Comparative performance of radiata pine genotypes with pasture understories

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Abstract

This paper presents results from a silvopastoral experiment at Lincoln University that investigated interactions between four different pasture types and growth and form of five different 'genotypes' of radiata pine (four micro-propagated clones and one seedling lot).

The five radiata pine tree 'genotypes' tested in this experiment displayed differences in growth and form 10 years after planting. However, there were no statistically significant interactions between tree genotype and understorey effects. The two best 'genotypes' were superior in nearly all respects (growth, branch size and stem form), on all pasture types. These results concur with other research results that indicate that the best radiata pine genotypes will perform consistently well across a range of environments in New Zealand. However, within a breeding programme, different selection criteria may be needed when selecting seedlots or clones for wide-spaced silvopastoral regimes, where trees with superior form, wood density and branch habit but only average growth rates may be preferred to more vigorous trees that rank lower for branching and form.

Introduction

In New Zealand the potential profitability of widely spaced trees in a silvopastoral system was first formally recognised in 1969 (Knowles 1972, Hawke & Knowles 1997) as a result of developments in plantation forestry with 'direct sawlog' regimes for radiata pine (*Pinus radiata* D.Don). 'Direct sawlog' regimes involve thinning to waste early, coupled with pruning to enhance the value of the butt log, by increasing the proportion of clearwood. Grazing these 'direct sawlog' stands was considered a good option for utilising pasture growth under the trees to provide additional and earlier financial returns.

In silvopastoral systems dry-matter production and physiological characteristics of trees may be different from those in plantation forests (Tombleson & Inglis 1988, West & Dean 1988, Bandara 1997). Compared with trees on plantation sites, wide-spaced radiata pine on fertile farm sites has exhibited increased malformation, toppling, decreased wood density and increased branch size (Knowles 1991, Cown 1992, Mead *et al.* 1993, Bandara 1997).

The increasing availability of genetically improved trees coupled with the use of rooted cuttings has enhanced the potential for successful silvopastoral systems. Genetically improved trees exhibit superior growth and form to trees from unimproved populations. The use of rooted cuttings leads to improvement in tree form due to the physiological ageing that occurs in the process of vegetative propagation (Menzies & Klomp 1988). These improvements in tree growth and form permit a reduction in the number of trees planted and consequently in the amount of pruning and thinning debris, pasture shading and cost of silviculture.

This paper presents results from a silvopastoral experiment at Lincoln University that investigated interactions between different pasture types and different 'genotypes' of genetically improved radiata pine.

Materials and methods

Experimental Site

The Lincoln silvopastoral experiment is located in Lincoln, Canterbury, New Zealand (latitude 43° 38´S, longitude 172° 30´E). The site is flat, but there is variation in soil depth (from 0.9 to 1.6 m) to the underlying gravels. The soil nutrient levels were considered adequate for tree growth (Yunusa et al. 1995). Using the Thornthwaite classification, the climate is described as subhumid, with cool winters and "very warm" summers (Garnier 1950). Further site details are reported in Peri et al. (2002).

Experiment and silviculture

Pinus radiata trees were planted in July 1990 at 1000 stems/ha (1.4 m within rows and 7 m between rows) in a split-plot randomised block design, which covered a total of 5.2 ha. The main plots were six different pasture understories, fully replicated in three blocks, which were expected to vary in their competitive effect on the trees. The main plot size was 46.2 m x 42.0 m (0.194 ha). The pasture treatments were sown in spring 1990. In the first two growing seasons the pasture was cut for silage and has been grazed by sheep since 1993. Details of the experiment were given in Mead *et al.* (1993) and Peri *et al.* (2002).

The final tree crop stocking was ca 200 stems/ha (7 m between rows). Four thinnings to waste and from below were carried out keeping an even distance between trees. The first three pruning lifts were carried out to a variable height aiming to leave a constant crown length of 4 m. The last pruning was carried out up to 6 m height. Crown closure had not occurred at age 10 years from planting, when the measurements reported in this study were taken.

Four pasture treatments were examined in this study: 1. Bare ground; 2. Wana cocksfoot (*Dactylis glomerata*) + clovers; 3. Yatsyn perennial ryegrass (*Lolium perenne*) + clovers; and 4. WL320 lucerne (*Medicago sativa*). The

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Table 1: Sub-plot treatments (radiata pine 'genotypes') at the Lincoln University silvopastoral experiment (Canterbury).

'Genotypes'	Description	Indicative GF Rating of Families
1	Set 38/6, open-pollinated offspring of "850" clone 55	GF15
2	Set 38/203, open-pollinated offspring of "850" clone 55	GF15
3	Set 11/8, control-pollinated offspring of "875" clone 7 x 292	GF16/17
4	Set 38/9 open-pollinated offspring of "850" clone 55	GF15
5	"850" open-pollinated seedlings	GF14

other two pasture treatments within the experiment were excluded from analysis because they did not prove to be persistent over the 10 year study period.

Within the main plots, sub-plot treatments were five 'genotypes' of radiata pine (Table 1). In each main plot four rows of trees were measured, with each 'genotype' replicated within a row i.e. 20 measured trees per plot.

The GF ratings are a guide to genetic quality for tree growth and form as applied to seedling-grown trees (Vincent & Dunstan 1989). 'Genotypes' 1-4 represented individual clones which were propagated by tissue culture, with set 38 being four years from seed and set 11/8 being six years from seed. This physiologically aged material was expected to have superior form and smaller branches compared to seedlings. Field test data also indicated that micro-propagated material could have lower growth rates than seedling stock of similar genetic quality (D.R. Smith 1986 quoted in Carson 1986).

Measurements and data analysis

Measurements of diameter at breast height (DBH) outside bark (to nearest mm) and total height (Ht) (to nearest 0.01 m) were taken at tree age 10. Diameter over pruned stubs (DOS), DOS height and pruned height were recorded at the time of each pruning lift. Total volume and form factor (ratio of stem cylinder volume and actual volume), sweep, and branch size of all experimental trees in each understorey treatment were measured or calculated from measurements. Details of these measurements and calculations are given in Peri *et al.* (2002).

Branch measurements were calculated according to Inglis and Cleland (1982). Branch index (BIX) is the mean diameter of the four largest branches in a nominated log length. Maximum branch size (MAXBr) is the diameter (to nearest mm) of the largest single branch in the second log length within each tree (6-12m). Tree stem form was classified for the first six metres (first log) as follows: straight, wobble, sweep, lean, kink. Any tree with more than one type of stem malformation was classified as belonging in all relevant categories. The condition of the tree leader was classified as: single live leader, double leader and multiple leader.

Volume, Ht, DBH, form factor, sweep, BIX, maximum branch (MAXBr) and maximum DOS at age 10 were subjected to analysis of variance (ANOVA). Standard error of means (sem) were used to evaluate least significant differences (lsd) at the 0.05 probability level for means separation of the studied variables. Statistical analyses were carried out using the Genstat statistical package (Genstat 5 1997). Tree stem form and leader condition were not statistically analysed, but the frequency of occurrence of the stem form and leader condition categories for each 'genotype' was shown in histograms and inspected for differences between 'genotypes'.

Results

The radiata pine tree 'genotypes' tested in this experiment displayed differences in growth and form. However, there were no statistically significant interactions ($p \geq 0.12$) between tree genotype and understorey effects over the test for all individual variables. For all studied variables there were also no significant second order interactions (genotypes x understoreys x replicates) ($p \geq 0.18$). Therefore the rankings of the five 'genotypes' with respect to growth and form criteria show no significant inconsistency across all understorey treatments (Table 2).

The proportion of stems affected by malformation (sweep, wobble, kink/lean, multi-leader and double leader) is presented in a histogram (Figure 1), and substantial differences between different genotypes are apparent.

Based on this analysis, 'genotype' 3 was consistently amongst the best performers in terms of growth and branching characteristics, while exhibiting reasonable stem straightness and form. 'Genotype' 4 was somewhat inferior in terms of growth, but displayed superior stem straightness, branch characteristics and tree form. 'Genotype' 1 was generally below average in terms of growth, stem straightness and form. 'Genotype' 5 (seedlings) was average in terms of growth but was below

Fig. 1: Proportion of tree stem form defects in the first six metres log and tree leader malformation for five radiata pine 'genotypes'

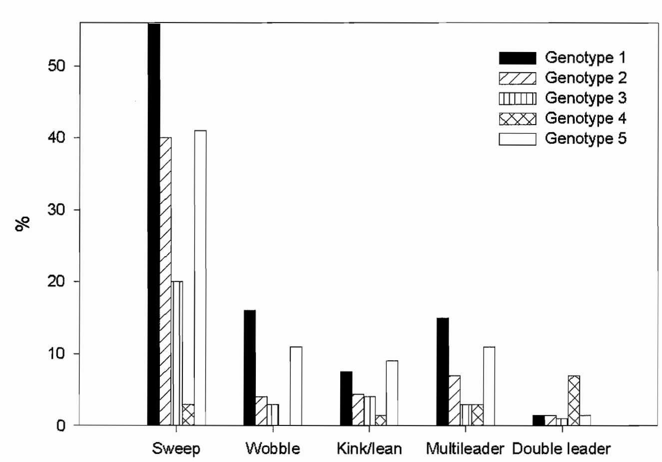

Table 2: 'Genotype' rankings and means for individual traits. 'Genotypes' are denoted by italic numbers.

Variable	***Best***				***Worst***
DBH (cm)	*3* (29.1 a)	*5* (27.5 b)	*4* (27.4 b)	*1* (26.5 c)	*2* (26.2 c)
Height (m)	*3* (13.9 a)	*4* (13.7 a)	*1* (13.3 b)	*2* (12.9 c)	*5* (12.2 d)
Form factor (dimensionless)	*3* (0.51 a)	*1* (0.50 ab)	*5* (0.49 b)	*4* (0.48 bc)	*2* (0.46 c)
Volume (m3/ha)	*3* (86.3 a)	*4* (78.0 b)	*5* (77.3 b)	*1* (73.3 bc)	*2* (70.7 c)
DOS (cm)	*4* (19.2 a)	*3* (20.4 b)	*1* (20.4 b)	*2* (21.8 c)	*5* (21.9 c)
BIX (cm)	*4* (5.0 a)	*3* (5.1 a)	*1* (5.4 ab)	*2* (5.7 bc)	*5* (6.1 c)
MAXBr (cm)	*3* (6.3 a)	*4* (6.3 a)	*2* (7.0 b)	*1* (7.1 b)	*5* (7.4 c)
Sweep (mm/m)	*4* (8.5 a)	*2* (10.5 ab)	*3* (11.7 ab)	*5* (15.8 bc)	*1* (18.0 c)

Note: Within rows, figures with different letters differ at 5% significance level, "a" denoting the best.

average in terms of branching and form, although its form was still superior to that of 'genotype' 1. 'Genotype' 2 was the poorest in terms of growth, but was reasonably straight and free from stem malformation.

Discussion

Growth

The radiata pine tree 'genotypes' tested in this experiment had substantial growth differences (Table 2). In the same experiment, tree growth varied significantly between the four different understorey treatments. For example, volume growth for the best understorey treatment was 34% higher than for the worst treatment [97.7m^3/ha (bare ground) versus 64.5 m^3/ha (lucerne), 10 years after planting] (Peri *et al.* 2002).

However, the five 'genotypes' did not show different patterns of responses to the different understorey treatments i.e. there were no interactions between tree genotype and understorey effects. Similarly, Mead *et al.* (1993) reported that there was no interaction between understorey effects and 'genotypes' at age two years for the same experiment. These results are also generally consistent with those from another trial on the Canterbury Plains (Mason & Kirongo 1999), where initial DBH growth was not materially affected by interactions between four levels of pasture competition and six radiata pine clones. However, pasture competition/clonal interactions did affect height growth in the second year of this trial.

In contrast, Carson (1991) reported that statistically significant genotype x environment (GE) interactions existed for DBH growth across 11 trial sites throughout New Zealand. However, an examination of rank changes between 'genotypes' over different sites suggested that there was no clear pattern favouring regionalised breeding programmes. Carson (1991) concluded that selection of parents for tree breeding could be based on trials from a small number of sites, with genotypic effects from these trials being repeatable throughout New Zealand. More generally, recent research demonstrated that increased rates of growth observed with genetic improvement of radiata pine were consistent over silviculture, stand age and forest region with 35 seedlots at final crop stockings of 200-1000 stems per hectare (S. D. Carson pers. comm.)

Form and branching

Silvopastoral systems with trees planted in wide spacing to enhance pasture production can result in trees with poorer stem form, larger branches, loss of apical dominance and less height growth (Maclaren *et al.* 1995, Menzies *et al.* 1991). Wider spacings can increase the likelihood of wind damage, mainly after thinning when the turbulence characteristics over the stand may change (Knowles & Paton 1989).

The use of physiologically aged plant material for planting may improve stem form in radiata pine (Menzies & Klomp 1988). Therefore in this experiment, it was expected that 'genotypes' 1-4 would exhibit superior form and branching compared to 'genotype' 5 (seedlings). The expectation was generally borne out, except that 'genotype' 1 was the lowest ranked for average sweep, and 'genotype' 2 values for BIX and DOS were not significantly different from those for seedlings.

In addition, histograms of percentage malformation versus genotype (Fig. 1) showed 'genotypes' 1 and 2 performing as badly as the seedlings for sweep, and 'genotype' 1 performing either similarly or even worse than the seedlings for wobble, kink/lean and multiple leader. This poor performance from 'genotypes' 1 and 2 is surprising given their similar genetic background to 'genotype' 4 (all are open-pollinated offspring of "850" clone 55.) In addition, all three clones were micro-propagated at the same age from seed (four years), and could be expected to display similar effects of physiological ageing on tree form and branching. That this did not occur suggests that physiological ageing effects are not consistent for all form and branching characteristics, across all genotypes, even when those genotypes are closely related.

'Genotype' 3 was consistently superior in terms of growth, form and branching but this superior performance may have been due either to its genetic background (controlled-pollinated offspring of '875' clone 7 x 292) or its greater physiological age (six years as opposed to four years for the other micro-propagated 'genotypes').

Conclusions

Different levels of pasture competition did not significantly influence the ranking of different radiata pine 'genotypes' with respect to growth and form. In the Lincoln silvopastoral experiment the best 'genotypes' (3 and 4) were generally superior in all respects (growth, branch size and stem form), on all pasture types.

These results suggest that vegetatively propagated trees will perform better than seedlings on exposed, high-fertility pasture sites such as the one at Lincoln, irrespective of the type of pasture understorey. However, some 'genotypes' were not much better than seedlings in terms of growth and form, suggesting that maximum gains from a vegetative propagation strategy may require careful selection of clonal genotypes to suit pasture sites.

In a silvopastoral system, tree form, wood density and light branching may be more important breeding objectives than in plantations where final stockings typically range from 250 to 600 stems/ha. This means that different selection criteria may be needed when selecting seedlots or clones for silvopastoral regimes, where trees with superior form, wood density and branch habit but only average growth may be preferred to more vigorous trees that rank lower for branching and form. Results from other research suggest that such selections can be made with reasonable confidence using results from genetic gain experiments on non-pastoral sites.

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