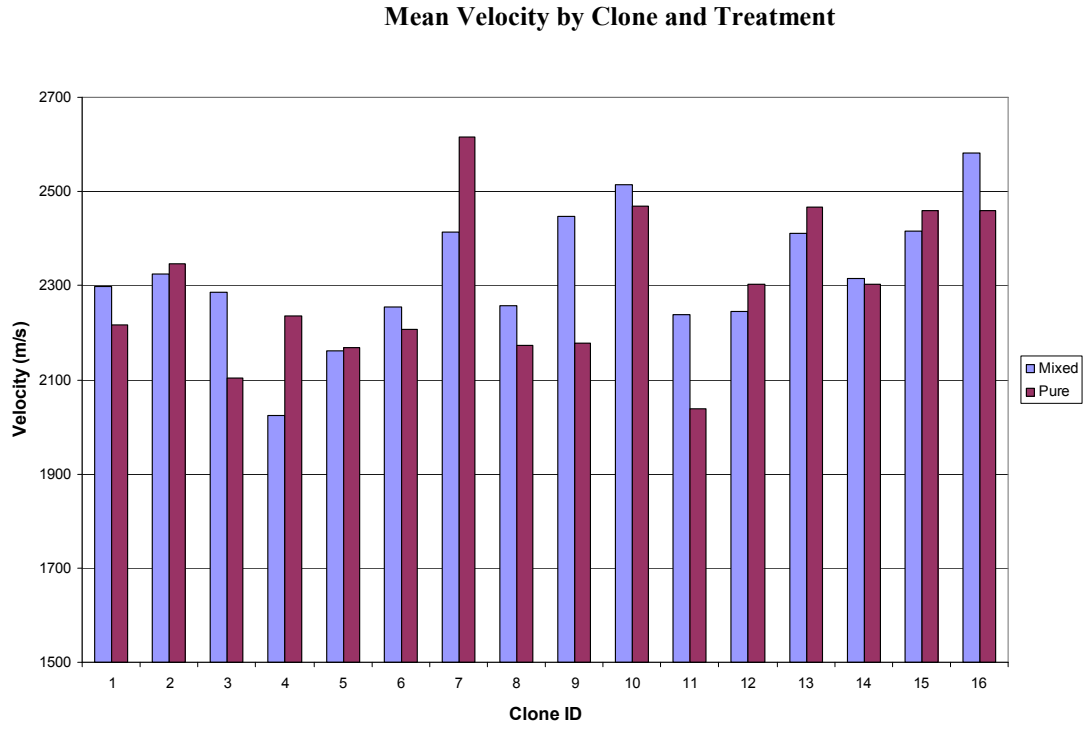

Figure 6. Mean acoustic velocity of pure clone blocks vs 16 mixture blocks.

Mean acoustic velocity (km/s) at age 12 of the 16 clones tested as pure blocks and 16 clone mixtures is summarised in Table 2. The mixed procedure was used to test for any difference in mean velocity between mixed and pure plantings. No significant difference at was found when clones were grouped individually or combined, between planting in pure clone blocks and mixture blocks for acoustic velocity.

Table 2. Comparison of pure versus 16-clone mixed plantings of acoustic velocity for each clone at tree age 12

Clone	Pure	Mixed	Significance of pure vs mixed planting (p=0.05)
1	2216.5	2299.6	n.s
2	2345.8	2324.2	n.s
3	2103.3	2286.0	n.s
4	2235.2	2140.6	n.s
5	2169.2	2161.1	n.s
6	2206.6	2207.9	n.s
7	2650.4	2413.7	n.s
8	2126.4	2257.1	n.s
9	2177.2	2446.5	n.s
10	2486.1	2514.3	n.s
11	2001.6	2182.5	n.s
12	2303.4	2244.9	n.s
13	2467.9	2411.3	n.s
14	2302.6	2421.7	n.s
15	2458.6	2415.0	n.s
16	2503.9	2582.0	n.s
Combined	2303.2	2336.4	n.s

Variation between trees in mixed and pure plots

The within-plot coefficient of variation (CV) of acoustic velocity for different treatments ranged from 7.9 to 12.5 (Figure one) in FR 450 and from 9.4 to 12.8 in FR 308 (Figure two). The CV within the control pollinated seedling and the mixed blocks were significantly higher than the pure blocks in both trials. The biggest difference in CV between the two trials is in the pure plots, where FR 450, age 19 shows less variation in the older clones compared to FR 308.

Table 3. Comparison of within-plot CV (coefficient of variation) of acoustic velocity for different planting stock and deployment treatments – FR 450.

	CV	Se(CV)
Control	12.5[a]	0.72
Mixture	11.8[a]	0.62
Pure	7.9[b]	0.73

Values in a column followed by the same letter do not differ significantly ($p<0.05$)

Table 4. Comparison of within-plot CV (coefficient of variation) of acoustic velocity for different planting stock and deployment treatments - FR 308.

	CV	Se(CV)
Control	12.8[a]	1.18
Mixture	11.9[a]	0.68
Pure	9.4[b]	0.38

Values in a column followed by the same letter do not differ significantly ($p<0.05$)

CONCLUSION

Measuring the mean acoustic velocity of different clones and seedlings enabled segregation from one another where the acoustic properties were significantly different. A similar range and variation in acoustic velocity was found between different clones in both trials, although the mean value for the older trial was found to be higher.

No clear pattern in wood quality could be discerned between the treatments over both sites, with some clones performing better when planted as mixtures and others when planted as pure blocks.

The coefficient of variation was found to be significantly greater within the control pollinated seedling and the mixed blocks when compared to the pure blocks in both trials. This shows that across a stand, there will be less variation in wood properties in blocks of pure clonal material, when compared to blocks of mixed clonal material, or control pollinated seedlings.

These trials show that there is no overall advantage, in terms of improved wood quality as indicated by acoustic velocity, to planting clones in pure blocks versus planting as mixtures. However, deploying multiple blocks of single clones will provide the increases in productivity and quality associated with clonal forestry while reducing the variation in wood properties between trees and spreading the risk across a number of clones.

This study adds to the growing body of evidence that the configuration of clonal forestry deployed has little impact on the growth and quality of trees. Analysis of FR 475 at age 17 (Kimberley and Dean 2006) and FR 308 at age 10 (Marshal 2007) demonstrate that the configuration of clonal forestry deployed has little impact on the growth of trees while the variability in tree size of clones planted in pure blocks is less than in mixtures or control pollinated seedling stands.

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