FOREST & FARM PLANTATION MANAGEMENT COOPERATIVE

EXECUTIVE SUMMARY

A PRELIMINARY ANALYSIS OF POTENTIAL FOR DEVELOPMENT OF GENETIC GAIN MODIFIERS FOR STEM STRAIGHTNESS

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In order to develop appropriate genetic gain modifiers for stem straightness there is a need to obtain objective measures of stem straightness for each parent contained in the New Zealand radiata pine breeding population. Previously measurement of parents in the breeding program assessed in progeny trials required subjective measures to be taken due to the large measurement requirements, and the need for relative rankings only, when analysing progeny trials. This study aimed to develop a relationship between the stem straightness national breeding values (NBV) derived by Genetics and Tree Improvement, from subjective measures of stem straightness, and recent objective measures made on a subset of parents. If there is a strong relationship between NBV and stem straightness, objective measures of stem straightness may be calculated from the NBV for each parent in the breeding population. This preliminary study was based on the progeny trials located at compartment 327, Kaingaroa Forest, which contained a high incidence of swept trees relative to other progeny trials. The use of a trial site with a higher incidence of swept trees in the trial was intended to aid the identification of a strong relationship between stem straightness and NBV. The analyses indicate that while there is a significant relationship between NBV and sweep, the levels of sweep measured in this study were not of sufficient economic significance, at a 1.5% decrease in value, to justify further development of the relationship.

OBJECTIVE

To evaluate the effect of genetic changes in stem straightness for improved "850" series *Pinus radiata* families in the 1975 "850" disconnected diallel and polycross trials at Kaingaroa Forest Compartment 327, by exploring the relationship between stem straightness NBV and measured sweep.

INTRODUCTION

Tree breeding research has shown that a considerable number of traits influencing tree quality can be manipulated to suit specific sites, management regimes, processing methods and markets. To this end the tree breeding programme can produce planting stock (designer trees) with altered quality features such as branch size, internode length, stem straightness and wood density. It is proposed that the New Zealand Tree Seed Certification will give seedlots separate ratings for growth rate (G), branch habit (B), straightness (S) and wood density (D) (Carson 1996).

The different radiata pine breeds may respond differently to specific site and management options. Forest managers will need to make decisions relating to market supply and processing options based on how the different seedlots of radiata pine respond to differing sites and management. To aid forest managers in making these decisions, the impacts of growing designer radiata pine breeds for different characteristics needs to be modelled. Development of these models will enable forest managers to make informed decisions regarding the management of new breeds of radiata pine. The ability to model these is essential because of the time it takes for radiata pine crops to mature and the need for yield and log quality information before rotation end.

Genetic gain modifiers have already been developed for *Pinus radiata* basal area and height growth (Carson, *et al.* 1990; Carson 1996). This has been possible because the impact of the breeding programme on tree growth has provisionally been quantified in terms of diameter and height growth in genetic gain trials. The impact of the tree breeding programme on branch habit, sweep and malformation however, has only been estimated in terms of a subjective scoring system. This scoring system has enabled relatively quick and low cost information for the ranking and selection of parents, but is not satisfactory for quantifying absolute differences among improved breeds.

Towards establishing a national ranking of families for branch habit, malformation and stem straightness, research in the Genetics and Tree Improvement (GTI) programme has been concerned with the development of breeding values[1] (Kumar, *et al.* 1996). These breeding values have been calculated for all 1080 parents in the breeding population, for branching habit and stem straightness, using the extensive amount of subjective data available from GTI field progeny trials (Kumar, *et al.* 1996).

This study aims to complement this development of breeding values by producing genetic gain modifiers for stem straightness related to the breeding values (Figure 1. These gentic gain modifiers will enable forest managers to evaluate the effect of different management strategies on improved material, and also the effect of using genetic material tailored for different end uses and sites can be analysed in financial terms.

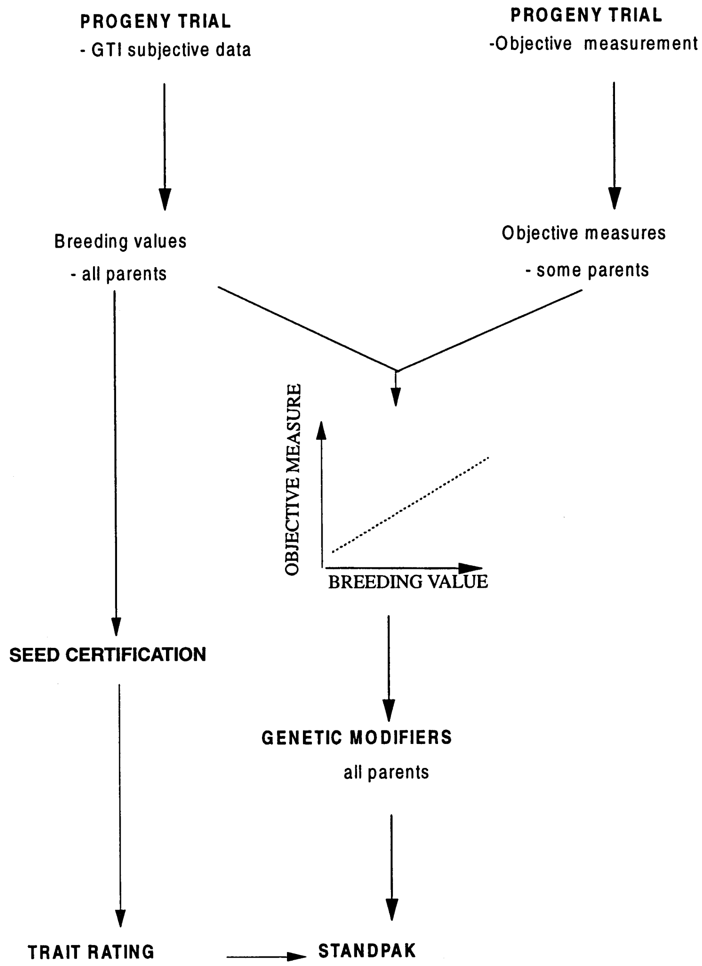

FIG. 1: Project strategy for developing genetic gain modifiers.

In order to develop the appropriate genetic modifiers there is a need to obtain objective, quantitative measures of stem straightness for each parent in the breeding programme across

[1]The breeding value judges the value of an individual in terms of the mean value of its progeny (Falconer, 1989).

New Zealand. If there is a strong relationship between the breeding values, based on GTI subjective scores, and objective quantitative measures, actual values could be using the genetic gain modifiers. Based on the established relationships quantitative measures of stem straightness may be predicted from the subjective scores for each family in the GTI breeding programme.

This preliminary study focuses on Kaingaroa Forest Cpt 327, a site which has a high occurrence of swept trees so that the relationship between stem straightness, and the stem straightness national breeding value (NBV) may be clearly determined.

METHOD

Site Selection

Kaingaroa Cpt 327 was chosen for measurement because of its close proximity to the New Zealand Forest Research Institute (FRI), and the relatively higher level of occurrence of swept trees compared with other progeny. The higher likelihood and greater degree of sweep on this site meant that stem straightness could be more readily identified by the measurement techniques used.

Progeny Trial and Family Selection

The 1975 "850" polycross and disconnected diallels were chosen because they contain a large number of families covering the range of possible sweep national breeding values (NBV). Eighteen families were selected from the 1975 "850" polycross, and eleven were selected from the 1975 "850" disconnected diallel. The families chosen covered the range of possible levels of sweep in GTI selected parents with emphasis placed on the extremes of no sweep, and high levels of sweep (Figure 2).

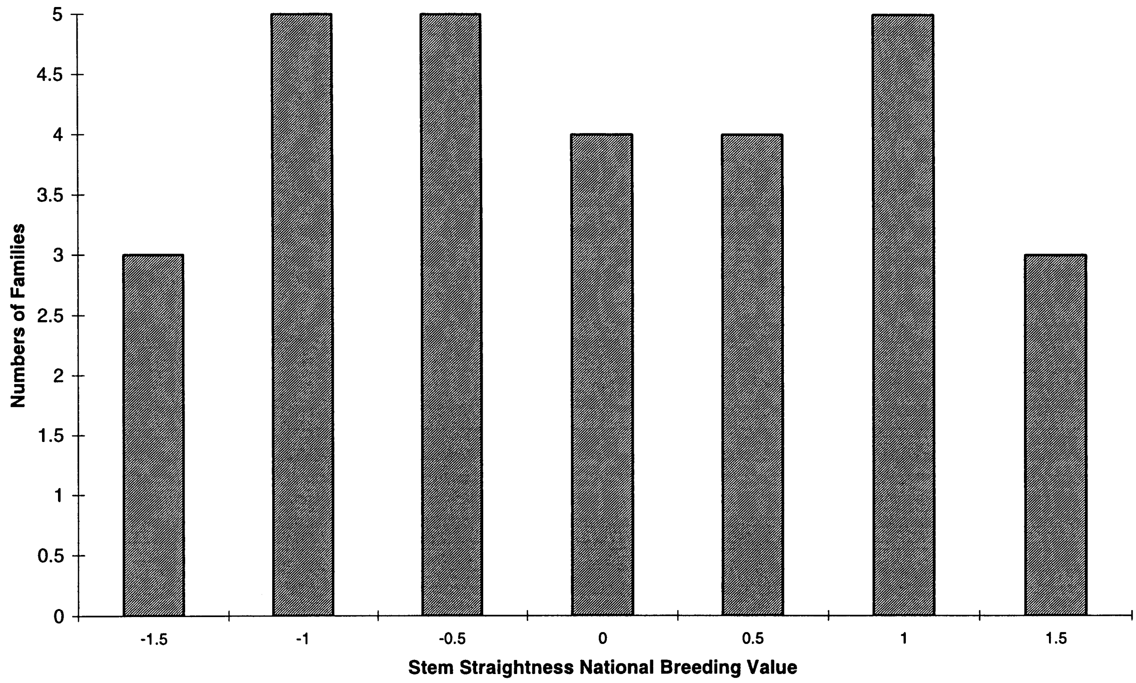

FIG. 2: Frequency distribution of family stem straightness national breeding value (NBV) for families selected for measurement in the study.

Measurement Technique

The sweep measurement technique is based on work by Grallelis and Klomp (1982), West and Kimberley (1991), and Turner (1996). West and Kimberley (1991) carried out an assessment of sweep on trees which had just received a high prune, ie., trees younger than those assessed in this study. Four sweep measurement techniques, straight edge, harp, height pole and s-gauge, were tested. They found the height pole to be the best method. While the height pole is not as accurate as the harp or the straight edge its ease of use meant the height pole could be used to measure sweep 50% faster than the harp or s-gauge and considerably more rapidly than the straight edge. The relative rankings of the 4 methods in terms of estimates of mean are given in Table 1. The straight edge method is assumed to be 100% accurate

TABLE 1. Estimated mean sweep of radiata pine, after the final pruning lift, by four methods of sweep assessment. The actual sweep is 6.2 cm. Source: West and Kimberley (1991).

METHOD	MEAN SWEEP (cm)
Straight edge	6.2
Harp	6.0
Height pole	5.8
S-gauge	4.6

The ability of the harp, height pole and s-gauge to estimate stem straightness for a range of levels of sweep was checked by West and Kimberley (1991). The harp, height pole and s-gauge all have a tendency to overestimate sweep when trees have < 4 cm sweep and underestimate stem straightness on trees with sweep > 10 cm

West and Kimberley (1991) had 3 sweep classes when using the height pole to assess stem straightness in terms of deviation expressed as a proportion of stem diameter at point of maximum sweep. These sweep classes are:

- 0 - D/4;
- D/4 - D/2;
- > D/2;

where **D** is stem diameter over bark at the point of maximum sweep.

These sweep classes were considered to be the minimum range that was practical to measure with the instruments tested. The height pole is reasonably accurate at differentiating trees into these 3 categories.

Based on this work by West and Kimberley (1991) and Grallelis and Klomp (1982) a method of sweep assessment was devised. Stem sinuosity was measured over a 6.0 m log length using a height pole at right angles to the plane of maximum sweep. The centre to centre method described by Grallelis and Klomp (1982) was used (Figure 4). The 5 sweep diameter deviation classes were:

- 0 - no sweep;
- 1 - < D/ 8;
- 2 - < D/ 4;
- 3 - < D/ 2;
- 4 - > D/ 2;

where **D** is the stem diameter over back at the height of maximum sweep.

In addition to the diameter deviation classes, each tree was also rated for stem straightness using 5 sweep mm classes:

- 1 - 0 to 10 mm;
- 2 - 11 to 30 mm;
- 3 - 31 to 60 mm;
- 4 - 61 to 100 mm;
- 5 - > 100 mm.

For the two measures of stem straightness, two measurements were made, the first used a stump height of 0.2 m, while the second used a stump height of 1 m. The use of a 1 m stump height avoids the effect of toppling on butt sweep, and allows a more direct comparison of sweep measured with the GTI score which is made on the stem above 1 m (Wilcox 1990).

The height of maximum sweep was also measured for both the 0.2 m and 1 m stump heights to enable a measure of sweep in terms of mm/ m in the 6 m log (Figure 3).

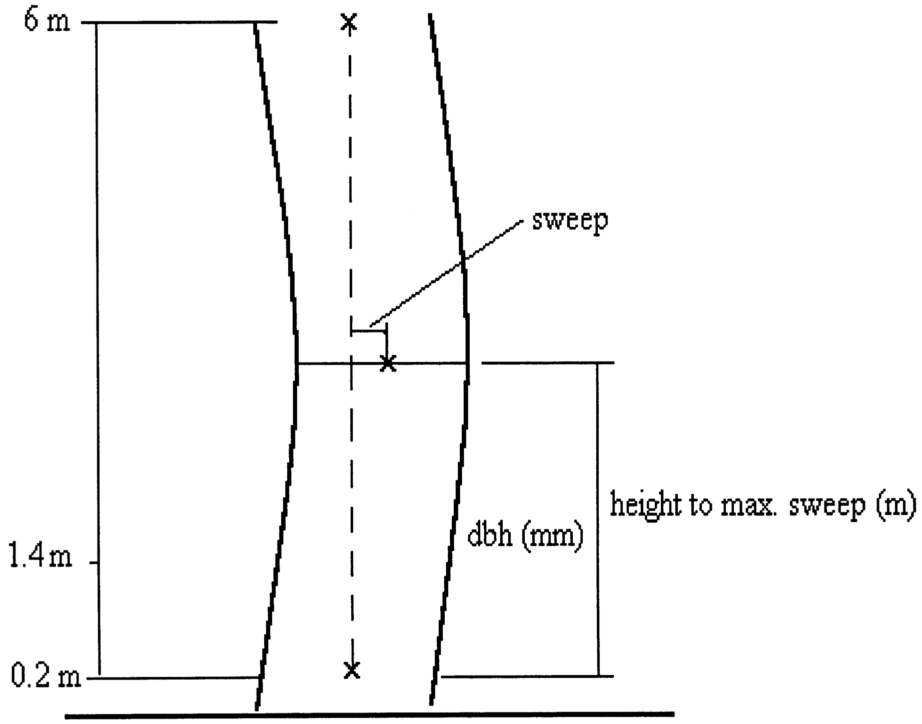

FIG. 3. The centre to centre method of sweep measurement. Source: Grallelis and Klomp, 1982.

The height pole was used because it is reasonably accurate as well as being 50% faster than the harp and s-gauge. It was decided to expand the number of sweep classes to 5, with more emphasis on the lower levels of sweep, due to the subtle levels of sweep found in GTI selected radiata pine. Stem straightness was measured for the first 6 m of the stem as this section of stem is normally pruned.

48 trees at the site, 24 from the disconnected diallel and 24 from the polycross were measured for total tree height using a Suunto. This information was used in a taper function (refer to the Analysis Section) to enable stem straightness to be expressed in terms of mm/ m.

Analysis

To calculate sweep in terms of mm/ m, and because the stem diameter at the height of maximum sweep could not be measured without substantially lengthening the time taken in the measurement process, the stem diameter at the point of maximum sweep needed to be calculated. This was achieved using the heights of 48 trees (stratified by experiment type) from the site, Petterson curves for the Kaingaroa 327 disconnected diallel and polycross trials (Appendix I) were produced. The Petterson curves enabled height to be estimated for all other trees measured based on their dbh measurements. Using estimated tree height and measured dbh, a volume function (volume function 326 for all New Zealand radiata pine on a direct sawlog regime (Eggleston, 1992)) was used to estimate tree volume. The tree volume, and height of maximum sweep information were then input into a taper function (taper function 326 for all New Zealand radiata pine on a direct sawlog regime (Eggleston, 1992)) to predict the diameter under bark (dib) at the height of maximum sweep. The diameter under bark (dib) was converted to diameter over back (dob) using a relationship between diameter over bark (dob), and diameter under bark (dib) developed by Gordon (1983). The process described above assumes there is no difference in taper between families.

The data collected was then analysed in an analysis of variance (ANOVA) using the PROC GLM procedure in SAS (SAS Institute Inc. 1986).

RESULTS AND DISCUSSION

The analysis of variance using the diameter and mm classes for sweep with a 0.2 m stump did not show a strongly significant relationship to the stem straightness NBV. These measures of sweep also do not reflect true genetic variation in stem straightness as they are confounded by any butt sweep arising from juvenile toppling. The use of the 1m stump is also the method used by GTI in scoring the progeny trials for stem straightness. As such the following analysis results have focused on the measures of sweep for a 1 m stump height.

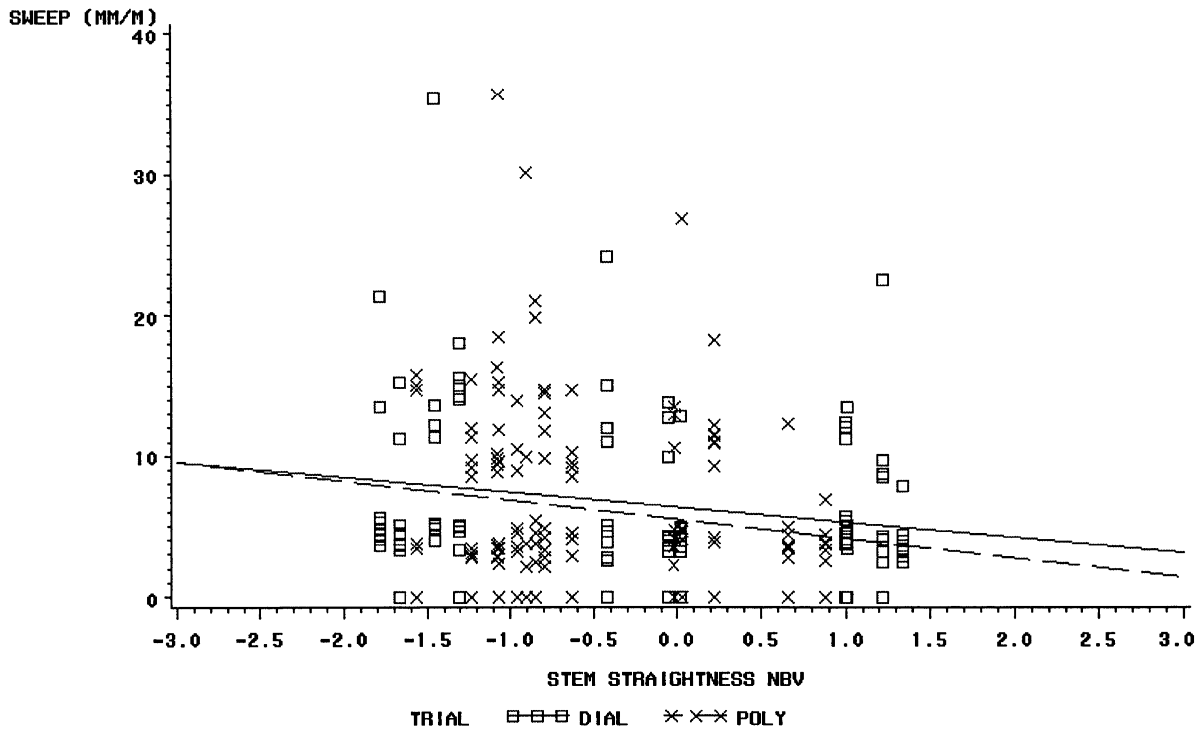

FIG 4: Individual tree stem straightness (mm/m) measured using diameter classes with a 1 m stump, against stem straightness national breeding value, for the polycross and disconnected diallel trials.

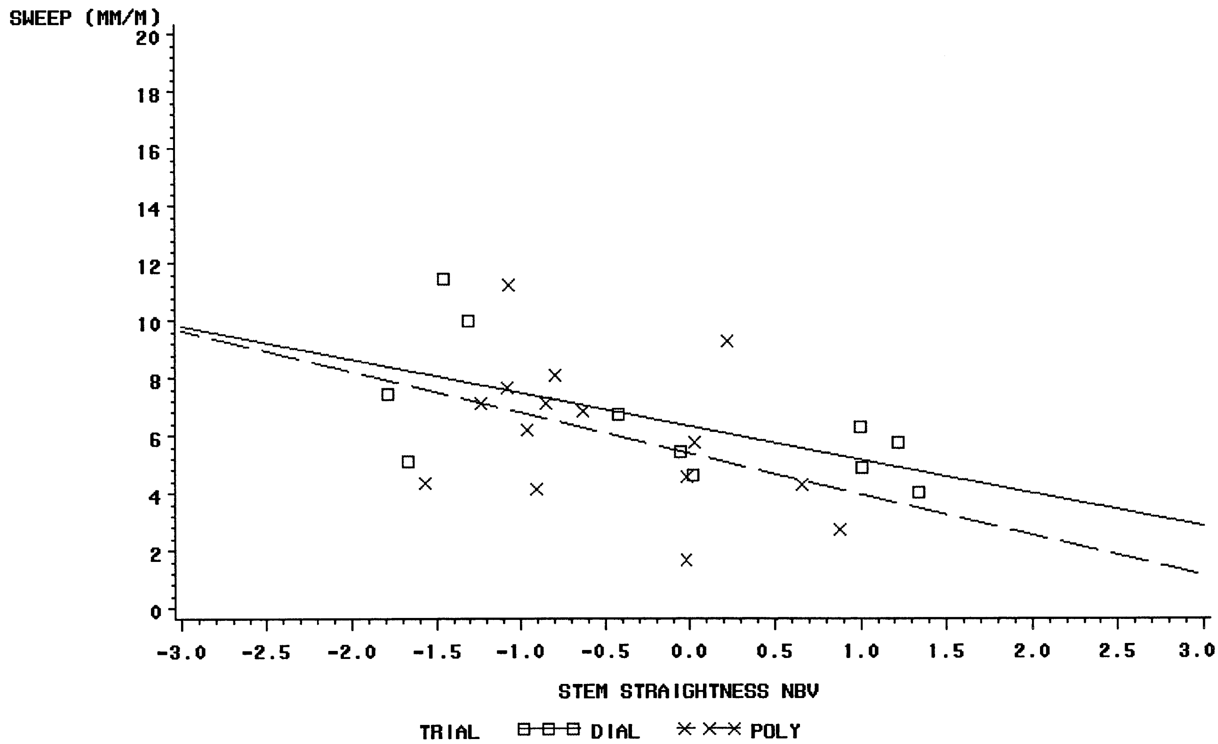

FIG 5: Stem straightness (mm/m) measured using diameter classes with a 1 m stump, against stem straightness national breeding value, using measured family average stem straightness for the polycross and disconnected diallel trials.

TABLE 2: Analysis of variance relating butt log sweep (mm/ m), measured using diameter deviation classes and a 1 m stump for the polycross and disconnected diallel trials at Kaingaroa Forest Cpt 327, trial, and stem straightness national breeding value.

Dependent Variable: BUTT LOG STRAIGHTNESS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRIAL	1	9.26	39.26	1.04	0.3093
NBV	1	284.11	284.11	7.51	0.0066
NBV*TRIAL	1	3.60	3.60	0.10	0.7579
ERROR	249	9419.83	37.83		

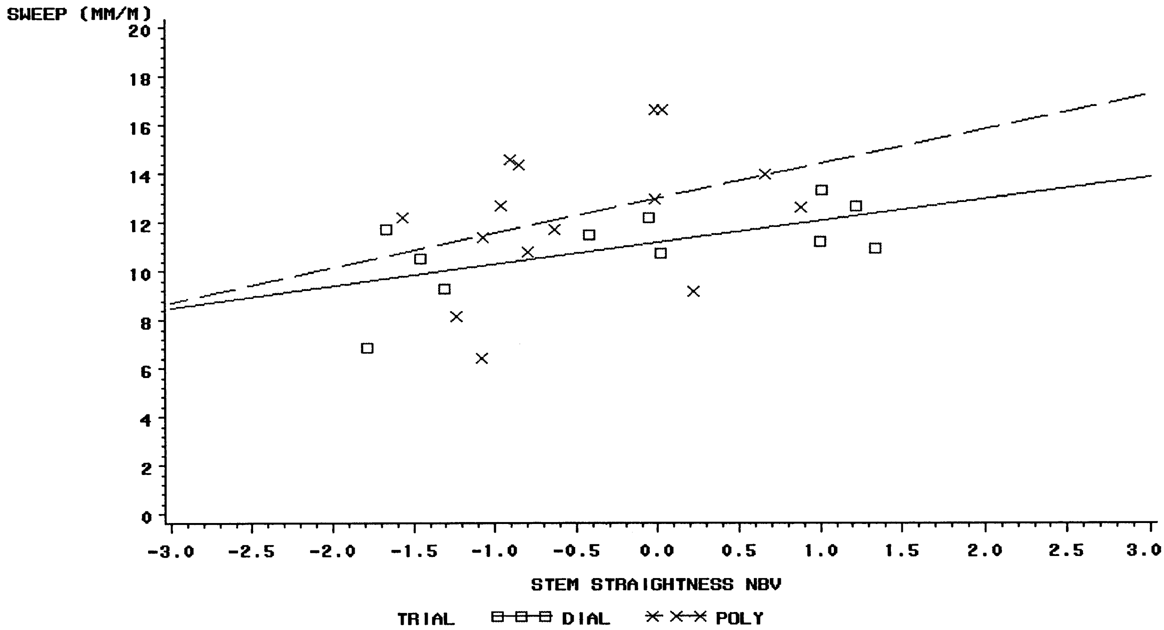

FIG 6: Stem straightness (mm/m) measured using mm classes with a 1 m stump, against stem straightness national breeding value, using family average stem straightness for the polycross and disconnected diallel trials.

TABLE 3: Analysis of variance relating butt log sweep (mm/ m), measured using mm classes and a 1 m stump, for the polycross and disconnected diallel trials at Kaingaroa Forest Cpt 327, trial, and stem straightness national breeding value.

Dependent Variable: BUTT LOG STRAIGHTNESS

Source	DF	Type III SS	Mean Square	F Value	Pr > F
TRIAL	1	118.47	118.47	3.31	0.0701
NBV	1	244.33	244.33	6.82	0.0095
NBV*TRIAL	1	7.58	7.58	0.21	0.6495
ERROR	250	8951.92	35.81		

The results of the analysis of variance (Tables 2 and 3) indicate that there is a significant relationship at the 1% level between the stem straightness national breeding value (NBV) and stem straightness measured using the height pole, with a *p-value* of 0.0066 for the diameter class, and a *p-value* of 0.0095 for the mm class. Despite the significant relationship there is apparently a high level of variability in sweep between trees that were measured for any particular GTI family (Figure 4). While the ANOVA using the mm classes indicate that there is a more significant relationship between stem straightness and the NBV (Table 3), this relationship is in fact negative (Figure 6), and therefore, would be an inaccurate predictor of stem straightness from the NBV, with negative NBV indicating the lower levels of sweep. The positive slope for the relationship between NBV and sweep measured using the mm classes compared with the negative slope for the same relationship using the diameter deviation classes reflects the difficulties of using mm classes (Turner, 1996).

The level of difference in the average stem straightness (Figure 5) measured for the straightest family (4 mm/m mature sweep, 12 mm/m juvenile sweep) versus that measured for the most swept family (12 mm/m mature sweep, 14 mm/m juvenile sweep) are not of economically significant levels. These estimates of stem straightness are also likely to be slight overestimates due to the bias introduced by the height pole when estimating low levels of sweep (West and Kimberley 1991). Based on their study of the decline in pruned log value (1985 Domestic and Export Prices) due to varying degrees of juvenile sweep (Table 4), West and Kimberley (1991) found a $3.70 (1985 price) decline in pruned log value arising from 7 mm/m of juvenile sweep.

TABLE 4: Change in pruned log price (1985 Domestic and Export Price List) due to juvenile sweep for a 5.4 m log with a stem diameter of 16 cm at the point of maximum sweep measured at the time of the final pruning lift. The percentage change in value is calculated based on a $200/ m^3 pruned log stumpage. Adapted from West and Kimberley, 1991.

JUVENILE SWEEP (mm/ m)	CHANGE IN PRUNED LOG VALUE ($/ m^3)	% CHANGE IN VALUE
0	0	0
7	-3.7	-1.5
15	-14.8	-7.4
22	-33.3	-16.7
30	-60.5	-30.3

In addition to the low levels of stem sinuosity measured in this study suggesting further measurements are unwarranted at present, there are a large number of causes of stem sinuosity which are difficult to untangle, such as site fertility (Birk *et al.* 1993), nutrient imbalances (Will & Hodgkiss 1977), and the various factors which contribute to the incidence of toppling (Mason 1985).

CONCLUSION

There is strong evidence from these analyses that stem straightness national breeding values are a good indicator of the level of sweep objectively measured using diameter deviation classes and a 1 m stump height which is apparent in the 1975 "850" disconnected diallel and polycross in Kaingaroa Cpt 327 in the 1 to 6 m log. The average levels of sweep which were measured for each of the families, however, are of such a level that they will lead to an economically insignificant decrease in log value of only 1.5%. The low levels of sweep measured in Kaingaroa Cpt 327 for this genetically improved material, would suggest that for other sites in New Zealand there will be even lower levels of sweep as Kaingaroa has a higher level of stem sinuosity due to higher levels of site fertility. The further exploration, therefore, of the relationship between stem straightness NBV and sweep is unlikely to be warranted.

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APPENDIX I: PETTERSON CURVES FOR KAINGAROA FOREST CPT 327.

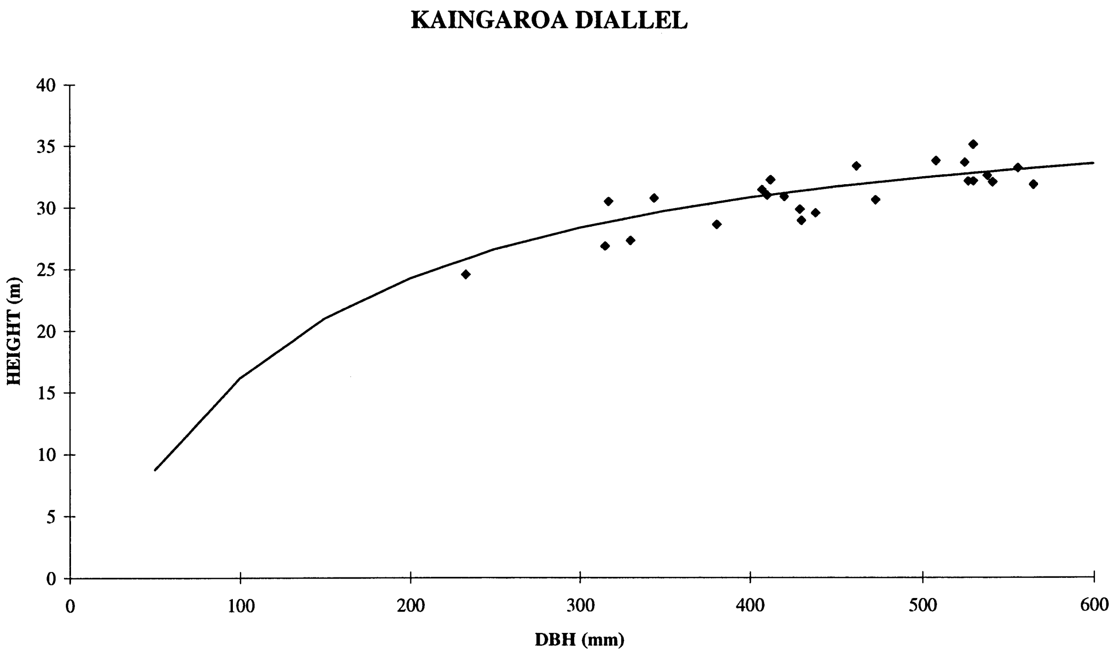

Fig I. Petterson curve for the Kaingaroa disconnected diallel.

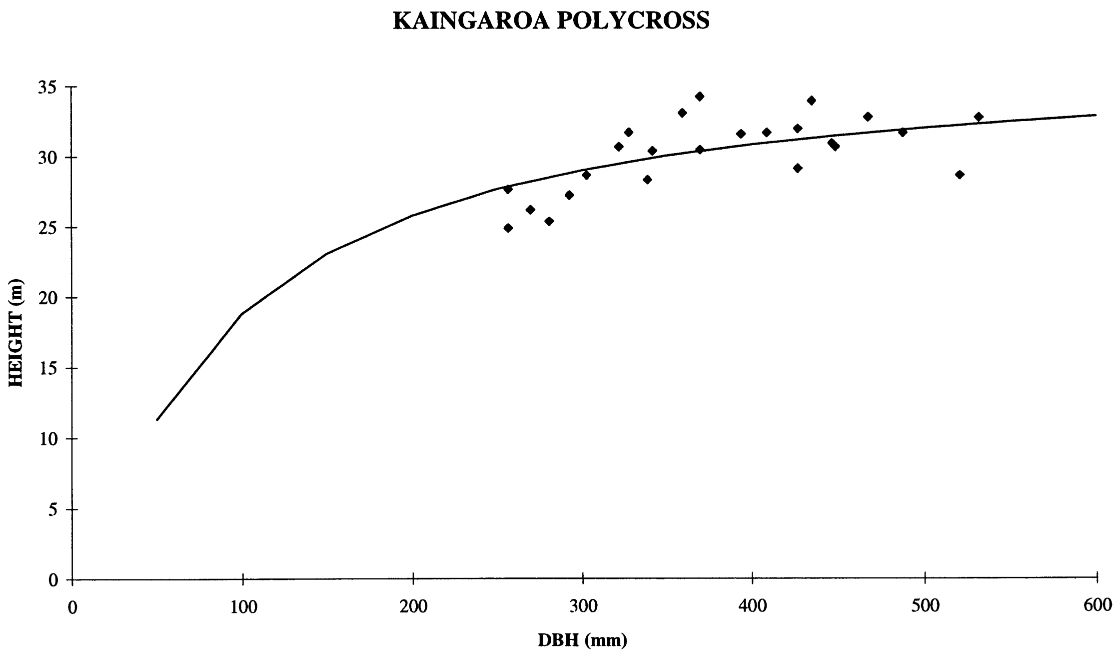

Fig II. Petterson curve for the Kaingaroa polycross.